

Electrical General Services Manual
Volume-I (Power Supply)

1st Edition - August 2022



Indian Railways

विनय कुमार त्रिपाठी
VINAY KUMAR TRIPATHI



अध्यक्ष एवं मुख्य कार्यकारी अधिकारी,
रेलवे बोर्ड
पदेन प्रमुख सचिव, भारत सरकार
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EX OFFICIO PRINCIPAL SECRETARY
GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS**

21st October, 2022

MESSAGE

I am happy to learn that the first edition of Electrical General Services Manual (Power Supply) has been brought out. Indian Railways is a vast organisation, with a complex organizational structure containing multilevel functioning. Also, in the current scenario of swift technological developments, Railways is adopting the latest technologies and practices in all fields. It is thus vital that the guidelines and instructions pertaining to operations and maintenance should be available to all our manpower, in an updated & consolidated form, to ensure uniformity in working systems and optimum productivity.

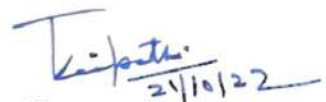
Electrical General Services play a vital role in serving our passengers as well as our manpower. Various instructions have been issued on Electrical General Services from time to time. This maiden manual is an effort in the direction of making available those comprehensive instructions, in the form of a single document by updating and supplementing the previous instructions to make it relevant and current up to date.

The manual contains aspects of reception and distribution of Electrical Energy used for General/Non-Traction purposes at Railway Stations, Installations, Offices and Colonies. It has also brought out statutory requirements and policies for efficient use of energy.

The making of this manual has been an arduous work and for the efforts put in by a number of Senior Officers as well as Staff of Railway Board, IRIEEN, RDSO, CAMTECH and Zonal Railways. I would like to give my appreciation to them for putting in such efforts.

The objective of making this manual would be served only by ensuring wide circulation at all levels in the field, so that its accessibility to all the personnel involved in General Services can be achieved. This will ultimately increase the satisfaction level of our passengers, customers and staff.

I hope that this manual will serve the intended purposes.


(Vinay Kumar Tripathi)

D.C. Sharma
Member Traction & Rolling Stock



31st October, 2022

MESSAGE

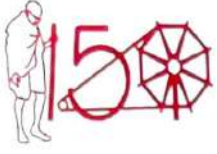
Indian Railways have issued manuals on various technical and non-technical disciplines and subsequently revised them on several occasions. However, there has been a long felt need for manual on Electrical General Services as they are essential and critical to safety and comfort of passengers at Railway stations as well as railway personnel. Electrical General Services Deptt. of Indian Railway is of paramount importance. Availability of guidelines and instructions pertaining to any function involving operation and maintenance, in a consolidated form is thus vital for ensuring uniformity in working system and practices to achieve optimum productivity.

The changing focus of Indian Railways towards Safety, Passenger Comfort and satisfaction has led to re-orientation in approach towards reliability, availability and optimal productivity of assets. This Manual covers theoretical and design aspects with emphasis on procedures and includes essential technical data of use to the operating and maintenance personnel. Numerous changes have taken place over the years in instructions, procedures and policies which have been duly incorporated in an effort to make them available in a single manuscript. This e-manual is also a step towards digital India.

Although efforts have been to make the manual comprehensive to include all possible scenarios in the field, there may arise situations requiring knowledge supplementing to what is contained in the manual. The Principal Chief Electrical Engineers of the Railways may then issue guidelines to suit the local conditions and share knowledge with their counterparts for the benefit of entire community. I am very glad to note that a lot of efforts have been put up in bringing out this manual in the present form. I am sure that it will serve the needs of Electrical engineers and working in the field of General Services and also it will increase the satisfaction level of our passengers and customers.



(D. C. Sharma)



सत्यमेव जयते



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Ram Prakash

Additional Member (Traction)



31st October, 2022

MESSAGE

Although providing traction to trains has been the most important highlight of electrical department, its role is also equally important in the field of general services. Electrical General Services are the basic blocks for serving not only passengers at railway stations but also railway personnel at their workplace and residences.

Rules and regulations have been framed and updated from time to time to envisage utmost reliability and safety. Although railway personnel in the field are working relentlessly to achieve the requisite standards of quality of services, there have been occasional untoward incidences which have occurred predominantly due to lack of knowledge/instructions.

This manual aims to bridge the knowledge gap of personnel working in the field of general services by aggregating the latest instructions, guidelines and procedures.

The manual covers general and railway specific aspects of generation, transmission and distribution of power. It covers technical details of Lighting, HVAC, Lifts and Escalators, installation, maintenance and operation. Renewable energy systems, key aspects of energy conservation and energy efficiency have been brought out, defining the role of Indian Railways as a designated consumer. Protection in electrical systems, fire safety and safety procedures have been explained along with role of EIG in terms of provisions contained in Indian Electricity Act.

In the digital age, it must be ensured that this manual is shared with each and every officer and staff working in the field of General Services to reap its benefits in ensuring highest standard of services with a zero tolerance towards breach in safety. Although utmost care has been taken to create this manual, omissions, error and suggestions are welcome for its continuous improvement.

Ram Prakash

(Ram Prakash)



INTRODUCTION

Technical Manuals play a major role in day-to-day working of any technical organization. In Indian Railways too, these Technical Manuals are available for various technical disciplines. In Electrical Engineering, the AC Traction Manual (ACTM) has proved its usefulness over the decades.

There has however been a long felt need for a Technical Manual for Electrical General Services. Railway Board have therefore decided that a Manual for Electrical General Services be developed and have entrusted this responsibility to IRIEEN. The Manual of Electrical General Services Volume-I (Power Supply) has now been developed. I acknowledge with thanks the work done by Shri A K Mathur, the then Sr.Professor/IRIEEN, Ms. Jyoti Bhaskar, Director/EM/RDSO and Shri H K Singh, Professor/IRIEEN towards preparation of the initial draft and the efforts of Shri Hukam Chand, Professor/IRIEEN, Shri G C Ingale, SSE/TL-AC/IRIEEN and Shri D B Marathe, Sr. Technician/TL-AC/IRIEEN in updating the draft. The manual consists of 16 Chapters and 02 Appendices spread 483 over pages. The Manual has covered all the important facets of Electrical General Services such as Power Supply Distribution System, Electrical Wiring, Energy Conservation & Efficiency, Safety, IE Rules & Protection System, etc. An important feature of the manual is that it has been made in the form of an ebook, enabling the reader to directly go to the content with just a click on the topic in the index itself. Inside the manual also, various hyperlinks have been provided for making it more user friendly.

Though every effort has been made to include the latest developments, nevertheless it is suggested that the manual may be thoroughly revised once every five years in order to keep pace with the fast changing technology.

(Amitabh Ojha)
DG/IRIEEN & Nodal Officer



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CHAPTER-1

POWER SUPPLY DISTRIBUTION SYSTEM

1.1 Introduction

Power supply distribution system consists of electrical general services sub-station, primary feeders, distributors and consumer services.

Power from the generating station, after being stepped up to extra high voltage (765/400/220kV) is carried through transmission lines to a sub-station where the voltage is stepped down to 132/66/33kV. This sub-station is called the primary sub-station. From the primary sub-station, sub-transmission lines carry power to secondary sub-stations where the voltage is stepped down to 11kV. The power is then carried through primary distribution lines (also called feeders) to distribution sub-stations. At distribution sub-station, the power is further stepped down from 11kV to 433/250Volts as per IS 1180 Part I 2014. The distribution sub-stations are situated at convenient locations as far as possible near the load center. From the distribution sub-station, power is supplied to the consumers (domestic, commercial, industrial etc.) through secondary distribution lines (also called distributors).

It must be noted that in the above description, the primary distribution line is considered to be at 11kV. This is generally true except at places where load densities are very high. In such places, the primary distribution lines operate at 33kV or even at 66kV. This is because very high voltages are used to effect economy in transmission of power.

1.2 Feeders and Distributors

For the purpose of uniformity of nomenclature, it is necessary to distinguish between the terms 'Feeder' and 'Distributor'.

'Feeder' is a line, which supplies a point of distribution network without being tapped at any intermediate point.

In the above definition, the expression 'without being tapped at any intermediate point' means that feeders are not tapped at any intermediate point to give supply for direct use to consumers. However, feeders are tapped for supply to distribution sub-stations.

Thus, on simple terms, the feeder may be defined as the line carrying power from the secondary sub-station to the distribution sub-station.

'Distributor' is a line from which tapings are taken along its length to provide supply to various consumers. The distributor is supplied from a distribution sub-station where a high voltage (11kV) is stepped down to a much lower distribution voltage (433/250Volts as per IS 1180 Part I 2014) for domestic, commercial and industrial use.

Distribution sub-stations are a link between feeders and distributors. These are so located that the total cost of conductor material for distributor is minimum.

The standard voltage transformation at a distribution sub-station is 11kV/433V. The declared consumer voltage as per IE Rules is 415V between phases and 240V between phase and neutral with a permissible voltage variation of +/- 6%.



In most power distribution systems, distribution transformers are located at some distance from the actual consumer. Therefore, distribution lines called distributors have to be run to carry power to the consumers. However, in the case of large consumers, such as factories, large commercial undertakings etc., power is supplied directly from the primary distribution system to a transformer located in the sub-station in the consumer's premises. The same is applicable to the supply system for a thinly developed rural area where individual consumers are directly given supply from the primary distribution line through a transformer.

1.3 Primary Distribution System

Primary distribution system include two important basic types -

- i. Radial system including duplicate and throw over system
- ii. Loop system

Radial System – The radial type system is simplest and is most commonly used. It comprises of separate feeders or circuits 'radiating' out of the substation or source, each feeder usually serving a given area. The feeder is considered as having a main or trunk portion to which radiates spurs or laterals to which distribution transformers are finally connected.

The spurs or laterals are connected to the primary main through fuses, so that a fault on the spur will not cause an interruption to the entire feeder. The circuit breakers at substations are available as back up protection. Diagram of a primary distribution radial distribution system is as follows in Fig. 1.

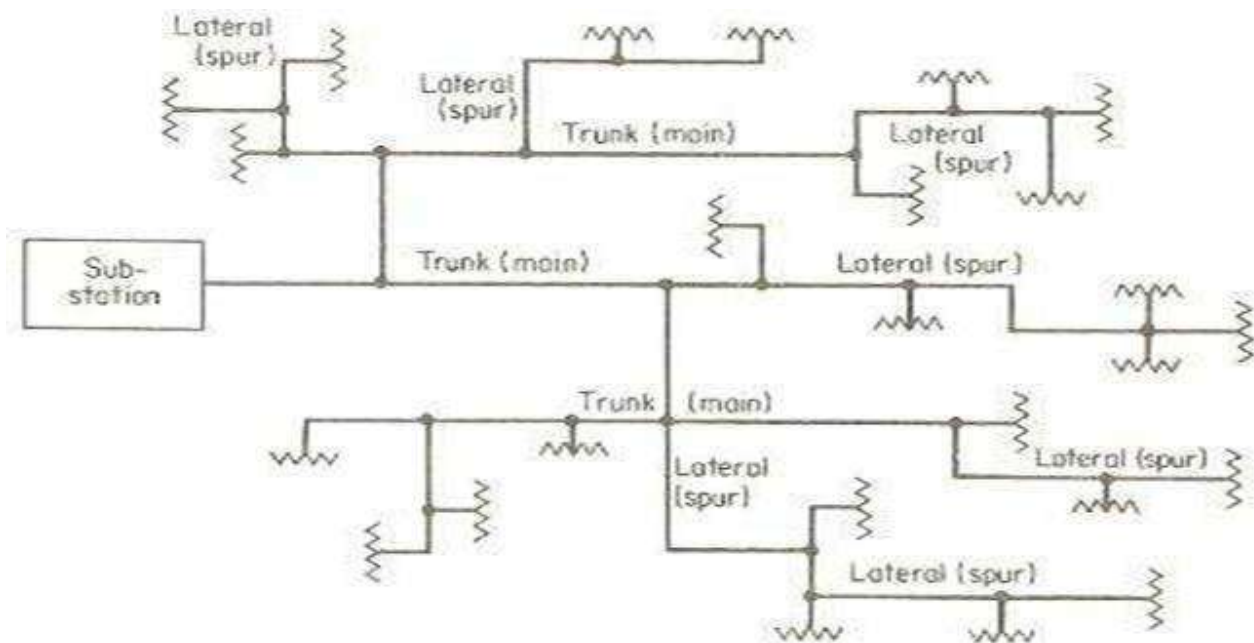


Fig. 1 – Primary Feeder schematic diagram showing trunk or main feeds and laterals or spur

For supplying important installations, a second feeder or additional feeder is often provided which is located in an adjacent route or separate route to provide another alternate source of supply. Switching from normal to alternate feeder can be accomplished by a throw over switching arrangement.

Loop System – In the open loop system (Fig. 2), several sections of the feeder are connected through disconnecting devices with the load connected to the several sections and both ends of the feeder connected to the supply. At a predetermined point in the feeder, the disconnecting device is left open by design. Essentially this constitutes two feeders whose ends are separated by a disconnecting device,

which may be a fuse, switch or circuit breaker. In case of a fault the section of the primary on which fault occurs can be disconnected at both its ends and service can be re-established to the healthy portions by closing the loop at the point where it is normally left open and re-closing the breaker at the substation on the other healthy portion of the feeder.

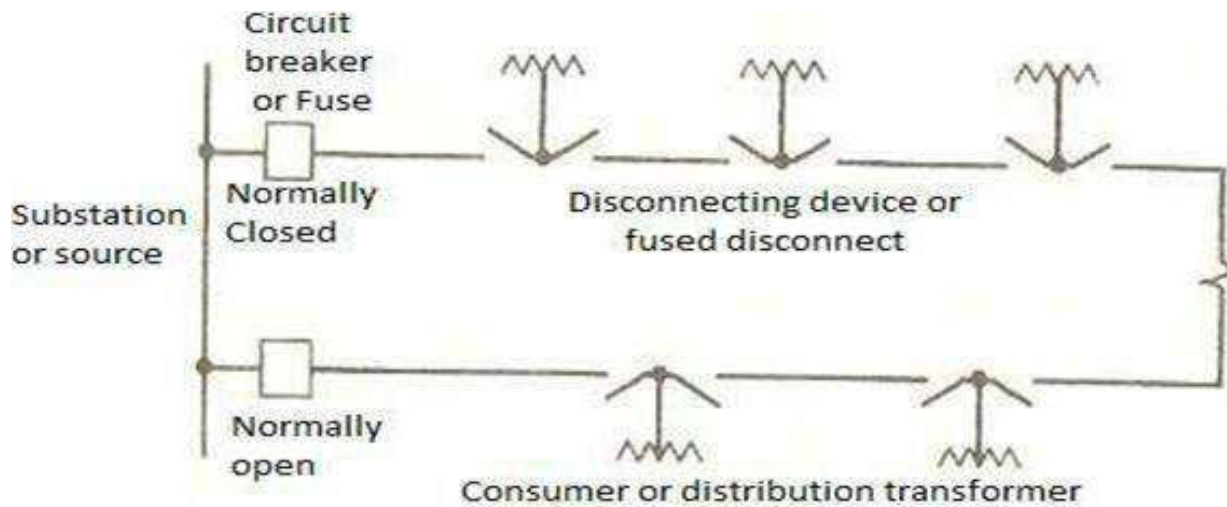


Fig. 2 – Open-loop circuit schematic diagram

1.4 Secondary Distribution Systems

When power is supplied to the consumers through the secondary distribution system, one of the following arrangements is used.

- i. Radial system
- ii. Loop system (Ring Main System)

Radial System - In this system, the LV distribution lines radiate out from the distribution substation. A number of consumers are supplied from each radial distributor as shown in Fig. 3.

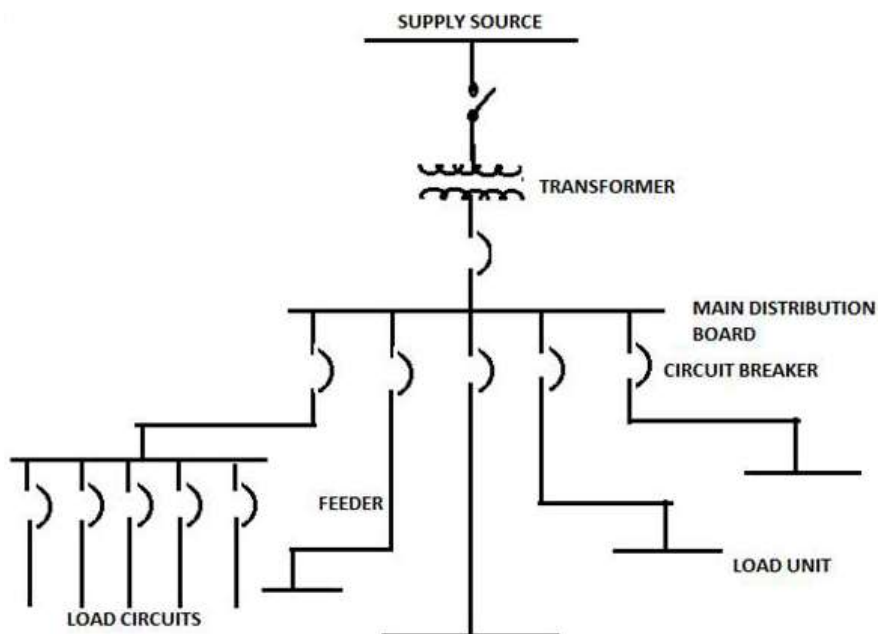


Fig. 3 – Conventional Simple-Radial Distribution System

The drawback in this arrangement is that there is no possibility of an alternate feed in the event of failure of a feeder. However, it can be overcome by providing a duplicate parallel distributor, it will necessitate extra expenditure.

For the protection of the primary distribution line (feeder) working at 11kV, a switch-end-fuse unit is employed. In the case of distribution transformers of rating 500 kVA and above, air circuit breakers with over current and earth fault protection are used. On the secondary distribution line (distributor), for currents of more than 200A, circuit breakers with over current and earth fault protection are used. For lower values of current switch-cum-fuse, units (HRC fuses) are used.

Advantages of radial system -

- i. Fault isolation is quick in radial system.
- ii. In the radial system, all distributors are conveniently controlled from a central point.
- iii. Conductor size of radial system is smaller.

Loop System (Ring Main System) - In this case, the reliability of supply is better than the radial system. In case of fault at any point in the system (Fig. 4), supply can be maintained to all the load centres by isolating the faulty distributor.

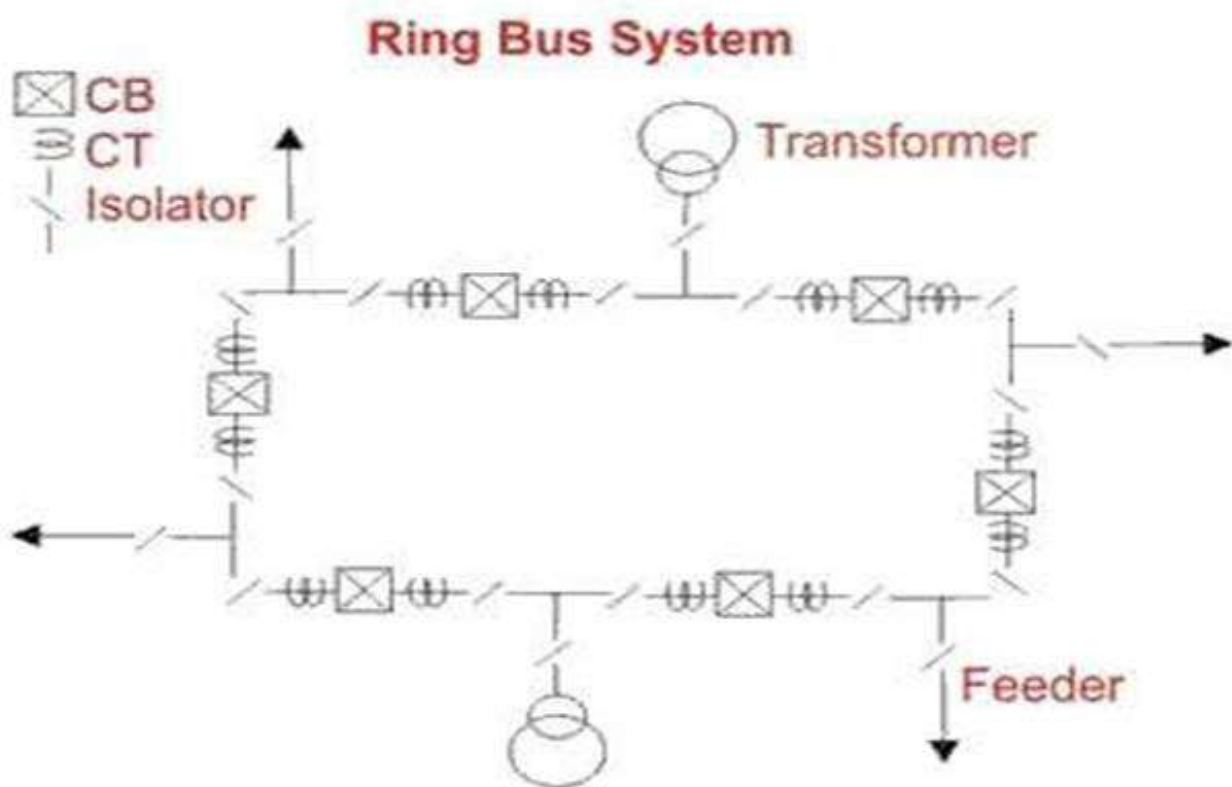


Fig. 4 – Looped System or Ring Main SystemAdvantages of loop system

Advantages of loop system -

- i. The loop system combines the advantages of duplicate mains with least cost.
- ii. The reliability of supply is more in loop system, because in case one transformer fails, load can be fed from another.
- iii. A better load distribution on each transformer is achieved in loop system by diversifying the load on a bank of transformers.

1.5 Method of Distribution

Electric power may be distributed by two methods viz. (i) overhead lines and (ii) underground cables.

A good system whether overhead or underground should fulfil the following requirements-

- The loss of power in the system itself should be a small percentage (about 10%) of the power transmitted. The distribution cost should not be unduly excessive.
- The maximum current passing through the conductor should be limited to such a value, as not to overheat the conductor or injure its insulation.
- The insulation resistance of the whole system should be very high, so that there is no undue leakage or danger to human life.

Comparison of Underground Cable with Overhead Line

Feature	Underground Cable	Overhead Line
Layout	Safe in any terrain and layout.	Unsafe in certain terrains and layouts.
	Practicable for any application.	Impracticable for densely populated areas.
	Acceptable for any Environment and Weather conditions.	Not acceptable for certain environments (viz. high speed of wind, varying climatic patterns).
Investment	Generally costly.	Becomes costly with Special considerations like high masts, or zigzag configurations.
Maintenance Failure rate or Reliability	Practically maintenance free. Generally not affected by natural calamities like storms, lightning or snow.	Costly maintenance. Prone to natural calamities like storms, lightning or snow.
Aerial Interference	Nil	May infringe the layout of airports and airways.
Aesthetics	Will not affect the beauty or get up of the surroundings.	Will affect the beauty or get up of the surroundings.
Replacement	Costly.	Cheaper because either the conductor or the insulators can be strengthened without affecting the cost of supports at times.
Application	Limited to maximum of 132 kV and becomes costly as well as bulky to handle beyond this voltage.	Can be used for any Voltage and power application.
Trouble shooting	Difficult to locate Faults.	Easy to localize faults and hence their rectification.

1.6 Distribution Sub-Station

Electrical General Services Sub-station (SS) is a distribution sub-station from which electric supply is distributed to the different users. In a sub-station, there are a number of incoming and outgoing circuits each having its isolator, circuit breaker, transformers etc. connected to bus-bar system. This equipment is mostly static type. Lightning arresters, earthing of equipment and fencing is done for the purpose of safety & protection. Proper maintenance of a sub-station is essential to ensure un-interrupted electric supply. It consists of many of periodic schedule maintenance, regular inspections, testing and rectification of defects. Single line diagram of a simple 33/11kV sub-station is shown in Fig. 5.



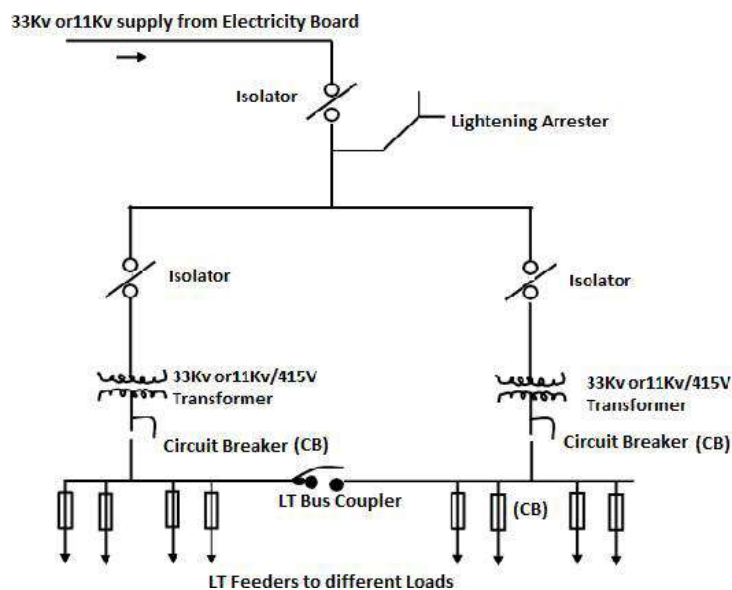


Fig. 5 – Single Line Diagram of 33/11 kV/440 V Sub-station

1.6.1 Site Selection

Site limitation is one of the important considerations in deciding the type of layout of a substation, it should be aimed that the load requirements of the areas are met with minimum overall capital investment and annual cost required for the transmission and distribution systems associated with the proposed sub-station. The annual cost comprises of system maintenance cost etc. The local considerations for the selection are:

- i. Land availability
- ii. It should be free of all obstructions from the point of view of convenience of terminating high voltage lines.
- iii. It should be accessible to the public road to facilitate transport of plant and equipment.
- iv. Where heavy equipment is to be transported by rail, the substation should be near a railway station so as to reduce the length of railway siding.
- v. It should be at higher level than the surrounding area.
- vi. It should have sufficient provision for future expansion. Experience indicates 5 to 10% growth of electrical load every year. Therefore, building should have adequate space provision for augmentation of electrical supply and associated distribution network.
- vii. It should be away from dumping ground.
- viii. In case the sub-station has to be located within the main building itself for unavoidable reasons, then it should be located on ground floor with easy access from outside. Location of sub-station in the basement floors should be avoided as far as possible on account of likely flooding and fire hazard. In case it is unavoidable, then foolproof anti-flooding measures have to be taken, which includes provision of automatic dewatering pumping and construction of waterproof basement. Such portion (for sub-station) should be isolated from the rest of basement and should have easy entry and exit arrangement. Also, suitable mechanical ventilation and fire detection/ protection system to be provided to conform to B.I.S. requirements and requirements of local fire authority. Only dry type transformers and switchgear to be provided, unless they are installed in a separate service building separated from the main building.

1.6.2 Design Parameters

The physical layout and design of the sub-station will be governed by the following factors.

- i. Number of incoming and outgoing feeders (existing and expected to come up in the future)
- ii. Expected load demand on the sub-station (existing and anticipated in future).
- iii. Incoming voltage.
- iv. Soil resistivity.
- v. Expected fault level at incoming and step down voltages.

1.6.3 Capacity of Substation

- i. The capacity of the sub-station is decided after having detailed load survey of various loads required to be fed from the sub-station.
- ii. Capacity of the sub-station also depends upon the type of loads, as different patterns of load will have different demand factors, which in turn governs the diversity factor.
- iii. Capacities of the transformers, switch-gear etc. is to be decided, after duly allowing sufficient margin to the anticipated loads in the near future, over and above the capacity arrived on the basis explained above.
- iv. In order to facilitate interchangeability and also to reduce inventory, it is better to standardize the capacity of transformers such as 100 kVA, 250 kVA, 500 kVA, 1000 kVA etc.

1.6.4 Layout Considerations

The substation layout is influenced to a great extent by the dimensions of the various equipment and their accessories within the sub-station. Characteristics of the various equipment to the extent they affect the sub-station are discussed in the following paragraphs. General considerations, which should be kept in mind, while deciding the layout and design of the substation are as follows

1.6.4.1 Economy

Economy in the sub-station layout and design can be affected by proper choice of equipment and design of supporting structures etc. While equipment like circuit breakers should be of adequate rupturing capacity and ratings, these need not be unnecessarily high which will add to the cost of the equipment. Length of power cables and control cables should be kept to the minimum by properly selecting cable routes etc. The design of bus-bar supports and other structures should be of proper strength but too high a factor of safety may not be necessary. Sometimes, it may be more economical to provide the power cables on higher voltage side up to 33 KV buried in earth with warning covers, instead of making concrete trenches. Low capacity transformers can be protected on the high voltage side by fuses instead of costly circuit breakers particularly on non-industrial loads, it is, however, important to ensure that a circuit breaker is available at the sending end of the feeder.

1.6.4.2 Flexibility of Operation

The layout should be so designed as to ensure flexibility in operation and continuity of supply to the extent possible. It should be possible to take out the faulty equipment for repairs without effecting the continuity of supply to the healthy circuits.

1.6.4.3 Safety

Safety considerations should be given paramount importance in the design of sub-station layout. Fencing should be provided around the switchyard to make it inaccessible to unauthorised persons and cattle etc. Adequate clearances should be provided between the equipment and the structures



for proper inspection, maintenance and movement of the staff. Suitable mechanical interlocking arrangements between the isolators and the associated circuit-breakers should be provided wherever possible to guard against isolators being operated on load, otherwise, ordinary locking arrangement for the operating handle of the isolator should be made. Isolators controlling lines and feeders should always be provided with earthing blades for earthing the line for maintenance work to be carried out on the line.

1.6.4.4 Provision for Future Expansion

Adequate provision should be in the substation layout for possible future extensions. In outdoor switchyards necessary provision should be made for additional outgoing feeders as expected in future. Outdoor bus bars should be so designed as to accommodate both existing and future feeders within the bus bar and in addition, suitable space may be kept at least at one end of the bus bar so that the bus bar can be extended, if necessary at a later date. Suitable provision for space should be made for incoming breakers even if such breakers are not considered necessary at the time of construction of the sub-station. Necessary space may also be provided on the high voltage side to accommodate additional incoming and outgoing feeders in the future. It would also be desirable to have suitable space for any extension of the control-room building to accommodate certain additional equipment, which may become necessary in future.

1.6.5 Equipment in Distribution Sub-Station

The following equipment /items are available in a sub-station:

- i. Distribution Transformers
- ii. Circuit breakers
- iii. Lightning Arrester
- iv. Isolators
- v. Distribution panel boards CT/PT
- vi. Bus-bar
- vii. Capacitor Bank
- viii. Safety items (Fire extinguishers, sand buckets, rubber mats, earthing rods, earthing chains, shock treatment charts etc.)
- ix. Circuit diagram boards

1.6.5.1 Distribution Transformer

The distribution transformer is a main equipment of sub-station. It is a static electrical device which steps down the primary voltage of 33kV to 11 kV & 11kV to secondary distribution voltage of 433/250Volts as per IS 1180 Part I 2014 through delta-star windings by electromagnetic induction without change in frequency.

Transformer consists of the following parts and components.

- i. Primary winding
- ii. Secondary winding
- iii. Transformer tank
- iv. Conservator
- v. Cooling tubes
- vi. Breather

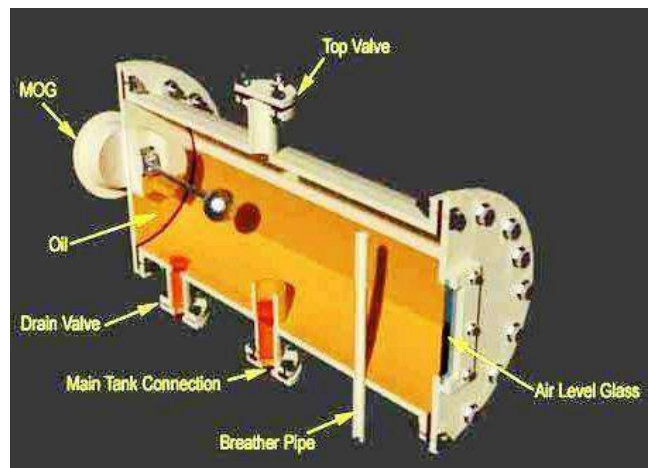
- vii. Buchholz Relay
- viii. Explosion vent
- ix. Tap changer
- x. Oil inlet valve
- xi. Oil outlet valve
- xii. Oil level indicator
- xiii. L.T. terminals
- xiv. H.T. terminals
- xv. Temperature gauge



A. Working of Important Components-

Conservator Equipped with transformer of rating 500kVA & above.

It is a drum containing transformer oil, mounted at the top of the transformer, and connected to the main tank by a pipe. As the volume of oil of transformer tank expands and contracts according to heat produced. This expansion and contraction of oil causes the level of the oil in conservator to rise and fall. The aim of conservator is to maintain the oil level in tank and provide space for the expanded oil.



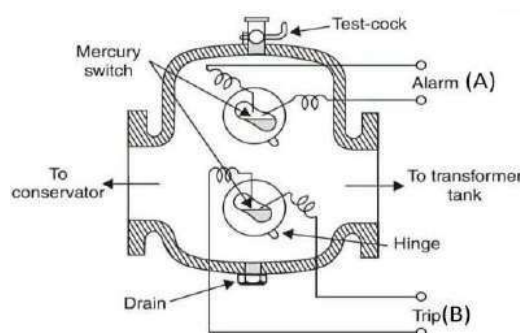
B. Breather



It is attached to conservator tank and contains silica gel, which prevents the moist air from entering into the tank during contraction of oil i.e. breathing of transformer. When oil is hot, there is expansion and gas passes to atmosphere through it. When oil is cooled, it contracts and the air enters in it. It prevents transformer oil from moisture contamination.

C. Buchholz Relay

It is a protective relay provided in transformers of 800 kVA or higher ratings, to act during incipient as well as through faults. This device signals the faults soon as it occurs and isolates the transformer out of the circuit immediately. This is gas operated protective relay. It is installed in between the pipe connecting the tank and the conservator. This relay works on the formation of excessive oil vapours or gas inside the transformer tank due to internal fault of transformer. It consists of two operating floats A and B. These are operated by two mercury switches, separately provided for each float. The float A is for bell alarm and float B is for operating the tripping circuit.



Whenever there is a minor fault or low level of oil, the bell alarm operated by float 'A' and whenever there is severe fault in the transformer, float 'B' operated due to excessive gases. It trips the circuit breaker and transformer is put out of circuit.

D. Explosion Vent

A major fault inside the transformer causes instantaneous vaporisation of oil, leading to extremely rapid buildup of gaseous pressure. If this pressure is not released within few milliseconds, the transformer tank can rupture, spilling oil over a wide area. An explosion vent provides instantaneous releasing of such dangerous pressure and protects the transformer.



E. Oil level Indicator

It indicates level of transformer oil at the conservator of the transformer. It has markings on transparent sheet for maximum & minimum levels.

F. Oil inlet Valve

It is the passage to pour the transformer oil in the tank during purification or in case of topping up of oil.

G. Oil outlet Valve

It is the passage to drain out the oil during overhauling or as and when required for oil sample testing.

H. Cooling Tubes

These tubes provide better and effective cooling of transformer oil by increasing the surface area of tank.

I. Tap changer

The tap changer is used to regulate the out-put voltage manually according to line voltage. The taps of transformer can be changed by the tap changer manually. It is provided on HV side so that the voltage on LV side feeding to the load can be maintained. Normally tap selection range is $\pm 15\%$ in steps of 2.5% .

**1.6.5.2 Circuit Breaker**

The circuit breaker is an equipment which automatically cuts off power supply of the system when any fault or short circuit occurs. It detects and isolates faults within a fraction of a second thereby minimising the damage at the point where the fault has occurred. The circuit breakers are specially designed to interrupt the very high fault currents, which may be ten or hundred times the normal operating currents.

There are many types of circuit breakers, e.g. oil, minimum oil, air, air-blast, vacuum, & SF₆, etc. being used at sub-stations depending on voltage level. This list is generally in order of their development and increasing fault rupturing capacity, reliability and maintainability. In distribution sub-station, generally air or vacuum circuit breakers are used.

1.6.5.3 Distribution Panel Board

Distribution panels both for incoming & outgoing supply and consisting of MCCBs, control equipment, meters and relays are housed in the control room. Panels shall be connected to the earth grid by an earthing conductor. Rubber mats of prescribed size and quality shall lay in front of panels for human safety.



1.6.5.4 Lightning Arrester

Lightning arrester is a most important protective device of distribution sub-station to protect valuable equipment as well as working personnel. It arrests and discharges over Voltages to earth during lightning strokes. These should be installed between line and earth near the equipment.

Representative values of a lightning stroke.
Voltage - 2×10^8 volts.



1.6.5.5 Isolator

Air break switches are used to isolate equipment for maintenance and also for transfer of load from one bus to another. Lay-out of sub-station depends upon type of Air break switches. These switches are of two types viz. vertical break type or horizontal break type. Horizontal break type normally occupies more space than the vertical break type.

1.6.5.6 Insulator

The main function of an insulator is to insulate live conductor or equipment at different voltages with reference to the ground structures as well as provide mechanical support. Provision of adequate insulation in a substation is of primary importance from the point of view of reliability of supply and safety of personnel.

1.6.5.7 Bus Bar Arrangement

The bus bar is a conductor used to connect two and more equipment located side-by-side when the currents are very high. These are usually rectangular, sometimes tubular, bare copper some times aluminium bars supported on insulators. The outdoor bus-bars are either of the rigid type or of the strain type. In the rigid type, pipes are used for making connections among the various equipment. The strain type bus-bars are an overhead system of wires strung between two supporting structures and supported on strain type insulators. Since the bus bars are rigid, the clearances remain constant.

1.6.5.8 Capacitor Bank

It is a series parallel combination of capacitors required to improve power factor of the system. They act as reactive power generators and provide the needed reactive power to accomplish active power of circuit. This reduces the amount of reactive power, and thus total power (kVA) or the demand. The bank should be provided as near as possible to load. These Automatic Power Factor correction (APFC) panels are mostly used.

1.6.6 Fencing Arrangement and Gravel/Crushed Rock

Fencing is provided at outdoor sub-station yard for restricting entry of unauthorised person and livestock. It must be earthed/ grounded separately. Height of fencing normally should not be less than 1.8 meters. Fencing should be painted once in a year by suitable paint

In outdoor switch yard, areas are usually covered with about 10cm of gravel of crushed rock of 40 mm size which increases the safety of personnel against shocks, prevent the spread of oil splashes and aids in weed control.

The resistivity of gravel, ρ , is 2000 ohm-meter while that of soil is 100 ohm-meter. Since r of gravel is high, only a high voltage can force the current through the body to cause injuries. The gravel act like insulator.

1.6.7 Sub-station Earthing

Provision of adequate earthing in a substation and switching stations are very important for the safety of operating personnel as well a electrical devices do not rise above tolerable thresholds and that the earth connection is rugged to dissipate the fault to the earth. The importance of an effective, durable and a dependable earth for ensuring safety from electrical hazards does not require to be elaborated upon more. By earthing, connecting the electrical equipment to the general mass of the earth, this has a very low resistance.

1.6.7.1 Purpose of substation earthing system

The object of an earthing system in a substation is to provide under and around the substation a surface that shall be at a uniform potential and near zero or absolute earth potential as possible. The provision of such a surface of uniform potential under and around the substation ensure that no human being in the substation subject in shock of injury on the occurrence of a short circuit or development of other abnormal conditions in the equipment installed in the yard.

The primary requirements of a good earthing system in a substation are:

It is stabilize circuit potentials with respect to ground and limit the overall potential rise. It is protect life and property from over voltage.

It is provide low impedance path to fault currents to ensure prompt and consistent operation of protective devices during ground faults.

It is keep the maximum voltage gradient along the surface inside and around the substation within safe limits during ground fault.

1.6.7.2 Maximum permissible resistance of earthing system

Large power station	:	0.5 ohms.
Major sub-station	:	1.0 ohms.
Small sub-station	:	2.0 ohms.
In all other cases	:	8.0 ohms.
The earth continuity inside an installation	:	1.0 ohms.

1.6.7.3 Touch voltage (e touch)

The potential difference between a ground metallic structure and a point on the earth's surface separated by a distance equal to the normal maximum horizontal reach of a person, approximately one meter.

1.6.7.4 Step voltage (e step)

The potential difference between two points on the earth surface separated by distance of one pace that will be assumed to be one meter in the direction of maximum potential gradient.

1.6.7.5 Earthing system in sub station

The earthing system comprises of earthing (or) grid, earthing electrodes, earthing conductors and earth connections.

A. Earth Mat or Grid

The primary requirement of earthing is to have a very low earth resistance. If the individual electrodes driven in the soil are measured it will have a fairly high resistance. But if these individual electrodes are interlinked inside the soil, it increases the area in constant with soil and creates a number of paralleled paths and hence the value of earth resistance in the interlink state, which is called combined earth resistance, will be much lower than the individual resistance.

However interlinking of earth pit electrodes is necessary. The sub-station involves many earthing through individual electrodes. In order to have uniform interconnection, a mat or grid or earthing conductor is formed inside the soil. Thus a mat is spread underneath the sub-station. Hence if a ground electrode is driven in the soil, the interlinking can be done by a small link between that electrode and earth mat running nearby. The spreading of such a mat in the soil also ensures the object of earthing that and surface under and around the sub-station is kept at as nearly absolute earth potential as possible.

B. Construction of Earth Mat

The sub-station site including the fence is segregated at intervals, of say four meters width along with length and breadth wise. Trenches of one meter to 1.5 meter depth and one meter width are dug along these lines. The earthing conductors of sufficient sizes (as per fault current) are placed at the bottom of these trenches. All the crossing and joints are braced. The trenches are then filled up with soil of uniform fine mass of earth mixed with required chemicals depending upon the soil resistivity.

If location of equipment is fixed, the intervals are also arranged that the earth mat passes nearby the equipment location to facilitate for easy interlinking.

It is preferable to extend the mat beyond the fence for about one meter that fence can also be suitably earthed and made safe for touching.

Normally the earth mat is buried horizontally at a depth of about half a meter below the surface of the ground and ground rods at suitable points.

C. Earth Mat in a Sub-Station

Earth Mat is connected to the Following in a Sub-Station:

The neutral point of such system through its own independent earth.

Equipment frame work and other non-current carrying parts of the electrical equipments in the sub-station.

All extraneous metallic frame work not associated with equipment. Handle of the operating pipe.

Fence if it is within 2 m from earth mat.

1.6.7.6 Location of Earth Electrode

The location of earth electrode should be chosen in one of the following types of soil in the given order of preference

Wet marshy ground.

Clay, loamy soil and arable land.

Clay and loam mixed with varying proportions of sand, gravel and stones. Damp and wet sand, peat.

Dry sand, gravel, chalk, limestone, granite, very stone ground and all locations where virgin rock is very close to the surface should be avoided.

C. Circuit Breakers

For every breaker there will be five earth connections to the earth mat with MS flat

(i) breaker body (ii) relay panel (iii) CTs of the breaker (iv) Two side of the breaker structure.

D. Transformers

The tank of each transformer shall be directly connected to the main grid. In addition there shall be as direct a connection as practicable from the tank to the earth side of projecting lightning arrestors.

The transformer track rails shall be earthed either separately or by bonding at each end of the track and at intervals not exceeding 60.96 meter (200 feet). The earthing of neutral bushing shall be by two separate strips to the earth grid and shall likewise be run clear to rank cell and coolers.

E. Current Transformers and Potential Transformers

The supporting structures of Current Transformer and Potential Transformer unit of bases, all bolted cover plates to which the bushings are attached connected to the earthing mat by means of two separate distinct connections made with MS flat. One connection is made with the nearest longitudinal conductor, while the other is made to the nearest transverse conductor of the mat.

F. Other Equipment

All equipment's, structures, and metallic frames of switches and isolators shall be earthed separately.

G. Fences

The Sub-station fence should be generally too far outside the substation equipment and grounded separately from the station ground. The station and the fence ground should not be linked. To avoid any risk to the person walking near the fence inside the station, no metal parts connecting connected to the station ground, should be near to the fence five feet and it is desirable to cover the strip about ten feet wide inside the fence by a layer of crushed stone which keeps its high resistively even under wet condition. If the distance between the fence and station structures, cannot be increased at least five feet and if the fence is too near the substation equipment structure etc., the station fence should be connected to the fence ground, otherwise a person touching the fence and the station ground simultaneously would be subjected to a very high potential under fault conditions.

In a fence very near to the station area, high shock voltage can be avoided by ensuring good contact between the fence stations and by grounding the fence at intervals. The station fence should not be connected to the station ground but should be grounded separately. If however, the fence is close to the metal parts of substation, it should be connected to the station ground.

H. Ground Wire

All ground wires over a station shall be connected to the station earth grid. In order that the station earth potentials during fault conditions are not applied to transmission line ground wires and towers, all ground wires coming to the station shall be broken at and insulated on the station side of the first tower or pole external to the station by means of 10" disc insulator.

I. Cables and Supports

Metal sheathed cables within the station earth grid area shall be connected to that grid. Multi-core cables shall be connected to the grid at least at one point. Single core cables normally shall be connected to the grid at one point only. Where cables which are connected to the station earth grid pass under a metallic station perimeter fence, they shall be laid at a depth of not less than 762 mm (2'-6")

below the fence, or shall be enclosed in an insulating pipe for a distance of not less than 1524mm (5') on each side of the fence.

J. Panels and Cubicles

Each panel or cubicle should be provided near the base with a frame earth bar of copper to which shall be connected the metal bases and covers of switches and contactor unit. The frame earth bar shall in turn be connected to the earth grid by an earthing conductor.

1.6.7.8 Distribution Transformer Structure Earthing

For earthing three earth pits in triangular formation at a distance of six meter from each other are to be provided. Earth pit should be digged for 45 cm x 45 cm size and 5 ft. depth. 3 Nos. of 40 mm dia and 2.9 mm thickness and 3 mts. (10 ft) length of earth pipe should be used for earthing. This earth pipe is erected in 5 ft. depth earth pit and for the balance length of earth pipe is driven by hammering into the ground.

When a pipe is driven into the earth, the earth surrounding the pipe can be considered to be consisting of concentric cylinders of earth which will be bigger in size and area, as they are away from the pipe. The current can travel into the earth with large area having little resistance.

3 m. length of electrode will have contact with the earth area of 3 m in radius. Hence to have better effect 3 m pipe should be fixed at a distance of 6 m (i.e.) twice the distance of pipe length.

For better earth connection, one G I clamp should be welded to the earth pipe and the other clamp bolted with 2 nos. 11/2 x 1/2 G I bolt nuts and 4 nos. G. I. washers to the earth pipe.

Two separate distinct connections through G I wire should be made from the transformer neutral bushing to the earth pit No. 2.

Two separate distinct connections through GI wire should be made from the transformer HT lightning Arrestor to the earth pit No. 1. As far as possible this earth wire should not have contact with other earth wire connections. If needed PVC sleeves can be used for insulation.

Two separate distinct connections through GI wire from the following parts of the structure should be made to the earth pit No. 3 as shown in Fig. 7.

Metal part of the disc and stay. Top channel.

AB switch frame, metal part of the insulator, side Arms. HG fuses frame and metal part of the insulator.

LT cross arm, metal part of the insulator, open type fuse frame. AB switch guide and operating pipe (At the top and bottom).

Transformer body. Belting angle.

Seating channel.

LT lightning arrestor.

The above earth connections should be made as far as possible without joints. Wherever joints are necessary, GI sleeves should be used by proper crimping.

The earth pits No. 2 and 3 can be interlinked to serve as parallel path and lower the earth resistance. If the earth resistance of the earth pit No. 1 is high, then another earth pit No. 4 can be formed as a counter poise earth and linked with the HT lightning arrestor pit.



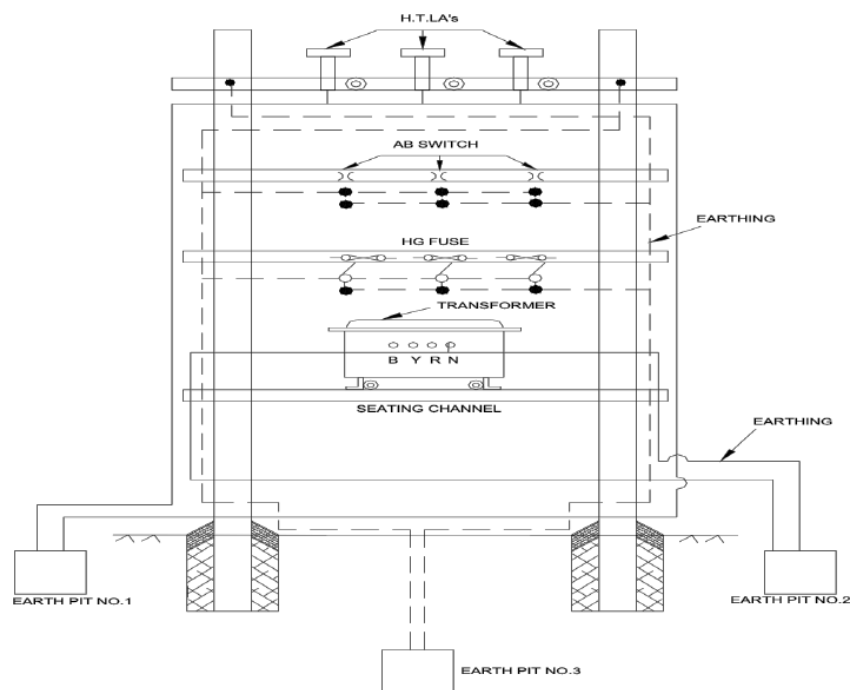


Fig. 7 - Earthing of Distribution Transformer Structure

1.6.7.9 Testing of Earthing System

Measurement of Earth Electrode Resistance

A. Fall of potential method

In this method, two auxiliary earth electrodes, besides the test electrode, are placed at suitable distances from the test electrode as shown in Fig. 8. A measured current is passed between the electrode 'A' to be tested and an auxiliary current electrode 'C' and the potential difference between the electrode 'A' and the auxiliary potential electrode 'B' is measured. The resistance of the test electrode 'A' is then given by:

$$R = V/I$$

where, R = Resistance of the test electrode in ohms

V = Reading of the voltmeter in volts,

I = Reading of the ammeter in amperes

In most cases, there will be stray currents flowing in the soil and unless some steps are taken to eliminate their effect, they may produce serious errors in the measured value. If the testing current is of the same frequency as the stray current, this elimination becomes very difficult. It is better to use an earth tester incorporating a hand driven generator. These earth testers usually generate direct current, and have rotary current reverser and synchronous rectifier mounted on the generator shaft so that alternating current is applied to the test circuit and the resulting potentials are rectified for measurement by a direct reading moving coil ohm meter. The presence of stray currents in the soil is indicated by a wandering of the instrument pointer, but an increase or decrease of generator handle speed will cause this to disappear.

At the time of test, where possible, the test electrode shall be separated from the earthing system. The auxiliary electrode consists of 12.5 mm diameter mild steel rod driven up to one meter into the ground.

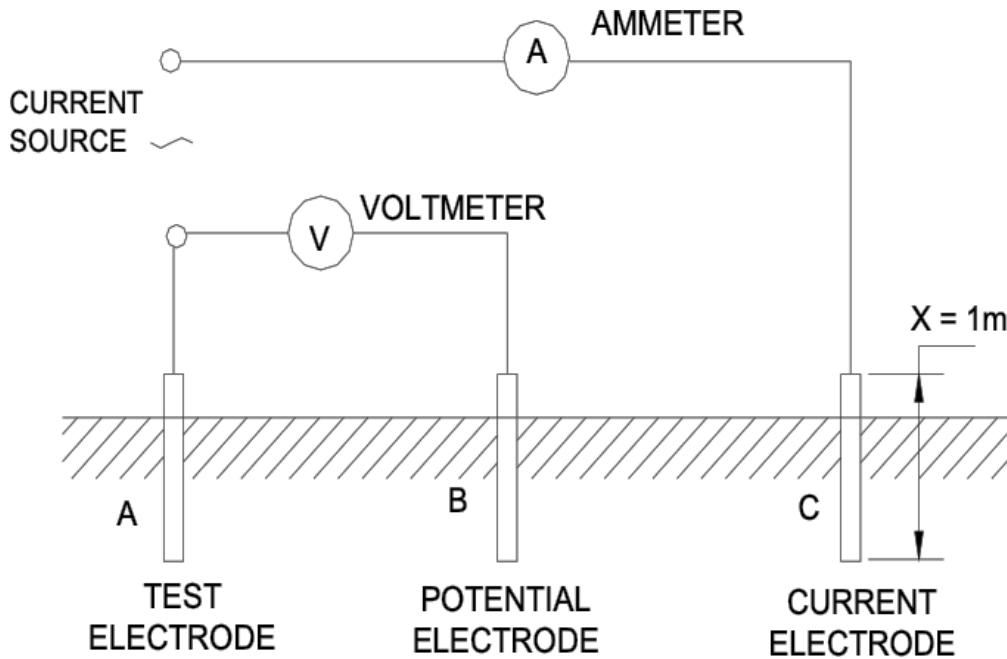


Fig. 8 - Fall of potential method

B. Details of Earth Tester (Hand Driven)

Earth resistance meter are employed for measurements of earth resistance in substation and other electrical installations. An Earth resistance meter comprises a hand driven magneto type D.C. Generator, a current reverser, rotary rectifier and ohm meter.

The current reverser and rotary rectifier are driven along with D.C. Generator by driving systems which incorporate a clutch mechanism for unidirectional rotation and a governor for speed control. The function of current reverser is to change the direction of flow of current in the soil and that of rotary rectifier is to maintain unidirectional current in the potential coils of the ohm meter.

The ohm meter consists of a current coil and a potential coil mounted on a common spindle and placed in the magnetic field of a permanent magnet. The current coil is connected in series with the earth electrodes and current electrodes. The potential coil is connected across the earth electrode and the potential electrode through the rotary rectifier. While measuring the earth resistance the terminals C1, P1 are connected to the main earth electrode P2 to the potential electrode and C2 to the current electrode. As per IS 3043: 2018, the potential and current electrodes are temporary electrodes placed in the ground 50 to 75 feet apart and 50 to 75 feet & from the earth electrode as shown in below Fig. 9.

When the megger is operated an ac current is produced in the coil. The voltage drop produced in the earth electrode is applied across the potential coil. The current coil produces a torque in the clock wise direction, and the potential coil produces a torque in anti-clock wise direction. The current applied to the current coil is inversely proportional to the earth resistance and the voltage drop applied across the potential coil is directly proportional to the earth resistance the torque opposes each other and brings the moving system to rest when they are equal. The pointer indicates the earth resistance values on a calibrated scale. Current Terminal: C1 or C2 Potential Terminal: P1 or P2

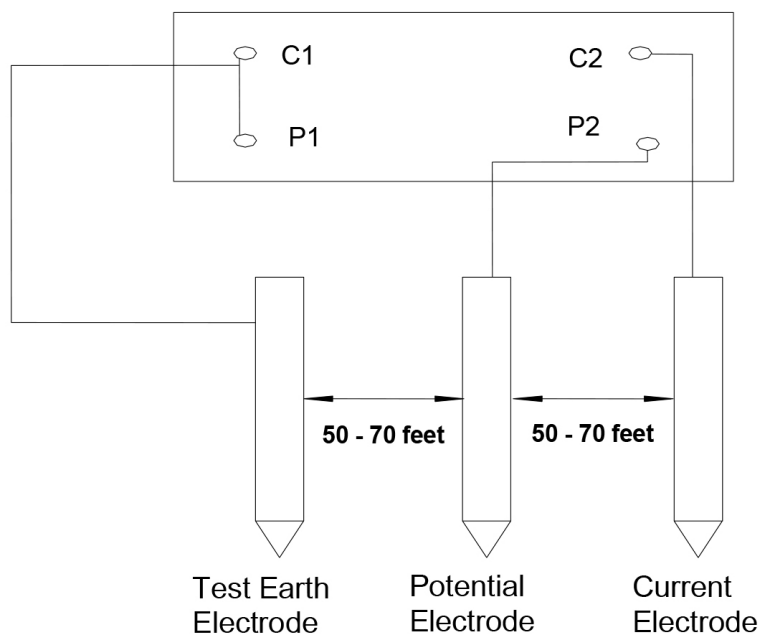


Fig. 9 – Earth Tester

1.6.7.10 Maintenance free Earthing

In conventional earthing system, GI pipe is used as earth electrode. It is provided with charcoal and salt as conducting media, which provides a reasonable earth. Corrosion of metallic parts is comparatively fast. It also requires maintenance by way of watering of earth pits and chiseling of corrosion prone parts and replacement. It also requires monitoring which may not always be feasible in certain crowded and inaccessible areas.

With technological developments in this field, modern maintenance free and durable earthing system employs steel conductors as electrode which are copper cladded and utilize graphitic compounds and non-corrosive salts as “Ground Enhancing Material” which do not lead to corrosion. Such earth pits also do not require the usual watering schedules to maintain the earth resistance within limits.

Where the earth pits are not easily accessible for schedule maintenance, maintenance free earth pits shall be provided. In areas where clusters of earth pits are required to keep the earth resistance low, provision of maintenance free earth pits should be made during initial installation.

A. Earth Resistance

The earth resistance value at earth bus bar should be less than 0.5 ohms for major electrical equipment & installation.

B. Applications

This earthing system may be used in following locations.

- i. Sub stations & switching stations
- ii. Remote Terminal Units
- iii. Transformer & Generator neutral earths
- iv. Lightning arrester earths
- v. Equipment earths including panels

1.7 Compact Substation

1.7.0 Introduction to compact substation

These sub-stations are used for locations covering long distances & wide areas where standby transformers are not installed. Their use is normally being restricted to 250 KVA. They are preferred where ring main high voltage distribution is planned in open space. The service conditions, rated characteristics, general structural requirements and test methods of prefabricated substations should generally conform to IS 14786: 2000.



1.7.1 Compact Substation Components

Compact Sub-station consists of 11 kV SF6 Insulated compact switchgear with VCB as protection to transformer and L.T. Switchgear with all connection accessories, fittings & auxiliary equipment in a pre-fabricated enclosure to supply low-voltage power from high-voltage system as detailed in this specification. The complete unit shall be installed on a sub-station plinth (base) as Outdoor sub-station. The 11 kV Load Break Cable Switches controls incoming–outgoing feeder cables of the 11 kV ring/ radial distribution system. The Vacuum Circuit Breaker shall be used to control and isolate the distribution transformer. The transformer's L.T. side shall be connected to

L.T. switchgear. Connection cables to consumer shall be taken out from the L.T. switchgear(s).

The pre-fabricated compact sub-station shall be designed for

- (a) Compactness
- (b) Fast installation
- (c) Maintenance free operation
- (d) Safety for worker/ operator & public

A. Outdoor Enclosure

The enclosure shall be made of galvanized sheet steel or such other material tropicalised to meet Indian weather condition. The base of the enclosure shall ensure rigidity for easy transport & installation.

The structure of the substation shall be capable of supporting the gross weight of all the equipment & the roof of the sub-station compartment shall be designed to support adequate loads.

There shall be proper / adequate ventilation inside the enclosure so that hot air inside enclosure is directed out with the help of duct. Louvers apertures shall be provided so that there is circulation of natural air inside the enclosure.

The complete design shall be modular i.e. small sheets shall be joined together to make a big sheet. This helps in avoiding skewing, bending, bending of the single sheets on doors and sides due to its own load under service. The doors shall be provided with proper interlocking arrangement for safety of operator.

B. Public Nuisance Protection

There shall be no bolting arrangement on the doors and sides (periphery) so that there is no access

of water & dust inside. This also ensures that the unit is well protected from outside from public nuisance owing to its being located in a crowded and compact places. Hinges and locks on the door shall be so designed that they are either not accessible to public from outside or cannot be

C. Interconnection

The connection of HT switchgear to transformer shall be with the help of suitable size of cables, from transformer to LT switchgear with the help of suitable size of Copper/ Aluminium bus bars. The interconnection inside the unit shall be the responsibility of the supplier.

D. Internal Fault

Failure within the unitized sub-station due to either because of a defect, an exceptional service condition or mal operation may initiate an internal arc. Such event may lead to the risk of injury, if persons are present. It is desirable that the unit shall be tested for Internal arc fault test as per latest IEC 61330.

E. Covers & Door

Covers & doors are part of the enclosure. When they are closed, they shall provide the degree of protection specified for the enclosure. Additional wire mesh may be used with proper danger board for safety of the operator. All covers, doors or roof shall be provided with locking facility or it shall not be possible to open or remove them before doors used for normal operation have been opened. The doors shall open outward at an angle of at least 90° & be equipped with a device able to maintain them in an open position. The top cover shall be slightly inclined so that there is no accumulation of water during rainy season or otherwise. Proper padlocking facility shall be provided for doors of each compartment.

F. Earthing

All metallic components shall be earthed to a common earthing point. It shall be terminated by an adequate terminal intended for connection to the earth system of the installation, by way of flexible jumpers/strips & lug arrangement. The continuity of the earth system shall be ensured taking into account the thermal & mechanical stresses caused by the current it may have to carry. The components to be connected to the earth system shall include.

- (a) The enclosure of sub-station
- (b) The enclosure of high voltage switchgear & control gear from the terminal provided for the purpose
- (c) The metal screen & the high voltage cable earth conductor
- (d) The transformer tank or metal frame of transformer
- (e) The frame &/ or enclosure of low voltage switchgear

G. Internal Illumination

There shall be arrangement for internal lighting activated by associated switch on doors for HV, Transformer & LV compartments separately.

H. Labels

Labels for warning, manufacturer's operating instructions etc. & those according to local Standards & regulations shall be pasted/ provided inside and shall be durable & clearly legible.

I. Painting and Fabrication Process

- (a) The paints shall be carefully selected to withstand tropical heat & rain. The paint shall not

scale off or crinkle or be removed by abrasion due to normal handling. For this purpose, polyurethane (or such other suitable) paint shall be used.

- (b) Special care shall be taken by the manufacturer to ensure against rusting of nuts, bolts and fittings during operation. All bushings and current carrying parts shall be cleaned properly after final painting.
- (c) The fabrication process shall ensure that there are no sharp edges on the GI sheets used. For modular structure the two smaller units shall be joined together by Clinching Technology so that there is no piercing of the material being joined. This type of joint shall ensure robust mechanical strength to the complete structure so made.

1.7.2 11 kV Switchgear (Gas Insulated Compact Switchgear)

Extensible SF-6 Insulated Compact Switchgear as required shall consist of following items.

A. Load Break Cable Switch

Load Break Cable Switch with integral earth switch both having full making capacity shall be used for Incoming and outgoing cables if used in a ring. Suitable arc proof tested cable covers shall be provided for each cable switch. The cable covers accessible from front shall be mechanically interlocked to its corresponding earth switch shall be mechanically interlocked to its corresponding cable switch for safety of the operator.

B. Vacuum Circuit Breaker

Vacuum circuit breaker shall be used for distribution network of HT switchgear. Vacuum Circuit Breaker complete with operating mechanism, self-powered microprocessor based protection relay with associated Current Transformers shall be used for control and protection of transformer. The VCB being fixed type shall be provided with an Isolator in series for isolation purpose for maintenance. An integral cable earthing switch with full making capacity shall be provided. The arc proof cable covers accessible from front shall be mechanically interlocked to the earthing switch, which in turn shall be interlocked to the isolator for safety of the operator.

The above load break cable switches, vacuum circuit breakers, bus bars should be mounted inside a robotically welded sealed stainless steel tank of 3 mm thick sheet metal. The operating mechanism of the switches and breakers shall be outside the SF-6 tank and accessible from front. The tank should be filled with SF-6 gas at adequate pressure. The degree of protection for gas tank should be IP67. There shall be provision for filling the SF-6 gas at site. Moreover, the stainless steel gas tank shall confirm to the sealed pressure system as per IEC and ensure the gas leakage upto 0.1% per year as per IEC.

The VCB is required to control distribution transformer and relay settings and current transformers shall be selected accordingly.

C. General Finish

Totally enclosed, metal enclosed, vermin and dust proof suitable for tropical climate use as detailed in the specification.

D. Ratings

The bus bars shall have continuous rating of 630 Amps. The isolator shall have a continuous rating of 630 Amps. VCB breaker shall have a continuous rating of 200 Amps in accordance with relevant IS/ IEC standard.



E. Breaking & Making Capacity

The load break cable switches shall be capable for breaking rated full load current. The same along with its earthing switch shall also be suitable for full making capacity of the system as specified. The complete switchgear shall be suitable for breaking capacity of 21 KA symmetrical at 11000 volts three phase.

F. Busbar

Switchgear shall be complete with all connection & bus bars etc. Copper bus bars should be of continuous rating of 630 Amps. The bus bars should be fully encapsulated by SF-6 gas inside the steel tank.

G. Protection

The circuit breaker shall be fitted with microprocessor based self-powered relay inside the front cover to avoid any tampering. The same shall be used in conjunction with suitable current transformer and tripping coil for fault tripping of the circuit breakers.

H. Cable Termination

Each cable compartment shall be provided with three bushings of adequate sizes to terminate the incoming and outgoing 11 KV, 3 core cables. There shall be enough height (Minimum 450 mm) from the base to the mounted switchgear so that the cables can be bent and taken vertically up to the bushings. The cable termination shall be done by Heat Shrinkable Termination method so that adequate clearances shall be maintained between phases for termination. Access to all the cables should be possible from the front of panel. Cable termination boots shall be supplied by the switchgear manufacturer.

I. Locking Arrangement

Suitable padlocking arrangements shall be provided as stated below.

- (a) CB manual operating handle in the “OFF” position.
- (b) Each feeder panel operation handles in ‘Closed’, ‘Open’ or ‘Earth’ position.
- (c) Each isolator operating handle in ‘Closed’, ‘Open’ or ‘Earth’ position.

J. Rating

Extensible radial compact switchgear with VCB		
	Switchgear Data	
(a)	Service	Outdoor but inside Enclosure
(b)	Type	Metal Enclosed
(c)	Number of phases	3
(d)	Voltage	11000 V
(e)	Rated Frequency	50 Hz
(f)	Rated Current	630 Amp (isolator)
(g)	Short Circuit rating	
	Breaking	21 kA rms for Breaker
	Short time withstand for 3 sec.	21 kA
	Rated S/C making	52.5 kA peak for Breaker
(h)	Short duration power frequency voltage	28 kV
(i)	Insulation Level	75 kV peak
(j)	System earthing	Solidly earthed at substation

Extensible radial compact switchgear with VCB		
Breaker Data		
(a)	Type VCB in SF6 tank	
(b)	Rated voltage	11 kV
(c)	Breaking current	
	(l) Load breaking	21 kA rms
(d)	Making current	52.5 kA peak
(e)	Rated current	630 Amps
(f)	No. of poles	3
(g)	Operating mechanism	Trip free & free handle type with mechanically operated indication & pad locking.
Isolators		
(a)	Type	Load breaking and fault making in SF6 tank
(b)	Rated current	630 Amps.
(c)	Rated breaking capacity	630 Amps.
(d)	Fault making capacity	52.5 kA peak
(e)	No. of poles	3
(f)	Operating mechanism	Operating handle with ON,OFF,earth positions with arrangement for padlocking in each position.
Bus bars		
(a)	Material	Copper
(b)	Type	SF6 insulated
(c)	Rated Current	630 Amps

Note: This is an indicative example actual rating of equipment differ manufacture to manufacture

K. Testing

Each type of 11 KV Switchgear shall be completely assembled, wired, adjusted and tested at the factory as per the relevant standards i.e. IS 9920, IS 3427, IS 13118, IEC 265 & IEC 298 during manufacturing and on completion. Details of type tests and routine tests is available at Annexure-A.

L. Routine Test

The tests shall include but not necessarily limited to the following.

- Operation under simulated service condition to ensure accuracy of wiring, correctness of control scheme and proper functioning of the equipment.
- All wiring and current carrying part shall be given appropriate High Voltage test. *Annexure-A*

M. Type/Routine Test of Compact Sub-Station

The offered compact sub-station should be fully type tested as per the IEC- 1330

Routine tests- The routine tests shall be made on each complete prefabricated sub-station.

- Voltage tests on auxiliary circuit
- Functional test
- Verification of complete wiring

N. Test Certificates

Test report for the test mentioned under type tests Clause shall be submitted along with the offer. Certified reports of all the tests carried out at the works shall be furnished in three (3) copies for approval of the owner.



O. Compact Bus Bar Trunking System Air Insulated/ Sandwich Specifications

Distribution Application upto 5000 A.

General. Busbar trunking shall be 415 V, 3- Phase, 4-wire with 50% capacity integral earth bus.

Short Circuit Rating and Tests. The short circuit rating of the bus bar trunking shall be determined according to IEC 60439. This rating must be based upon actual tests at the rated short circuit current.

P. Basic Construction Housing

1. The busbar trunking housing shall be constructed of cold gauge steel and aluminium to reduce hysteresis and eddy current losses and shall be provided with a suitable protective finish (ANSI 49 gray epoxy paint).
2. The bus bar trunking housing shall be totally enclosed & non-ventilated for protection against mechanical damage and dust accumulation.
3. The totally enclosed housing shall be manufactured by the bus bar trunking manufacturer. Modifications of bus bar trunking to make it totally enclosed by other than the bus bar trunking manufacturer voids the manufacturer's warranty. Bus bar trunking so modified is unacceptable without the written consent of the manufacturer.

Q. Joint

1. The busbar trunking joint shall be of on-bolt type which utilizes a high strength steel bolt Grade 9 and Belleville washers to maintain proper pressure over a large contact surface area.
2. The bolt shall be torque indicating and at earth potential.
3. The bolt shall be two-headed design to indicate when proper torque has been applied and require only a standard long handle wrench to be properly activated.
4. Access shall be required to only one side of the bus bar trunking for tightening joint bolts.
5. One bus bar trunking 800 A and above, it shall be possible to remove any joint connection assemble to allow electrical isolation or physical removal of a busbar trunking length without disturbing adjacent bus bar trunking lengths.

R. Bus Bars

1. Bus bar joints shall be tin plated or silver flashed or nickel plated.
2. Each bus bar shall be insulated with calls B rated 130° C vendor certified polyester film.
3. The temperature rise at any point in the bus bar trunking shall not exceed 55°C rise above ambient temperature when operating at rated load current.
4. Both feeder and plug-in bus bar trunking (800 A and above) shall be of sand with construction, meaning no air gap shall exist between bus bars except at plug-in openings.

S. Plug-in Opening.

1. On plug-in busbar trunking there shall be suitable dead front, covered type plug-in openings as per site requirement.
2. All openings shall be usable simultaneously.
3. Bus bar trunking shall be installed so that plugs are side mounted to permit practical use of all openings.
4. It shall be possible to inspect the plug-in opening and bus bars prior to the installation of the plug-in units.

As requirement is for a compact bus bar system, clearance and creepage distances are to be

kept to minimum i.e. clearance in vicinity of 15 mm and creepage distances corresponding to pollution degree 3 and material group III a i.e. 16 mm.

For guidance, the overall cross section should be limited to following dimensions and not vary more than $\pm 10\%$

T. Aluminium Bus Bar

Current rating (Amp.)	160	250	400	500	630	800	1000	1250
Dimensions (mm)								
Width	150	150	150	150	150	150	150	150
Depth	60	75	100	120	140	200	230	280

U. Copper Bus Bar

Current rating(Amp.)	125	250	315	400	500	630	800	1000	1250	1500	1750	2000
Dimensions (mm)												
Width	150	150	150	150	150	150	150	150	150	150	150	150
Depth	60	60	75	75	95	95	115	135	190	230	130	270

Temperature rise of the enclosure and terminals are to be restricted to 40 deg. C and 70 deg. C respectively.

V. Support of bus bar Trunking

- Hanger spacing shall be noted on layout drawing and shall not exceed manufacturer's recommendations.
- Indoor Feeder and plug-in bus bar trunking shall be approved for hanger spacing of upto 3 metres for horizontally or vertically mounted runs.

W. Voltage Drop

- The voltage drop (input voltage minus output voltage) specified shall be based on the bus bar trunking operating at full rated current and at stabilised operating temperature.
- The three-phase, line-to-line voltage drop shall not exceed 3.1 volts per hundred feet at 40% power factor concentrated load which may exist during motor starting.
- The line-to-line voltage drop shall not exceed 4.0 volts per hundred feet at the load power factor which produces maximum voltage drop in the bus bar trunking.

X. Plug-in Units

- Plug-in Units (Circuit breaker type or fusible switch type) shall be operated with visible blade quick-make and quick-break mechanism.
- Plug-in Units which cannot be operated directly from the floor shall be equipped with suitable means for hook stick operation.

Y. Plug-in Unit Safety Devices

- Plug-in unit enclosures shall make positive earth connection with the earth bus before the jaws make contact with the phase bars. The earthing method shall be such that it cuts through painted surfaces to make the positive earth connection.

- (b) The Plug-in units shall be equipped with internal barriers to prevent accidental contact of tape and conductors with live parts on the line side of the protective device during time of wire pulling.
- (c) Covers of all plug-in units must have interlocks to prevent the cover from being opened when the switch is in the ON position.
- (d) The rising mains shall have neutral of 100% capacity as of phases.
- (e) IP protection shall be IP 54.
- (f) The joints shall be silver (or such other system) for high reliability.

1.8 Commissioning of Substation

Before commissioning a substation, it is essential to perform the following tests:

A. Transformers

- i. IR value between primary winding and earth.
- ii. IR value between secondary winding and earth. IR value between primary & secondary windings.
- iii. Voltage ratio between primary & secondary windings. Di-electric test of transformer oil.
- iv. In addition to the above tests, the following checks shall be made:
- v. Oil level.
- vi. Functioning of tap changer.
- vii. Functioning of Buchholz relay if provided and its connections to the trip circuit.

B. Circuit breakers

- i. IR value between incoming contacts and earth. IR value between outgoing contacts & earth.
- ii. IR value between incoming and outgoing contacts.
- iii. In addition to the above, it is essential to check up all relays for proper functioning.

C. Equipment

It is necessary to check the IR values of the following equipment in addition to ensuring proper sizes of fuses in the metering circuits.

- i. CTs. PTs.
- ii. Metering circuit. Cables.
- iii. Bus bars.

1.8.1 Maintenance of Sub-station

a. Function

Electrical General Services Sub-station is a distribution sub-station from which electric supply is distributed to the different users. In a substation there are numbers of incoming and outgoing circuits each having its isolator, circuit breaker, transformers etc. connected to bus-bar system. These equipment are mostly static type. Safety and protection of equipment as well as working personnel is also a considerable factor. Lightning arresters, earthing of equipment and fencing is done for this purpose. Maintenance of a sub-station is essential to ensure un-interrupted electric supply to the using points which involves vigilance, care and well-defined scheme of procedures. Such scheme indicates

the authority and responsibility of persons at various levels. It consists of many of periodic schedule maintenance, regular inspections, testing and rectification of defects.

b. Permit to work for Maintenance

The “permit to work” is to be issued through permit card only by an authorized person. As the name suggests it authorizes the maintenance supervisor and his team to carry out work. Further, this card will indicate unambiguously the points at which it is safe to work, the time interval when it is to be done, steps to be taken to ensure safety such as earthing, display of danger notices etc. at the nearest live point. It should have the signature of the authorized person. After the work is completed the permit card should be cancelled and it should be taken back. Danger notices should be put up or removed by the responsible supervisor who will take the charge of keys equipment, rooms, etc.

c. Equipment in Distribution Sub-station

The following equipment are installed in Electrical General Services Sub-station:

- i. Distribution Transformer
- ii. Circuit breaker
- iii. Lightning Arrester
- iv. Air Break (AB) switches/ Isolator
- v. Insulator
- vi. Bus-bar
- vii. Capacitor Bank
- viii. Earthing
- ix. Fencing
- x. Distribution panel board

d. Maintenance schedules of substation equipment

The schedule maintenance of equipment installed in sub-station is essential to ensure trouble free service and avoiding un-necessary interruptions. Following safety precautions should be observed during maintenance of transformers:

- i. Ensure all arrangements are safe.
- ii. Isolate the transformer from supply and earth the terminals properly.
- iii. Check & record the oil level in the tank before unseal the tank and unscrew the nuts and bolts.
- iv. Ensure the work place is fire proof; care should be taken to prevent fire.
- v. Put a caution board “NO SMOKING”.
- vi. The staff should not have anything in his breast pocket and should not wear watch or ring.

Item wise activities involved in various schedules of sub-station equipped with transformers up to 1000 kVA are as follows:

A. Daily Schedule (Manned Substation)

Items	Schedule Inspection	Action required
Switch yard		
All jumpers & other connections	Check visually for flash/spark marks	Check visually for flash/spark marks
Transformer		

Items	Schedule Inspection	Action required
Temperature	Check oil temperature during peak load hours. Check ambient temperature	Either switch off some load or share with other transformer
Tank	Check for oil leakage	Arrest the leakage
Dehydrating Breather	Check visually colour of silica gel	Ensure blue colour of silica gel
Control Panel Room		
Relays	Check visually target position	Take corrective action
MCCB/Fuse	Check visually for flash/ Spark/overheat marks	Tighten the clamp/ connection and replace if defective
Load (amp.)	Check against rated figure	Reduce load if higher
Voltage	Check against rated figure	Take corrective action
PF meter	Monitor the PF reading	Take corrective action. It should be nearly unity
General	Ensure general cleanliness of room and panels	
Capacitor Bank		
All connections	Check visually for flash/ spark marks	Tighten the clamp/ connection

See Annexure- A

B. Monthly Schedule

In addition to daily maintenance, carry out following works:

Items	Schedule Inspection	Action required
Switch yard		
Yard	Growth of unwanted shrubs, garbage etc.	Keep the yard free from shrubs, garbage etc.
Earth pits	Check neatness and tidiness	Maintain tidiness and do watering
Earth connections	Check all connection ends at earth pits and metal parts	Ensure solid connection
Transformer		
Oil level	Check oil level in conservator	If low, top up with dry oil
Connections	Open terminal box cover and check connections visually for flash/spark marks	Take corrective action
Dehydrating breather	Check air passages. Check colour of silica gel	Clear passages, if required. Reactivate silica gel if found pink
Cleaning	Entire transformer body externally	Clean entire transformer externally including bushings
Buchholz Relay	Check gas in the chamber	Take corrective action
Control Panel Room		
Load (amp.)	Check load balancing	If found unbalance, distribute the load equally on all phases
MCCB/Fuse	Check current ratings	Provide proper size of MCCB/Fuse according to load condition

See Annexure –B

C. Quarterly Schedule

In addition to monthly maintenance, carry out following works:

Items	Schedule Inspection	Action required
Switch yard		
Support Insulators	Examine for cracks, rust and flash/spark marks	Clean and replace if required
Lightning arresters	Check line and earth connection	Clean and ensure rigid connection
AB switch/ Isolator	Check for proper operation Check line and earth connection	Clean and lubricate Ensure rigid connection.
Jumpers	Check all jumpers.	Tighten, if required.
HT bus bars	Examine bus-bar expansion joints etc.	Tighten, if required
Transformer		
Bushing	Examine for cracks, rust and flash/spark marks. Check for oil seepage	Clean and replace if required. Arrest leakage
Control Panel Room		
Load (amp.)	Check load balancing	If found unbalance, distribute the load equally on all phases
MCCB/Fuse	Check condition of overheating	Replace, if required
LT Bus bars	Check visually for overheating, flash/spark marks	Take corrective action

See Annexure- C

D. Half Yearly Schedule

In addition to quarterly maintenance, carry out following works:

Items	Schedule Inspection	Action required
Transformer		
Oil	Check BDV	If BDV < 30 kV/cm, do Filtration to restore quality of oil.
Cable box, gasket joints and gauges	Inspect for leakage and cracks	Take corrective action
Control Panel Room		
Load (amp.)	Check load balancing	If found unbalance, distribute the load equally on all three phases
Oil Circuit Breakers	Check oil level in the tanks. Test the oil, if shows signs of moisture, carbonization or dirt. Check all valves for oil leakage. Check the condition of all gaskets provided to prevent entrance of water and leakage of oil.	Maintain at the proper height. Filter or replace if necessary. Arrest leakage Ensure they are healthy.
Air Circuit Breakers	Check entire unit Check contacts Operation Check tripping of relay	Clean with lint free cloth Clean fixed and moving contacts Clean and lubricate operating mechanism Re-set if required

See Annexure- D

E. Yearly Schedule

In addition to quarterly maintenance, carry out following works:

Items	Schedule Inspection	Action required
Switch yard		
Concreting/coping of the supports	Check the condition of the concreting/ coping of the supports of the structures. The supports fixing to earth become wear and during the time of heavy rains, cyclone or flooding, the structure may fall, leading to a major breakdown.	If there are cracks or the coping of concreting is coming off, preventive action may be taken to concrete or coping.
Gravel/crushed rock	Check leveling, oil stain and dust accumulation	Spray water to remove oil stain and accumulated dust. Maintain leveling to avoid formation of waterpools.
Earth resistance	Measure the earth resistance of individual equipment earth pit, preferably during summer	If it is beyond permissible limits, take corrective action
Earth connection of metal parts	Check the earth connection of metal parts to ensure that the metal parts are properly connected to the earth so that any earth fault of the metal parts is cleared quickly and efficiently. If not, accidents may happen.	Take corrective action
Air Break switches	Check operation Check the line and earth connection of AB switches	Lubricate and ensure proper operation Ensure they are connected properly
HT lightning arresters	Measure IR value Line-Earth. Check the line and earth connection of HT lightning arresters	If low, replace it. Ensure they are connected properly
Connections from and to bus-bars	Check the connections	Tighten the connections properly from the bus bars and bars to the lines
Transformer		
Winding	Measure IR value HV-Earth HV-LV LV-Earth	If low, investigate and take corrective action
Oil	Check BDV Check for incipient faults	As per IS 1866: 2017 for Class C Transformer BDV should be >40 for good 30 to 40 for fair <30 for poor Value. Good: Continue normal sampling. Fair: More frequent sampling. Check other parameters, e.g. water content and perhaps acidity. Poor: Recondition the oil
Buchholz relay, alarms and their circuits etc.	Check floats, alarm contacts, their operation, fuses etc. Check relay accuracy, etc.	Clean components and replace contacts and fuses if necessary. Change the setting, if necessary.
Earth resistance	Check values of earth resistance	If high, investigate and take corrective action
Body	Check for peelings/ rusting/ damage	Repaint, as required
Cable Box	Check the sealing arrangement for filling holes	Ensure sealing arrangement for filling holes

See Annexure- E

Additional Yearly Schedule

In addition to yearly maintenance, carry out following works:

Items	Schedule Inspection	Action required
Switch yard		
Gravel/crushed rock	Check condition, up layer and size	Remove rounded pieces and muck by screening. Maintain up layer of 100 mm by additional quantity of size 40mm
Transformer		
Conservator	Inspect inside for sludge etc.	Clean or flush inside with oil
Core and windings	Overall inspection including lifting of core and coils	Wash with clean dry oil.
Rollers	Examine carefully during overhauling	Grease them properly
Circuit breaker	Examine carefully during overhauling	Overhaul every circuit breaker completely

1.9 Maintenance Details of Important Equipment

1.9.1 Transformer

The principal object of transformer maintenance is to maintain the insulation in good condition. Moisture, dust and excessive heat are the main reasons of insulation deterioration and avoidance of these will keep insulation in good condition

1.9.1.1 Oil

- Leakage of excessive oil to be investigated and repaired as early as possible.
- Maintain the record of oil used and always prefer the same make of oil for topping up or replacement. The oil of different makes may be separated into layers. The mixture of oil have greater tendency to form acidity or sludge.
- Never use the released oil even if the same make.
- Never mix the transformer oil to the oil of switchgear equipment.
- Only the dielectric strength does not indicate the healthy condition of oil. Therefore in addition to chemical tests other tests such as acidity test, test for polar contaminants, sludge also to be carried out.
- If the acidity exceeds limits, open the cover to ascertain the condition of interior of tank, core and windings. Take suitable action if sludge or corrosion is evident.
- DGA: Dissolve Gas Analysis** to assess the internal condition of the transformer.

1.9.1.2 Transformer Body

- Ensure correct pressure for tightening the nut and bolt at joints. Replace the gaskets as and when opened the gasket joints.
- Measure the insulation resistance without disturbing thing.
- Properly clean the tank cover before opening it.
- Remove all nuts and bolts etc. and keep them properly, before removing the cover.
- Dismount bushings, if mounted on top. Remove the cover carefully if core and windings are separate. If core and windings are suspended from tank cover, provide eye bolts on the cover for lifting along with core and winding. Care should be taken to ensure vertical removal of the core. After lifting the core, recount and tally the spanners and tools used.
- The spanner should be cleaned and to be held by cotton strap or string tied round.
- The waist or wrist of the staff opening tank cover.



1.9.1.3 Core and Windings

1.9.1.4 Lifting the Core and Coils

- i. Remove the fixing devices if core and coils are suspended, from each end near the top.
- ii. Unload the connections of bushings and remove the bushings from tank walls.
- iii. Remove mechanical connection to the tap changing switch handle, if any.
- iv. Remove any earthing strips between the core clamps and tank.
- v. Lift the core and coils vertically by slinging it from lifting lugs provided on core. Make sure that the sling does not foul against connections, tapping switch etc.
- vi. Allow the core and coils to drain oil into tank for some time.
- vii. Now lower them on beams placed in a metal tray filled with saw dust or sand.

1.9.1.5 Inspection

- i. Ensure that everything is intact correctly.
- ii. Leads are not pulled out of their places.
- iii. Ensure tightness of nuts and bolts.
- iv. Clean the sludge by transformer oil and ensure that ducts are not blocked.
- v. Clamp the windings firmly without any movement. Adjust the vertical tie bars to tighten loose windings or spacers. Properly tight the special coil adjustment bolt, if provided.
- vi. Check the proper operation of tap changing switch.
- vii. Tighten all connections.
- viii. Conduct insulation resistance test and take the corrective action.
- ix. Remove sludge deposition at the bottom of tank.

1.9.1.6 Bushing

- i. Clean the bushing porcelain and examine for cracks and chips. Replace if required.
- ii. If the bushing is below oil level, lower the oil until it is below the bushing hole.
- iii. If only the porcelain is to be changed it may not be necessary to undo the internal bushing connection, for, in some cases the bushing stems are joined by an insulated bar to prevent them from turning when the nuts are undone. All the nuts at the top of the bushing should be removed and the old porcelain lifted straight up over the central stem, which remain in place. Slide the new porcelain down over the stem and tighten the nuts. Too much strain on the porcelain should not be applied when tightening the connections. Change only one porcelain at a time. If the insulated bar between the bushing stems is not provided, the internal connections should be undone and the whole bushing removed before the porcelain is changed and then replace the porcelain.
- iv. When a complete bushing is to be changed the internal connection to the bushing should be undone. If the replacement bushing has a socket at the bottom end, the old bushing should be unclamped and withdrawn from the tank. Now unplug the flexible lead from the old bushing and plugged into the new one, which is then lowered into the hole in the tank and re-clamped firmly but not too tightly.

1.9.1.7 External Connection

- i. The bluish tinge characteristic of metal indicates overheating. Either it become loose or dirty or the size of conductor is not suitable for carrying current.
- ii. A small copper loop to bridge the top cover of the transformer and the tank may also be provided

to avoid earth fault current passing through the fastening bolts when there is a lightning surge, high voltage surge or failure of bushings.

1.9.1.8 Conservator and Magnetic Oil Gauge

- i. The oil level indicator should always be kept clean.
- ii. Replace the broken transparent material of level indicator immediately.
- iii. Examine the mechanism of oil gauge functioning properly during cleaning of conservator.

1.9.1.9 Breather

There are generally two types of breathers used on a transformer:

- (a) Plain breather
- (b) Silica gel breather
- (c) The end of the plain breather should be kept clean and the ventilation holes free of dust. If an oil seal has been provided, the oil should be wiped out.
- (d) Silica gel dehydrating breathers are fitted with a sight glass so that the colour of the crystals may be seen. The colour changes from blue to pink as the crystals absorb moisture. When the crystals get saturated with moisture they become predominantly pink and should therefore be reactivated. The body of the breather should be removed by undoing the nuts. If the crystals have been kept in an inner container, the container should be removed, but if they are not, the crystals should be removed into a shallow tray. The crystals should be backed at a temperature of about 200°C until the whole mass is restored blue colour. Clean the breather and place the dry and blue crystals. Renew the oil in the sealing cup at the bottom.

1.9.1.10 Buchholtz Relay

- i. During operation if gas is found to be collecting and giving alarm, the gas should be tested and analyzed to find out the nature of fault. Sometimes, it is noticed that the gas collecting is only air. The reasons for this may be that the oil is releasing any absorbed air due to change in temperature or due to leakage on the suction side of pump. The absorbed air is released in initial stages only when no vacuum is applied during filling of oil. The internal faults can be identified to a great extent by a chemical analysis of gas.
- ii. Routine operation and mechanical inspection/tests should be carried out at one and two yearly intervals respectively.
- iii. The operation is tested by injecting air into the relay through the lower petcock of a double float relay for the 45° petcock of a single float relay. After inspection, any air which has accumulated in the upper gas chamber must be released by the upper petcock, by filling the chamber with oil.
- iv. To carry out mechanical inspection, the oil level must be brought below the level of relay. Both floats should be able to rise and fall freely. Relay should give alarm/trip due to the oil level falling below the Buchholtz level. The mercury switches should be tightly clamped. If the glass of a mercury switch is cracked, it must be replaced.

1.9.1.11 Explosion Vent

- i. Frequently inspect diaphragm of the vent and replace if required.
- ii. An investigation should be carried out to determine the nature and cause of the fault before replacing the broken diaphragm.

1.9.1.12 Gaskets

Check the tightness of all bolts fastening gasketed joints. To avoid uneven pressure, the bolts should be tightened evenly round the joints. Leaking gaskets should be replaced as soon as the circumstances permit.

1.9.1.13 Pipe Work

- i. Inspect the pipe work for leakage due to slack unions, mis-alignment.
- ii. Align the pipe and remade the joint.

1.9.1.14 Temperature Indicators

At each yearly maintenance inspection, the level of oil in the pockets holding thermometer bulbs should be checked and the oil replenished, if required. The capillary tubing should be fastened down again if it has become loose. Dial glasses should be kept clear and if broken, replaced as soon as possible to prevent damage to the instrument. Temperature indicators should be calibrated with standard thermometer immersed in hot oil bath if found to be reading incorrectly.

1.9.1.15 Spares

It is a healthy practice to have essential spares like one member of each type of bushings, one spare limb winding, one thermometer, one cooling fan, etc, for each group of similar transformer.

1.9.2 Oil Circuit Breakers

Circuit breakers usually need more frequent and more prolonged maintenance. In general, for maintenance of CB the instructions of manufacturer should be followed. A few salient points on maintenance of CB are given below

Under normal operating conditions during regular inspections following checks should be done:

1. The contacts should be checked for proper alignment.
2. The oil level should be checked and maintained.
3. The oil condition should be tested, if dielectric strength is lower than specified, oil should be filtered. While taking oil samples normal precautions should be followed. If water is found an investigation of the cause should done and a remedial action should be taken.
4. All insulating parts should be thoroughly cleaned to remove all traces of carbon which may remain after the oil has been drained from the tank.
5. Check the functioning of the breaker through devices which will have to function on fault or overload.
6. Check indicating devices such as mechanical ON and OFF indication, as an incorrect indication may at sometimes lead to a fatal accident.
7. Check auxiliary switches for cleanliness and correct contact making.
8. If a CB operate under fault conditions to interrupt a fault, then maintenance after Such occurrences should be carried out giving special attention to the following items:
 - i. Current carrying parts: All contacts including isolator contacts should be examined,dressed or replaced if necessary.
 - ii. Insulation should be cleaned to remove carbon deposits. Examination to be made of cracks, tracking or other damages.
 - iii. Arc control devices should be checked and dismantled, if any carbon or metallic deposits are found, these should be removed.

- iv. All joints and seal should be examined for tightness.
- v. Oil should be checked in case of oil circuit breaker.
- vi. The general inspection for any mechanical damage or distortion of the structure and mechanism should be made. The switch gear should be closed and tripped by each of the methods provided.

1.9.3 Air Break Switch/Isolators

The ease of maintenance is mainly a question of access. This is influenced by the method of mounting. Isolators mounted upside down, or with their insulators horizontal often present access problem. During maintenance insulators are cleaned with lint free cloth slightly soaked in gasoline. The conditions of all contacts are checked and on detecting any trace of burning, defective contacts are cleaned or replaced with new ones. Old grease is washed from the insulation rubbing the part with kerosene and a thin layer of fresh grease is applied. Loose bolts and nuts are tightened at all points. The operating mechanism of isolator is checked by closing and opening each isolator several times with the line de-energized.

When adjusting the mechanical part of 3 phase isolators, the switch blades are checked for simultaneous closing isolator blades are checked for ease of engagement with fixed contact jaws.

Isolator contacts must make a close fit in order to avoid excessive heating when closed. This is checked by feeler gauge of 0.05mm (10mm wide). Contact springs are checked both in compressed and free state. Contact surface are coated with acid free petroleum jelly containing minute quantity of graphite.

1.9.4 HT/LT panels

Control panel equipment comprise of HT and LT panels and it is centralized location where all automatic and manual commands are generated. It is central location to perform monitoring, protection and maintenance of substation. HT panels comprise switchboard assembly which includes bus-bars, relays and instruments, control wiring, cable boxes and Vacuum Circuit Breaker (VCB). LT panel comprises switchboard assembly which houses bus-bars, instruments, control wiring, MCCB and Air Circuit Breaker (ACB). Details of preventive maintenance and tests to be conducted on them are enumerated.

1.9.5 Switchboard Assembly

1.9.5.1 Preventive maintenance

Perform the following visual inspections and tests including evidence of moisture.

Also visually inspect all doors, panels and sections for paint, dents, scratches and fit

- (a) Inspect for physical, electrical and mechanical condition.
- (b) Compare equipment nameplate information, including CT and PT ratio, fuse sizes and communication links with the latest one-line diagram and report discrepancies. If nameplate is damaged/missing, install properly labeled engraved plastic nameplate, using rivets or screws.
- (c) Inspect for proper alignment, anchorage, grounding and required area clearance.
- (d) Key interlock systems must be physically tested to ensure proper function. Closure attempt must be made on locked open devices. Opening attempt must be made on locked closed devices.
- (e) *Note - When working on key interlock systems, the key exchange procedures must be observed at both the beginning and end of the job, to ensure that the system cannot be energized without the knowledge of all individuals involved.*



- (f) Inspect for cleanliness and need of lubrication.
- (g) Exercise all active components (providing plant operation is not jeopardized).
- (h) Inspect all indicating devices for proper operation.
- (i) Enter switchboard and perform complete inspection looking for:
 - i. Proper anchoring
 - ii. Grounds or shorts
 - iii. Evidence of overheating or arcing
- (j) Cable arrangements and supports, cracked or damaged insulator
- (k) Inspect fuse clips for tightness and alignment.
- (l) Inspect operation of shutters.
- (m) Inspect all internal heaters.
- (n) Inspect and align all disconnects.
- (o) Thoroughly vacuum and clean interior (especially the insulating supports for the bus).
- (p) Examine assembly for evidence of leakage from an outside source, such as roof or wallseams, and report any deficiencies found.
- (q) Examine vents and verify filters are clean (i.e., equipped with filters).

1.9.5.2 Test Requirements

- (a) Measure insulation resistance of each bus section phase-to-phase and phase-to-ground for one (1) minute. Test voltage and minimum acceptable resistance values must be in accordance with relevant IS. If additional criteria are utilized, they must be documented as to their source.
- (b) Perform a DC over potential test on each bus section phase-ground. Voltage application must be for one (1) minute. Test voltage must be in accordance with manufacturer's recommendations.
- (c) Measure insulation of control wiring to ground.
- (d) Where applicable, use the elementary diagrams of the metal clad switchgear to identify each remote control and protective device. Conduct tests as required to verify satisfactory performance of each of the control features.
- (e) Determine available fault current from utility or primary source and compare with main circuit breaker interrupting capability.
- (f) If heat is evident with IR scanning/testing, then a high resistance test is required using a resistance ohmmeter and check tightness by using a calibrated torque wrench.
- (g) NOTE - Refer to manufacturer's instruction for proper torque levels. If connections are not accessible, an infrared survey should be made with system in operation to identify high resistance connections.
- (h) Bolt torque levels must be in accordance with manufacturer's recommendations.
- (i) Perform insulation-resistance tests on Control and Power Transformers. Perform measurements from winding-to-winding and each winding-to-ground.
- (j) Verify correct function of control transfer relays located in switchgear with multiple power sources.
- (k) Perform insulation-resistance tests on Voltage Transformers. Perform measurements from winding-to-winding and each winding-to-ground. Verify secondary voltages.

1.9.6 High Voltage Vacuum Circuit Breaker (HV VCB)

A. Preventive maintenance

Perform the following inspections and test

- (a) Inspect for physical damage, cleanliness, and adequate lubrication. Clean and lubricate as necessary.
- (b) Inspect anchorage, alignment, and grounding.
- (c) Perform all mechanical operational tests.
- (d) Check tightness of bolted bus joints with a calibrated torque wrench. Refer to manufacturer's instruction for proper foot pound levels.
- (e) Check the cell fit and element alignment.
- (f) Ensure that all maintenance devices required to service and operate the equipment are available.

B. Test Requirements

- (a) Measure contact resistance.
- (b) Perform minimum pickup voltage tests on trip and close coils.
- (c) Perform insulation resistance tests, pole to ground, pole to pole, and across open pole.
- (d) Perform insulation resistance test at 1000 volts DC on all control wiring. (Do not perform the test on wiring connected to solid state relays.)
- (e) If charging motors are used, check condition of brushes and limit switches.
- (f) Perform vacuum bottle integrity (over potential) test across each vacuum bottle with the breaker in the open position in strict accordance with manufacturer's published data. Do not exceed maximum voltage stipulated for this test. Provide adequate barriers and protection against x-radiation during this test. Do not perform this test unless the contact displacement of each interrupter is within manufacturer's tolerance. (Be aware that some dc high-potential test sets are half-wave rectified and may produce peak voltages in excess of the breaker manufacturer's recommended maximum.)

C. Test Values

- (a) Contact resistance must be determined in micro-ohms. Resistance values must not exceed 500 micro-ohms. Consult the manufacturer for acceptable range.
- (b) Power factor and arc chute watts loss must be no greater than the manufacturer's allowable value.

1.9.7 Low Voltage Air Circuit Breaker (LV ACB)

1.9.7.1 Preventive maintenance

Perform the following inspections and tests:

- (a) Inspect for physical damage, cleanliness, and nameplate compliance with one-line diagram. Clean and lubricate as necessary.
- (b) Mechanical operational tests must be made in accordance with manufacturer's instruction manual.
- (c) Check the cell fit and element alignment.
- (d) Check tightness of connections.
- (e) Dashpots must be removed, inspected, cleaned, refilled with proper oil, and tested for operation.



- (f) Closely inspect the operation of main and arcing contacts of the circuit breaker to ensure that the springs responsible for maintaining primary contact pressure are in good condition.
- (g) If circuit breakers are of the draw out type, closely examine the disconnecting devices at the rear of the circuit breaker. Inspect for any deterioration of springs that might result in high contact resistance of primary disconnects.

1.9.7.2 Test Requirements

- (a) Perform a contact resistance test.
- (b) Perform an insulation resistance test at 1000 volts DC for one (1) minute from pole-to-pole and from each pole-to-ground and across open contacts of each phase.
- (c) Determine the long time delay by primary injection at three hundred percent (300%) pickup current. (See EXCEPTION)
- (d) Determine the short time pickup and time delay by primary injection of current. (See EXCEPTION)
- (e) Determine the instantaneous pickup current by primary injection. (See EXCEPTION)
- (f) Verify the trip unit reset characteristics.
- (g) If provided, adjust the final settings in accordance with the engineer's prescribed settings, based on a coordination study.
- (h) Activate the auxiliary protective devices, such as ground fault or under-voltage relays, to ensure operation of shunt trip devices.
- (i) If the circuit breaker has a charging motor, the springs and other devices associated with this charging motor must be inspected closely. The circuit breaker must be electrically operated to verify the performance of the limit switches responsible for stopping and starting the charging motor.
- (j) Test circuit breakers with solid state trips according to manufacturer's instructions.

EXCEPTION - Breakers equipped with solid state trip units may perform secondary injection in lieu of primary injection at every other test interval. (e.g., 10-year intervals for primary injection and 5-year intervals for secondary injection).

NOTE - Primary injection is recommended to evaluate complete trip circuit operation. Secondary injection can be used for evaluating the electronic portion of the trip unit.

1.9.7.3 Test Values

- (a) Determine contact resistance in micro-ohms or voltage drop in millivolts. Values that deviate from adjacent poles or similar breakers by more than fifty percent (50%) must be investigated.
- (b) Insulation resistance must not be less than fifty (50) mega-ohms.
- (c) Do not use a mega-ohm meter on solid state devices.
- (d) Minimum pickup current, trip times and instantaneous pickup values should be adjusted to engineered settings. Test values must fall within manufacturer's published time-current characteristic tolerance band.

1.9.8 Moulded Case Circuit Breaker (MCCB)

1.9.8.1 Preventive maintenance

Visual and Mechanical Inspections

Perform the following inspections and tests:

- (a) Clean and Check the circuit breaker for proper mounting, conductor size, and feed designation.
- (b) Operate circuit breaker to ensure smooth operation.
- (c) Inspect case for cracks, heat damage, or other defects.
- (d) Check tightness of connection with a torque wrench in accordance with manufacturer's recommendations.
- (e) Open all unsealed breakers and check internal components for tightness.

1.9.8.2 Test Requirements

- (a) Measure the contact resistance.
- (b) Perform a time-current characteristic test by passing three hundred percent (300%) rated current through each pole separately. Trip time must be determined and compared to manufacturer's specifications. (See EXCEPTION).
- (c) Determine the instantaneous pickup current by run up or pulse method. Clearing times must be within four (4) cycles or less. (See EXCEPTION).
- (d) Determine the insulation resistance pole-to-pole, across pole, and pole-to-ground. Test voltage must be 1000 volts DC. (See EXCEPTION).

EXCEPTION - Breakers equipped with solid state trip units may perform secondary injection in lieu of primary injection at every other test interval. (e.g., 10-year intervals for primary injection and 5-year intervals for secondary injection).

1.9.8.3 Test Values

- (a) Compare contact resistance to adjacent poles and with similar breakers. Deviations of more than fifty percent (50%) must be investigated.
- (b) Insulation resistance must not be less than fifty (50) Mega ohms.
- (c) All trip times must fall within those given in NETA Maintenance Test Specifications Electrical Power Distribution Equipment and Systems. Circuit breakers exceeding maximum three hundred percent (300%) time must be replaced.
- (d) Instantaneous pickup current levels must be within twenty percent (20%) of manufacturer's published values.

1.9.9 Protective Relay

A. Preventive maintenance

Perform the following inspections and tests:

- (a) Inspect relays for physical damage, cleanliness, mechanical and electrical operation.
- (b) Inspect cover gasket, cover glass, condition of spiral springs, and disc clearance.
- (c) Inspect for presence of foreign material, moisture, and rust on all contacts.
- (d) Check mechanism for freedom of movement, proper travel and alignment, and tightness of mounting hardware and tap screws.
- (e) All settings should be in accordance with the coordination study.
- (f) Inspect all shorting contacts for normal operation.
- (g) Examine condition of bearings.
- (h) Examine contacts and backstops.
- (i) Clean and remove foreign matter from permanent magnet and disc.



B. Test Requirements

- (a) Perform an insulation resistance test on each circuit to frame. (Do not perform this test on solid state relays.)
- (a) Perform the following tests with nominal settings as specified by the manufacturer:
 - 1. Pickup parameters on each operating element.
 - 2. Perform timing at three (3) points on performance curves.
 - 3. Pickup targets and seal in units must operate properly.
 - 4. Perform special tests as required to check operation of resistance, directional and other elements per manufacturer's instruction manual.
- (c) Perform phase angle and contribution tests on all phase sensitive relays.
- (d) Check all protective relays to ensure they are subjected to the correct electrical signals (amps, volts, watts, etc.).

1.9.10 Instrument Meter

1.9.10.1 Preventive maintenance

Perform the following inspections and tests:

- (a) Examine all devices for mechanical or electrical damage and wire connection tightness.
- (b) Check condition of meter face and face gaskets.
- (c) Clean unit.

1.9.10.2 Test Requirements

- (a) Verify all instrument multipliers.
- (b) Meter selector switches must be inspected for proper application and operation.

1.10 Infrared Thermal Scanning

Abnormal heating associated with high resistance or excessive current flow is the main cause of many problems in electrical systems. Infrared thermography allows to see these invisible thermal signatures of impending damage before the damage occurs. Thermal imagers enable human eyes to see the heat signatures associated with high electrical resistance long before the circuit becomes hot enough to cause an outage or explosion. There are basically two basic thermal patterns associated with electrical failure:

- (a) a high resistance caused by poor surface contact and
- (b) an over loaded circuit or multi-phase imbalance problem.

Hence, Infrared Thermal Imaging has emerged as a powerful tool for carrying out Preventive maintenance. The biggest advantage is that it allows testing while the equipment are in live state.

1.10.1 Procedure for Infrared Thermal Imaging

Perform the following inspections and tests:

- i. Inspect the physical, electrical, and mechanical condition.
- ii. Remove all covers required to permit scanning prior to the scanning

Equipment to be Scanned Under Load:

Switches, bus duct, switchgear, transformers, cables, cable connections, circuit breakers, terminations, motor control centers, junction boxes and battery system.

NOTE - The survey should be performed with the equipment to be scanned in an energized state, and loaded to at least forty percent (40%) of load capacity and under load for at least an hour; for beneficial test results.

1.10.2 Scanning Report

Provide Report Indicating the following:

- i. Problem area with location of “hot spot” to include building name, panel or component number, floor or mezzanine and column coordinate. Provide coloured IR images and digital photos of each deficiency identified during the IR testing.
- ii. A prioritized listing of the deficiencies listed in the report.
- iii. The suspected cause of the abnormal temperature.
- iv. Any phase imbalance.
- v. An index of areas scanned.
- vi. The report shall be submitted in hard copy and in soft-copy (CD or other as specified). The soft copy shall include all images scanned of major components

1.11 Maintenance Proforma

Maintenance schedules of substation equipment have been detailed in Section 3.3.

Maintenance proforma pertaining to these schedules are enclosed as Annexures

- (a) Daily Maintenance Proforma (Annexure A)
- (b) Monthly Maintenance Proforma (Annexure B)
- (c) Quarterly Maintenance Proforma (Annexure C)
- (d) Half Yearly Maintenance Proforma (Annexure D)
- (e) Yearly Maintenance Proforma (Annexure E)

1.12 Do's and Dont's

1.12.1 Do's

- i. Ensure all safety arrangement while working on electrical installation.
- ii. Ensure that all tools & tackles are in good & working condition.
- iii. Check and thoroughly investigate the transformer whenever any alarm or protection isoperated.
- iv. Check the protection system periodically.
- v. Ensure every employee is familiar with the instructions for restoration of persons suffering from electric shock.
- vi. Trained the staff in operating the fire-fighting equipment.
- vii. Always avoid un-balance loading on phase.
- viii. Do earthing of all points before starting maintenance.
- ix. Keep all spares away from dirt.
- x. Work with full confidence.
- xi. Ensure thorough and full cleaning of insulators, since partial cleaning is worse than no cleaning.
- xii. Ensure perfect isolation of supply before commencement of maintenance work.
- xiii. Put a caution board when on work.

1.12.2 Don'ts

- i. Don't use low capacity lifting jacks on transformer.
- ii. Don't leave circuit tap switch unlock.
- iii. Don't leave any loose connection.
- iv. Don't meddle with protection system.
- v. Don't allow conservator oil level to fall below minimum level mark of indicator.
- vi. Don't parallel transformers which do not full fill the necessary requirement.
- vii. Don't allow unauthorised entry in the sub-station.
- viii. Don't overload the transformer other than the specified limit mentioned.
- ix. Don't tight the nuts & bolts in excess to arrest any leakage.
- x. Don't avoid any unusual noise/occurrence noticed in the substation..
- xi. Never use fuses higher than the prescribed ratings on HT and LT sides.
- xii. Earthing connections should never be done in loose manner. Simply twisting of GI wires would be dangerous. The earthing connections should as far as possible be done by using continuous wire or providing suitable connectors. It should be ensured that these connections are tightened rigid.
- xiii. Never keep the breather pipe open or exposed.
- xiv. Don't ignore safety rules during maintenance work.

1.12.3 Maintenance of a Substation

Most of the equipment installed in a substation are “static” in nature. This fact may lead you to form an opinion/impression that this equipment need no maintenance. However, this is NOT correct. Many cases of fault occurrences are because of lack of proper maintenance. Maintenance operation includes regular inspections, testing and rectification of defects when necessary. It is an orderly programme with predetermined intervals between inspections for proper maintenance. Furthermore, maintenance of complete records of each inspection is essential. If any replacement is carried out or adjustment of certain setting is done then these must be entered in a log-book. Such a rigid system of maintenance will ensure long life, trouble free service and reduction in unnecessary interruptions.

Since, in a sub-station there will be a number of incoming and outgoing circuits each having its isolators, circuit-breakers & instrument transformers etc. connected to busbar system, maintenance of a particular piece of equipment is necessarily to be carried out with minimum interruption of the system. This situation particularly calls for vigilance, care and well defined scheme of procedures to be followed in planning, organising and carrying out maintenance work. Such a scheme will indicate the authority and responsibility of persons at various levels/ stages. Only then safety to personnel and equipment can be ensured. In the following paragraphs, typical standard procedure, common safety precautions, maintenance of transformer, CB, isolator and switch yard etc. are dealt with.

All work on major electrical installations shall be carried out under permit-to-work system which is now well established.

The “permit-to-work” card can be issued only by an authorised person. As the name suggests it authorises the maintenance supervisor and his team to carry out work. Furthermore, this card will indicate unambiguously the points at which it is safe to work, the time interval when it is to be done, steps to be taken to ensure safety such as earthing, display of danger notices etc., at the nearest live point. It should have the signature of the authorised person. After the work is completed the permit card should be cancelled and removed from the possession of those doing the work.

Danger notices should be put up or removed by the responsible person / supervisor who will take the charge of any keys to lock out items.



ANNEXURE A

PROFORMA FOR SUB-STATION MAINTENANCE

Daily Maintenance Proforma

STATION:

LOCATION:

DATE:

Items		Work to be done	Work done/ Remark if any	
Switch yard				
	All jumpers & other connections	Check visually for flash/ spark marks		
Transformer			TR - 1	TR - 2
	Temperature	Check oil temperature during peak load hours. Check ambient temperature		
	Tank	Check for oil leakage		
	Dehydrating breather	Check visually colour of silica gel		
Control Panel Room				
	Relays	Check visually target position		
	MCCB/Fuse	Check for overheating		
	Load (amp.)	Check against rated figure		
	Voltage	Check against rated figure		
	PF meter	Monitor the PF reading		
Capacitor Bank				
	All connections	Check visually for flash/ spark marks		

Signature of supervisor

Signature of operator/ technician

Signature of in-charge

ANNEXURE B**Monthly Maintenance Proforma**

STATION:

LOCATION:

DATE:

Note: In addition to daily maintenance, carry out following works:

Items		Work to be done	Work done/ Remark if any	
Switch yard				
	Earth pits	Cleaning		
		Watering		
	Earth connections	Check all connections both at earth pits and metal parts		
	Yard	Growth of unwanted shrubs, garbage etc. Keep the yard free from shrubs, garbage etc.		
Transformer			TR - 1	TR - 2
	Buchholz Relay	Check gas collection		
	Oil level	Check oil level in conservator		
	Connections	Open terminal box cover and check connections visually for flash/ spark marks		
	Dehydrating breather	Check air passages		
Check colour of silica gel				
	Cleaning	Clean entire transformer externally		
Control Panel Room				
	Load (amp.)	Check load balancing. If found unbalance, distribute the load equally on all phases		
	MCCB/Fuse	Provide proper size of MCCB/Fuse according to load condition		

Signature of supervisor

Signature of operator/ technician

Signature of in-charge

ANNEXURE C

Quarterly Maintenance Proforma

STATION:

LOCATION:

DATE:

Note: In addition to monthly maintenance, carry out following works:

Items		Work to be done	Work done/ Remark if any	
Switch yard				
	Support Insulators	Clean and examine for cracks		
	Lightning arresters	Clean and check line and earth connection		
	AB switch	Clean and lubricate for proper operation		
		Check line and earth connection		
	Jumpers	Check and tighten all jumpers		
	HT bus bars	Examine and tighten bus-bar expansion joints etc.		
Transformer			TR - 1	TR - 2
	Bushing	Clean and examine for cracks		
		Check for oil seepage		
Control Panel Room				
	LT Bus bars	Clean and check visually for overheating, flash/ spark marks. Tighten all connections.		

Signature of supervisor

Signature of operator/ technician

Signature of in-charge

ANNEXURE D

Half Yearly Maintenance Proforma

STATION:

LOCATION:

DATE:

Note: In addition to quarterly maintenance, carry out following works:

Items		Work to be done	Work done/ Remark if any				
Transformer			TR - 1		TR - 2		
	Oil	Check BDV, if BDV < 30 kV/cm, do filtration to restore quality of oil.					
	Cable box, gasketed joints and gauges	Inspect for leakage and cracks					
Control Panel Room							
	Oil circuit breakers		OCB1	OCB2	OCB3	OCB4	OCB5
		Check oil level in the tanks.					
		Test the oil, if shows signs of moisture, carbonization or dirt. Filter or replace if necessary.					
		Check all valves for oil leakage.					
		Check the condition of all gaskets provided to prevent entrance of water and leakage of oil.					
	ACB		ACB 1	ACB 2	ACB 3	ACB 4	ACB 5
		Clean with lint free cloth					
		Clean fixed and moving contacts					
		Clean and lubricate operating mechanism					

Signature of supervisor

Signature of operator/ technician

Signature of in-charge

ANNEXURE E

Yearly Maintenance Proforma

STATION:

LOCATION:

DATE:

Note: In addition to half yearly maintenance, carry out following works:

Items		Work to be done	Work done/ Remark if any	
Switch yard				
	Concreting/ coping of the supports	Take preventive action, if there are cracks or the coping of concreting is coming off.		
	Gravel/crushed rock	Check leveling, oil stain and dust accumulation. Spray water to remove oil stain and accumulated dust. Maintain leveling to avoid formation of water pools.		
	Earth resistance	Measure the earth resistance of individual equipment earth pit <ul style="list-style-type: none">▪ Major sub-station : 1.0 ohms▪ Small sub-station : 2.0 ohms		
	Earth connection of metal parts	Check the earth connection of metal parts is properly connected to the earth.		
	AB switches	Check the line and earth connections		
		Lubricate and check proper operation		
	HT lightning arresters	Measure IR value between HV terminal and earth, if low, replace it.		
	Bus-bars	Check the line and earth connection Tighten the connections properly from the bus bars and bars to the lines		
	Insulators	Clean and check all insulators for any crack or damage. Change if required		
Transformer			TR - 1	TR - 2
	Winding	Measure IR value between HV-Earth HV-LV LV-Earth If low, take corrective action		
	Oil	Check BDV, if < 30 kV/cm, do filtration to restore quality of oil.		
		Perform dissolve gas analysis (DGA) as per annexure - B to check for incipient faults		
	Buchholz relay	Clean and check components of floats, alarm contacts and their operation. Replace if necessary		
		Check accuracy of relay. Change the setting, if necessary.		
	Earth resistance	Check earth resistance of neutral and body. If high, take corrective action		
	Body	Check for peelings/ rusting/ damage. Repaint, as required		

Signature of supervisor

Signature of operator/ technician

Signature of in-charge

1.12.4 Common Safety Precautions

Whenever in a substation, any maintenance work is undertaken following safety precautions should be observed:

Access to live parts should be prevented e.g. using locked enclosures. Verify that the equipment to be maintained is isolated from all sources.

All auxiliary supplies to be isolated, springs of spring mechanism to be discharged and air system of the pneumatic mechanism to be exhausted.

Equipment which is isolated from supply for maintenance to be earthed before touching it. For earthing either a permanent earthing switch or a temporary earthing device to be used.

Whenever safety interlocks are provided no steps should be taken to defeat their purpose. (Otherwise dangerous occurrences are likely to occur).

Apart from above precautions, factors like clarity of layout, accessibility of installation, live line indicators and segregation can contribute substantially to the safety during operation and maintenance work. They are to be taken care of during designing or planning stage.

1.13 Overhead Power Lines

1.13.1 Introduction

All overhead power lines are expected to comply with the latest provisions of Indian Electricity Act and Rules made there under and the regulations or specifications as laid down by Indian Railways, Department of Telecommunications, roadways or navigation or aviation authorities, local governing bodies, defence authorities and Power and Telecommunication Coordination Committee (PTCC), where applicable. Relevant matters requiring attention of such authorities should be referred to them and their approval obtained before planning the layout and installation during construction work. Such references should be made within appropriate time to ensure smooth progress. Before deciding the basic parameters of the line, information regarding the total load including future extensions, point of supply or area to be covered should be exchanged between the designer and distribution authorities. Based on this load and the length of the line the designer should predict the most economic system of voltage and conductor size.

1.13.2 Choice of Voltage

The cost of the lines is one of the deciding factors in the choice of voltage. The general rule is that the voltage of the line is taken as 0.6 kV per km of the length of the line. For short distances, power supply distribution voltage of 33/11 kV is most common, distribution at other voltages such as 3.3kV and 6.6kV is restricted to within industrial premises. For distribution to consumers, 415/240V is standard.

- i. Besides other considerations, the following factors should be looked into before making the choice of voltage.
- ii. Magnitude of the power to be transmitted
- iii. Length of the line
- iv. Cost of the terminal equipment and
- v. Economy consistent with the desired reliability
- vi. While making choice of voltage the main consideration with feeders is economy and with distributors, it is the voltage drop.

The voltage shall be in accordance with the recommendations of IS:12360. The preferred values of ac nominal system voltages are given in the table below:

Preferred ac system	Nominal Voltage	Highest system Voltage	Lowest system Voltage
1-Phase	240 V	264 V	216 V
3-Phase	415 V	457 V	374 V
3 -Phase	3.3 kV	3.6 kV	3 kV
3-Phase	6.6 kV	7.2 kV	6 kV
3 -Phase	11 kV	12 kV	10 kV
3-Phase	33 kV	36kV	30 kV

1.13.3 Conductor

There are good range of conductors available these days for carrying power through overhead lines. The most commonly used conductors for distribution of power up to 11kV are Aluminium Conductors Steel Reinforced (ACSR), all aluminium conductors, galvanized steel conductors and copper conductors.

Due to the shortage of copper and zinc in the country, it is recommended not to use copper and galvanized steel conductors. Attention is drawn to the use of steel reinforced aluminium conductors and aluminium alloy stranded conductors. Requirements for these types of conductors have been covered in the appropriate parts of IS:398.

1.13.3.1 Aluminium conductors steel reinforced (ACSR)

These conductors are made up of a galvanized steel core surrounded by stranded aluminium wires. The principal advantages of these conductors are high tensile strength, light weight giving small sags, longer spans and much higher corona limit due to bigger diameters. The principal disadvantage is that larger diameters increase the pole loading due to windage necessitating heavier poles. Their ultimate strength ranges from 125% for small size to about 180% for large sizes as compared with 100% of copper.

In coastal, industrial and other corrosive atmosphere, it is preferable to coat the steel core with suitable corrosion preventive grease to mitigate galvanic action and galvanic corrosion

1.13.3.2 All Aluminium conductors

These are stranded conductors made of aluminium wires. These conductors are strong, durable, light weight and possess high conductivity. The average ultimate strength of stranded aluminium is about 65% of stranded copper. They need special care in handling. All aluminium conductors cannot take much tension as compared to ACSR conductors and, therefore, the span lengths get restricted.

1.13.3.3 Galvanized steel conductors

These are stranded conductors made of galvanized steel wires. The principal disadvantage with these conductors is their relatively short life, which is about 16 years in rural areas and about 9 years in industrial areas and during which period iron insulator binders require frequent renewal owing to rapid corrosion. They are easy to handle, have greater strength and are cheaper.

Physical and electrical properties of ACSR, all aluminium conductors and copper conductors shall be in accordance with IS:398 and IS:282 respectively.

1.13.4 Earthing of Overhead Lines

There are two methods of earthing associated with overhead lines for reducing the damage to life and plant in case the protection system fails to operate or in case of lightning hazard:



Continuous overhead earth wires and

Individual earthing of each pole. Continuous overhead earth wire is more commonly used and its main functions are:

- i. To form a continuous and low resistance return path for earth leakage currents necessary for the operation of protective systems and
- ii. To reduce the effects of induced voltage in adjacent communication circuits under fault conditions.
- iii. Individual earthing of poles does not provide a continuous return path for earth currents although it reduces the effects of induced voltage in adjacent communication circuits under fault conditions.
- iv. Galvanized steel wires are very commonly used as earthing conductors. The size of the wire depends upon the span and the expected fault current.

1.13.5 Size of Conductors

The physical and electrical properties of different conductors shall be in accordance with relevant Indian Standards. All conductors shall have breaking strength of not less than 350 kg. However, for low voltage lines with spans less than 15 m and installed either on owner's or consumer's premises, conductors with breaking strength of not less than 140 kg may be used. The choice of the size of the conductors for a line mainly depends upon the following:

- i. Power to be transmitted
- ii. Length of the line
- iii. Line voltage
- iv. Permissible voltage regulation and
- v. Mechanical strength

1.13.6 Spacing of Conductors

To have proper insulation clearance, in order to avoid trouble due to birds and to avoid conductors clashing due to wind, it is very essential that conductors in an overhead power line are adequately spaced.

There are no fixed rules for spacing arrangement of overhead line conductors. However, the following formula gives an economical spacing of conductors.

$$D = 500 + 18 U + L^2/50$$

where, D is spacing in mm

U is phase to phase voltage in kV

L is span length in m

For 33 kV lines, minimum electrical clearance, horizontal and vertical, between the conductors is 1.5 m both for lines on poles and towers.

1.13.7 Spans

1.13.7.1 Sag-Tension

In practice, for overhead line design, the general theory for sag-tension is based on the fact that if a flexible wire of uniform weight is suspended at two points at the same level, it sags and assumes the shape of a catenary curve. For short spans normally adopted for distribution lines, the catenary is very

nearly a parabola and hence the sag is calculated by the following formula:

$$s = WL^2/8T$$

where, s is sag in (m)

W is weight of loaded conductor in kg/m

L is span length in m

T is Maximum working tension in conductor in kg

1.13.7.1 Span lengths

As per IS: 5613, the recommended span length for lines up to 11 kV are, 45, 60, 65, 75, 90, 105 and 120 m. For 33 kV line onwards (single circuit and double circuit) range of spans is 180 - 305m and for line on poles (single circuit) range of span is 90-135m.

1.13.8 Clearances

In terms of Para 58 of Central Electricity Authority Measures relating to Safety and Electric Supply Regulations, 2010, minimum clearances for any conductor of an overhead line from ground and buildings at different places shall be as given below:

Sl. No.	Description	For low & Medium Voltage lines (m)	For High Voltage Lines (m)
a)	Minimum height of any conductor of an overhead line across any street.	5.8	6.1
b)	Minimum height of any conductor of an overhead line along any street.	5.5	5.8
c)	Minimum height of any conductor (bare) of an overhead line erected elsewhere.	4.6	4.6*
d)	Minimum height of any conductor (insulated) of an overhead line erected elsewhere.	4.0	4.0**
e)	Minimum clearance of overhead line conductor from buildings.	2.5(vertical) 1.2(horizontal)	3.7(vertical) 1.2*** (horizontal)

Note: As per NEC 2011, for Low Voltage, $V < 250V$, for medium voltage, $250V < V < 650V$ and for high voltage, $650V < V < 33kV$

* For 33 kV line minimum height is 5.2 m.

** Not applicable for 33 kV lines.

*** For 33 kV line clearance is 1.83 meter.

1.13.9 Choice of Route

The proposed route of Line should be the shortest practicable distance. The following factors shall be considered in the choice of the route.

- It is advantageous to lay the line near to and along roadway or railway.
- The route should be as short and as straight as possible.
- The line should be as away as possible from telecommunication lines and should not run parallel to these.
- Crossing with permanent objects, such as railway lines and roads should be minimum and preferably at right angles.
- Difficult and unsafe approaches should be avoided.
- The line should be away from the buildings containing explosives, bulk storage oil-tanks and oil or gas pipelines.



1.13.10 Maintenance of 33kV, 11kV, Medium and Low Voltage Distribution Lines

1.13.10.1 Introduction

The maintenance work pertaining to the overhead lines, generally consists of: Systematic pre-planned routine inspection followed by necessary preventive maintenance.

Special inspection before the usual difficult operating period of line during the year such as before the on-set of monsoon followed by necessary maintenance to prevent possible outages

Special inspection after each and every interruption of line to pin point the nature of defect on the lines followed by necessary repairs.

The important components of 33 kV, 11 kV, and LT distribution lines are:

- i. Supports and cross-arms
- ii. Insulator and fittings
- iii. Conductors and accessories
- iv. Guys and accessories
- v. Gang operated switches and fuse units

1.13.10.2 Maintenance of Lines

The overhead lines should be inspected periodically for maintenance purposes to detect any fault which may lead to breakdown of electric supply and necessary repairs should be programmed soon thereafter.

All overhead lines should be patrolled periodically at intervals not exceeding one month at ground level while the line is live. The main points to be noted while patrolling the lines are as under.

Tilted poles, deformed or tilted cross arms, settling or bulging of soil around pole foundations, yielding of foundations, cracks or breaks in the poles (PCC/RCC) above the ground level, missing/ loose nuts, rust and cracks in the cross arms etc.

The patrolling party should write inspection reports and pass them on to the concerned Official for arranging necessary repairs.

A. Special Inspections

Interruptions and break-downs on the overhead lines are usually much more during particular season of the year. If suitable preventive maintenance is carried out, it is possible to minimise these power failures. Usually, many break-downs occur soon after the monsoon break out. Therefore, it is worthwhile programming a special inspection of the lines just before the monsoon period. The inspection is normally carried out with the overhead lines without current to enable very close inspection of the line.

In order to avoid prolonged and repeated interruption for this work, the normal practice is to pool all available men and concentrate on a stretch of line. Side by side, with this inspection, the repairs obviously necessary are also carried out simultaneously to the extent possible.

B. Emergency Inspection

When an overhead line trips on a sustained fault, it should be inspected to find out the nature of fault such as loose sag, snapping of conductors, tree branches touching the line & conductors falling on cross arms etc. The improvement with a view to avoid reoccurrence of such faults in future should be arranged and carried out soon after.

C. Tree Clearance

Trees or branches of tree, which come very close to the lines, should be felled or trimmed. An adequate clearance on each side of the line has to be maintained by such trimming of the branches. All the dead woods are also to be removed from the line. Any extraneous object such as creeper, kite, etc. should be removed.

D. Supports

Various types of supports and cross arms are being used for 33 kV, 11V and distribution lines. Steel supports (rails, RS joists, fabricated structures),

- i. PCC poles
- ii. RCC poles
- iii. Tubular
- iv. poles

All metallic supports should be painted once in 5 years.

The supports along the roads should be painted with black and yellow strips up to a height of 1.80 m to protect them against possible damage during the night by the fast moving vehicles on the road.

The condition of concrete foundation, if provided, may be examined and ensured that no undue damage has occurred. If any soil erosion has been noticed at the foundation, corrective steps for strengthening of the foundation may be taken to protect the pole from falling/tilting. The muff provided on the foot of pole should be repaired if found damaged.

E. Cross Arms

All metallic cross arms should be either galvanized or protected by suitable anti-corrosive paints like Zinc rich coatings.

F. Insulators and fittings

While inspecting the lines, the following defects in the insulators and their fittings should be observed.

- i. Broken or chipped porcelain insulators
- ii. Accumulation of dust, coal or salt etc. on the insulators

Excess rusting of fittings

The insulators of an overhead line are subject to mechanical and electrical stresses which shorten their life. Deterioration of insulator is also caused by pollution and temperature changes. Damaged insulators can be detected during periodical inspection. These should be replaced as soon as shut down of the line can be taken. The other defects as pointed above should be attended by taking line block.

Where insulators are observed to have been polluted because of atmospheric contamination, such as, in saline and chemically contaminated areas, they will have to be cleaned after taking necessary line clear.

G. Conductors and accessories

Measurement of clearance of lines

Ground clearance of the conductor should be checked periodically at least once in a year as they may change due to changes in atmospheric conditions or any other reasons. If ground clearance of the conductor is found not in conformity with the IE Rules corrective steps such as re- tensioning of the lines have to be taken after taking line clear.

Pole to pole inspection. Other points, which need checking, are given below.

- i. Looseness of binding
- ii. Broken strands
- iii. Unequal sagging
- iv. Slipping of conductors from the clamps
- v. Broken or burnt strands of the jumpers. The following corrective measures should be taken:
- vi. Slipped conductors or broken/burnt strands of the jumpers may be replaced
- vii. Repairs of loose binding and broken strands may be done. Checking for loose connections and signs of overheating at the point of jumper connections may be done
- viii. Checking for crowding or jumbling of wires and jumpers of the tee-off point may be done and adjusted where necessary.
- ix. Checking for general conditions of other line accessories such as parallel groove clamps jointing sleeves and other fittings may be done. Readjust and replace where necessary.

H. Stays/Guys and its accessories

At the time of inspection, the following points shall be kept in sight:

1. Loose or over tensioned guys
2. Broken or chipped stay insulators
3. Absence of storm guys in the fields
4. Missing of earthing arrangements for the stay
5. Rusting of stay wires
6. Corrosion of stay rods
7. Condition of the stay anchoring

Wherever necessary, the defects noticed in the above places should be attended immediately.

I. Gang operated switch and fuse units

At the time of inspection, the gang operated switches should be usually examined for

- i. Defective closing of switch
- ii. Missing earth lead connection & locking arrangement
- iii. Earth wire cut or corroded or cracked or chipped insulators.
- iv. The above defects should be rectified after taking line clear and the following works should be carried out.
- v. Clear all dust and other deposits with neat dry cloth
- vi. Check contacts for alignment, adequate contact pressure, smooth operation and adjust where necessary
- vii. Examine for burning/overheating of contacts

- viii. Check arcing horns for damages or burnt out ones & replace wherever necessary
- ix. Check all mechanical parts and examine and replace worn out pans, lubricate and check for correct operation of the moving parts
- x. Replace old fuse wires with new ones of right capacity and proper length
- xi. Examine condition of the insulators & lightning arresters

During the periodical inspection, the lightning arresters should be checked for any damaged or broken porcelain and for any external indication of fused or sparked over arresters. Whenever any repairs or maintenance is being carried out after taking line clear, opportunity should be utilised for checking up the line and earth connections for their tightness etc.

J. Earthing system

The earthing connections of supports and metal fittings shall be periodically checked for their tightness and proper contact.

1.14 Power Cables

1.14.1 Types and Applications

Presently PVC and XLPE cables are being used in electrical installations. The discussion is restricted to these two types only. The voltage ratings covered are up to and including 33 kV.

1.14.1.1 PVC Insulated Cables

PVC insulated cables, covered by IS:1554 are used where combination of ambient temperature and temperature rise due to load results in conductor temperature not exceeding 70°C under normal operation and 160°C under short circuit conditions.

1.14.1.2 XLPE Insulated Cables

XLPE insulated cables, covered by IS:7098 are used where combination of ambient temperature and temperature rise due to load results in conductor temperature not exceeding 90°C under normal operation and 250°C under short circuit conditions.

XLPE cables are particularly suitable in following situations.

- i. On vertical runs of unlimited difference in level
- ii. At locations having severe vibration problems
- iii. At locations having higher ambient temperatures up to 70°C
- iv. At conditions demanding short time overload up to 120°C
- v. In systems having higher short circuit levels

1.14.2 Cable Insulations Levels

Selection of cable for a particular application may involve determination of the following parameters:

- i. The rated power frequency voltage between each conductor and screen or sheath for which the cable and its accessories are designed or manufactured.
- ii. The rated power frequency voltage between any two conductors for which the cable and its accessories are designed or manufactured.
- iii. The maximum rms power frequency voltage between any two conductors for which the cables and accessories are designed. It is the highest voltage that can be sustained under normal

operating conditions at any time and at any point in a system. It excludes temporary voltage variations due to fault conditions, and the sudden disconnection of large loads.

- iv. The peak value of impulse withstand voltage between each conductor and screen or sheath for which the cable and its accessories are designed.

1.14.3 Current Rating of Cables

1.14.3.1 Continuous current rating

The continuous current rating of the cable is dependent upon the evacuation of the heat generated in the conductor and is a function of following parameters:

- i. Thermal conductivity of the core-conductors and armour (if provided)
- ii. Thermal resistivity of the soil
- iii. Specific resistivity of the material of the conductor
- iv. Thermal resistivity of the soil
- v. Maximum conductor temperature permissible from the point of view of life of the insulation
- vi. Surrounding ambient temperature
- vii. Temperature coefficient of the conductor
- viii. Type of cable installation

While Indian standards is to be referred to obtain recommended ratings of cable, it is recommended that manufacturer's catalogue should also be consulted.

For derivation of formulas for computing the continuous current carrying capacity of cables, one may refer to several text books, but the designer can take guaranteed data regarding continuous current rating capacity of cables from the data furnished by the manufacturer respect of cables buried direct in ground. For cables supported in air, the standard current rating being based on a set of conditions pertaining to temperature and other influences to which the cable is exposed due to site installation conditions.

Another set of tables furnish the correction factors (rating factors) to be applied to the current rating obtained from the first set of current rating to derive the rating applicable to the actual installation.

IS:3961 gives rating of a single, 650/1300V, 3 core 300 mm² aluminium cable laid direct in ground at 305A, under following assumptions:

Maximum conductor temperature	-	70°C
Thermal resistivity of soil	-	150°C cm/W
Thermal resistivity of PVC	-	650°C cm/W
Ground temperature	-	30°C
Ambient air temperature	-	40°C
Depth of laying	-	750mm.

Now, if this cable is laid in soil with thermal resistivity of say 200°C cm/W, a rating factor of 0.92 is applicable. If depth of laying is 1 metre, a rating factor of 0.89 is to be applied. If the ground temperature is 35°C, a rating factor of 0.94 is applicable.

Thus effective rating of this cable will be = 0.92 x 0.89 x 0.94 x 305A
 = 234.7A.

Recommended current ratings of cables and rating factors applicable for different type of installations are given in IS:1554 (part I).

The short time current rating of a cable for a specified short duration is based on the assumption that

the heat generated during the short duration is retained without any dissipation. This rating assumes the conductor temperature should not exceed the maximum permissible temperature. Under this condition, temperature rise will be proportional to product of square of current and duration of the current, the temperature rise being limited by the characteristic of insulation.

The short circuit withstand capability of a cable has therefore, to be expressed in terms of current and the duration in seconds over which it can withstand short circuit current. The cables should have a short circuit withstand capability for a short duration so that the faults are detected by the relays and cleared by the circuit breakers or by the fuses without the cable being damaged by way of short time heating. The duration of short circuit should be decided keeping in view time of relaying and CB opening time. The Indian Standards and manufacturer's tables indicate short circuit rating of the cables for various durations of short circuits.

Hence while designing the size of the cable for high voltage like 11 kV, 22kV, 33kV etc, the cable size should be normally so selected that it will be able to with stand short circuit current for one second. The manufacturer's tables as well as the IS give the sizes of conductors with the short circuit current ratings of one second duration.

1.14.4 Conductor Selection

Proper sizing of a conductor involves three factors:

- i. Continuous current rating of "Thermal ampere capacity" being the current that the cable can carry on a sustained basis after thermal equilibrium conditions are attained without causing impairment to the insulation
- ii. Voltage drop restrictions
- iii. Short circuit current
- iv. Ampere capacity will determine the minimum size of conductor that can be used for a given type of installation.

1.14.5 Voltage Drop

Voltage drop restrictions will determine a maximum length that a conductor selected can be used before an increase in size is necessary to maintain the voltage at the load above a desired minimum value.

1.14.6 Types of Cables

Following are the types of cables used for distribution of electrical energy.

1.14.6.1 PVC - Poly-Vinyl Chloride

1.14.6.2 XLPE- Cross linked Polyethylene

1.14.6.1 PVC Cables:

PVC insulated power cables have been developed as a suitable alternative in many instances to PILC Cables. PVC, introduced as a substitute for rubber, applied as continuous seam free extrusion as insulation and sheath, provides many advantages to the cable engineer. The neat appearance of these cables, bright colour, comparatively lighter in weight, more adoptive to installing conditions in circuits due to easier handling, simplified termination and jointing techniques and inherent flexibility makes it eminent suitable for use among many other applications in power stations, distribution systems & utility networks.

A. Properties and Advantages of PVC Cables

- i. A basic advantage of PVC cable is that insulation resistance and breakdown strength are practically unaffected by moisture. In fact PVC cables may even be laid directly under water.
- ii. PVC cables may be overloaded in short periods without any effect on cable life.
- iii. These cables can be laid vertically and on steep slopes, since there is no impregnating compound in these cables. Further, there is no danger of bleeding at lower level sealing ends.
- iv. PVC cables have high short circuit safety, since they can withstand a high transient conductor temperature without any deformation of insulation or displacement of conductors.
- v. PVC cables are resistant to practically all chemicals encountered in practice, most of the common acids, alkalis and saline solutions have no effect on PVC.
- vi. PVC cables are flame retardant since PVC ignites with great difficulty and that too when directly exposed to a flame, it does not propagate the flame & extinguishes itself as soon as the source of fire is removed.
- vii. PVC cables are easy to install and handle, due to their light weight. Besides there is a saving in cable supports. These cables have small bending radii that permit the termination of these cables in limited space. This eases the termination of PVC cables in switch boards and control panels.
- viii. Low tension PVC cables do not require sealing of ends when installed indoors, hence termination is done quickly and economically.
- ix. PVC cables have a smooth outer surface resulting in a neat appearance when installed & outer sheath is tough and abrasion proof.

B. Selections of PVC Cables:

For selection of any type and size of cable, the following general points should be considered:

- i. The system voltage and the type of system.
- ii. DC system or AC system.
- iii. Single phase or 3 phase.
- iv. Earthed or unearthed.
- v. What are the conditions of installation

For example, if there is no likelihood of subsequent mechanical damage after laying cable, cheaper un-armoured cables can be used instead of armoured cables.

While choosing the conductor size for a particular current, proper care is to be taken for all rating factors depending upon actual conditions of installations. Moreover type of protection should also be checked.

The voltage drop that will occur when the cable is carrying full load current should be especially checked for L.T. distribution cables having longer runs.

On the basis of short circuit current expected and the time of clearance, the appropriate conductor size for cables may be selected. Usually the time of clearance for HT cables for selecting the short circuit rating can be taken as 1 sec, though fault clearances are accomplished in much less than a second wherever circuit breakers are provided.

While factors given above decide the minimum conductor cross-section, economics govern the optimum size, which will give the minimum running costs. For this purpose, the minimum size along with two or three higher sizes are considered and annual running costs are worked out by calculating



IR losses (in money terms) and interest/depreciation of the cable cost. The total of the two give running costs. The size, which gives the minimum running cost, can be chosen.

C. Testing of PVC Cables

1. Routine Tests

- a. Conductor resistance test
- b. High voltage test.

2. Type Tests

- a. Annealing test (copper)
- b. Tensile test (Aluminium)
- c. Wrapping test (Aluminium)
- d. Conductor resistance test
- e. Test for armour wires
- f. Test for thickness of insulation and sheath
- g. Physical tests for insulation, sheath
- h. Fire resistance test
- i. Test for bleeding and blooming of pigments
- j. Insulation resistance test
- k. High voltage test (water immersion test)
- l. Cold bend and cold impact test (optional)
- m. Oil and heat resistance test

3. Acceptance tests

The following are the tests carried out by buyer on samples taken from a lot for the purpose of acceptance of the lot –

- a. Annealing test (for copper)
- b. Tensile test (for aluminium)
- c. Wrapping test (for aluminium)
- d. Conductor resistance test
- e. Test for thickness of insulation and sheath.
- f. Insulation resistance test.
- g. High voltage test.

1.14.6.2 XLPE (Cross Linked Polyethylene) Cables

The continuous research for a better power cable insulation material ultimately resulted in the discovery of ‘cross linked polyethylene’ It was in 1960 that the first publication concerning its use in high voltage cables appeared and from 1964 onwards that its use gathered momentum. In addition, rapid progress in XLPE technology has resulted in a steady increase in the voltages for distribution by electric cables from 66kV through 220 kV and beyond.

Thus, the customer Engineers are now faced with a choice between the traditionally available paper Insulated power cables (PILC) and the new XLPE insulated cables. There are many factors which can influence their decision.

The rapid growth in the use of XLPE cables can be attributed to their excellent performance resulting from the following:

- i. Excellent physical and electrical properties of XLPE insulation.
- ii. Availability of adequate supplies of good quality insulation and conductor shielding compounds.
- iii. Development of effective material handling and production processes for manufacture of finished cables.
- iv. Good operational electrical stress.

A. Charging currents

The charging currents are considerably lower permitting close setting of protection relays.

Easy laying and installation,

Low weight and small bending radii make laying and installation of cable very easy. The cable requires less supporting due to low weight. High safety, High safety against mechanical damage and vibrations.

B. Application of XLPE cables

XLPE cables are being used extensively in all power stations and industrial plants. They are ideally suited for chemical and fertilizer industries, where cables are exposed to chemical corrosion or in heavy industries where severe load fluctuations occur and for systems where there are frequent over-voltages. Cables can also be used at higher ambient temperature on account of their higher operating temperature. The excellent installation properties permit the cable to be used even under most difficult cable routing conditions and also in cramped conditions e.g. city distribution net-work. Single core cables due to their excellent installation properties are advantageously used in power stations, substations and, industrial plants.

C. Advantages of XLPE cables

- i. XLPE cables have higher operating temperature.
- ii. XLPE cables have a proven capacity for carrying emergency loads.
- iii. XLPE cables have higher circuit current ratings.
- iv. XLPE cables have superior dielectric properties and hence lower dielectric losses.
- v. XLPE cables are suitable for unrestricted vertical installation.
- vi. XLPE cables are more damage resistant. XLPE cables can be installed in air or, directly buried in the ground or can be laid in ducts and trenches. Being lighter they need less labour, lesser number of supports, clamps and cleats (when installed in air).
- vii. The conditions of installation should be as stipulated in IS:1255-1983 Jointing and termination of XLPE cables
- viii. XLPE insulation is highly resistant to moisture and hence jointing and termination are simpler. A full range of new generation of kits for jointing, modular units for, termination, resin encapsulated moulded push on type, cold shrink and heat shrink systems have all been developed for the XLPE cables, which provide easier and faster jointing and also assure reliable service.

D. Tests on XLPE cables

Governing specification IS: 7098 [Part 2] -1985.

1.14.7 Precautions Required in Erection of Cables

1.14.7 Laid directly in ground

The depth of trench may vary between 75 to 100 cm. The bottom of the trench is levelled, freed from stones and sharp edges of rock. A layer 100 mm thick of clear river sand is laid at the bottom of the trench. After laying the cable, it is covered once again with a 100 mm layer of sand, where the soil conditions are not good. In other cases soft earth may be employed instead of sand.

R.C.C. slab or one layer of bricks is usually laid, not only as a protection against mechanical damage, but also to facilitate identification of the cable route.

1.14.7.2 Drawn in pipes or ducks

The pipes may be of earthen ware, cast iron, galvanised iron or spun cement pipe. This is resorted to when crossing across streets or under railways tracks. The size should be sufficiently large to put in additional cables later if required. The advantage of laying ducts is that the cable may be drawn out and replaced without disturbing the ground above.

1.14.7.3 Laid solid in bitumen

This is done where the soil is chemically very active and/or corrosive and therefore, damaging to the cable. R.C.C channel sections 6.0 to 90mm long are first laid level at the bottom of the trench, and after the cable is laid bitumen is heated and poured over until cable is entirely covered, the whole being protected by wearing R.C.C top caps.

1.14.7.4 Supported on brackets

When the cable is installed above the ground, it should be suitably supported or suspended at sufficiently close intervals. On vertical runs suitable clamps should be used.

Whatever the type of construction it is extremely important to handle the cable carefully and ensure that it is not under any circumstances bent unduly. The minimum bending radius during installation should be as under.

Cable upto and including 11 K.V	-	12 D.
22000 Volts cables	-	15 D.
33000 Volts 3-core cables	-	20 D.
33000 Volts single-core cable	-	30 D.

Where, 'D' is the diameter of the cable.

When planning trenches or ducts a bending radius of 2.7M should be kept for high voltage cables and 1.8 M for lower voltages. For smaller sizes of L.T. cables, a radius of 1.2 M may be permitted.

Sufficient number of cable route indicators should be provided, at points which will not be disturbed, to show the route of the cable, as well as at every deviation in its direction, straight through or T joint box.

1.14.8 Cables - Common Failures and Causes

1.14.8.1 Insulation Failure

It is generally accepted that the insulation fails because of the combined presence of the factors listed below:

- Electrical stress is a significant factor affecting cable life. Voltage surges are caused by typical switching operations, clearing earth faults or lightning.



- ii. Presence of moisture - Only the forced ingress of moisture may cause the insulation resistance drop to a point where deterioration of the cable insulation starts.
- iii. Presence of contaminant or void and consequent ionization especially for extruded insulation such as PVC, PE, XLPE, EPR. Cables are more susceptible to these faults either due to defective manufacturing process or developed during the operation of the cable under varying load.
- iv. Mechanical damage to the cable insulation such as abrasion, crushing, cutting, flexing, necking and crimping etc. is the major factor affecting the life of direct-buried cables especially low voltage cables of 1.1 KV grade. Mechanical embrittlement, cracking and shrinking caused by insulation aging also causes cable failures.
- v. Due to localized heat, certain gases may be evolved and certain chemical deterioration of cable insulation may occur.
- vi. Electrical discharges will chemically and thermally erode the insulation and a small track of irregular shape {like a tree shape} may be carbonized. This process may be very slow initially and the rate of erosion increases exponentially with time and thus an effect known as a conducting tree may be formed through the insulation.

1.14.8.2 Unscientific laying and jointing

Although electrical cable withstands far more bending than most electrical equipment, there are limits to how far it can be bent, squeezed, or dragged over rough surfaces. Lack of attention to these limitations is the cause of most of the problems with high voltage cables. It is most important to note that failure is caused by damage at just one point along the cable, even though the cable may be undamaged elsewhere.

- i. Abrasion is one of the most frequent problems. Cable can be damaged by dragging it over rough surface, gravel dirt, on concrete, pulling it through ducts without adequate lubrication compound, or dragging it into cable trays without using rollers. In many cases when a cable has flashed and failed, the arc damage obliterates the tell-tale signs of abrasion and so the real cause of failure is never discovered.
- ii. Puncture of cable insulation which causes voids from which trees can start to grow can be caused by a variety of objects during installation. Sharp tools, nails in cable reels, and climbing spikes are among the chief culprits. Indirectly buried cable, puncture can occur even from the sharp rocks in the backfill. Cable trays which are increasingly popular method of distributing cable, can be a source of cable puncture especially if both are installed pointing inwards, cable can also be punctured by tools dropped into the trays.
- iii. In order to avoid over stressing of insulation, cables should not be bent at short radius. Bending of cable is limited by the shielding and by the armour. If the cable is bent too far the metal shield turns may pull apart so that when the cable is re-straightened the strands buckle and cut into the insulation. The same is true of interlocking strap armour, which may pull apart exposing sharp edges if the cable is over bent.
- iv. Over sharp bending during installation can occur in ducts, where the cable is brought out for splicing in conduit and surprisingly in cable trays. This latter problem occurs where the cable is dropped out of the tray. Care should be taken to install the proper transition fittings at the points where the cable leaves the trays. Bending may be too severe at tray corners if undersized sheaves are used when pulling cable around corners.
- v. Corrosion of shielding tape and drain wires can occur as a direct result of allowing water to enter the cable. Galvanic action between the carbon in semiconductor and the metal of the shield wire corrodes the shield material. Once the shield parts, which can easily happen because

of its light construction, the charging current arcs across the gap and quickly causes failure of the insulation.

- vi. Pressure on a cable can deform the insulation and reduce its ability to withstand voltage. The most common cause of excess pressure occurs when the cable is pulled around bends in ducts or cable trays.
- vii. Jointing of modern PVC, XLPE Cables is extremely simple compared with the skilled work required to joint the older type of insulation. It is important that jointing works be done carefully according to manufacturer's instructions, otherwise joints can become another obvious source of cable failure. Most of the faults are located in cable joints and terminations. A sizable proportion of these two types of faults is attributed to bad workmanship like use of improper jointing materials and incorrect process of jointing.

1.14.8.3 Improper selection of cables

- i The proper selection and de-rating of power cables shall be matched to the environment and operating conditions.
- ii. Various factors affect safe working current carrying capacity of the cables in order not to damage the conductor or its insulation. The normal current carrying capacity is governed by maximum allowable conductor temperature and is specified by the manufacturer or by standard. It needs modification by de-rating the current carrying capacity taking into consideration the relevant characteristics of thermal circuit as governed by such factors, as grouping factor, spacing, variation in ground resistance, variation in thermal resistivity of soil, depth of laying, variation in ambient air temperature etc.
- iii. Failure to check the conductor size for short circuit heating could result due to disintegration of insulation material which may be accompanied by smoke and generation of combustible vapour.
- iv. It is essential to investigate its behavior under short circuit conditions. Short circuit currents produce thermal as well as dynamic electro-magnetic stresses in power cables. The electro-magnetic forces between adjacent conductors in a multi-core cable will tend to disrupt the internal structure of the cable.

1.14.8.4 Failures during operation

Properly designed and laid cables have a high reliability but after installation they are exposed to numerous hazards which ultimately may result in their failures.

- i. The most common cause of failure in underground cables is accidental disturbance during excavation, or adjacent to the cable route without knowledge of the cable route or by third parties as water supply department, telephone department or soil drifting. Frequently the damage sustained by the cable is only slight and time may elapse before insulation deteriorates sufficiently to cause the circuit protective devices to operate.
- ii. Cable failure may arise due to overvoltage surges caused by lightning or switching transients. Periodical inspection of lightning arrester near the cable end shall be-carried out to avoid this type of failures.
- iii. Faults in joints and termination are caused by over heating at bad contacts, which result in loss of continuity in either the conductor or cable sheath. The life of cable is reduced appreciably through over loading. It is therefore necessary to ensure that cables are not generally loaded beyond their safe current carrying capacity.

- iv. The cable as a rule is not under constant observation and although 'size' or more properly 'cross sectional area' may have been correctly determined at the time of installation in relation to the load expected, the latter may increase as time goes and often lapse of years may lead to overheating unless records have been kept and loading watched.
- v. High temperature is probably the most frequent cause of decreased cable life and failure. The life of cable insulation is halved and average rate of thermally caused service failures doubled for each 5°C - 15°C (average of 10°C) increase in normal daily load temperature.
- vii. PVC insulation may undergo degradation during service on prolonged exposure to heat and radiation. Degradation is further accelerated during service on account of higher temperature rise (I^2R) under conditions of overloads. In physical terms degradation causes loss of insulation and increased brittleness and the loss of plasticity and colour. Structural degradation causes formation of micro-voids in the layer of insulation. In chemical terms, degradation of the PVC results in the liberation of HCL from the polymer. The corrosion action of hydrogen chloride on the surface of aluminium is localized and manifests itself as corrosion pits on the surface of the conductor.

1.14.8.5 Environmental conditions affecting failure

Certain factors external to the cable may affect the life of the cable. Useful life of cables is affected by chemical/electrolytic/bacteriological corrosion depending on such factors as soil acidity, free moisture etc. For all metal sheathed cables which are to be installed underground it should be ensured that the metallic sheath and armouring is adequately protected against corrosion.

- i. The cable route and soil condition should be properly studied for the presence of aggressive chemicals. The intensity of corrosive attack depends upon the composition, moisture content of the soil and access to free air. Sandy ground is least aggressive. Acid, boggy and saline soils are most aggressive. Soil with pH value of 7 to 9 are taken as neutral soils. The lead sheathing will also be affected if the cables are laid in ground containing drainage water or waste water of chemical plants. Chemical seepage into ground water, or direct contact due to process mal-operation may result in chemical coming into contact with a cable, system and affect the cables.
- ii. In certain environments, cable systems may be subject to attack by animals, insects, plants and fungus, all of which may possibly cause cable failure. Rats, other rodents and insects may eat organic materials, cutting through them or weakening them so that they fail under load. Plasticisers used in manufacture of plastic insulation are susceptible to growth of fungi.
- iii. Periodic inspections should be made on all cable installations. It should include check for excessive cable temperature, discolorations caused by excessive temperature, the accumulation of water in cable ducts, built up trenches, dripping of water, oil or other liquids onto cables, indication of insulation swelling, brittleness, corrosion of lead sheath, armour, or other signs of deterioration.

Testing of cables is conducted for two reasons. Firstly without any special cause, perhaps as a routine inspection to find out whether the cables are in good order and secondly to determine the fault.

The insulation resistance of a cable depends on its length and operating temperature. A longer cable has more leakage paths than a shorter cable hence the insulation resistance of a longer section of the same cable is less than that of a shorter section. Insulation resistance alone is not a primary indication of the condition of the cable insulation. Normally the level of the insulation resistance is not a value by which the operational reliability of the cable may be judged. Only the forced ingress of moisture may cause the insulation resistance to drop to a point where deterioration of the cables reliability must

be expected. This is the reason why test regulations for power cables issued in various countries do not give specific insulation resistance values. An abnormally low insulation resistance is frequently indicative of a faulty joint or termination or grossly deteriorated insulation condition.

Absorption of moisture affects the insulation resistance measured after the application of the voltage for a longer period, say, ten minutes. The most practical approach to establish the initial insulation level is to employ the 'polarization Index Method' for high voltage cables. This method appears to be the most safe, reliable and predictable means to track the progress of the cable over the extended period of time. The test voltage level employed shall be decided considering the voltage rating of the cable. Once the level is determined it must be applied in all future tests. The key to meaningful results is consistence in all aspects of testing. If a periodic test program is established it should be performed approximately the same time of the year under the same set of conditions as near as possible, using the same test voltage and same type of instrument. It is a safe test that will not overstress the insulation and yet will reveal its condition. A steadily rising insulation resistance curve indicates clean dry insulation while a flat curve indicates moisture. A good to excellent index is 3 to 4, a poor to questionable index is 2 to 1. When the polarization index level starts at 3 to 4 base level and begins to fall one or two years later to 1.5 to 2 it is apparent that either the cable has become dirty or wet or the insulation has become weakened to an unsafe condition.

1.15 Standby Generator Set

In the event of mains power failure, it is necessary to provide standby generating sets to meet the requirement of essential power supply, so that the normal working of offices and other institutions, which provide service to the public/users, do not suffer. The essential power loads are as below:-

A. Residential

- i. Water supply pump sets.
- ii. Lifts.
- iii. Fire protection/ Firefighting system.
- iv. Street lighting.
- v. Essential Community needs.

B. Non-residential

- i. Water supply pump sets.
- ii. Lifts.
- iii. Fire protection/ Firefighting system.
- iv. Lights and fans.
- v. Exit lights.
- vi. Staircase lights etc.
- vii. Other requirements like critical air-conditioning, AHUs, essential power out lets etc.

1.16 Power Factor Management

Low power factor results in higher current resulting in higher voltage drop and system losses. In order to have control over these parameters power factor of not less than 0.95 lag to be maintained by the power consumers, at the point of connection.



Initial PowerFactor	Power FactorImprovement	Percentage Reduction in Load Current	Percentage Reduction in Transmission Losses
0.7	0.9	23.7	40
0.7	1.0	30.0	51
0.8	0.9	10.0	21
0.8	1.0	20.0	36
0.9	1.0	10.0	19

Percentage reduction of load current and transformer loss due to power factor improvement is given in table below: Effect of Leading Power Factor.

Leading power factor causes higher voltage; resulting in:

- Increase in hysteresis and eddy current losses.
- Transformer may operate in saturated BH curve, resulting in generation of harmonics, which may lead to heating, and failure of capacitor.

Automatic Power Factor Correction Capacitor Banks

Properly designed APFC panels shall be provided to maintain power factor automatically at desired level.

CHAPTER-2

ELECTRIFICATION & WIRING OF INSTALLATION

2.1 Introduction

Proper designing of electrification of an installation is very important. The system should neither be under designed nor over designed.

A good design of electrification of an installation & its wiring takes into cognizance the following factors. Before attempting design of wiring systems, the various load systems should be designed to meet the requirement of the building/workshop/industries etc.

Estimation of load-

- (a) Lighting load
- (b) Fan load (ceiling/pedestal/table/exhaust)
- (c) Heating load (oven, electric iron, electric kettle, geyser & water heater etc.)
- (d) FHP motor load (washing machine, water pump, dish washer, refrigerator, evaporative cooler & air-conditioner etc.)
- (e) Heating/ventilation/refrigeration/air-conditioning load- for industries
- (f) Machine/equipment load- for industries

2.2 Supply System

In India we have the following supply systems:

	Voltage(V)	Frequency (Hz)	No of Phases
Domestic Consumption	240($\pm$ 6%)	50($\pm$ 3%)	1
Industrial and multi-storey buildings(4 wire)	415($\pm$ 6%) (Ph to Ph) 240($\pm$ 6%) (Ph to N)	50 ($\pm$ 3%)	3

2.2.1 Load Assessment

In order to assess the total load of a building when number of outlets has been decided, a sample calculation has been provided for mere illustration purpose. The user may modify the values as per site conditions.

Load Assessment chart

SI. No.	Element	Rating (Watt)
i)	Incandescent Lamp	60
ii)	Ceiling Fan	60
iii)	Table Fan	60
iv)	6 Amp Socket outlet	100, unless the actual value of loads are specified
v)	16 Amp Socket outlet	1000, unless the actual value of loads are specified



Sl. No.	Element	Rating (Watt)
vi)	Fluorescent Light :	
	Length:	
	a) 600 mm	25
	b) 1200 mm	50
	c) 1500 mm	90
vii)	High Pressure Mercury Vapour (HPMV) Lamps ,High Pressure Sodium Vapour (HPSV) Lamps	According to their capacity, control gear losses shall be also considered as applicable
viii)	Compact Fluorescent Lamp (CFL)	20
ix)	Light Emitting Diode (LED)	10
x)	Exhaust Fan	50
xi)	Geyser (Storage Type)	2000
xii)	Geyser (Instant Type)	3000
xiii)	Computer Point	150
xiv)	Computer (Laptop)	50
xv)	Printer (Laser)	1500
xvi)	Printer (Inkjet)	70
xvii)	Kitchen outlet	1500
xviii)	Air Conditioner :	
	1 TR	1250
	1.5 TR	1875
	2 TR	2500
	2.5 TR	3200

2.3 Reception and Distribution of Main Supply

2.3.1 Circuit Breaker

A circuit breaker or a linked switch shall be provided on live conductor of the supply at the point of entry. Wiring shall be done in such a way that there is no break in the neutral wire in the form of switch or fuse.

10.1 All main switches should be of either metal clad enclosed pattern or of any insulated enclosed pattern and should be fixed at close proximity to the point of entry of supply.

IS : 732 - 1983 stipulates that,

- Open type switch boards shall be placed only in dry situations and in ventilated rooms and they shall not be placed in the vicinity of storage batteries or exposed to chemical fumes,
- In a damp situation or where inflammable or explosive dust, vapour or gas is likely to be present, the switch board shall be totally enclosed or made flame proof as may be necessitated by the particular circumstances.
- Switch boards shall not be erected above gas stoves or sinks, or within 2.5 m of any washing unit in the washing rooms of laundries, or in bath-rooms, lavatories or toilets and kitchens,
- In case of switch boards unavoidably fixed in places with abnormal moist atmosphere, the outer casting shall be weatherproof and shall be provided with glands and bushings or adapted to receive screwed conduit, according to the manner in which the cables are run.

Metal clad switchgear should preferably be mounted on any of the following types of boards

- Hinged type metal boards
- Fixed type metal boards
- Teak wood boards
- MCB distribution panel board or PVC of fiber glass mounting.

For small installations connected to single phase, 240V, supply, teak wood boards may be used as main boards or sub-boards. These should be of seasoned teak or other durable wood with solid back impregnated with varnish of approved quality.

2.3.2 Arrangement of Apparatus on Switchgears or otherwise be as follows

- i. Equipment should be so mounted on the switchboard that there is no possibility of an inadvertent contact with live parts whenever a person is performing operations like changing fuses, manipulating switches etc.
- ii. No apparatus should project beyond any edge of the board. No fuse body should be mounted within 2.5 cm of any edge of the board and no hole, other than the holes by means of which the panel is fixed, should be drilled closer than 1.3 cm from any edge of the board.
- iii. No live parts, unless they are effectively screwed by substantial barriers of non- hygroscopic, non-inflammable insulating materials, should be so spaced as to cause an arc to be struck between live pans and earth.
- iv. The arrangement of all the accessories shall be such that these connections shall be easily accessible and. traceable. Whenever switches and fuses are fitted on the same pole, these fuses should be arranged such that they are not alive when their respective switches are in the off position.
- v. For further details IS: 732 may be referred to.
- vi. Height of batten- 2.5 m above floor level (0.5 m below ceiling)
- vii. Height of switch - 1.3 m above floor level
- viii. Height of distribution board - 1.5 m above floor level
- ix. Height of brackets for light points - 2.5 m above floor level

2.4 Conductors & Cables

Copper and aluminium conductors are extensively used for electrical purposes. Insulation on conductors is an important item as it prevents electric shock to people & animals etc. and also for preventing faults due to short circuiting. Faults lead to heating of conductors and insulation resulting in fire. Conductors covered with insulation are known as cables.

Multi strand copper cables are used for house wiring. Stranded cable sizes are expressed by giving number of strands and diameter of conductor in mm. For example 3/0.029 size cable will have 3 strands of conductor wire and each strand has 0.029 mm diameter.

Cables are designed considering the voltage and current to be handled by the cable during the normal use. Cable manufactures supply chart giving various characteristics of their cables which could be used for selection of cables. Every cable is assigned a rating which is based on the temperature that can be withstood by it. It should be noted that such rating is applicable when cable is in normal use. When cables are bunched or they run through conduit/duct or the cables are laid in ground, heat dissipation of the cables will be less than when they are used as single cable in air. This increases the operating temperature of the cable. Therefore, when cables are bunched or run through conduit/tray or laid, normal rating should be reduced or derated by multiplying with derating factor specified in manufacturers catalogue as per IS: 3961.

2.4.1 Selection of Cables

Economic size of cable should be such that it can carry the maximum expected current without damaging its insulation and at the same time voltage drop in the cable does not exceed the permissible



voltage drop as specified in IS: 732. Voltage drop between the supply point in any building and any outlet should not be more than 3% of nominal voltage in case of power load and 1% of nominal in case of light load. Voltage drop restriction is necessary otherwise voltage available at outlet may not be sufficient to give desired service. Cable size shall be calculated from IS: 3961.

2.4.2 Colour Coding & Size of Wiring Wires

- i. Phase: Red/Yellow/Blue. (Three phase wiring)
- ii. Live: Red (Single phase wiring)
- iii. Neutral: Black
- iv. Earth: Yellow/Green.

SI. No.	Types of Circuit	Minimum Copper Wire Size	Number of Circuits
i)	Lighting	1.5 mm ²	2 or More
ii)	Socket –outlets, 6 Amp	2.5 mm ²	Any Number Areas such as Kitchens and Laundries 3 X double Socket-outlets per circuits, Other areas up to 12 double socket-outlets.
iii)	Signaling & Control Circuits	0.5 mm ² (see Note No 1)	-----
iv)	Socket –outlets, 16 Amp	2.5 mm ²	1
v)	Water Heater < 3 KW	2.5 mm ²	1
vi)	Heaters or Electric Equipment more than or equal to 3 KW	4.0 mm ²	1
vii)	Free standing electric range separate oven and/or cook Top	4.0 mm ²	1
viii)	Air conditioner > 1.5 TR	4.0 mm ²	1
ix)	Permanently connected appliances including dish washers, heaters, etc,	2.5 mm ²	1 above 10 Amp, up to 10 Amp can be wired as part of a socket-outlet circuit
x)	Appliances rated > 3KW & < 6 KW	6.0 mm ²	---
xi)	Sub mains to Garage or out Building	2.5 mm ²	1 for each
xii)	Mains Cable	_____	It should be based on Demand Loads/Peak Loads & Feature Loads

Note 1:- In Multi-core Flexible Cables containing 7 or more cores and in signaling control circuits intended for electronic equipment a minimum Nominal cross section area of 0.1 mm² is permitted.

2.5 Type of Supply

2.5.1 Single phase supply

All loads in a single phase installation are connected in parallel and supplied at the same voltage. The feeder cables and the installation wiring should be designed such that switching on or off any load in the system does not affect other loads in the system.

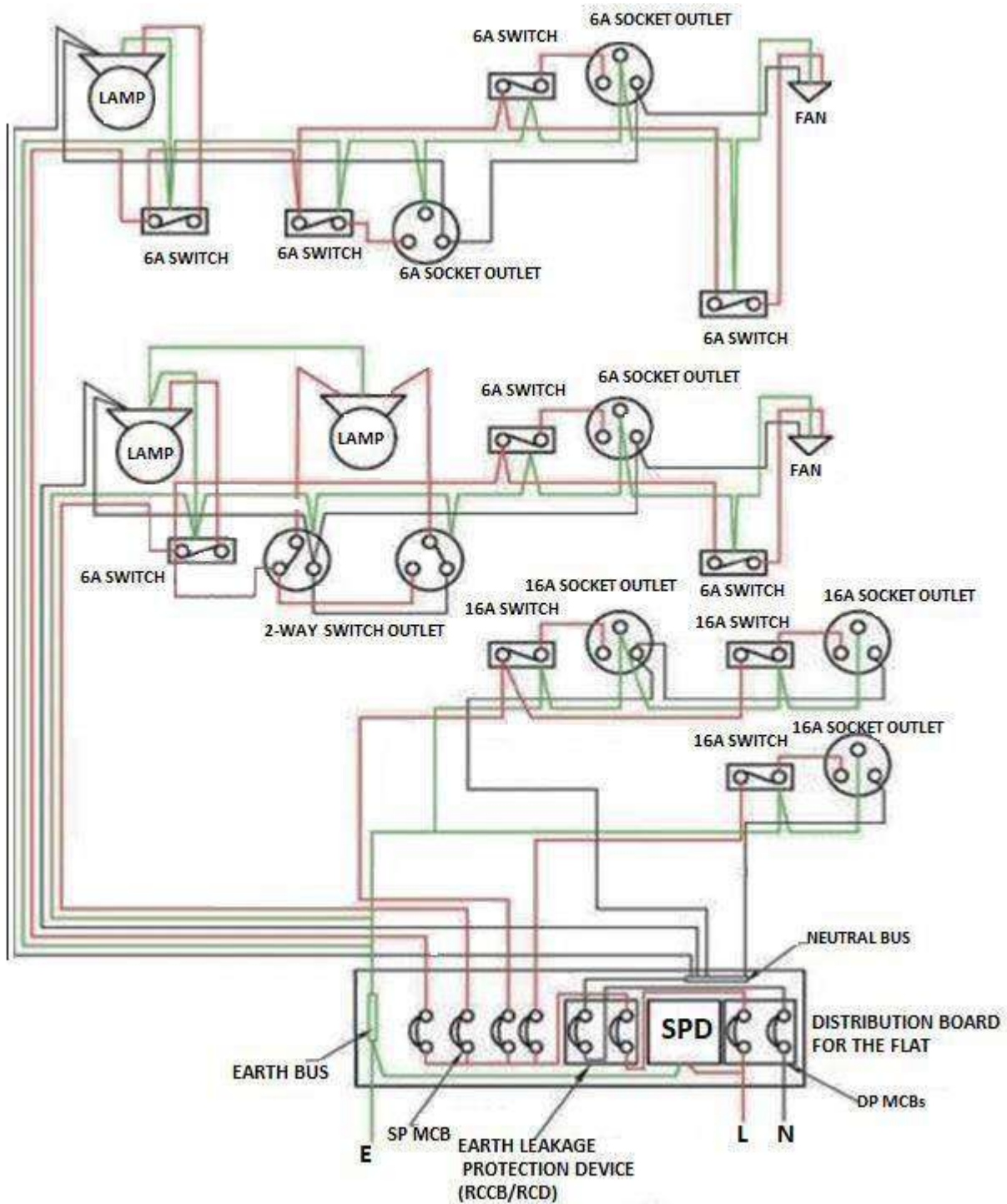


Fig.1 – Schematic of single phase installation

The consumer's main switch fuse is connected after the meter and feeds a distribution fuse board. It is important to note that fuses should be placed only in the live (or phase) wire and never in the neutral wire. Similarly all switches should be installed on the live lines only and never on the neutral. This is because if the fuse is in the neutral and has blown, there will be no flow of current. But the appliances connected will be having full supply voltage applied to them, which is dangerous, because a person could touch the live parts thinking that since the appliance is not working the supply must be off. Similarly, if the switch is on the neutral side and if it has not made foil contact, the appliances will not work causing an impression that the supply is off, when in fact full voltage is acting on the appliance which is dangerous.

The neutral, which is earthed at the supply authority's sub-station, is connected through a copper link at the main switch fuse, and must not contain a fuse either at the switch fuse or at any point in the installation. Nor should the continuity of the neutral be interrupted by the insertion of a switch.

The wiring of each sub-circuit should be electrically separate from that of every other sub-circuit. This means that every sub-circuit must have its own neutral wire as well as phase wire drawn from separate points on the distribution fuse board. This will be understood by reference to fig.1, which shows, how the wiring for the light and power sub-circuit have been taken from separate points on the distribution fuse board.

Fig.2 shows an arrangement where several distribution fuse boards are employed, in this case, for each floor such as in multistory buildings. The distribution fuse-boards are looped together as shown in the figure. The wiring by which the different distributions boards situated on different floors are looped together is called the rising mains. Thus the distribution boards are in fact connected in parallel.

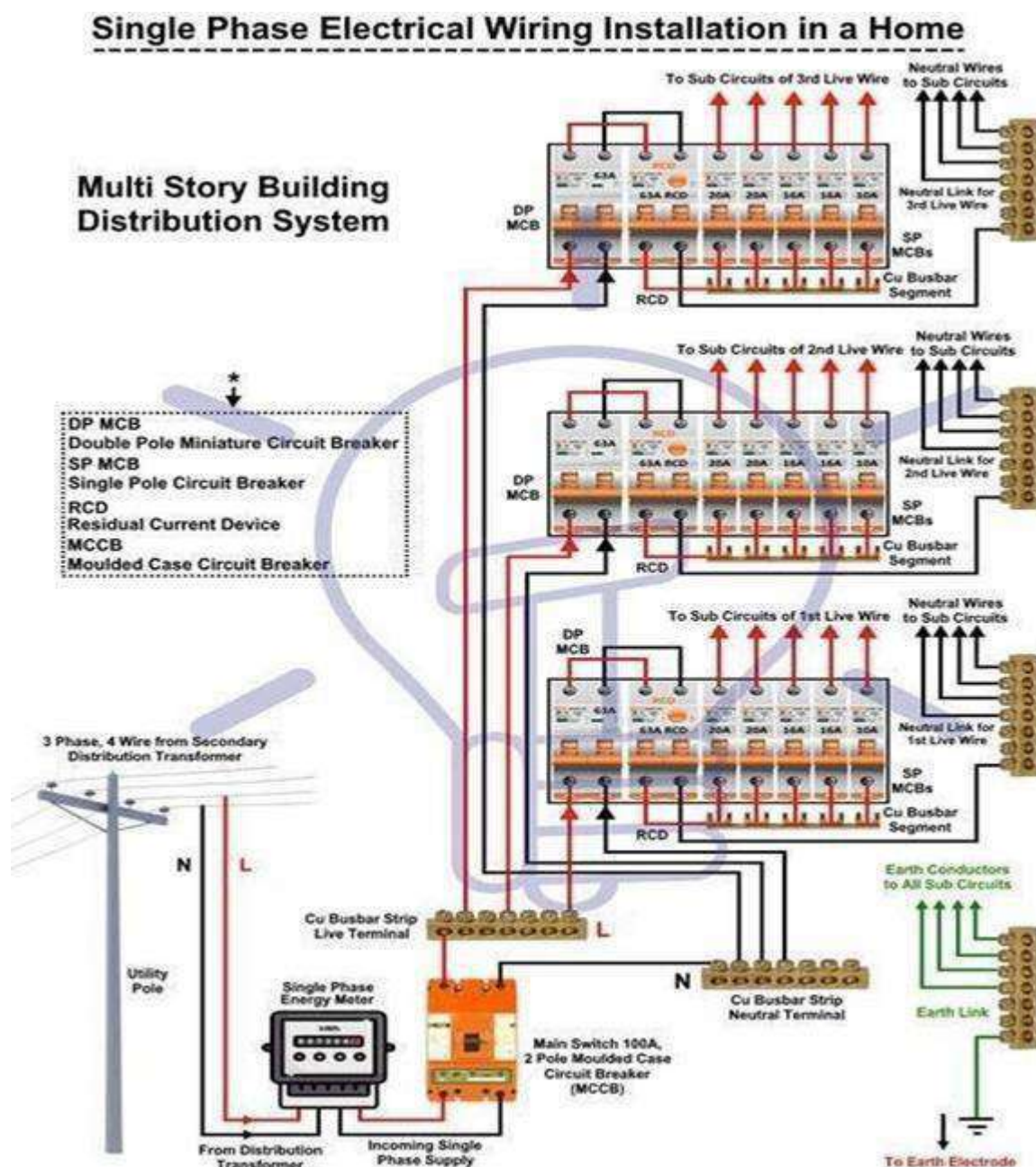


Fig.2 – Single Phase installation with number of sub distribution boards with common main switch fuse

This is an economical arrangement but suffers from the drawback that if a fault occurs in the rising mains, the main fuse, i.e. the consumer's main switch-fuse, will blow, disconnecting the complete installation.

Fig.3 shows a better, although slightly more expensive, circuit arrangement. This employs a main distribution board from which separate connections from separate points are taken to the three sub-distribution boards on the three floors. There is a separate fuse on the main distribution board in respect of each sub-distribution board. The draw back explained in the arrangement of figure 2 is thus avoided.

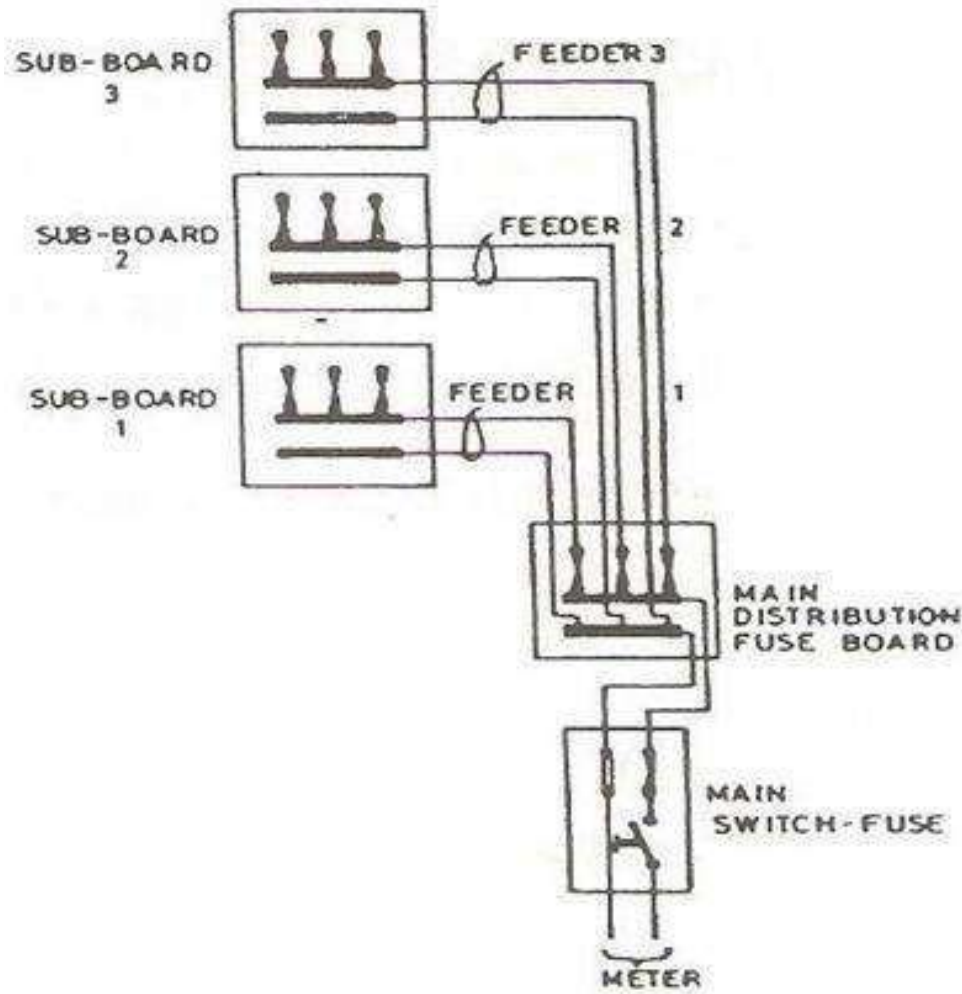


Fig.3 – Single Phase installation with number of sub distribution boards each connected to the mains through separate fuse

In certain places power for electrical heating and other heavy current consuming appliances is sold at cheaper rates than the power for lights and fans. In such cases, the heavy current supply is measured by a separate meter as shown.

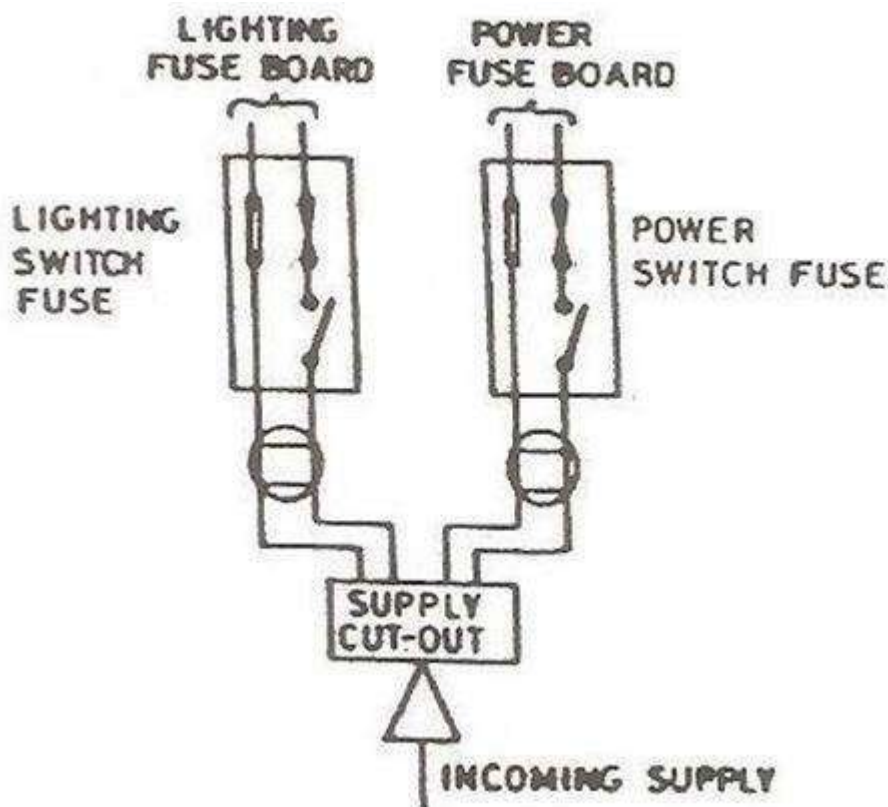


Fig.4 – Single Phase installation with separate energy meters for light and power loads

2.5.2 Three phase, Four-wire supply

Industrial premises and multi-storied buildings are given 3-Ph, 4-wire supply because of the following.

- i. In industries most of the motors above 1.5 hp are usually wound for 415 V, 50 HZ, 3-ph, supply because they are cheaper than 1-ph motors of the same rating and have better factor and higher efficiency.
- ii. In the case of large multistoried buildings the distribution system of a 3-ph, 4- wire system is more economical than that for a 1-ph system.

It is necessary that the load on the distribution system of the supply authority must be balanced. In the case of domestic single phase consumers, this is achieved by running the 3-ph, 4-wire distribution line along the residential area and connecting the first consumer between R-phase and neutral, the second consumer between Y-phase Outlets and neutral, the third consumer between B- phase and neutral and repeating the same sequence for the subsequent consumers. In the case of industries and large buildings with large load requirement, 3-ph supply is provided, so that by giving 3-ph supply to 3-ph motors, the 3-ph load balancing is automatically obtained. Balancing of the 3 phases in respect of 1-ph loads is achieved by appropriate distribution of the 1-ph loads on the 3 phases.

Basically a 3-ph, 4-wire installation is similar to that of a 1-ph type. The service cable enters a triple pole and neutral cut-out and from there the consumer's distribution starts after the meter. Fig. 14 shows the supply after leaving the energy meter, entering the triple pole and neutral (TP & N) switch fuse. The TP & N switch fuse controls a 3-Ph distribution fuse board. From the 3 phase distribution fusion board are fed the power circuits, such as motors, lighting and other small power loads. It is good practice to designate the phases by red, yellow and blue and to employ conductors using these colours of insulation for easy identification. The neutral is usually black.

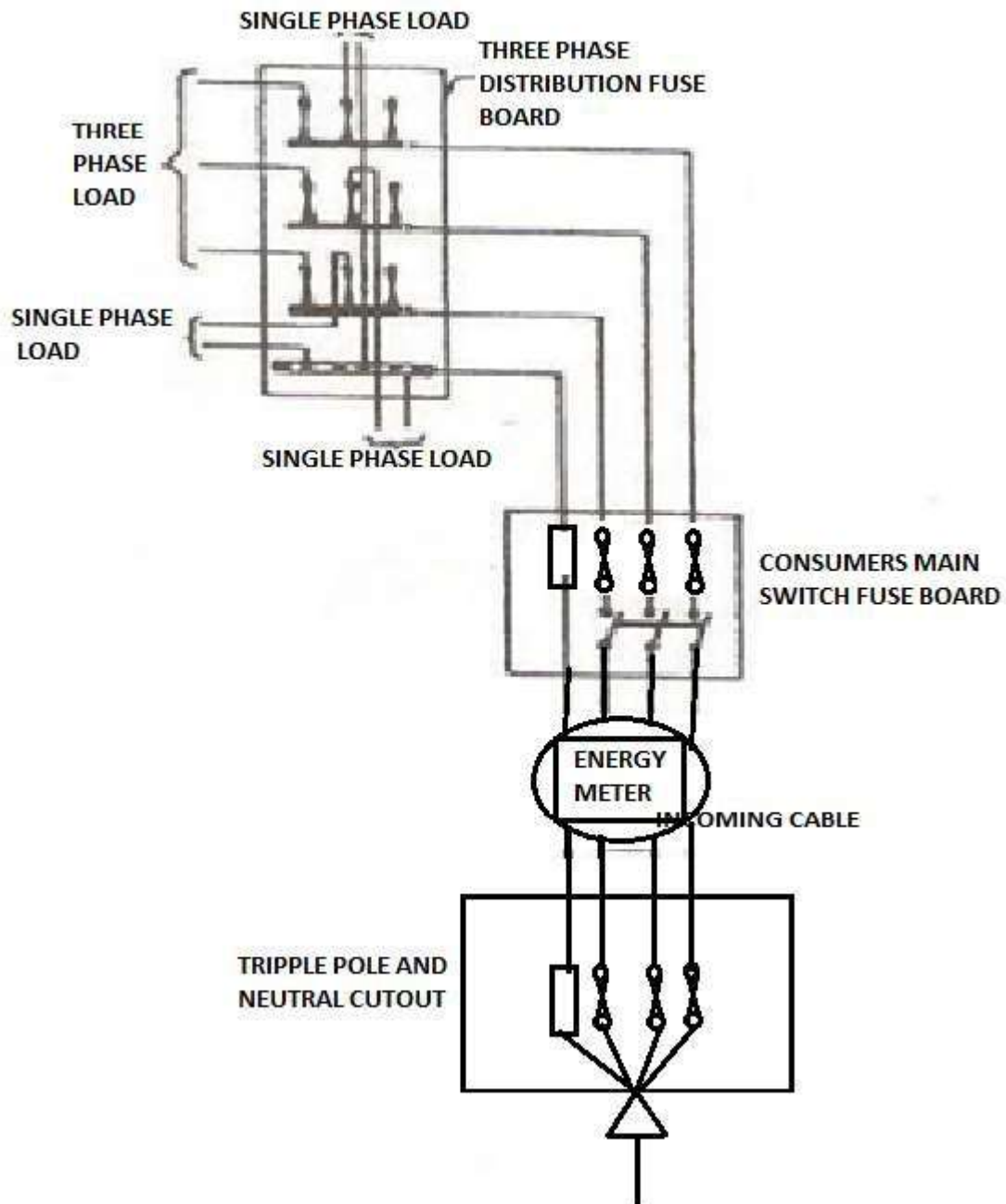


Fig.5 – Three-phase four-wire distribution for single and three-phase loads with common main switch fuse

In a balanced system the neutral carries no current. In such a case the line voltage is $3\frac{1}{2}$ times the phase voltage. For a line voltage of 415V, phase voltage is 240 V.

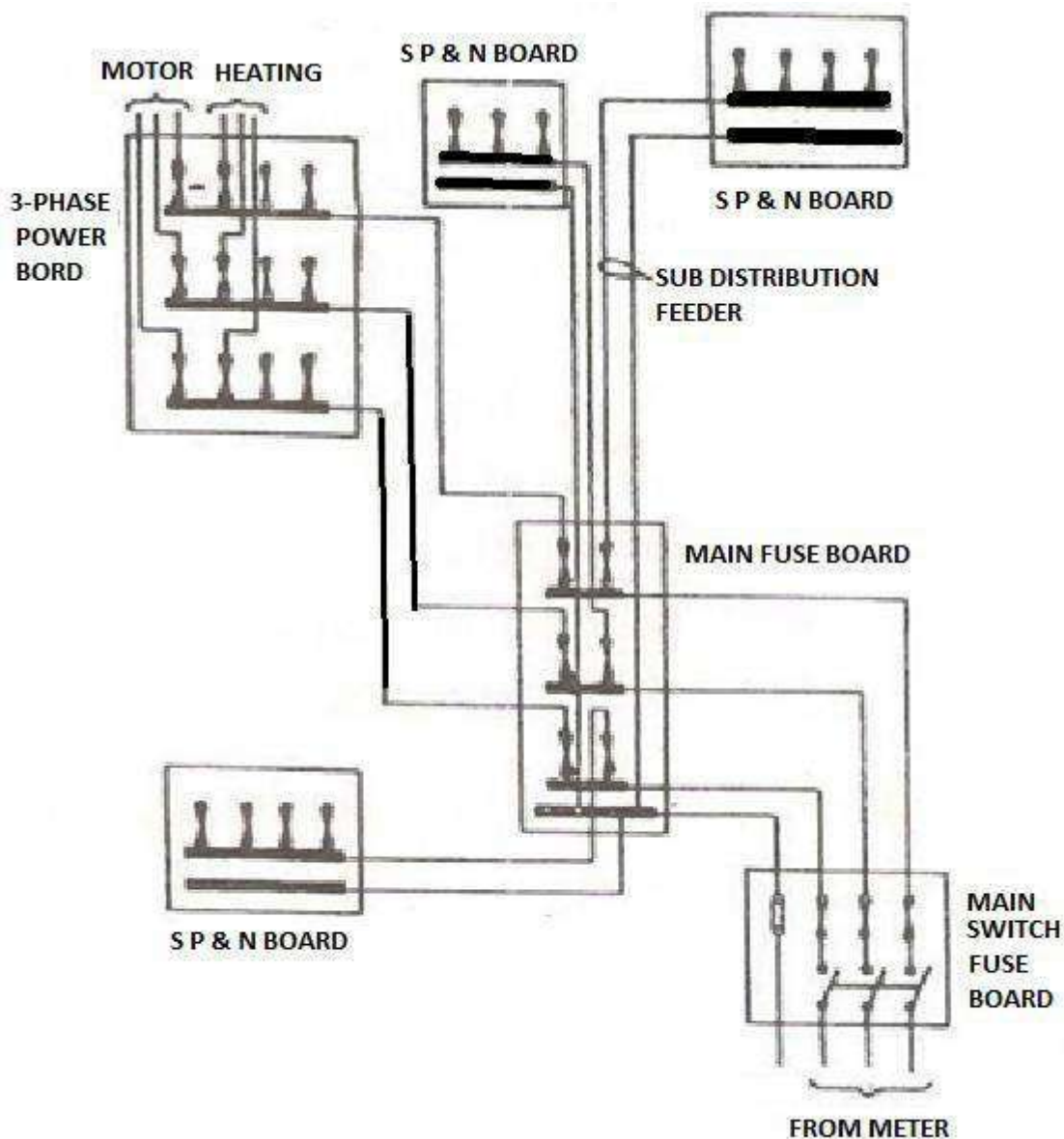


Fig.6 – Three-phase 4 wire distribution for single and 3 phase loads with separate sub-distribution boards

The drawback of the arrangement shown in Fig. 5 is that if a fault should occur in the cables feeding the distribution board, the fuses of the main switch shall blow out. This will cause the electric supply to be interrupted to all parts of the consumer's premises supplied by this main switch. It is therefore, usual to insert an extra fuse board, after the main switch to control the sub-distribution feeders as shown in fig.6.

In the case of larger installations, distribution boards with bus-bar chambers are usually employed (see fig. 7). In this case the main switch fuse feeds into a bus-bar chamber. From the bus-bar chamber, connections are taken to switch fuses which control all outgoing sub-circuits. This allows for flexibility and enables future extension with ease. Thus it is seen that all main feeders are separately controlled with independent fuse elements.

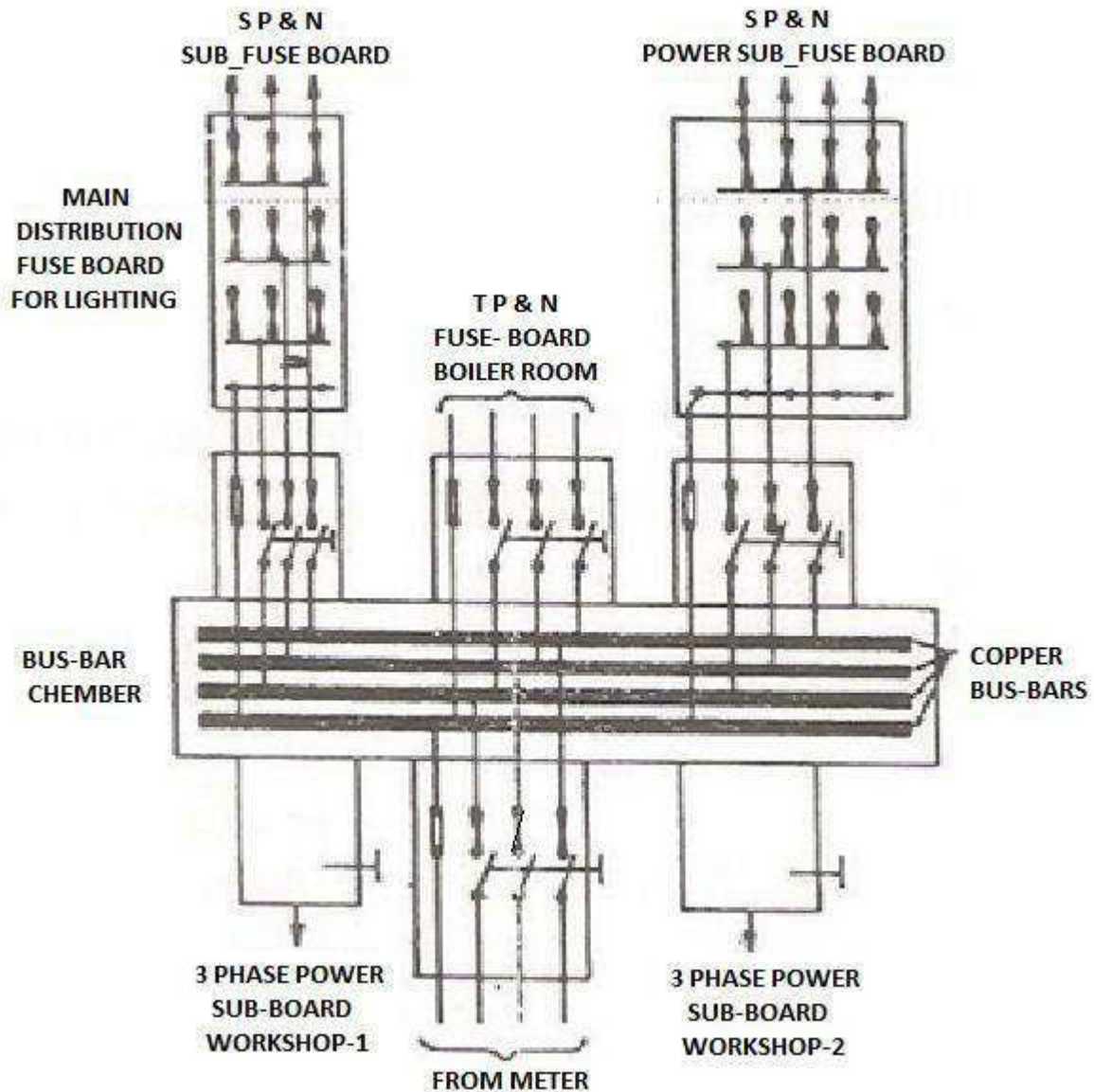


Fig.7 – 3 phase, 4 wire distribution wiring bus bar chamber

2.6 Diversity

The term diversity is used in two ways. One way is in terms of diversifying the electrical installation. By reference to fig. 8 it is seen that if a fault develops in any of the loads or in any part of the circuit, the fuse 'F' will operate and the supply to all loads will be disconnected. To ensure continuity of supply to the healthy parts of the installation it is usual to branch the load as in fig. 9.

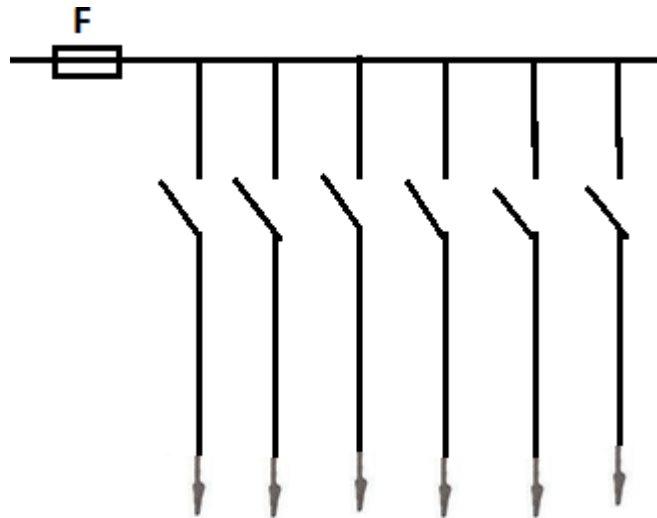


Fig.8 – Schematic of different loads connected to same supply

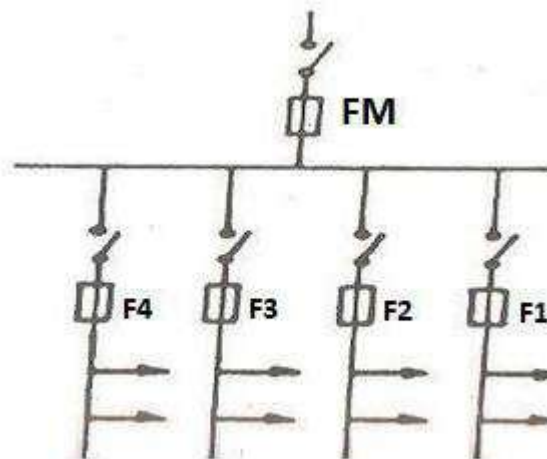


Fig.9 – Branching of load. Each branch protected a fuse

This branching of the load is called diversification of the load. Diversification enables selectivity whereby only the faulty section is disconnected by the operation of the fuse, other sections remaining connected to the supply. In the case of larger installations, further diversification becomes necessary as shown in fig. 10.

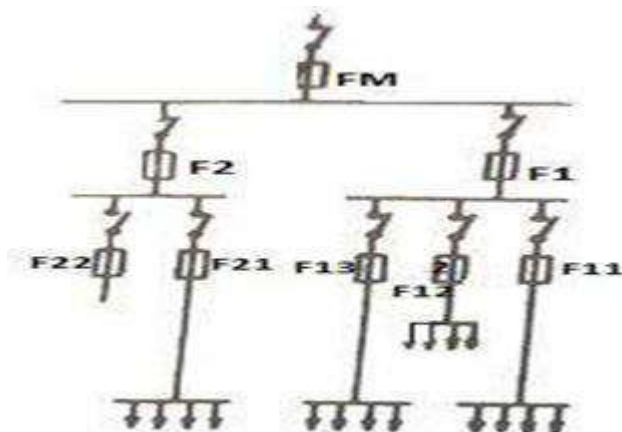


Fig.10 – Diversification of load for a large installation

The principle of diversification has in fact, been incorporated in the installation shown in figures 5, 6 and 7.

Such diversification enables maintenance and extension work on certain parts of the installation without having to switch off the whole installation.

Diversity, when used in theoretical context indicates the difference between the total connected load and the actual maximum load. By the term “Total connected load” is meant the total provision made for the utilization of power through outlet points in an installation. If the conductor size is worked out on the basis of the Total connected load with a margin for extension, it is very likely to result in thicker wires than actual load at any time might require. It must be realized that it is not only the cost of cable that matters; the larger the cable the longer is conduit size or batten size depending upon which type of wiring is used.

The total connected load is not likely to be switched on simultaneously. Thus the actual maximum load at any time in a day will, therefore, generally be less than the total connected load in an electrical installation. Therefore, while designing the conductor size for cables, care will have to be exercised on one hand to see that we do not provide too liberally for the conductor size and thus raise the capital cost too high and on the other hand to ensure that the conductor size is big enough to carry the current that is likely to be drawn by any circuit for a sustained period.

In other words the difference between the total connected load and the actual maximum load assumes importance. It is impossible to state with hundred percent accuracy what will be the maximum load on a circuit because for one thing it will vary from one type of building to another, and for another one cannot be exactly sure how much load a user may switch on from time to time. However, on the basis of experience some guidelines are available which are discussed in the following paragraphs.

2.6.1 Diversity Factor for Sub-Circuits

The calculations are based on considering that each socket outlet carries the current for which it is rated. Each lamp holder is assumed to hold a 60 W lamp unless we are sure that it will be a larger size. Other outlets are considered for the value at which they are rated. The total connected load estimated in this way is added up for each sub-circuit and one third of the total value is deducted. The remaining two thirds (66%) represents the minimum rating of cable to be provided.

However, in no case must this rating be less than that of the largest point on the sub-circuit. Further, it is not permissible to apply the 66 % rule, if there is only one point on the sub-circuit.

Considerations governing diversity factor for different types of load are discussed below:

(a) Light and Fan

On lighting and fans in domestic installations, it is permissible to assume that only 66 % of the total connected load will be switched on simultaneously. For hotels it is safer to increase the figure to 75 %. For business buildings the figure may be 90 %.

(b) Cooking Appliances

For cooking appliances in an ordinary residential house the main cable may be rated at 100 % up to 10 A and at 50 % for all loads in excess of this.

When designing the main cable for a large block of residential flats, considerable diversity is permissible in respect to electrical cooking appliances. For this purpose, we may take full load for the largest cooker, plus 50 % for the second largest, plus 33 % for the third largest, plus 20 % for the remainder. However, in hotels and other public places this large diversity is not accepted. In such cases, it is safer to take full load for the largest appliance, 80 % for the second largest and 60% for all remaining ones.



(c) Socket outlets

As stated earlier, the permissible diversity on sub-circuit wiring in respect of socket outlets is not large (about 66 %). However, the diversity is taken on a larger and more liberal basis, when calculating the loading on the main cables supplying the sub- distribution boards. In residential houses, full load rating of the sockets is taken for the largest outlet and only 40 % for all others. In hotels, rest house/ hostels and other public places a higher percentage is taken viz. 100 % for the largest, plus 75 % of the capacity of the socket outlets in the main rooms plus 40 % of the remainder.

On water heaters up to 3 KW loading, air-conditioners and refrigerators, no diversity factor may be allowed, even if several are in use.

Fuses should not be rated higher than the actual current carrying capacity of the cables they protect, otherwise protection cannot be derived.

Finally, it must be stated that the allowances for diversity as mentioned in the preceding paragraphs are rather complicated and are more as guidelines than as set rules. They should be used judiciously and with discretion, depending upon the data available for a given installation design.

2.7 Wiring

There are various types of wiring namely-surface conduit/recessed conduit, steel/PVC & channel etc. Surface wiring shall run as far as possible along the walls and ceiling, so as to be easily accessible for inspection. Above false ceiling, in no case, open wiring shall be allowed. Wiring will be done in recessed conduit or surface steel conduit. In recessed conduit system, routes of conduit will be planned, so that various inspection boxes provided don't present a shabby look. Such boxes can be provided 5 mm above plaster level, and they can be covered with plaster of paris with marking of junction boxes.

Where number of electrical services like electrical wiring, telephone wiring, computer cabling, pass through corridors, it may be proper to plan such service with properly designed aluminium/PVC channels duly covered by a false ceiling, so that subsequently such service can be maintained and additional cables can be provided. Generally conduits for wiring will not be taken in floor slabs. When it is unavoidable special precaution to be taken to provide floor channels with provision for safety and maintenance. Alternatively false flooring can be provided. When wiring cables are to pass through a wall, these shall be taken through a protection (steel/ PVC) pipe or porcelain tube of suitable size such that they pass through in a straight line without twist or cross in them on either porcelain, PVC or other approved material.

2.7.1 Wiring Connections

Wiring systems based on method of connection are of two types viz.

- (a) Joint box and
- (b) Looping in system

A. Joint Box System

Here load is connected to its controlling switch in series. Positive supply is connected to one end of control-switch by making a T joint in the main-line-positive and the other end of load is connected to neutral by similar T joint in main line neutral. These points are kept inside a wooden box (called joint box). (Fig-11)

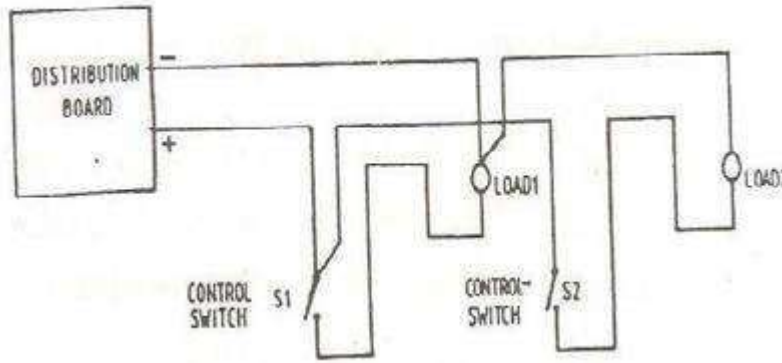


Fig – 11 Joint-box system of wiring

B. Looping in System

Instead of puncturing the main lines, here lines are brought to first load and its control switch as shown below. Now lines are brought from first load and control switch to another load and control switch. This process is repeated. (Fig-12)

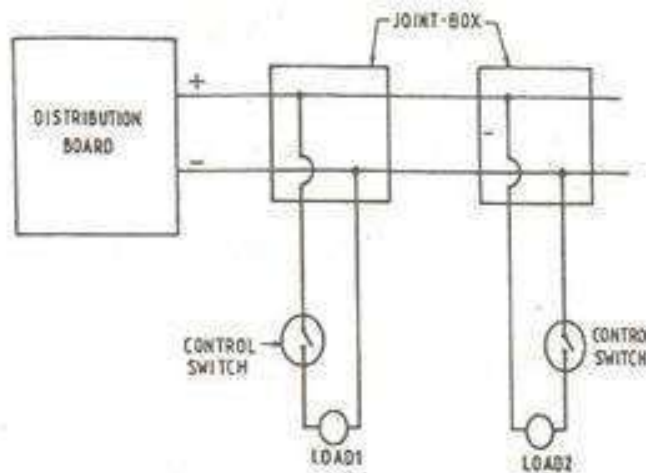


Fig – 12 Loop in system wiring

Joints in Wiring

- (a) No bare conductor in phase and/or neutral or twisted joints in phase, neutral, and/or protective conductors in wiring shall be permitted.
- (b) There shall be no joints in the through-runs of cables. If the length of final circuit or sub-main is more than the length of a standard coil, thus necessitating a through joint, such joints shall be made by means of approved mechanical connectors in suitable junction boxes.
- (c) Termination of multi-stranded conductors shall be done using suitable crimping type thimbles.

2.7.2 Wiring Types

Internal wiring (refer IS: 732) can be classified as.

- (a) Conduit wiring
- (b) PVC casing and capping wiring.

A. Conduit Wiring

Vulcanized Indian rubber (VIR) or PVC wires run through rigid steel/rigid PVC conduit pipes

conduit may run over the walls/ceiling or may be concealed under the masonry work. IS: 1653 may be referred for specification of steel conduit. In the portion exposed to sun/rain/atmospheric hazards the surface of conduits, bends, mains shall be rust proof.

For factory lighting and wiring of motors, conduit wiring is most ideal because it provides protection against mechanical damage and fire due to short circuits. Besides the system is water proof and there is ease in replacement of defective wiring.

(Concealed) Conduit Wiring

Conduit is placed in a recess cut in the wall or when building is under construction, conduit is provided in the wall/ceiling etc. Stables/saddles shall be used to fix the conduit. PVC conduit shall not be used in places prone to fire hazards.

2.7.3 Type and Size of Conduit

The Conduit wiring shall be carried out as under:

- i. All the non-metallic conduit pipes and accessories shall be of suitable materials complying with IS-2509:1973 and IS-3419:1989 for rigid conduits and IS-9573 (Part 5):2000 for flexible conduits. Internal wiring in the buildings shall be done with ISI marked PVC rigid conduit of size not less than 25 mm diameter and thickness 2.0 mm (Nominal size). PVC conduit shall be used with all its associated accessories such as bends, couplers, saddles, metal deep boxes (100 mm deep for ceilings), PVC bends etc.
- ii. Normally, concealed wiring shall be provided in all the buildings. Surface conduit wiring shall be provided if specifically given in BOQ or where it is not practicable to provide concealed wiring with approval of the RVNL.

2.7.4 Limitations

The maximum number of PVC insulated 650/1100 V grade copper conductor cables that can be drawn in conduit pipes shall be limited to 45 % of the capacity of the conduit. Table indicating the capacity is as under:-

S. No.	Size of Conduit	100 % capacity in Sq mm	45% capacity in Sq mm
1.	25 mm	490	220
2.	32 mm	804	362

2.7.5 Conduit joints-

Conduits shall be joined by means of screwed or plain couplers depending on whether the conduits are screwed or plain. For conduit fittings and accessories reference may be made to the good practice (IS : 2667, IS:3419, IS:9537 Part-I II III).

Conduit pipes shall be fixed by heavy gauge saddles, secured to suitable PVC plugs with screws in an approved manner at an interval of not more than 600mm, but on either side of couplers or bends or similar fittings, saddles shall be fixed at a distance of 300 mm from the center of such fittings except that the spacing between saddles or supports is recommended to be 600 mm for rigid non-metallic conduits.

2.7.6 Bends in conduits

Wherever necessary, bends or diversions may be achieved by bending the conduits or by employing normal bends, inspection bends, inspection boxes, elbows or similar fittings. Conduit fittings shall be avoided, as far as possible, on outdoor systems. All bends in the system may be formed either

by bending the pipes by an approved method of heating, or by inserting suitable accessories such as bends, elbows or similar fittings, or by fixing non-metallic inspection boxes, whichever is most suitable. Where necessary, solid type fittings shall be used.

2.7.7 Outlets

In order to minimize condensation or sweating in-side the conduit, all outlets of conduit system shall be properly drained and ventilated, but in such a manner as to prevent the entry of insects.

Heat may be used to soften the conduit for bending and forming joints in case of plain conduits. As the material softens when heated, sitting of conduit in close proximity to hot surfaces should be avoided.

2.7.8 Fixing of conduit in chase (concealing in plaster of wall)

The conduit pipe shall be fixed by means of staples or by means of non-metallic saddles placed at not more than 80 cm apart or by any other approved means of fixing. Fixing of standard bends or elbows shall be avoided as far as practicable and all curves shall be maintained by sending the conduit pipe itself with a long radius which will permit easy drawing in of conductors. At either side of bends, saddles/staples shall be fixed at a distance of 15 cm from the center of bends.

2.7.9 Inspection boxes (for concealed wiring)

Suitable inspection boxes to the nearest minimum requirements shall be provided to permit periodical inspection and to facilitate replacement of wires, if necessary. The inspection/junction boxes shall be mounted flush with the wall or ceiling concrete. Where necessary deeper boxes of suitable dimensions shall be used. Suitable ventilating holes shall be provided in the inspection box covers, where required.

Maximum No. of single core cables in rigid metallic/nonmetallic conduit

Size of wires		Size of conduit (dia in mm)						
mm ²	No. & Dia	16	20	25	32	40	50	60
1.5	1/1.4	3	5	10	14			
2.5	3/1.06	2	5	8	12			
4	7/0.85	2	3	8	10			
6	7/1.06		2	5	8			
10	7/1.40			3	5			
16	7/1.70				3	6		
25	7/2.24				2	6		
35	7/2.50					4	6	7
50	19/1.80					3	5	6

Maximum Number of Single-Core Cables that can be drawn into Casing and Capping

Size of wires		Size of Casing					
mm ²	No. & Dia	10/15mm x 10mm	20mm x 10 mm	25mm x 10mm	30mm x 10mm	40mm x 20mm	50mm x 20mm
1.5	1/1.4	3	5	6	8	12	18
2.5	3/1.06	2	4	5	6	9	15
4	7/0.85	2	3	4	5	8	12
6	7/1.06		2	3	4	6	9



Size of wires		Size of Casing					
10	7/1.40		1	2	3	5	8
16	7/1.70			1	2	4	6
25	7/2.24				1	3	5
35	7/2.50					2	4
50	19/1.80					1	3
70						1	2

2.7.10 Surface Conduits

- Surface or open conduit pipes shall be fixed by heavy gauge saddles, secured to suitable approved plugs embedded in walls/ firmly secured with tresses etc. with screws in an approved manner at an interval of not more than 60 cm on either side of the coupler or bends or similar fittings. The saddles shall be fixed at a distance of 30 cm from the center of such fittings. Open conduit wiring shall be laid parallel/ perpendicular to the walls and suitable clamps shall be fixed properly. For 25 mm diameter conduit, width of clamp shall be 19 mm and of 20 SWG wall thickness. For conduits of 32 mm and above, width of clamp shall be 25 mm and of 18 SWG wall thickness.
- Where conduit pipes are to be laid along trusses, steel joints etc., the same shall be secured by means of special clamps made of mild steel. Where it is not possible to drill holes in the truss members, suitable clamps with bolts and nuts shall be used
- Where conduit pipes are to be laid above false ceiling, conduit pipes shall not be clamped to false ceiling frame work and shall be suspended with suitable supports from the suffix of slab. For conduit pipes to run along with wall, the conduit pipe shall be clamped to wall above false ceiling in uniform pattern with special clamps approved by the Engineer at site.

2.7.11 Installation of Conduit system

Common aspects for both concealed and surface conduit works

- The erection of conduits of each circuit shall be completed before the cables are drawn in.
- All joints shall be sealed/ cemented with approved cement. Damaged conduit pipes/fittings shall not be used in the work. Cut ends of conduit pipes shall have neither sharp edges nor any burrs left to avoid damage to the insulation of conductors while pulling them through such pipes.
- Radius of bends in conduit pipes shall not be less than 7.5 cm. No length of conduit shall have more than the equivalent of four quarter bends from outlet to outlet.
- Care shall be taken while bending the pipes to ensure that the conduit pipe is not damaged, and that the internal diameter is not effectively reduced.
- Outlets- All switches, plugs, fan regulators etc. shall be fitted in flush pattern. The fan regulators can be mounted on the switch box covers, if so stipulated in the tender specifications, or if so directed by the Engineer.
- Painting- After installation, all accessible surfaces of metallic accessories shall be painted.
- Casing and Capping- PVC casing and capping shall conform to BIS Specification No.14927 Part 2 and for wiring application with the required accessories viz. bends and tees etc., as per site conditions. They should be properly fitted along with the required accessories viz. couplers, junction box, bends, tees, PVC round blocks, sockets, clamps, bolts, nuts, and screws etc., as per the site conditions. They shall be used in suitable size to accommodate the wiring and shall be laid straight horizontally/vertically on the wall/roof etc.

2.8 Attachment of Fittings and Accessories

(a) Conduit Wiring System

- i. All accessories like switches, socket outlets, call bell pushes and regulators shall be fixed in flush pattern inside the switch/regulator boxes. Accessories like ceiling roses, brackets, batten holders etc. shall be fixed on outlet boxes. The fan regulators may also be fixed on outlet boxes, if so directed by the Engineer-in-charge.
- ii. Aluminium alloy or cadmium plated iron screws shall be used to fix the accessories to their bases.
- iii. The switch box/regulator box shall normally be mounted with their bottom 1.25 m from floor level, unless otherwise directed by the Engineer-in-charge.

(b) Fixing to Walls and Ceiling

- i. Wooden plugs for fixing to wall/ceiling will not be allowed. Fixing will be done with the help of PVC sleeves/Rowel plugs/ dash fasteners as required.
- ii. Drilling of holes shall be done by drilling machines only. No manual drilling of hole will be allowed.

2.9 Protection Schemes

Every electrical installation shall be so designed that,

- i. There should be a ready means of isolation of a circuit from power in case of accident or when servicing of circuit is needed by use of suitable switches.
- ii. All conductors/cables are able to carry maximum expected current producing minimum heat and voltage drop.
- iii. Protection is provided against excessive current (due to fault conditions or otherwise) by means of either fuse or circuit breakers.
- iv. Protection is provided against electric shock by use of Earth Leakage Circuit Breaker (ELCB) or residual current breakers (RCB).

2.9.1 Earthing

All metallic portions of equipment (except current carrying conductors) shall be properly earthed. System earthing shall be done as per IS: 3043. Electric supply authority provides an earthed terminal on consumer premises. Consumer is expected to provide his own earthing system with an independent electrode. Consumer's earth wire should be connected to supplier's earth terminal. All metal parts in wiring (except current carrying cable conductors) shall be securely earthed by running a continuous earth wire along the wiring and connecting to it all metallic fittings, lamp brackets, three pin socket, body of fans and regulators, cooking ranges & geysers etc.

2.10 Fuses and Circuit Breakers

Most of the electrical loads take high initial current for a fraction of a second before falling to normal value. Therefore, protective-scheme against excessive current must be so sensitive as to interrupt the supply for transitory current that persists before any damage to equipment results.

Fuses are rated in amps. Rating amps, of a fuse is usually 60-90% of current that is going to melt the fuse (critical current). A fuse wire to protect a circuit of 5A may have a critical current of $5/0.9 \text{ Amp.} = 5.5\text{A}$.

Simple rewirable fuse is most common, but High Rupturing capacity (HRC) fuses are gradually replacing the rewirable fuses, particularly in industrial applications.



2.10.1 Cartridge fuses

Here fuse wire is in a sealed ceramic cartridge packed with filler material which prevents deterioration of fuse-wire in normal use and protects the system in case of fault.

Cartridge fuses are of two types viz.

- i. D-type cartridge fuse.
- ii. Link type, often called HRC fuse link.
- iii. Link type cartridge fuse may be of knife blade type or bolted type

A. Diazed or D-Type cartridge fuse

D-type cartridge fuses have rating ranging from 2 to 63 amperes. The fuse element with quartz as the filler materials is enclosed in a high compression ceramic material designed to withstand the mechanical and thermal stresses which are likely to arise from short circuit currents. The filler material is used for cooling the arc after the melting of the fuse element. A small coloured disc on top of the cartridge fuse is used as indicator for the fusing of a contact. The indicating disc is kept in position by a spring wire. When the fuse is blown the indicating disc is thrown off by the spring. After fusing, the cartridge has to be replaced. The cartridge fuse is placed in a fuse base.

B. Link Type HRC fuse

HRC fuse links are fuses with high rupturing (i.e. breaking) capacity and are available in ratings from 2 to 1250 amperes. A HRC fuse consists mainly of a fuse base and a fuse link.

The construction of the fuse link is basically same as that of the D-type cartridge fuse. The body is designed to withstand very high pressures. The fuse element, made of silver or silver plated copper, is a flat strip, which is perforated. The strip is made flat to provide for better cooling. Owing to the higher rupturing capacity, higher speed of operation under short circuit conditions, silent operation and non-deteriorating features and low temperature-rise cartridge fuses are replacing the rewire-able fuses.

2.10.2 Moulded case air circuit-breaker (MCCB)

This breaker has received wide acceptance in industry. It is particularly adoptable in large buildings and industrial plants to replace fused knife switch-es. It was originally built to have only 5000A breaking capacity, but the larger breakers now have a capacity upto 42000A at 600V ac or 50,000A at 250V, dc. The moulded case circuit breaker, in smaller sizes, is adaptable, in home lighting circuits where convenience of automatic protection with manual-reset of the breaker is required. The interrupting capability of the moulded case breaker and that of silver-sand type of fuse in series with it have been combined to produce a low voltage circuit-breaker with wide application possibilities.

2.10.3 Miniature circuit breaker (MCB)

Miniature version of moulded case circuit-breakers are also available to cater the need of interruption of small currents usually encountered in house-holds. These are quite compact and reliable.

The usual construction makes use of two fixed terminals mounted one above the other in a vertical plane, which, when the breaker is closed, are bridged under heavy pressure by a bridging member operated by a system of linkages. Auxiliary and arcing contacts close before and open after the main contacts, so as to relieve the main contacts from damage due to arcing. The breaker is held closed by a latch or the equivalent which may be tripped- electrically or mechanically. Modern breakers are trip free. Barriers between poles are generally furnished with breakers on ac and dc circuits, 250V and above and, special arc chutes, quenchers or deionizing chambers are also used.

MCBs to be used shall conform to IS:8828.

The current ratings of miniature circuit-breakers shall be chosen from the values given below 6, 10, 16, 20, 25, 32, 40, 50, 63, 80, 100 and 125 A.

2.11 Miscellaneous items for reference

- i. Unless the flexible cables are mechanically protected by armour, or tough rubber, or PVC sheath, these shall not be used in workshops and other places where they are liable to mechanical damage.
- ii. Flexible cable connection to bell push from ceiling rose shall be taken through steel conduit/ metallic casing and capping. Wiring Accessories
- iii. Control Switches for Point
 - (a) Control switches (single pole switch) carrying not more than 16A shall be modular type. The switch shall be 'On' when the knob is down.
 - i. In type I, II & III quarters, Barracks & school buildings (except principal's & staff rooms) etc. Piano type switches shall be provided (unless specifically asked for by the user department / Architect.)
 - ii. Modular type switches to be provided for remaining types of buildings i.e. in all types of remaining non-residential buildings & residential buildings of type IV & above & Transit hostel or as may be decided by the Architect/ user department. (Note: Provision is meant for new constructions and in existing buildings during rewiring if the building work renovation is also in progress in the area. Otherwise existing type of piano switches will be continued.)
 - (b) It is recommended to provide double pole MCB in proper enclosure as power outlet for window type AC units, geysers etc.

iv Switch Box

- (a) Switch box shall be hot dip galvanized, factory fabricated, suitable in size for surface/ recess mounting and suitable in size for accommodating the required number of switches and accessories (where required to be used for applications other than modular switches/ sockets).
- (b) Switch box also can be of non-metallic material. The technical sanctioning authority will approve specified makes of reputed quality and specifications.

v. Switch Box Covers (for application other than modular type)

Phenolic laminated sheets of approved shade shall be used for switch box covers. These shall be of 3 mm thick synthetic phenolic resin bonded laminated sheet as base material and conforming to grade P- I of IS 2036 : 1974.

Note: Specification for switch boxes is covered in the chapters on the various types of wiring.

vi. Ceiling Rose

- (a) A ceiling rose shall not be used on a circuit, the voltage of which normally exceeds 250V.
- (b) Only one flexible cord shall be connected to a ceiling rose. Specially designed ceiling roses shall be used for multiple pendants.
- (c) A ceiling rose shall not embody fuse terminal as an integral part of it.



vii. Fittings

Types: The type of fittings shall be as specified in tender documents.

(a) Indoor Type Fittings

- i. Where conductors are required to be drawn through tube or channel leading to the fitting, the tube or channel must be free from sharp angles or projecting edge, and of such size as will enable them to be wired with the conductors used for the final circuit without removing the braiding or sheathing. As far as possible all such tubes or channels should be of sufficient size to permit looping back.
- ii. Wires used within prewired fittings shall be flexible with PVC insulation and 14/0.193 mm (minimum) copper conductors. The leads shall be terminated on built- in-terminal block, ceiling rose or connector, as required.
- iii. Fittings using discharge lamps shall be complete with power factor correction capacitors, either integrally or externally. An earth terminal with suit-able marking shall be provided for each fitting for discharge lamps.
- iv. Fittings shall be installed such that the lamp is at a height of 2.4m above floor level, unless otherwise directed by the Engineer-in-charge.
- v. Fittings made of CRCA shall be phosphatized and powder/epoxy painted. For coastal areas and humid area like toilets, kitchen, for prolonging the life of such fittings, corrosion free materials like engineering plastic, aluminium, stainless steel etc. should be used.

(b) Outdoor Fittings

Outdoor fittings shall have suitable IP protection. It is preferable that street light fittings are of cast aluminium body of IP 65, for reducing recurring maintenance cost and improved performance. Where required IP 66 fittings also can be provided for reducing maintenance frequency and cost. Other fittings, which are not available with tested IP 65/54 protection, can be properly fabricated with weatherproof features, proper gasketing etc. As far as possible corrosion free material like cast aluminium, stainless steel, engineering plastics may be used for fabrication of such fittings, to prolong life of such fittings. There should not be any exposed wiring in such outdoor fittings.

2.12 Power Supply at Railway stations

Electrical practice for general power supply at railway stations has been detailed in RDSO guidelines ED/EEM letter No-EL/EM/0025/PSRS, dated 14.08.2019 is placed at Appendix-II.

CHAPTER-3

MAINTENANCE OF GS EQUIPMENT

3.1 Introduction

Indian Railways owns a huge inventory of General Services Equipment which is catering to internal customers like Workshops, Sheds, Maintenance depots, Offices and colonies and external customers like passengers and Goods/Parcel merchants. The activities involve receiving of power from supply utilities at distribution stations and its transportation to various load centers by means of lines/cables. Maintenance is the work of keeping the plant and equipment in good condition for operation. It is the action taken to prevent plant and equipment from failing and to repair normal degradation experienced with the operation and to keep it fit for operation.

Adequate maintenance of plant and equipment is necessary to ensure that the plant and equipment is working reliably and effectively. Maintenance can be part of a planned program or may have to be carried out at short notice after a breakdown. It is carried out to prevent equipment problems and to put fault right. It always involves non-routine activities and can expose those involved and others as well to a range of risks. An effective maintenance program can result into more reliable plant and equipment. Fewer breakdowns will mean less dangerous contact with machinery is required. This ultimately results into reliable service with minimal interruptions and better productivity.

3.2 Scope

Maintenance schedules of various power supply equipment at the receiving/sub stations will be explained. At load centers, details of maintenance activities for equipment like lights, fans, air conditioning units, and pumps will be taken up. Further maintenance schedules of solar power plants will be exhibited as their population is constantly rising and their performance has a direct financial implication.

3.3 Maintenance of Air-Conditioning Plant

3.3.1 Maintenance of Centralized Air-Conditioning Plant

Inspection and Routine Maintenance of Air-Conditioning Equipment

Details of preventive maintenance checks of Air-Conditioning Equipment are as follows-

A. Daily schedule

- i. Checking of lubrication.
- ii. Check pump glands.
- iii. Check water level in cooling towers.
- iv. Do visual check and operate the plant and ensure the working of the plant.
- v. Check operating pressures.
- vi. Check for unusual noise and vibration.



B. Weekly schedule

- i. Clean water strainers.
- ii. Check the earth connection and fuses.
- iii. Clean the condenser and other equipment.
- iv. Check for leakage of gas (exterior).
- v. Clean the controls.
- vi. Clean all the air filters.

C. Monthly schedule

- i. Check compressor oil for discoloration or contamination.
- ii. Check starting and running current and voltage while running.
- iii. Check the insulation resistance valve.
- iv. Defrost cooling coil, close suction line slowly and note the efficiency.
- v. Check oil level.
- vi. Check leak in the seal of shaft.
- vii. Check leak LP and HP cut-outs i.e. 5 lbs/inch² for LP and 150 lbs/inch² for HP.
- viii. Check expansion valves.
- ix. Check for entire system with the help of water & soap.
- x. Clean the drip tray with water.
- xi. Check the condition of blower fans, shafts and its direction of rotation.
- xii. Check the ducting condition.
- xiii. Check the working of the plants and limits of vibration and noise.
- xiv. Carry out the capacity test.

D. Yearly schedule

In addition to daily, weekly and monthly schedule, following checks should be done:

- i. Check suction and delivery of the compressor and its efficiency.
- ii. Change the compressor oil.
- iii. Clean the condenser with compressed air, brush and water carry out pressure test at 250 psi of CO₂ for any leaks.
- iv. Dismantle the weather make chamber by removing duct connections and opening the return air box, clean the evaporator coil, drip tray, ducting and repair the return air box (if required), paint the system and re-install the same.
- v. Overhaul the blower motor including cleaning of runners.
- vi. Check the service valves for wear.
- vii. Overhaul the compressor motor and starter.
- viii. Clean the contacts of LP/HP switches.
- ix. Check and adjust the alignment of belts and their tension.
- x. Check the wiring and all the connections including meggering.
- xi. Complete test for leaks.
- xii. Check thermostatic switch and clean the contacts.
- xiii. Leak test the entire system.

E. Long shutdown and Restart of Centralized AC Plant

It is necessary to shut down the system for a long time to perform preventive maintenance and annual overhaul. Besides the system may not be required in cold weather, particularly in Northern locations. It is desirable to pump down the refrigerant chances of refrigerant leak from the line joints and the compressor shaft seal. The following steps should be taken:

- i. In order to avoid freeze up in chiller during pump down make sure water is circulating through the chiller.
- ii. Make sure that there are no refrigerant leaks on the condenser. Rule out leaks on the hit-gas inlet and liquid outlet joints and the valves. Make sure the valves are holding.
- iii. Pump down the refrigerant as described under compressor pump-down. To ensure that there is no refrigerant left behind the lines, open the liquid solenoid valve.
- iv. Open the main electric dis-connection switch, sealing it in that position with a warning tag against possible un-authorised attempts of operating the system.

After the system shut-down for a long time, observe the following sequence in starting the system:

- i. Close all water drain, inspect all lines and auxiliary equipments such as cooling tower and water pump.
- ii. Manually rotate the shafts of all auxiliary equipments to make sure, they are free.
- iii. Fillip the condenser water and chilled water circuits.
- iv. Open the compressor discharge shut-off valve and make sure that the suction shut-off valve is open.
- v. Close the system's main electric dis-connection switches.
- vi. Open the liquid line valve and let out some refrigerant to fill up system by energising the solenoid valve for a short while.

F. Operating procedure of Centralized AC

1. Plant Starting Procedure

Before starting the plant ensure that all electrical controls, interlocking, safety controls are set correctly. Direction of rotation and greasing of bearing are correct. AC supply is available at 415 V, 3 phase.

- i. Ensure that the water in the cooling tower sump tank is upto the prescribed level and if not, fill the water upto the required level.
- ii. Open all the valves at the suction and discharge of condenser water pump and condenser. Start the condenser water pump and ensure that the water flow across the condenser is adequate. Start the cooling tower fan (in case of induced draft). Ensure water in the make-up water tank during the operation of the plant.
- iii. Open all the valves at the suction and discharge off chilled water pump and chiller. Start the chilled water pump and ensure that the water flow across the chiller is adequate. Also ensure that water level in expansion tank is adequate during the operation of the plant (in case of chilled water plants).
- iv. Start the air handling units. Dampers on AHU should be kept open.
- v. Ensure that the oil in the compressor crankcase is upto the prescribed level.
- vi. Ensure that both suction and discharge valves of the compressor (in case heater has been provided).
- vii. Start the compressor on unload and put on load of 50% and 100% gradually. Observe the HP, LP and OP carefully.



viii. On full load : HP should be 14 - 18 Kg/cm²

LP should be 3.5 - 4.5 Kg/cm² OP should be 1.5 - 2 Kg/cm²

ix. Tank temperature readings every two-hour along with currents and pressure readings of plants and enter properly in the logbook.

2. Shutdown Procedure

Stopping of the plant should be in following order:

- i. Stop the compressor unit.
- ii. Close the discharge valve, Condenser inlet globe valve, liquid line valve and suction of compressors.
- iii. Stop condenser water pump.
- iv. Stop cooling tower unit.
- v. Stop Air handling unit

H. Troubleshooting of Centralized AC Plant

Before attempting any repairs, the cause of trouble should be determined as accurately as possible. Correct identification of fault will result in an efficient service operation. To help identify the fault the following aspects need to be examined:

- i. System sufficiently charged. Overcharged/Undercharged.
- ii. Functioning of evaporator.
- iii. Condition of the cooling coil.
- iv. Voltage within the allowed tolerance.
- v. Sufficiently water supply to the condenser. Temperature within limits.
- vi. Auxiliary equipment (pump and fans) in good working condition.
- vii. Proper working of expansion valve.
- viii. Setting of safety controls as per operating conditions.

Definite symptoms will accompany a faulty operation in the system. The condition which cause these symptoms must be corrected to restore proper operation. The trouble-shooting chart help to determine the sources of the trouble and correct them promptly.

Trouble 1: Compressor fails to start

Possible Cause	Corrective Steps
Main disconnect switch open	Close switch
Fuse blown	Check electrical circuits and motor winding for short or grounded. Investigate for possible overloading. Replace fuse after fault is corrected.
Defective contractor	Repair or replace
System shut down by safety device	Determine type and cause of shutdown and correct it before resetting safety switch
Thermostat setting too high	Check evaporator temperature. Lower thermostat setting, if possible without freeze-up.
Liquid line solenoid not opening	Repair or replace
Motor (electrical) trouble	Check motor for open/short circuits, or burnt-out
Loose wiring.	Check all wire junctions. Tighten all terminal screw.

Trouble 2: Compressor noisy or vibrating

Possible Cause	Corrective Steps
Improper isolation	Check isolator operation
Improper piping support	Relocate, add or remove hangers
Improper clearances	Excessive wear of moving parts. Overhaul compressor and replace defective parts
Flooding of refrigerant into crankcase	Check rating and setting of expansion valve
Belts/Coupling loose or aligned.	Tighten/Re-align.

Trouble 3: High discharge pressure

Possible Cause	Corrective Steps
Discharge shut-off valve partially closed	Open valve
Condenser water flow insufficient or temperature too high	Check water shut-off valve. Investigate ways to increase water supply
System overcharged with refrigerant	Remove excess
Choked/Clogged condenser tubes	Clean
Non-condensable in system	Purge the non-condensable.

Trouble 4: Low discharge pressure

Possible Cause	Corrective Steps
Low water temperature	Adjust water shut-off valve to reduce water quantity
Suction shut-off valve partially closed	Open valve
Insufficient refrigerant in system	Check for leaks. Repair and add charge
Low suction pressure	See corrective steps for low pressure
Compressor operating unloaded.	See corrective steps for failure of compressor to take load
Condenser too large	Check condenser rating table against the operation
Worn piston rings. Worn discharge valve	Overhaul compressor

Trouble 5: High suction pressure

Possible Cause	Corrective Steps
Excessive load	Reduce load or add equipment
Expansion valve over feeding	Check remote bulb. Regulate superheat. Check valve operation. Repair or replace if necessary
Compressor operating unloaded	See corrective steps for failure of compressor to load up

Trouble 6: Low suction pressure

Possible Cause	Corrective Steps
Chilled water pump not operating (Applicable to indirect expansion systems only)	Check and start pump
Lack of refrigerant	Check for leaks. Repair and add charge

Possible Cause	Corrective Steps
Evaporator dirty or iced up	Clean or defrost
Clogged liquid line filter-drier	Replace cartridge (s).
Clogged liquid line or compressor suction gas strainers.	Clean strainers
Expansion valve malfunctioning	Check and reset for proper superheat. Repair or replace if necessary
Condensing temperature too low	Check means for regulating condensing temperature
Compressor not unloading	See corrective steps for failure of compressor to unload
Evaporator fan not operating	Check and start fan. If interlocked, check the circuit

Trouble 7: Compressor not unloading

Possible Cause	Corrective Steps
Solenoid Valve in the oil line stuck closed, not relieving oil pressure on the unloader mechanism	Repair or replace the valve after ruling out physical block due to foreign matter
Faulty unloader mechanism	Repair or replace after ruling out other possibilities
Reduction in the compressor capacity not called for	No action
Defective automatic control	Check setting and verify operation

Trouble 8: Compressor not loading

Possible Cause	Corrective Steps
Inadequate oil pressure	Rule out a clogged oil strainer and foam in the oil, failing which check the oil relief valve and as a last resort verify oil pump and moving parts clearance after disassembly
Solenoid Valve in the oil line not opening for oil flow	Check whether Solenoid Coil is getting energised properly
Faulty unloader mechanism	Repair or replace after ruling out the possibilities
Defective automatic control	Check setting and verify operation

Trouble 9: Compressor indicates little or no oil pressure

Possible Cause	Corrective Steps
Low oil pressure	See corrective steps for loss of oil. Add oil.
Excessive liquid refrigerant in crankcase.	Energise crankcase heater. Reset expansion valve for higher super heat. Check liquid line solenoid valve operation.
Leaky oil line	Locate the leak and repair
Oil pressure gauge defective	Oil pressure gauge defective
Defective oil pump relief valve	Repair or replace

Possible Cause	Corrective Steps
Oil-failure safety switch defective	Repair or replace
Worn out oil pump	Replace
Broken oil pump tang	Replace pump assembly
Clogged suction oil strainer	Replace pump assembly
Worn out bearings	Overhaul compressor

Trouble 10: Compressor short cycles.

Possible Cause	Corrective Steps
Thermostat differential set too close.	Reset differential.
Leaky liquid-line solenoid valve.	Replace solenoid valve, if a non-recycling relay has been provided in the circuit, cycling will not occur.
Refrigerant overcharge	Remove excess to bring down the discharge pressure. If the high pressure switch has a manual reset, cycling will not occur.
Inadequate refrigerant	Check for leaks. Repair and add make up charge. If the low-pressure switch has a manual reset cycling will not occur.

Do's and Dont's

Do's

- Do evaluate the Compressor before carrying out maintenance.
- Do understand the problem while carrying out the repairs.
- Do keep all the tools, gauges and instrumentation in working condition.
- Do work with full confidence.
- Do keep plant room clean.
- Do ensure that in three-phase supply, the neutral is available.

Dont's

- Don't use the compressor to build up pressure. If used to compress air, overloading and damage may result.
- Don't use Oxygen to build up pressure. When using dry Nitrogen, guard against building up dangerous pressure in the system.
- Don't use system compressor to evaluate the system.
- Don't pump the compressor below 0-15 kg/cm² (2 psi). Negative pressure pulls moisture and dirt into crankcase.
- Don't overcharge the cylinder while removing refrigerant from system as it is dangerous.
- Don't use a metallic wire brush to clean fins of coils.
- Don't wear loose clothes and slippers.

3.3.2 Maintenance of room air conditioners/split air conditioners

A. General features of Periodic maintenance

To enable the conditions of both of the atmosphere and unit to be healthy it is imperative to give a



periodic maintenance to the unit. The period is to be fixed as per the experience gathered or as specified by the manufacturer. The following are the important aspects to be looked after during maintenance.

- Give attention to condenser coil, cooling coil and fan. 'Dust off these either by compressed air or brush it. CO₂ may be used if available.
- Hold the naked light in front to check the cleanliness in between. A hooked wire should be used to remove the foreign material. Cooling coil need not be cleaned so frequently.
- Fresh air ducts should be cleaned and checked.
- Check the compressor mounting springs if external mounting is done. Replace them if necessary. Spring tends to loosen its tension with age and this leads to noisy operation of the unit.
- Check the earthing connections.
- If necessary, oil the dampers. View the unit slope. It should be 1/2" to 3/4" towards outside in room air conditioner and towards drain end in split AC indoor unit.
- Check the air filters.

B. Filter cleaning

This is one single most important aspect of air conditioner maintenance which not only enhances performance of the machine but also results in energy saving and longevity of compressor.

Although filter cleaning is recommended as a monthly activity, its frequency can be adjusted depending upon its extent of use.

- The air filters supplied with the unit are high-efficiency washable and recyclable filters.
- To establish, how frequently these should be cleaned, the operating conditions must be taken into account.

C. Filter cleaning procedure

Open the return grille without removing the two screws and the central clamp from their position. Locking arrangement may vary for different models.

- Remove acrylic-fiber filters for cleaning.
- First clean the filter with a vacuum cleaner or a blower.
- Rinse filter under running water, and dry it

D. Periodical checks

For a good operation of the air conditioner, it is recommended to carry out checks and maintenance as indicated.

Recommended maintenance intervals may vary depending on the installation environment, e.g. dusty zones, etc.

Indoor Unit	Every Month	Every 4 Months	Every Year
Clean air filter	✓		
Clean drain pipe		✓	
Change controller batteries			✓

Outdoor Unit	Every Month	Every 4 Months	Every Year
Clean outdoor coil from outside		✓	
Clean outdoor coil from inside			✓
Blow air over electric parts			✓

Outdoor Unit	Every Month	Every 4 Months	Every Year
Check electric connection tightening			✓
Clean fan wheel			✓
Check fan tightening			✓
Clean drain pan			✓

E. Troubleshooting guide

Trouble	Reason	Action
Compressor and outdoor fan dose not start	Power failure. Fuse blown or / and circuit breaker tripped. Defective contactor. Low line voltage Incorrect or loose wiring. Temp. setting too low	Call Power Company. Replace fuse or reset circuit breaker. Replace Determine cause and eliminate. Check wiring diagram and rewire correctly Reset temp. setting.
Compressor does not starts, but outdoor fan runs	Faulty wiring or loose connections in compressor circuit. Compressor motor burnet out, stuck or internal over-load open. Defective run capacitor	Check wiring and repair or correct. Replace compressor and determine cause. Replace.
Compressor runs on internal overload (other than normally satisfying thermostat)	Refrigerant over or under charge. Air or non-condensable refrigerant in system. Defective compressor Low or too high line voltage. Blocked outdoor coil. Outdoor fan stopped. Defective run capacitor. Faulty fan motor of outdoor section Restriction in refrigerant system Capillary restricted or ice clogged.	Blow refrigerant, evacuate system and recharge. Blow refrigerant, evacuate system and recharge. Replace and determine cause. Determine cause and correct. Determine cause and replace. Determine cause and replace. Replace. Replace. Locate restriction and remove. Blow refrigerant, evacuate system and recharge.
Compressor operates continuously	System undersized for load. Temp. setting too low. Defective outdoor fan Air or non-condensable refrigerant in system. Air restricted or indoor section filter dirty	Decrease load or increase system size. Reset temp. setting Check for source and replace Blow refrigerant, evacuate system and recharge Clean filter or remove restriction
Excessive head pressure	Dirty outdoor coil Defective outdoor fan Refrigerant over charged Air or non-condensable refrigerant in system Outdoor section air restricted	Clean coil. Replace Purge excess refrigerant Blow refrigerant, evacuate system and recharge Remove restriction
Head pressure too low	Low refrigerant charge Restriction in liquid tube Indoor section air filters dirty.	Check for leaks, repair and recharge. Remove restriction. Clean filter.
Excessive Suction Pressure	Reversing valve hung up or internal leak Internal pressure relief open. Refrigerant over charged.	Replace. Check for source and eliminate. Purge excess refrigerant.
Suction pressure too low (Low pressure control cuts out & pilot light for low pressure control off)	Low refrigerant charge Indoor unit frosted Low indoor air or short cycling Restriction in suction tube Capillary restricted or ice clogged	Check for leaks, repair and recharge See next trouble Eliminate cause, check for fan working Locate restriction and remove Blow refrigerant, evacuate system and recharge

Trouble	Reason	Action
Outdoor fan stopped or cycling on overload	Defective fan motor capacitor Loose leads at fan motor. Fan motor burnout Motor bearing sized	Replace Check for cause and eliminate. Replace Check for cause and eliminate
After batteries have been placed into the remote control, the display is not lit.	Batteries are exhausted or have the wrong polarity.	Replace batteries or check polarity.
When pressing the recessed lock adjustment button, hour figures on display do not flash.	Recessed button has not been pressed correctly.	Press with a round point, avoid exerting strong pressure.
When pressing any button, all symbols appear on display.	Recessed button for time setting is blocked due to excessive pressure during use.	Check and repair.
When pressing start button, unit does not acknowledge signal with a beep.	Remote control has been irreversibly damaged. Main switch is OFF. Remote control batteries are exhausted. Remote control has not been pointed correctly to the receiver of indoor unit. There are obstacles (curtains, walls, etc.) between the remote control and the indoor unit Receiver on the indoor unit or the remote control is under intense sun radiation. Signal transmission is obstructed by severe interference from an electromagnetic field.	Replace with a new one. Switch it to ON position. Replace batteries. Turn remote control OFF and repeat the operation in the correct direction. Repeat the operation after having removed the obstacles. Avoid direct sun on the unit, shut curtains or shades. Avoid sending signals when computers or household appliances (Food processors, coffee makers, etc.) are operating close by cellular or cordless telephones may also interfere with the control.
When pressing stop button, unit does not acknowledge signal with a beep.	Remote control batteries are exhausted. Remote control has not been pointed correctly to the receiver of indoor unit. There are obstacles (curtains, walls, etc.) between the remote control and the indoor unit Receiver on the indoor unit or the remote control is under intense sun radiation. Signal transmission is obstructed by severe interference from an electromagnetic field.	Replace batteries. Turn remote control OFF and repeat the operation in the correct direction. Repeat the operation after having removed the obstacles. Avoid direct sun on the unit, shut curtains or shades. Avoid sending signals when computers or household appliances (Food processors, coffee makers, etc.) are operating close by cellular or cordless telephones may also interfere with the control.
When pressing any function button, the remote control shows the function requested on the display, but unit does not acknowledge signal receipt with a beep and does not carry out the function.	Main switch is OFF. Remote control batteries are exhausted. Remote control has not been pointed correctly to the receiver of indoor unit. There are obstacles (curtains, walls, etc.) between the remote control and the indoor unit Receiver on the indoor unit or the remote control is under intense sun radiation.	Switch it to ON position. Replace batteries. Turn remote control OFF and repeat the operation in the correct direction. Repeat the operation after having removed the obstacles. Avoid direct sun on the unit, shut curtains or shades.
	Signal transmission is obstructed by severe interference from an electromagnetic field.	Avoid sending signals when computers or household appliances (Food processors, coffee makers, etc.) are operating close by cellular or cordless telephones may also interfere with the control.



Trouble	Reason	Action
Air conditioner does not start.	Main supply switch is OFF Fuses of main switch are blown Protection against frequent compressor cycling is ON Selected temperatures are higher than the room temperature in the cooling mode (or lower in the heating mode).	Switch to ON Replace fuses Wait for 3 minutes. Correct selected temperature.
Air conditioner is not cooling enough.	Air flow cannot circulate freely Dirty filters reduce air quantity circulating. Doors and/or windows are open. Fan speed has been set to "Low" Air flow direction is not correct Selected temperature is higher than the room temperature in the cooling mode.	Remove obstructions. Clean air filters Close doors and windows Set fan speed at high speed. Adjust airflow direction as per the mode chosen. Correct selected temperature.
Air conditioner is not supplying enough heating.	Air flow cannot circulate freely Dirty filters reduce air quantity circulating. Doors and/or windows are open. Fan speed has been set to "Low" Air flow direction is not correct Selected temperature is Lower than the room temperature in the heating mode	Remove obstructions. Clean air filters Close doors and windows Set fan speed at high speed. Adjust airflow direction as per the mode chosen. Correct selected temperature.
A slight mist is emitted from the indoor unit during cooling	The cool air from the indoor unit is coming into contact with the room air.	Normal operation
A slight whistling noise is heard when the air conditioner starts or stops.	This is due to the refrigerant beginning to circulate or an adjustment of the refrigerant pressures.	Normal operation
Water vapor (mist) emanating from the outdoor unit.	It is normal in heat pump operation, when defrost is automatically activated.	Normal Operation
Unpleasant smells coming from the indoor unit.	Unpleasant smells can be caused by substances accumulated in the air filters	Switch the system OFF and contact an authorized service center to have the filters cleaned. Restart unit in the ventilation (fan only) mode and open windows to change room air.
Strange noises coming from the indoor unit.	Occasionally the indoor unit can emit some strange short noises during operation or when it has stopped. These are generally due to the of temperature changes on the plastic parts.	Normal operation
Starting in heating mode for heat pump systems	If the system starts at low ambient temperatures, it takes a little while to reach a comfortable room temperature. When the system is started by the remote control, it emits a signal beep, but the louvre does not swing and the fan does not run until the operating temperature has been reached.	Normal operation
Timer LED is Blinking	Faulty return air sensor Faulty return indoor coil sensor Faulty return outdoor coil sensor	Determine reason and replace Determine reason and replace Determine reason and replace
Power LED is blinking	Compressor overheat Anti-overheat Low ambient	Determine reason and correct Determine reason and correct Determine reason and correct



3.4 Maintenance of Solar Power Plant

3.4.1 Equipment and their function

Various equipment comprising a solar power plant along with their function is enumerated:

A. Solar PV module

A solar PV module consists of a series and parallel combination of solar cells made from Photovoltaic (PV) materials. The PV materials convert light energy into electrical energy.

B. Solar inverters

A solar inverter is an important electronic device that converts DC electrical power generated by a solar PV array into clean AC power supply. Other functions offered by an inverter are:

- i. Extracting the maximum possible power from solar PV modules for a given radiation (MPPT feature).
- ii. Synchronisation of output power with the utility grid.
- iii. Providing real time operation data and signalling.
- iv. Providing advanced utility controls.
- v. Active and reactive power control.
- vi. Electrical protection and safety, etc.

C. Balance of system

All the components of an SPV power plant, other than solar PV modules and inverter, are encompassed in the balance of system (BoS). Brief information of all the components used in the BoS is presented below.

D. Cable

Cabling in SPV power plants are of two types: DC and AC. Irrespective of the type and capacity of the system, DC cabling is considered one of the most complex undertakings. Cables are subjected to thermal, mechanical and external loads. Like all other components in a SPV power plant, cables need to last the planned 25 years. Compared to AC cables used in SPV power plants, DC cables are more exposed to harsh environmental conditions like temperature fluctuations and direct ultraviolet (UV) rays, etc.

E. DC connectors

DC connectors are used for interconnecting PV modules, junction boxes and/or the inverter. The provision of DC connectors with a DC cable connected to junction boxes has made installations easy and saved installation time. Failure of a DC connector will lead to loss of generation in one string and eventually in the entire MPPT. Nowadays, the MC4 connector is mainly used in solar plants. The letters “MC” stand for Multicontact, and digits 1 to 4 stand for the contact pin cross section in sq.mm.

F. Array junction box (AJB)

Combiner boxes usually called array junction boxes (AJBs) are an integral part of PV installations. They serve as a “meeting place” where the output of solar strings is combined to generate a single set of output. The main functional features of an AJB are:

To obstruct sudden surges due to lightning strikes during cloudy and rainy conditions and to ground the surges immediately.

- i. Efficient string monitoring (Optional).
- ii. Disconnect DC at the source.
- iii. Fuses for overcurrent protection on each string.
- iv. Blocking Diodes for reverse current flow protection.
- v. DC-termination.
- vi. String cable management.
- vii. To enable step by step trouble shooting methodology.
- viii. Reliable electrical safety to avoid hazard. The term combiner box/array junction box (AJB) is applicable only to central inverters, where several strings are combining together and a single positive and negative cable is routed to the inverter. In case of string inverters there is no junction box required between string and inverter; each string can be routed separately to the inverter. However, in O&M and from a safety perspective, it is always recommended to use an AJB even in case of a power plant using a string inverter.

G. AC distribution board (ACDB)

Power generated from the inverter/s is connected to AC distribution board, where the utility reference supply is connected from main distribution board (in case of captive power plants) or from the grid directly (in case of utility scale power plants). ACDB are equipped with isolation, protection and measurement devices.

G. Solar module mounting structures (MMS)

Solar module mounting structures (MMS) are one of the key components of SPV power plants and should comply with all applicable standards. They must also withstand on-site loading, wind and other climatic conditions, for a period of 25 years. GI material with galvanization of 80 to 120 microns is used in solar MMS. In case of rooftop power plants, aluminium MMS are commonly used to reduce weight on a rooftop.

H Earthing

A SPV power plant is defined as a grounded system when one of the DC conductors (either positive or negative) is connected to the grounding system, which in turn is connected to the earth. In general, it is recommended to earth the mounting system and other conductive parts of the power plant for potential equalization. All PV modules are grounded through MMS by way of using serrated washer based nut bolt system of separate earthing wire. Proper earthing of the generating systems is mandatory because of the following reasons:

- i. Provides safety to persons and animals.
- ii. Protects the installation and equipment.
- iii. Enhances quality of signal (reduced electromagnetic distortion).
- iv. Provides a fixed reference voltage for equi-potentialization.

I. Lightning arrestor

Lightning arrestors are particularly aimed at providing personal protection when there are direct lightning strikes. SPV plants can get damaged by direct lightning strikes to MMS or power lines, or from indirect strikes caused by cloud to ground or cloud to cloud strikes which cause induction and surge.



J. Surge arrestors

Surge protection devices (SPD) help to protect the SPV power plant's components from transient power surges that may occur if the PV system or nearby power lines or structures are struck by lightning, switching actions and electrostatic discharges. A power surge is an increase in voltage significantly above the designed voltage over a short duration of time which can damage the PV modules and other electronic equipment.

An SPD is connected in parallel between the energized conductor and the ground. It changes its state from a high impedance device to a low-impedance device when overvoltage occurs and discharges the associated transient current, thereby minimizing the overvoltage present at the equipment terminals.

K. Data monitoring system

A solar PV monitoring system is installed for continuous monitoring and performance evaluation of power plants. All data monitoring systems have the facility to record generation details, measured weather parameters and event logs. Except in small residential systems, it is always recommended to install data monitoring systems which will enable continuous monitoring of plant performance for optimization of generation and O&M.

Currently, two types of monitoring methods are widely used in the industry, namely:

- (b) Web based remote monitoring system,
- (b) SCADA system.

Web based remote monitoring system: It has more footprints in case of small and medium scale SPV power plants. It can also be termed as inverter based monitoring due to acquisition of data from the inverter. Most inverter manufacturers provide their own solution for web-monitoring, or their inverters have the facility to integrate with web monitoring systems of different service providers.

SCADA (supervisory control and data acquisition) based data monitoring: SCADA is being used in the power industry for the last few decades. Functions and methodology of SCADA systems is the same in the solar industry as well. Large capacity solar PV plants having installed Class A weather monitoring systems are recommended to use SCADA based monitoring.

3.4.2 Preventive maintenance schedule

All preventive maintenance activities are scheduled for specific time periods. Periodicity of different maintenance activities proposed for solar PV power plants of various capacities are tabulated -

- i. Small plant: Upto 10 kWp
- ii. Medium plant: Greater than 10 kWp and upto 100 kWp
- iii. Large industrial: Greater than 100 kWp and upto 1 MWp

Sr. No.	Plant component-wise preventive maintenance activity	Frequency of attention		
		Small plant	Medium plant	Large industrial
1.	PV module			
	Visual Inspection, plant layout check	Regularly	Regularly	Daily
	PV module cleaning	Regularly	Regularly	Daily
	Electrical parameter check* (described below)	6 months	3 months	Daily
	DC connection check (IR imaging), cleaning	6 months	3 months	1 month
	PV module tightening (as per OEM recommendation)	Annual	Annual	Annual
2.	Array junction box			
	Integrity inspection, documents inspection, cables visual and IR inspection.	6 months	3 months	3 months



Sr. No.	Plant component-wise preventive maintenance activity	Frequency of attention		
		Small plant	Medium plant	Large industrial
	String identification ferrule inspection, electrical parameter checks, overall IR inspection.	6 months	3 months	3 months
	Monitoring sensors functional verification, surge protection device check, fuse status check.	6 months	3 months	2 months
	Cables' terminals check, AJB cabinet cleaning.	6 months	3 months	2 months
3.	Inverter			
	String connection inspection, cables visual inspection, soiling and general cleaning, nearby vegetation check.	6 months	6 months	2 months
	IR imaging of inverter cabinet (string and central), internal IR imaging (central), string connection point IR imaging.	Annual	Annual	2 months
	Internal sensors functional verification, check ventilation system operation, ventilation fan functional check, ventilation cleaning.	Annual	Annual	6 months
	Electrical protections' visual inspection, electrical protection correct operations, fuse status check, display inspection.	Annual	Annual	6 months
	Labelling and identification inspection, documents inspection, parameters check.	Annual	Annual	6 months
	Inverter software updation check, warranty date check.	Annual	Annual	Annual
4.	DC cable			
	Integrity inspection, cables visual inspection, labelling and identification.	Annual	Annual	Annual
	Cable conduit inspection, cable conduit opening inspection, cable trench	Annual	Annual	Annual
	IR imaging of cable terminations	Annual	Annual	6 months
5.	AC distribution board or solar ACDB			
	Cabinet's general cleaning, nearby vegetation (outside IP56) check, cables visual inspection	6 months	6 months	3 months
	Multi-function meter check, CT/PT calibration check.	Annual	Annual	6 months
	IR inspection of cable termination, ventilation check.	Annual	Annual	2 months
	Electrical protections' visual inspection, fuses and surge protection devices status check.	6 months	6 months	2 months
	Labelling and identification, documents inspection.	Annual	Annual	Annual
6.	AC cables			
	Integrity inspection, cables visual inspection, labelling and identification	Annual	Annual	Annual
	Cable conduit inspection, cable conduit opening inspection, cable trench inspection.	Annual	Annual	Annual
	IR imaging of cable terminations.	Annual	Annual	6 months
7.	Energy meters			
	Integrity inspection, general cleaning, labelling and identification.	Annual	Annual	Annual
	Calibration of meters.	Annual	Annual	Annual
8.	Monitoring system			
	Integrity inspection, general cleaning of sensors, circuit check.	Annual	Annual	6 months
	Sensor protection system's status check.	Annual	Annual	Annual
	Document check and calibration.	Annual	Annual	Annual
9.	Control room			
	Visual inspection, general cleaning.	Daily	Daily	Daily
	Auxiliary power supply and inverter check.	6 months	6 months	Daily
	Documentation checks, IT system checks.	Annual	Annual	6 months
10.	Field			



Sr. No.	Plant component-wise preventive maintenance activity	Frequency of attention		
		Small plant	Medium plant	Large industrial
	Visual inspection, vegetation control,	Daily	Daily	Daily
	Fence or field boundary inspection, drainage inspection, approach road and internal road checks.	3 months	3 months	3 months
	Roof access check, structure integrity check.	6 months	6 months	6 months
	Plant security systems check, security log book check.	6 months	6 months	6 months

* Electrical parameter check (Item 1 (c))

Parameters	Purpose of measurement
1. Array level measurement Array Voltage DC Array Current DC Array Power	String level power monitoring, fault identification. Measurement taken using AJBs with string level monitoring. Commonly used in utility scale power plants with central inverters. Fault identification is easy for wide spread utility scale power plants having string level monitoring.
2. Inverter level measurement Inverter MPPT voltage DC Inverter MPPT current DC Inverter MPPT power DC Output voltage AC Output current AC Output power AC Output Energy (kWh) Power factor Frequency Temperature	DC measurement is used for calculating DC losses, fault identification. AC and DC parameters can be used to calculate the system's performance. Power factor, frequency, active/reactive power output, voltage, etc., are measured to monitor power quality related compliance. Inverter level monitoring is used to record instantaneous and cumulative generation.

3.4.3 Failure responseEmergency shutdown

In an emergency situation:

- If the inverters have Emergency Stop buttons, push them in on each inverter.
- If the inverter has an on/off switch, turn it to the off position (this may require a key). Each inverter should be manually turned to the off position. This will immediately open the internal ac and dc contactors (if present) inside the inverter.

Note that some inverters do not have an on/off switch or an Emergency Stop button. For these inverters, it will be necessary to turn the systems off using the disconnect switches attached to or located near the inverters. Do not open switches that are specifically labeled “Do not disconnect under load” until a load-break switch has been opened and current flow is stopped. Generally, the first available upstream load-break ac switch or circuit breaker is safer to operate first (before the dc switch), because the inverter instantly shuts down the transistor bridge when ac voltage is removed. Once the system is off, the remaining switches can be opened and the system can be locked out until the fault condition is repaired or it is safe to turn it back on.

3.4.3.1 Isolation procedure – Inverter pad equipment

To isolate the inverter pad safely:

- Shut the inverters off through a controlled shutdown.
- Turn off all dc and ac disconnects that feed the pad.
- Always wear appropriate PPE and test for voltages with a properly rated meter to confirm the system is completely isolated.

3.4.3.2 Isolation procedure – Inverter pad equipment

To isolate field combiner boxes:

- i. Turn off the inverters as described above.
- ii. Operate the switch of the combiner (if applicable) by turning the handle to the off position.
- iii. Use a dc clamp on the meter to confirm there is no current passing through the ungrounded conductors in the combiner box, and then open all of the fuses.
- iv. If further isolation of the box is needed, use the string diagrams to locate the homeruns (end connectors of the PV strings).
- v. Use a clamp-on dc current meter to confirm that the homerun does not have any current passing through it, and then disconnect the string by opening the homerun positive and negative connectors and putting caps on the source circuit connectors.
- vi. Go back to the combiner box and use a voltmeter to confirm that each string has been successfully disconnected.

3.4.3.3 Isolation procedure – Inverter pad equipment

After turning off the inverter, switches, and combiner boxes and isolating the combiner boxes from the array, disconnect individual modules from the string:

- i. Before disconnecting any string, use a dc clamp-on meter to confirm there is no current passing through the string.
- ii. Use the appropriate connector unlocking tool to disengage the module connector.
- iii. Repeat for each module to be isolated from the system.
- iv. If modules are removed from a system, even temporarily, technicians must ensure that the equipment grounding system remains intact for the remaining modules.

3.5 Maintenance of Diesel Generating (DG) Set

3.5.1 Equipment in DG set

Diesel Generator set consists mainly following parts/assemblies:

- i. Diesel Engine
- ii. Alternator
- iii. Fuel Tank
- iv. Auxiliary Alternator
- v. Starter Motor
- vi. Battery
- vii. Control Panel
- viii. Acoustic Enclosure (Canopy)

Parts of diesel engine and their function

A. Crankcase & oil pan

These two components form the load bearing housing of the engine. They absorb the forces occurring during operation in the cylinder and at the crank assembly. The crankcase accommodates the cylinder liners, the crank assembly and the camshaft.



B. Cylinder heads

A cylinder head closes the top end of the cylinder. It makes a confined space for compressed air and the gases. Each cylinder head contains the inlet and exhaust valves and fuel injection valve. For cooling of the valve seats and injection valve, coolant is piped through cooling chambers arranged in the cylinder head.

C. Driving mechanism

The crank shaft is driven via the connecting rods by means of the gas acting on the pistons. The forces of the rotary masses at the individual crank throws are compensated by means of balance weights. The crank shaft provided rotation of the camshaft via gear drive and also rotates the injection pump drive. The cams of the camshaft actuate inlet and exhaust valve via the push rod and rocker arm.

D. Fuel pump, injection pump and fuel system

By means of fuel pump, the fuel is pumped from fuel tank into the injection pump via filter. By means of the injection nozzles the fuel is squirted very finely into the combustion chamber.

For the purpose of cooling the injection pumps more fuel than the required for injection through the system by the fuel feed pump. The surplus fuel is returned to the fuel tank via an over flow valve at the injection pump.

E. Lube pump and system

The bearings and the cylinder liners are lubricated to reduce friction and to dissipate heat. The lube oil pump draws the lube oil from the oil pan and pumps to the points of lubrication through oil cooler and filter.

F. Radiator and cooling system

The thermal energy generated during fuel combustion can only be partly converted into mechanical energy. The part of the residual heat is eliminated by means of cooling the combustion chamber walls by coolant. The heat absorbed by coolant is passed on to atmosphere by means of radiator and fan.

G. Turbocharger

The turbocharger is provided to increase the power output and efficiency of an engine by supplying compressed air to the engine intake manifold. The power to drive the turbocharger is expected from energy in the exhaust gases.

H Exhaust system

Exhaust bellow connects engine and DG silencer to drive away hot gases generated during operation of DG to atmosphere through silencer. Exhaust muffler reduces noise level of the engine as per designed parameter and exhaust extension pipe, connected to DG silencer outlet ensures that the hot gases are driven out to atmosphere.

3.5.2 Engine systems

There are four principle engine systems such as Air, Fuel, and Lubrication & Cooling system. Understanding of engine systems is important in preventive maintenance and troubleshooting.

A. Air system

Air enters through air cleaner (filter) to turbocharger inlet. Turbocharged air passes through intake manifold, gets distributed to all power cylinders. After combustion, burnt gases go out through exhaust manifold & rotate the turbine wheel. Exhaust gases emit out through flexible bellow & muffler.

B. Fuel system

Fuel is sucked from base (fuel) tank by suction inlet pipe and suction strainer. Lift pump (feed pump) lifts the fuel & delivers to the filtration system. There are two stages of fuel cleaning; once by water-separator & then by micro-fine fuel filter.

Cleaned fuel enters to fuel injection pump which pressurize and delivers the high pressured fuel to fuel injectors fitted on each cylinder. Returned fuel is routed back to the tank through return pipe.

C. Lube system

Lubricating pump draws oil from the oil pan & forces it to the lubrication system. The pressure regulating valve controls oil pressure. The filter bypass valve ensures supply of oil when filter gets choked. The piston pins are lubricated by the splash from piston cooling nozzles. Oil pump idler gear is forced lubricated. The remainder of the front gear train is lubricated by oil carry over splash.

D. Cooling system

Coolant is sucked by the engine driven water pump from the bottom tank of the radiator. Coolant passes through oil cooler, all cylinder jackets and cylinder heads to reach finally at thermostat housing. Coolant get divided either to the inlet of the water pump or to the radiator depending on coolant temperature. Complete coolant gets diverted to the radiator after coolant temperature reached to thermostat setting.

3.5.3 Preventive Maintenance of DG sets

Maintenance schedules across various makes of DG sets are not standardized, although the underlying goal is same to keep the above mentioned four systems in good fettle. For the purpose of understanding the work involved in scheduled maintenance, Diesel Engine has been considered. For more details and completeness of maintenance schedule, respective maintenance manual supplied with the DG set by OEM must be consulted. It is also recommended that a detailed logbook giving full parameters of the engine working, maintenance carried out etc. should be maintained for individual DG set.

Generic maintenance practice of Diesel Engines**A. Check (Daily Maintenance)**

Sr. No.	Proposed Maintenance	Work Involved	Remarks
1	Cleaning	Clean engine and premises.	
2	Checking of engine oil level.	Check engine oil level before starting the engine, top-up if required.	It should be between H and L mark of dipstick
3	Checking of cooling system	Check coolant level in radiator, top-up if required with premix coolant. Check belt condition.	Before starting
4	Checking of fuel system	Check fuel strainer Clean breather on fuel tank Drain sediments/water from fuel water separator. Fill up the fuel tank at the end of each working day.	Never wait until the tank is empty
5	Checking of air system	Check vacuum indicator for air restriction (red band). Check sealing and condition of air filter.	
6	Other checks	Check for leaks and rectify if required. Run engine and record all parameters.	

B. Check (Every 225-250 hrs. or 6 months whichever is earlier)

Sr. No.	Proposed Maintenance	Work Involved	Remarks
1	Changing of lubrication oil	Warm up the engine and stop Remove drain plug and drain engine oil in a pan of 20 liters capacity. Refit drain plug Fill the recommended new engine oil to H mark on dipstick.	
2	Changing of lube oil filter	Clean filter head and its surroundings before removing it. Remove the filter and clean the gasket surface. Fill the new filter with clean lubricating oil and apply a light film of lube oil to the gasket-sealing surface. Fit the filter manually.	
3	Checking of cooling system	Repeat all A- checks Check fan hub and fan drive arrangement. Check seal of radiator cap.	
4	Changing of fuel filter and water separator	Repeat all A- checks Remove the two filters from the dual filter adapter. Fill the new filters with clean fuel and apply a light film of lube oil to the seal. Fit the filters manually. Drain sediments from fuel tank.	
5	Checking of air filter/ system	Repeat all A- checks. Clean air filter in reverse direction using dry air with maximum pressure 0.5 kg/cm ²	
6	Other checks	Repeat all A checks. Check electrolyte level and specific gravity of battery. Add distilled water if required. Check terminals tightness and clean the battery. Secure all connectors in engine electrical system.	

C. Check (Every 475-500 hrs. or 12 months whichever is earlier)

Sr. No.	Proposed Maintenance	Work Involved	Remarks
1	Checking of engine oil level.	Repeat all A & B checks Clean breather	
2	Checking of cooling system	Repeat all A & B checks Check coolant condition Check recovery bottle and seal. Check connections and sealing of radiator Clean radiator externally by blowing pressurized air in the reverse direction of the flow of radiator fan.	Do not spill water on radiator fins
3	Checking of fuel system	Repeat all A & B checks Check all joints in fuel lines and tighten. Check feed pump and clean baby filter	
4	Checking of air filter/ system	Repeat all A & B checks	
5	Other checks	Repeat all A & B checks. Check AVMs (anti vibration mountings) and replace if required	

D. Check (Every 950-1000 hrs. or 24 months whichever is earlier)

Sr. No.	Proposed Maintenance	Work Involved	Remarks
1	Changing of lubrication system	Repeat all A, B & C checks. Clean breather. Check Blow Bye.	
2	Checking of cooling system Checking of belt, belt tension, belt tensioner Replacement of coolant	Repeat all A,B & C checks Remove the drive belt and inspect the belt for damage. Check the tensioner bearing by spinning pulley under hand pressure, it should spin freely with no rough spots feelings. Check the fan hub bearing by spinning fan hub under hand pressure, it should spin freely without excessive end play. Install the good/new drive belt Measure the belt deflection at the longest span of the belt. Replace coolant by premix coolant. Replace radiator cap.	Max. Deflection 9.5-12.7 mm
3	Checking of fuel system Cleaning of fuel tank Checking of fuel hoses	Repeat all A, B & C checks. Clean the fuel tank thoroughly with diesel. Check fuel hoses condition and replace if required.	Do not use water for cleaning.
4	Checking of air filter/system	Repeat all A, B & C checks. Check turbocharger end clearances.	
5	Other checks	Repeat all A, B & C checks. Tighten all clamps Check valve clearances and adjust if required.	Intake clearance =0.254mm Exhaust clearance =0.508mm

The above maintenance checklist is indicative in nature & OEM maintenance manual may be referred for specific make/model.

3.5.4 Sample format of DG Set log book

Capacity :- 500 KVA

Make :- Crompton Graves

Year of Mfg.:- 2014

Date	D.G. Set Start Hrs.	D.G. Set Stop Hrs.	Total Working Hrs.	POH Hrs.	RPM	Lube Oil		Water Temp.	Freq. (Hz)	Voltage (V)	Current (A)			HSD Oil			Remarks
						Pressure	Temp				R	Y	B	Received	Issued	Balance	
3.6.22	15:00	15:20	00:20		1502	2.6	89°C	75	50	425	186	142	185				

3.6 Maintenance of High Mast Tower Lights**3.6.1 Parts of High mast tower light**

Various equipment comprising a high mast tower light along with their function is enumerated:

3.6.2 Mono tubular shaft

Mono tubular shaft is a tapering steel structure with polygonal cross section, made of hot dip galvanized steel, composed of two or more sections to be joined at site by forced overlapping (slip on joint). The anchorage to the base can be either by direct burying the foundation plinth or by base plate and anchor bolts. The shaft is equipped at the base of grounding connection, reinforced door for access to the internal equipment and, in the case of direct burying, a slot for cable entry. A flange is provided at the top for fixing the trailing head.

3.6.3 Trailing head (head frame)

The trailing head is made of hot galvanized steel, consisting of a 3-arms arranged at 120 ° housing the lifting cables and / the cord / the electric, designed for attachment to the stem by means of flange and bolts. The bracket is completely covered to grant the protection of the movement devices composed of pulleys mounted on self-lubricated bushes and stainless steel pivots. A system which prevents the hoisting and electric cable to go out of their groove is provided. The brackets of the ropes are provided with hooking and centering system of the mobile crown. The trailing head is supplied assembled and completed with the lifting ropes. The wiring ropes and the power cables are fixed at one end to the connection cylinder (distributor), while the other end is passed on relative arms and subsequently anchored to the mobile crown.

3.6.4 Mobile crown (lantern carriage)

Mobile crown is made of hot dip galvanized steel profiles composed of two concentric rings connected by three ribs at 120 °. On each rib is fixed the elastic hooking system composed of stainless steel pivots and double steel metal foils. This enables the crown to be firmly attached to the trailing head completely releasing the hosting ropes from any load during normal operation of the mast. An additional safety brake system can also be installed that locks the mobile crown to the shaft in the case of failure of the lifting ropes or the hoist chain.

It is provided an anti-rotation system that prevents the movement on the horizontal plane of the crown. The floodlights and their control gear boxes are mounted on special brackets made of hot galvanized steel and are fitted to mobile crown by bolts.

3.6.5 Electrical system

The electric cable for the power supply to the floodlight is of self-supporting type having adequate cross-section to carry power requisite power. At the base of the mast (nearby the connecting drum) the cable is provided with plug for connection to the interlocked socket fixed nearby the door, while on the top ends inside the junction box, it is fixed to the mobile crown.

The electrical control panel, complete with pre-wired terminal board, comprising equipment like MCCB, contactors, timer etc. is also provided.

3.6.6 Electric hoist (winch with power tool)

Electric hoist with suitable bearing capacity is used to lift the the load to be lifted. The mast can be provided hoist which is either integrated type (the hoist is placed inside of the shaft) or trolley mounted (the hoist is mounted in a separate structure from the mast).

3.6.7 Maintenance Schedule

High mast tower lights generally do not require frequent scheduled maintenances. Most of the electrical problems of failure in control panel like failure of MCCB, timer, contactor etc are attended on condition basis. An annual maintenance which consists of a check-up of the mobile crown brought to ground level, of all the elements that constitute it, as well as a control of the electrical components, and a check of what is placed inside the shaft is sufficient to ensure trouble free operation.

3.6.8 General maintenance

Sr. No.	Item	Remarks
1	Check that the earth connection is connected to the structure	
2	Check that the doors locking device is functional	

Sr. No.	Item	Remarks
3	Make sure the safety chain is positioned as per instructions and not too tight	
4	Check the electrical connections at the base of the mast	
5	Check that the phase sequence is such that the lifting unit works with correct logic (Can be verified by operating the lifting units)	
6	Check the working of safety limit switch (connecting the lifting unit and verifying that acting on the rod at the bottom, it does not work in UP direction)	
7	Check the condition of the wire ropes and the electric cables on the distributor which must not be pulled (with mobile crown hooked)	
8	Check the tightening of the clamps on the ropes (on the distributor)	

3.6.9 Maintenance with mobile crown in lowered position

Sr. No.	Item	Remarks
1	Make sure the sheath of the ropes, as well as electric /s cable/s is intact	
2	Check the tightening condition of all bolts and nuts	
3	Check the tightening conditions of the clamps on the ropes	
4	Check the condition of elastic plates of the elastic coupling system (rods)	
5	Check that the brackets for floodlights and ballasts support are securely fastened to the mobile crown	
6	Check that electrical cables are in good condition and that wiring in boxes, on floodlights and control gear	
7	Check that the distribution boxes always ensure the protection degree	
8	Check the correct balancing of the mobile crown	
9	Check the operation of the floodlights (ground test)	

3.6.10 Maintenance with mobile crown in service position

Sr. No.	Item	Remarks
1	Check that the hooking and unhooking operations of the mobile crown to the trailing head occur smoothly and consistently	
2	Make sure that the safety limit switch is positioned correctly	

3.6.11 Maintenance with mobile crown landed on ground

Sr. No.	Item	Remarks
1	Check the condition of the springs	
2	Check the condition of stainless wheels	

3.6.12 Maintenance of trailing head

Sr. No.	Item	Remarks
1	Check tightening of bolts and nuts securing the trailing head to the shaft	
2	Check conditions of carpentry	
3	Check condition of stainless steel pulleys, pivots	

3.6.13 Maintenance of the structure

Sr. No.	Item	Remarks
1	Check condition of the structure and galvanization.	

Note: Regarding maintenance of the hoisting unit, instruction provided in the user manual from the OEM may be followed.



3.6.14 Maintenance procedures of components

Component	Checking procedure	Normal condition	Remedial measure
Socket	Check the Integrity of the external structure. Check operation by performing a number of open/close circuit tests	The peculiarity of the lock socket is that it doesn't allow the plug to slip out when the circuit is closed (position I), as well as the circuit cannot be closed during transition from 0 to I, if a suitable plug it is not inserted before	In the case the conditions listed left do not occur replace the socket with one having the same characteristics.
Steel ropes	Check integrity of the sheath, tightening of the clamps at the ends of the cables and threaded tighten	The cable must have perfect sheath all over its length, without fraying, obvious signs of bending. Clamps must be well made and regularly checked.	In case of loss on sheathing, and consequent worn ropes, it is to be checked and assessed and replaced if required.
Electric cable	Check the conditions of all electrical wiring.	All electrical connections must be perfectly done	Any connections not well executed or that are worn out with the time being, make new connections replacing electric cables, if any
Brackets for floodlight support and ballasts support	Check the straightness of the brackets and check the ballast support to be orthogonal, check tightening of the coupling bolts with the mobile crown, as well as the tightening of the floodlight.	The brackets for floodlight support must be straight also after being loaded with the floodlights. The same applies to the brackets for ballasts support.	Mount the expected number of floodlight (if one floodlight for each bracket is foreseen do not put two floodlights). Observe the executive design in order not to install floodlight with different weights, which could create stress conditions on carpentry
Hooking elastic system	Check feature of the connecting rods.	The structure must appear intact, you don't have to find bent parts, and the operating parts (elastic plates) if stressed will have to create the vibration of the overlying part (connecting rod).	Any sign that could be related to stressful situations or nonalignment with the trailing head should be replaced. Should some elastic plates had lost their elastic characteristic it is possible to replace them without changing the whole system.
Bolts and nuts	Check tightening of the bolts	The bolts must be perfectly tightened	If the bolts and nuts are not well tightened, make the tightening once again
Stainless steel pulley and pivots	Check the wearing conditions of the pulleys wiring ropes and cables, the respective pivots on the trailing head, the pivots supporting the elastic hooking system (connecting rods), on the mobile crown, as well as the driving whirl and respective pivot inside the base section for the shaft.	The pulleys must not show signs of wearing that can affect the sliding of the rope (on the trailing head) and the chain (driving whirl). The pivot must be undamaged and self-lubricating bushings free to rotate.	If the conditions reported are not observed the replacement of worn parts must be ensured

Component	Checking procedure	Normal condition	Remedial measure
Safety sensor (limit switch)	Check that the limit switch intervenes correctly in the hooking and unhooking phases of the mobile crown to the trailing head.	<p>HOOKING MOBILE CROWN The switch limiter intervenes at the point where the connecting rod entered into the labyrinth of the trailing head, is free, and then it makes a step forward, then, with a descent it leans against the seat of the labyrinth in the working position.</p> <p>RELEASE MOBILE CROWN The switch limit rod intervenes at the point where the piston rod exits from the labyrinth, and then from the coupling seat. At this point, the crown can be lowered (DOWN). The intervention of the switch limit prevents that the clutch intervenes into the hoist</p>	If during the phases HOOKING – UNHOOKING of mobile crown to the trailing head it occurs that the engine clutch intervenes before the switch limiter, the status of the electrical contacts of the same must be checked; also the status of the switch limit rod that may not be well-placed must be checked. If the suitability of the switch limiter is verified, its position on the adjustment rod must be modified to reestablish the correct operation of movement system (which must hook and unhook without the intervention of any security of the electric motor). If on the contrary encounter any problems on the rod or on electrical contacts, the switch limiter must be promptly replaced.
Connection to the ground ring	Check existence of the metallic mass connection to the earthing system	The earth conductor must be connected to the appropriate connections on the shaft	If it is not connected, restore the connection immediately.
Electric hoist	Check tyre pressure	The trolley must have wheels at a suitable pressure to allow the easy handling at site	If the wheels are deflated inflate them, while if they are punctured they must be repaired or replaced

3.7 Maintenance of Submersible Pumps

3.7.1 General

The pumping unit consists of a special under water electric motor coupled directly to a centrifugal pump. The unit is designed to operate completely submerged under water, for pumping clean cold water only. By nature of its application and design, the unit is generally small in diameter, but long, forming an integral “in line” unit suitable for installation under water in relative small diameter boreholes.

A submarine armored cable and a small copper oil tube form the only connection beside the discharge pipe between the pumping unit and the surface of the ground. The cable joints between power cable and motor leads must ensure complete insulation from surrounding water (waterproof) and must be robust enough to prevent damage. Earth connections must be to the earth core on the motor and also insulated from the surrounding water to prevent corrosion in service.

The motor is a squirrel cage induction type motor and the rotor is carried on two ball bearings, one of which is a radial thrust bearing to take both the weight of the rotating parts and the hydraulic load. The other ball bearing is of radial type, and its chief function is to center the rotor. A high dielectric oil is circulated through the entire windings at all times and, although a small copper tube affords a means for replenishing the oil supply, motors have operated continuously for several years without having the oil supply added to or changed. Water is sealed out at the top by mercury in a rotating cup that is attached to motor shaft. A cylindrical sleeve is placed around the motor shaft, with one end attached to the motor casing and the other end submerged in the mercury. Thus the water and the motor oil are sealed off on their respective sides.



In another design of submersible pump, the pump is of centrifugal type with diffusion vanes, built in varying numbers of stages with bronze impellers to meet head requirements. The rotor of the motor, which is of the squirrel cage type, operates in the water, but the stator is completely protected from the water by a rust proof stainless steel cylinder. The motor runs extremely cool because the stator is surrounded by water. Such motor has bearings separately enclosed in its own grease chamber and require greasing only after several thousand hours of operation.

3.7.2 Maintenance & repair

A submersible unit correctly installed will operate for many hours without maintenance, depending amongst others on the pumped water and the system quality. The majority of problems that develop with submersible pumps are electrical, and most of these problems can be corrected without pulling the pump from the well. The following chart covers most of the submersible service work. As with any troubleshooting procedure, start with the simplest solution first; always make all the above-ground checks.

3.7.3 Preliminary tests & periodicity

Parameter to be monitored	Measurement Procedure	Purpose
Supply voltage (Daily)	By means of a voltmeter, which has been set to the proper scale, measure the voltage at the control box or starter. On single-phase units, measure between line and neutral. On three-phase units measure between the legs (phases.)	When the motor is under load, the voltage should be within $\pm 10\%$ of the nameplate voltage. Larger voltage variation may cause winding damage. Large variations in the voltage indicate a poor electrical supply and the pump should not be operated until these variations have been corrected. If the voltage constantly remains high or low, the motor should be changed to the correct a supply voltage.
Current Measurement (Daily)	By use of an ammeter, set on the proper scale, measure the current on each power lead at the control box or starter. Current should be measured when the pump is operating at a constant discharge pressure with the motor fully loaded.	If the amp draw exceeds the listed service factor amps (SFA) or if the current unbalance is greater than 5% between each leg on three phase units, check for the following: Burnt contacts on motor starter. Loose terminals in starter or control box or possible cable defect. Check winding and insulation resistances Supply voltage too high or low. Motor windings are shorted. Pump is damaged, causing a motor to overload.
Winding Resistance (Six monthly)	Turn off power and disconnect the drop cable leads in the control box or starter. Using an ohmmeter, set the scale selectors to Rx1 for values under 10 ohms and Rx10 for values over 10 ohms. Zero-adjust the meter and measure the resistance between leads. Record the values. Motor resistance value and cable resistance value must be added and their individual values can be found in respective OEM manual.	If all the ohm values are normal, and the cable colors correct, the windings are not damaged. If any one ohm value is less than normal, the motor may be shorted. If any one ohm value is greater than normal, there is a poor cable connection or joint. The windings or cable may also be open. If some of the ohm values are greater than normal and some less, the drop cable leads are mixed.
Insulation Resistance (Six monthly)	Turn off power and disconnect the drop cable leads in the control box or starter. Using an ohm or mega ohmmeter, set the scale selector to Rx100K and zero-adjust the meter. Measure the resistance between the lead and ground (discharge pipe or well casing, if steel).	For ohm values, refer to the BIS standard.

3.7.4 Troubleshooting chart

Fault	Possible causes	How to check	How to correct
A. Pump does not start	1. No power at pump panel.	Check for voltage at panel.	If no voltage at panel, check feeder panel for tripped circuits.
	2. Fuses are blown or circuit breakers are tripped.	Remove fuses and check for continuity with ohmmeter.	Replace blown fuses or reset circuit breaker. If new fuses blow or circuit breaker trips, the electrical installation and motor must be checked.
	3. Motor starter overloads are burnt or have tripped out (three-phase only).	Check for voltage on line and load side of starter.	Replace burnt heaters or reset. Inspect starter for other damage. If heater trips again, check the supply voltage and starter holding coil.
	4. Starter does not energize (three-phase only).	Energize control circuit and check for voltage at the holding coil.	If no voltage, check control circuit. If voltage, check holding coil for shorts. Replace bad coil.
	5. Defective controls.	Check all safety and pressure switches for operation. Inspect contacts in control devices.	Replace worn or defective parts.
	6. Motor and/or cable are defective.	Turn off power. Disconnect motor leads from control box. Measure the lead-to-lead resistances with the ohmmeter (Rx1). Measure lead-to-ground values with ohmmeter (Rx100K). Record measured values.	If open motor winding or ground is found, remove pump and recheck values at the surface. Repair or replace motor or cable.
	7. Defective capacitor (single-phase only).	Turn off the power, then discharge capacitor. Check with an ohmmeter (Rx100K). When meter is connected, the needle should jump forward and slowly drift back.	If there is no needle movement, replace the capacitor.
B. Pump starts but does not deliver	1. Groundwater level in well is too low or well is collapsed.	Check well draw-down. Water level should be at least 3 ft. above pump inlet during operation.	If not, lower pump if possible, or throttle discharge valve and install water level control.
water	2. Integral pump check valve is blocked.	Install pressure gauge, start pump, gradually close the discharge valve and read pressure at shut-off. After taking reading, open valve to its previous position. Convert PSI to feet (For water: $\text{PSI} \times 2.31 \text{ ft/PSI} = \text{ft.}$), and add this to the total vertical distance from the pressure gauge to the water level in the well while the pump is running. Refer to the specific pump curve for the shut-off head for that pump model. If the measured head is close to the curve, pump is probably OK.	If not close to the pump curve, remove pump and inspect discharge section. Remove blockage, repair valve and valve seat if necessary. Check for other damage. Rinse out pump and re-install.
	3. Inlet strainer is clogged.	Same as B.2 above.	If not close to the pump curve, remove pump and inspect. Clean strainer, inspect integral check valve for blockage, rinse out pump and reinstall.
	4. Pump is damaged.	Same as B.2 above.	If damaged, repair as necessary. Rinse out pump and re-install.



Fault	Possible causes	How to check	How to correct
C. Pump starts but at reduced capacity	1. Wrong rotation (three-phase only).	Check for proper electrical connection in control panel.	Correct wiring and change leads as required.
	2. Draw-down is larger than anticipated.	Check draw-down during pump operation.	Lower pump if possible. If not, throttle discharge valve and install water level control.
	3. Discharge piping or valve	Examine system for leaks.	Repair leaks.
	4. Pump strainer or check valve are clogged	Same as B.2 above.	If not close to the pump curve, remove pump and inspect. Clean strainer, inspect integral check valve for blockage, rinse out pump and reinstall.
	5. Pump worn.	Same as B.2 above.	If not close to pump curve, remove pump and inspect.
D. Pump cycles too much	1. Pressure switch is not properly adjusted or is defective.	Check pressure setting on switch and operation. Check voltage across closed contacts.	Re-adjust switch or replace if defective.
	2. Level control is not properly set or is defective.	Check setting and operation.	Re-adjust setting (refer to manufacturer data.) Replace if defective.
	3. Insufficient air charging or leaking tank or piping.	Pump air into tank or diaphragm chamber. Check diaphragm for leak. Check tank and piping for leaks with soap and water solution. Check air to water volume.	Repair or replace damaged component.
	4. Plugged snifter valve or bleed orifice.	Examine valve and orifice for dirt or corrosion.	Clean and/or replace if defective.
	5. Tank is too small.	Check tank size. Tank volume should be approximately 10 gallons for each GPM of pump capacity.	If tank is too small, replace with proper size tank.
E. Fuses blow or circuit breakers trip	1. High or low voltage.	Check voltage at pump panel. If not within 10%, check wire size and length of run to pump panel	If wire size is correct, contact power company. If not, correct and/or replace as necessary.
	2. Three-phase current unbalance	Check current draw on each lead. Unbalance must be within $\pm 5\%$.	If current unbalance is not within $\pm 5\%$, contact power company.
	3. Control box wiring and components (single phase only)	Check that control box parts match the parts list. Check to see that wiring matches wiring diagram. Check for loose or broken wires or terminals.	Correct as required.
	4. Defective capacitor (single phase only)	Turn off power and discharge capacitor. Check using an ohmmeter (Rx100K). When the meter is connected, the needle should jump forward and slowly drift back	If no meter movement, replace the capacitor.
	5. Starting relay (for select single- phase motors only).	Check resistance of relay coil with an ohmmeter (Rx1000K). Check contacts for wear.	Replace defective relay.

3.8 Maintenance of General Purpose Appliances

A large amount of power is consumed by lighting and air conditioning appliances used at work



places, station platforms and homes. Their service is directly availed by the users and their poor performance or failure results into discomfort which ultimately leads to direct loss of productivity and complaints. So it is of utmost importance to keep these appliances which provide basic amenities in good fettle. The following sessions are dedicated to maintenance of lights, ceiling fans and room air conditioners.

3.8.1 Maintenance of lights

Once installed, the efficiency of a light source depends to a large extent on how well the fixtures are maintained. A lamp that produces 80 lumens per watt when installed may actually distribute only 40 lumens when covered with dust. Bulbs should be replaced when they first begin to dim, before they completely burn out.

When lighting systems are over designed and generate too much light initially, a 15 percent depreciation in output was neither noticed nor important. Now with the high cost of power, closely designed energy efficient systems cannot tolerate dirt accumulation.

Lighting system maintenance procedures are relatively few but most effective. The following procedures are recommended.

- i. Lamps should be wiped clean at regular intervals to assure maximum efficiency. Lamps which are exposed to an atmosphere with substantial amounts of dust, grease, or other contaminants should be cleaned more frequently than lamps in relatively clean atmosphere.
- ii. Cleaning of ceilings, walls and floors should be done frequently to improve reflective qualities. In rooms or areas where natural day light is used to maintain light levels, washing of windows should be done frequently.
- iii. If any renovating or painting is planned, the use of white or light colour will improve light quality. The choice for walls and ceilings has a surprising effect on the efficiency of the lighting system. Light colour reflect more light than they absorb. Dark colour absorb more light. A given lighting system may be as much as twice as efficient in a light colored area as it is in a predominantly dark one.

The periodicity of cleaning is recommended as six months. However, depending upon the local conditions, the same may be reduced to ensure proper illumination.

In the event of any light fitting getting out of order, its defective part must be replaced or replaced entirely in case of an integral unit.

The lighting standards of existing installations and the design of new installations should be checked to ensure that most energy efficient lighting system possible is installed or is to be installed.

3.8.2 Maintenance of ceiling fans cleaning and care

Periodic cleaning of your ceiling fan is the only maintenance required. Use a soft brush or lintfree cloth to avoid scratching the paint finish. Periodicity of cleaning at platforms must be ensured bi-monthly during fan operating months. Frequency of fan cleaning in office space and other closed places is recommended as four months.

Some fan motors have permanently lubricated ball bearing which does not require oiling while some ceiling fans require periodic lubrication to operate smoothly. Use any light oil (similar to the oil used on a sewing machine), to fill the oil hole that is located on the top side of the motor. Fill this hole till the oil flows over and rinse the excess with a tissue or rag.

During pre-summer preparation, critical examination of down rod and tightening of all screws must be ensured and recorded, apart from regular cleaning and oiling.

In case fan speed is slow, it could be attributed to three reasons:

1. Degradation of bearing: Normally bearing failure would be accompanied with unpleasant noise. This can be attended by replacing the bearing
2. Weakening of capacitor: Fan speed should restore once a faulty capacitor is restored with a new capacitor.
3. Winding damage: Fan winding comprises of several stator coils. In case a few of them fail/weaken on account of partial insulation failure, fan speed cannot be restored by changing bearings or the capacitor. Such fans must be rewound to restore their performance.

A. Wobble

- i. Ceiling fan tend to move during operation due to the fact that they are not generally rigidly mounted—if they were, they could generate excessive ceiling vibration and stress on their mountings.
- ii. Movement of a couple of centimeters is quite acceptable and does not suggest the fan will fall down.
- iii. Ceiling fans are mounted very securely on steel brackets with rubber cushioning or with ball-joints to allow free movement.
- iv. However, if excessive wobbling/noise is observed, fan must be taken off service, unloaded and attended. A new rubber cushioning must be provided with the ceiling hook while hanging the fan again.

B. Troubleshooting checklist

Trouble	Probable causes	Suggested remedy
1. Fan will not start	A. Fuse or circuit breaker blown.	Check main and branch circuit fuses or circuit breakers.
	B. Loose power line connections to the fan.	Check line wire connections to fan
2. Fan Wobbles	A. Fan blades are not horizontal to ceiling.	The blade may require adjustment at the blade mounting screws; The blade is out of shape, thus causing wobbling. New blades set will require to be replaced.
	B. Blade screws are loose.	Make sure all screws are securely fastened.
	C. Blade/s are out of shape	Remove blade and lay on a flat surface to check if blades are out-of-shape. Replace if deformed
3. Fan sound noisy	A. Top canopy touching ceiling.	Lower canopy from ceiling to ensure minimum 3 mm clearance.
	B. Loose fan blade screws.	Re-tighten all screws on fan blades but never over-tighten.
	C. Ceiling fan not secured against ceiling.	Re-tighten all screws in the hanging bracket or plate.
4. Mechanical Noise	Bearing damaged	Replace bearing
5. Fan speed slow	Capacitor weakened/damaged	Replace the capacitor
	Winding coils damaged partially	Rewind the fan motor

3.8.3 Maintenance of Refrigerators and Water Coolers

Small refrigerators, water coolers and domestic air conditioners employing sealed type units are designed to operate satisfactorily, for long periods without any-attention if used; with reasonable care. Leave well alone is an excellent rule to follow, tinkering should never be permitted. The insulation resistance of the wiring and bonding to earth of the body of the equipment should be checked at intervals of say once in 6 months to ensure safety. Defrosting the cooler unit and giving a general cleaning is necessary every now and then.

CHAPTER-4

LIGHTING DESIGN AND ILLUMINATION

4.1 Introduction

Lighting is an important requirement of any facility, as it profoundly affects the way people work, feel and interact.

While in the industrial sector, lighting constitutes nearly 2 % to 5% of the facility's total energy consumption, it may go up to as much as 30 % in the case of commercial buildings, hotels, and information technology complexes. Thus there are more energy saving opportunities are pursued in the proper sequence. Recognizing the importance and benefits of energy efficiency, the Government of India enacted the Energy Conservation Act, 2001, which came into force on 1st march, 2002.

Nearly 40 % of energy saving can be achieved in normal office building by retrofitting existing fixtures with efficient ballasts, lamps and reflectors. Even larger savings may be gained through comprehensive redesigning of lighting and control system.

4.2 Basic Lighting Terminologies

Light- Light is any radiation capable of causing a visual sensation on the eye directly. The band of wave length that corresponds to visible light lies between 380 nm and 760 nm ($1 \text{ nm} = 10^{-9}\text{m}$)

Visual spectrum- The band of wave length that causes a visual sensation. The various colour bands

380 nm - 435 nm	violet
435 nm - 500 nm.	Blue
500 nm - 566 nm.	Green
566 nm - 600 nm.	Yellow
600 nm - 630 nm.	Orange
630 nm - 760 nm.	Red

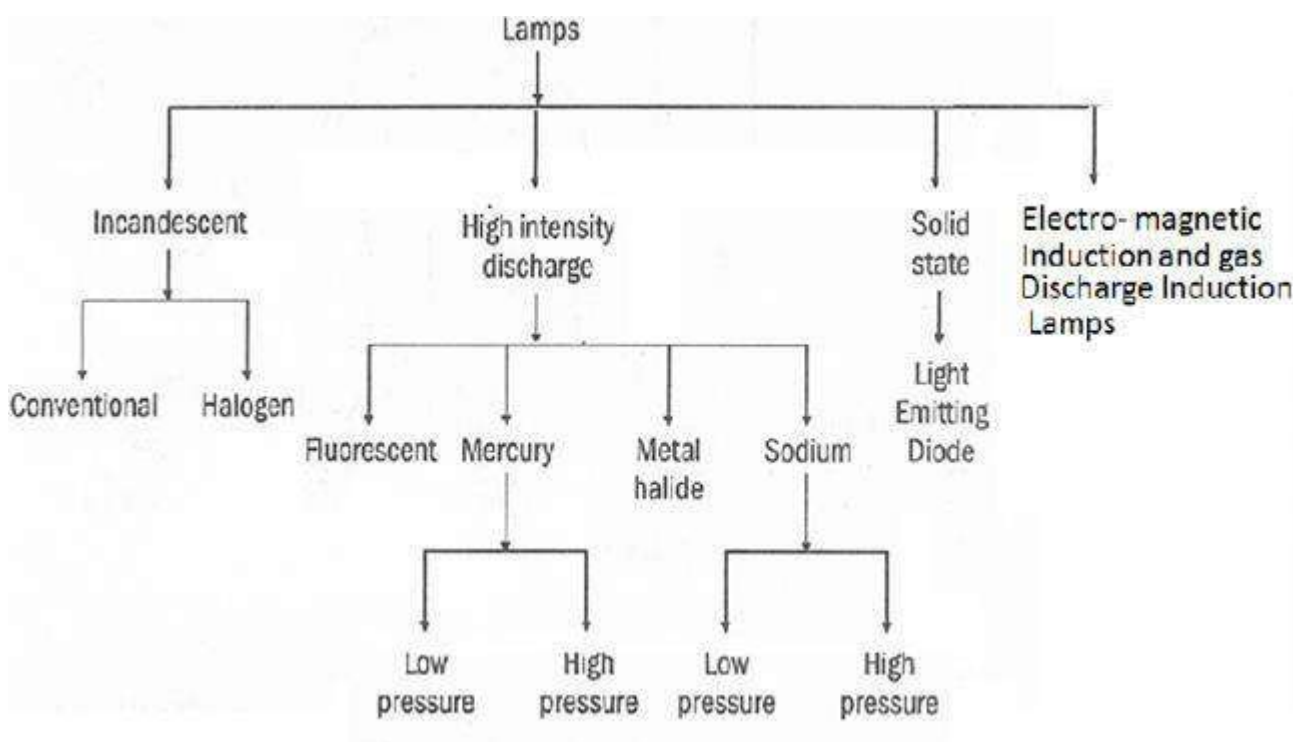
- Luminous flux-** Quantity of radiant flux (light) emitted by a lamp. The unit is 'lumen'
- Luminous efficacy** Quantity of light (lumen) emitted for each unit of electrical power (watt) consumed. The unit is 'lumen/watt' (lm/W).
- Illuminance (E)** - Quantity of light (lumens) incident on a surface per unit area (m^2). The unit is 'lux' (lumen/ m^2).
- Luminance (L)** - Intensities (candela) of light reflected back from a surface per unit area (m^2) in a given direction. The unit is candela/ m^2
- Colour rendering** -Expression for the effect of an illuminant on the colour of an object in conscious comparison with their colour as seen under a reference illuminant (daylight)
- Colour rendering index (Ra)** - Measure of the degree to which the colour of objects illuminated by a source conform to that when illuminated by a reference source (daylight).
- Glare-** A condition which leads to discomfort or a reduction in the ability to see objects, or both, due to distribution of intensities/ extreme contrasts in the field of vision.



- viii. Coefficient of utilization- It is the ratio of the lumens reaching the working (C.O.U.) plane to the total lumens produced. It is also called “Utilization Factor”. C.O.U. depends on, light distribution of the luminaire; light output ratio of the luminaire; reflectance of the ceiling, walls & working plane; room index and arrangement of the luminaires in the room. C.O.U. is based on new, clean equipment and in practice a maintenance factor is introduced to convert initial to in- service illumination.
- ix. Maintenance Factor- The maintenance factor is the ratio of the lumens produced by the system while in service to the lumens produced by system when newly installed.

4.3 Light Sources

The following figure illustrates the classification of lamps that have been in practice since the inception of lighting technology. As most of the technologies are now obsolete and Indian Railways have switched over to 100% LED lighting, details of such lamps are not explained further.



LED Lamps

Like a normal P-N junction diode the LED consists of a chip of semi-conducting material doped with impurities. When voltage is impressed across the junction, current flows from the p-side or anode to the n-side or cathode but not in the reverse direction. Charge carriers, electrons and holes flow into the junction from electrodes with different voltages. When an electron meets a hole,



it falls into a lower energy level and releases energy in the form of photon. The wavelength of the light emitted, and therefore its colour depends on the band gap energy of the materials forming the p-n junction. In silicon or germanium diodes the electrons and holes recombine by a non-radiative transition which produces no optical emission, because these are indirect band gap materials. The materials used should have a direct band gap with energies corresponding to near – infrared, visible or near ultraviolet light.

LED development began with infrared devices made with Gallium Arsenide. Advances in material science have made possible the production of devices with ever shorter Wave lengths, producing light in a variety of colours. LED's are usually built on an n-type substrate, with an electrode attached to the p-type layer deposited on its surface. P-type substrates are also used but less common. Blue LEDs are based on the wide band gap semiconductors Gallium nitride (GaN) and Indium Gallium Nitride (InGaN).

One way to produce white light is to use individual LEDs that emit three primary colours red, green and blue and then mix all the colours to produce white light. This method is involved with electro-optical design to control blending and diffusion of different colours. The other method is to use phosphor material coating to convert the ultraviolet or blue light of LED to broad spectrum white light similar to fluorescent lamp. The phosphor based LED method involves coating an LED of one colour (mostly the blue LED made of InGaN) with phosphor of different colours to produce white light. A fraction of the blue light is re-radiated by the phosphor coating to light of longer wave lengths. When several phosphor layers of different colours are applied, the emitted spectrum is broadened effectively increasing the CRI value of the LED. The phosphor method is the most popular technique for manufacture of high intensity white LEDs.

One of the key advantages of LED lighting is its high efficiency as measured by light output per watt. Research has made it possible to commercially produce LEDs with efficiency of about 130 lumens per watt which is better than that of any other light source. It should be noted that high power LEDs are necessary for practical general lighting applications. High power (one watt) LEDs have been developed for practical general lighting operations. LEDs have several advantages over other light sources.

The main advantages are:

1. Long burning life of more than 60,000 burning hours
2. High luminous efficacy of 120 lumens per watt
3. Wide variety of colour LEDs have been developed which are suitable for canopy and façade lighting

However when power LEDs are used suitable design of thermal management should be made so that the junction temperature increase is kept within specified limits. The LED should have a proper electronic driver circuit to drive the LEDs with constant current. If it is not driven by constant current the light output will depreciate when the LED burns for more time and will not give the desired performance.

Currently the prices of LED luminaries are still high. Recently street light fittings of 75 watt and higher rating have been developed by reputed manufacturers which have good potential for street and colony lighting. Continuous research is in progress in various countries in the field of LED lighting and the future for LED lighting is indeed very bright.



4.4 Calculation of Illuminance

4.4.1 Lumen method

The idea of a lumen method of interior design had been proposed earlier, but it was not until 1920 that M/s. W. Harrison and E.A. Anderson introduced standardised procedures which include both direct and reflected lumens. This gives a simple solution to the problem of providing average horizontal illuminance. Units of lighting

The units of lighting are derived from a combination of human response and of the physical units of power, and hence may be described as psychophysical. They stand on their own and cannot be directly related to other physical units. The four units generally used in lighting are:

- i. Light output or luminous flux
- ii. Luminous intensity
- iii. Light level or illuminance and
- iv. Brightness or luminance.

The Indian Standards **3646 (Part 1): 1992**: Code of practice for interior illumination defines these four units.

4.4.2 Light output or luminous flux

Luminous flux is the quantity derived from radiant flux by evaluating the radiation according to its action upon a selective receptor whose spectral sensitivity is defined by the standard spectral luminous efficiencies. The SI unit of luminous flux is **lumen**, and is abbreviated as **lm**. Light sources are labelled with an output rating in lumens.

4.4.3 Luminous intensity

Luminous intensity is the quotient of the luminous flux leaving the source, propagated in an element of solid angle containing the given direction, by the element of solid angle. The SI unit of luminous intensity is candela and is abbreviated as **cd**.

4.4.4 Light level or illuminance

Illuminance at a point on a surface is the quotient of the luminous flux incident on an element of the surface containing the point by the area of that element. The SI unit of illuminance is lux and is abbreviated as **lx**. The other unit of illuminance is foot-candles (1 foot-candle = 10.76 lux). Illuminance may be measured by a light/lux meter located on the work surface.

4.4.5 Brightness or luminance

Luminance is the intensity of light emitted in a given direction per projected area of a luminous or reflecting surface. In other words, it is the intensity of light at a point on the surface of the source or a receptor or at a point on the path of a beam. The SI unit of luminance is candela per metres square and is abbreviated as **cd/m²**.

4.4.6 By definition

Illuminance (lux) = Luminous flux / Area (Lumens / Sq.mtr.)

To obtain this average illuminance we need to determine the total luminous flux reaching the work plane. This flux is composed of two components.

- i. Flux which comes directly from the luminaire to the work plane (direct component)

- ii. Flux which is reflected from room surfaces and reaches the work plane (reflected component)

In the Lumen method the fraction of the initial lamp lumen which ultimately reaches the work plane both directly and from reflection is called co-efficient of utilisation (C.o.U.). It should be realised that C.o.U. includes both, the efficiency in room surface in redirecting these lumens to the work plane.

The C.o.U. is the function of three factors.

- i. Room surface reflection.
- ii. Room size and proportion.
- iii. Luminaire (efficiency and intensity distribution).

For example, if a particular luminaire has C.O.U' of 0.70, then 70% of the lumens produced by the lamp would reach the work plane and 30% of the lumens would be lost, some would be trapped inside the luminaire and others would be absorbed by the room surfaces, such as walls, floors. These factors will be examined individually.

4.4.7 Room surface reflectance

All surfaces in the room (walls, ceilings, floors, furniture, machines, and people) absorb and reflect light. If these surfaces are highly reflective, less light is absorbed and more light is reflected back into the space. Since some of the reflected light will eventually reach the work-plane, luminaires will perform more efficiently in rooms with high reflectance surfaces than in rooms with surfaces of low reflecting value.

4.4.8 Room size and proportions

Except from a totally indirect system, light travels directly from the luminaire to the work- plane while other light travels to the walls where some is absorbed and some reflected towards the work-plane. In small rooms, a larger percentage of the total light produced by the luminaires strikes the walls than in large rooms (fig. 1).

Note that in the small room a large part of the light from the luminaire strikes the walls whereas in the large room, some light from the end luminaire hits the wall, but the luminaires in the centre send all their light to the work-plane. This means that luminaires have a higher C.o.U. in large rooms than in small rooms since a larger percentage of the total light produced by the systems goes directly to the work plane.

4.4.9 Luminaire (efficiency and intensity distribution)

The design and light distribution characteristics and efficiency of the luminaire also affect the

C.o.U. It depends upon the following factors:

- i. Light distribution of the luminaire.
- ii. Efficiency and light output ratio.
- iii. Spacing to mounting height ratio.

Determination of C.o.U.:

- i. Get the C.o.U. table from the luminaire manufacturer for a particular luminaire,
- ii. Find out the room index (K) of the room:



$$K = \frac{L \times W}{Hm. (L + W)}$$

Where, L = length of the room

W = width of the room

Hm = Mounting height (Distance between the centre of the luminaire to the working plane)

- Select reflectance factors depending upon the colour of the walls, ceiling or working plane.
- Knowing K and wall reflectance, ceiling reflectance and work plane reflectance, C.O.U has to be read from the photometric data sheet which is given below Coefficient of utilization (C.o.U.) (Typical data for a luminaire provided by manufacturer)

C.o.U. calculated in accordance with IS: 3646 (Part 3) – 1968

Room reflectance		Room index										
F	C	W	0.60	0.80	1.00	1.25	1.50	2.00	2.50	3.00	4.00	5.80
10	70	10	.56	.62	.67	.71	.74	.78	.79	.82	.83	.85
		30	.52	.59	.63	.68	.71	.75	.78	.79	.82	.83
10	50	50	.55	.61	.66	.70	.73	.76	.79	.80	.82	.83
		30	.52	.58	.63	.67	.70	.74	.76	.78	.80	.82
10	30	30	.52	.58	.62	.67	.69	.73	.75	.77	.79	.80
		10	.49	.53	.60	.64	.66	.71	.74	.76	.78	.79

Coefficient of utilization (C.o.U) = D.C + U.C

D.C = Downward co-efficient

U.C = Upward co-efficient

C.o.U = (LFU x DLOR) + (UFU x ULOR)

LFU = Lower flux utilance

DLOR = Downward light output ratio

UFU = Upward flux utilance

ULOR = Upward light output ratio

In the IS 3646 Part II for each type of fitting classified under the BZ class (BZ-1 to BZ-10) the values of LFU as well as UFU are given for particular room index values. The LFU values and UFU values are different for different reflectance factors for ceiling, floor and walls. Type of fitting should be given by the manufacturer. Generally a metal halide high bay fitting comes under BZ-1 class and fluorescent tube fitting falls between BZ-5 and BZ-6. The classification of the BZ class is based on the intensity distribution based on the polar curve.

The value of DLOR and ULOR is the ratio of downward output fraction to upward output fraction which depends on the luminaire. The COU value is now calculated

Initial Lumen Output

Luminous flux x COU.

Illuminance = $\frac{\text{Luminous flux x COU}}{\text{Area}}$

This illuminance corresponds to the initial value of the brand new lighting installation.



Maintained Illuminance

We are interested in average maintained illuminance rather than average initial illuminance, we must include a light loss factor (maintenance factor) in our calculation. Hence, the equation becomes:

$$\text{Illuminance} = \frac{\text{Lamp Lumens} \times \text{COU} \times \text{M.F.}}{\text{Area}}$$

4.4.10 Maintenance Factor (Light Loss Factor)

Total light loss is divided conventionally into unrecoverable and recoverable losses and the light loss factor should include as many of each of these as are quantifiable.

4.4.11 Recoverable Losses

There are four recoverable losses:

- (a) Lamp Burnouts (LBO)
- (b) Lamp Lumen Depreciation (LLD)
- (c) Luminaire Dirt Depreciation (LDD)
- (d) Room Surface Dirt Depreciation (RSDD)

4.4.12 Lamp Burnouts

It may not be feasible to replace a lamp every time one burn out. If burnt-out lamps are not replaced immediately, the average illuminance level will be tolerated in a given installation before they are replaced. Then the LBO factor is the ratio of the number of lamps remaining lighted to the total number of lamps, when the maximum number of burnouts is reached.

4.4.13 Lamp Lumen Depreciation

The Lumen output of a lamp decreases as it ages. The LLD factor is generally taken at the 70% life point for high intensity discharge lamps, and fluorescent lamps. Lamp lumens at 70% life is divided by the initial lamp lumens to obtain the LLD.

4.4.14 Luminaire Surface Depreciation (LSD)

Effects such as yellowing of plastic with age and pitting and dis-colouration of enamel overtime can cause a reduction in light reflected within the luminaire and transmitted through the diffuser. No numbers are available for this factor.

4.4.15 Room Surface Dirt Depreciation

Dirt on room surfaces reduces the reflected component of luminous flux and thus the illuminance on the work plane. The resulting RSDD factor is a function of the dirtiness of the environment, the time between cleanings, the luminaire flux distributions, and the room proportions.

4.4.16 Unrecoverable Factor

(a) Luminaire Ambient Temperature (LAT)

Fluorescent lamp and luminaire ratings are established in still air at 25°C. Furthermore, fluorescent luminaire photometry is relative in that the luminaire output is adjusted for a 25°C lamp operating temperature. In an actual installation, the luminaire operating temperature is likely to differ from the test condition. Operation above or below the test value decreases lumen output. For example, if the operating temperature for a fluorescent luminaire is 30°C, the lamp output would decrease by about

7.5%, giving a temperature correction factor of 0.925. There is no significant variation with ambient temperature for incandescent and HID Lamps.

(B) Voltage at the Luminaire (VL)

Deviations in supply voltage from rated value can affect the light output of all types of lamps. A 1% change in voltage causes a 3% change in-lumen output for incandescent lamps.

(C) Luminaire Surface Depreciation (LSD)

Effects such as yellowing of plastic with age and pitting and discolouration of enamel overtime can cause a reduction in light reflected within the luminaire and transmitted through the diffuser. No numbers are available for this factor. Lighting for Offices and Educational Buildings

People working in today's offices spend just as much of their time on telephone and in communicating with the computer and office colleagues as they do reading and writing. Each of these tasks has its own specific visual requirements and it is necessary that the lighting be designed accordingly. Moreover, since feelings of well-being, interest and enthusiasm, which are so important to productivity, are affected by the office environment, it is clear that the lighting should be designed to make 'this as pleasant as possible.

4.4.17 General Guidance Illuminances

Levels

For the vast majority of office tasks, the "working plane is usually horizontal at a height of between 0.75m and 0.85m above floor level. The recommended average illuminances on this plane for various types of office interiors are given in IS:3646 (Part-II) 1992.

Research into the illuminances preferred in working interiors has shown that there is no value at which everyone is satisfied. Added to this is the fact that various office tasks are often being performed simultaneously in one and the same office.

Clearly, each individual should be able to decide for him or herself exactly what level of lighting is needed at a given moment, provided that this can be arranged without causing disturbance to others. Such control, ideally should be possible from the desk or work station concerned, and can be achieved by either switching or dimming individual luminaries.

4.4.18 Uniformity

Uniformity Ratio of Illuminance (on a Given Plane) is defined as a ratio of the minimum illuminance to the average illuminance on the plane.

Certain considerations are useful and may be necessary in specific area applications in offices, in addition to compliance with the general requirements brought out so far.

The illuminance and its distribution on the task area and the surrounding area have a great impact on how quickly, safely and comfortably a person perceives and carries out the visual task. Ranges of useful reflectances for the major interior surfaces are:

- a) Ceiling: 0.6 to 0.9;
- b) Walls: 0.3 to 0.8;
- c) Working planes: 0.2 to 0.6; and
- d) Floor: 0.1 to 0.5.

The illuminance of immediate surrounding areas shall be related to the illuminance of the task area and should provide a well-balanced luminance distribution in the field of view.

Large spatial variations in illuminances around the task area may lead to visual stress and discomfort. It is important to keep a balance between task illuminance and its surrounding areas {see Table I}.

Table 1 Relation between Task Illuminance and Illuminance of Immediate Surrounding Area

Clause-9.1 of National Lighting Code (NLC- 2010)

Task illuminance (lux) surrounding areas (lux)	Illuminance of immediate
≥ 750	500
500	300
300	200
Uniformity: ≥ 0.7	Uniformity: ≥ 0.5

4.4.19 Luminance

Excessively large differences in luminance in an office can create visual adaptation problems or, in extreme cases, glare. Conversely, if the luminance differences are too small, the surroundings will appear dull and uninteresting. Both these effects can be avoided by ensuring that the luminance ratios in the field of view are proper.

The luminance ratio between the visual task itself and its immediate background (viz. the desk) should be smaller than 3:1, but greater than 1:1.

Some recommended luminances are listed in the table below:

Surface	Luminance (cd/mxm)
Walls	50-150
Ceiling	100-300
Task area	100-300

The above recommendations can be satisfied by adhering to the reflectance ranges listed in the table below:

Surface	Reflectance
Ceiling	0.7 or above
Walls	0.5-0.7
Partitions or screens	0.4-0.7
Floors	0.1-0.3
Furniture and equipment	0.2-0.5
Window shades	0.4-0.6

4.4.20 Glare Control

Glare is experienced if lamps, luminaries, windows or other areas are too bright compared with the general brightness. Glare is defined as a condition of vision in which there is discomfort or a reduction in the ability to see significant objects or both due to an unsuitable distribution of intensity or extreme contrasts in range of luminance in the field of vision. Glare index is a number representing the amount of discomfort glare in a lighting installation to which upper limits are given for variety of room sizes and surface reflection factors. For an office the permissible glare index is given as 19. The glare index for interior spaces where light fittings with equal spacing are provided can be obtained with the help of photometry data and IS3646. The glare increases when the glare index is more.

4.4.21 Lamp Colour

(a) Colour Appearance

The choice of the colour appearance of the lamps employed in a particular office depends on the illuminance level, the presence or absence of daylight, climatic conditions and, of course, personal preference.

The lamps normally employed in interior lighting may be divided into three groups according to their colour appearance as described by their colour temperature.

Correlated colour temperature (CCT)	Colour appearance
> 5300 K	Cool (bluish white)
3300 - 5300 K	Intermediate (white)
< 3300K	Warm (reddish white)

Research has indicated that a higher colour temperature (colder colour appearance) is preferred at higher lighting levels, and that in the absence of day light, a low colour temperature (warm appearance) is preferred. In warmer climates, the personal preference is usually for higher colour temperatures, while in cooler climates the preference is more for low colour temperatures.

Light sources should not be mixed without first establishing that their colour appearances match.

(b) Colour Rendering

Light sources with a colour rendering index (Ra) of at least 80 are recommended for all office

4.4.22 Office Types

(a) General offices

i. General (Fixed) Lighting

Most general offices are moderate to large and their layout is seldom fixed: office furniture is re-arranged from time to time, and partition walls may be added, shifted or removed. One way of ensuring that all work positions will be adequately illuminated, no matter what the office layout, is to install a system of general lighting in which luminaires (surface mounted or recessed) are arranged in a regular, fixed pattern over the ceiling.

If the building is designed with provisions for the future erection of partition walls along the axis of its modules, the lighting arrangement should be planned with this possibility in mind. This normally means that the layout of the luminaires will be a function of the modular building structure and window spacing.

ii. Flexible lighting

Energy savings can be obtained by employing a flexible approach to the design and use of the lighting. There are two alternatives namely: lighting controlled by switching and/or dimming and task lighting with uplighters. A further possibility is supplementary local lighting, which allows the level of general lighting to be reduced.

Desk lights (decorative or otherwise) fitted with incandescent lamps are not really suitable, not only are they insufficient, with high heat emission, but they also create a far from uniform luminance distribution over the task area.

It is better to employ desk-mounted reflector luminaires equipped with LED lamps. These have the broad, even light distribution needed for an even luminance distribution, and the heat emission is negligible. They should be mounted above the line of sight (viz. higher than 0.6m above the desk-top) and equipped with an adequate louvre to screen the lamp(s) from view. Adjustable (pivoted) luminaire mounting is appreciated because it allows for easy repositioning for various tasks.

These lighting systems should be carefully planned if an irregular, and possibly unpleasant luminance pattern is to be avoided. The local lighting should, of course, allow a task to be performed in comfort for all possible positions of the worker, and the low-level general lighting should provide approximately 50% of the total task illuminance

4.4.23 Drawing offices

As drawing involves the accurate discrimination of fine detail, the illuminance in drawing offices should be at least 1000 lux.

Ceiling reflections can occur on the surfaces of drawing boards that are badly positioned with respect to the luminaries. The easiest way of minimizing such reflections is to position the boards accordingly. Disturbing shadows and all forms of glare can be avoided by using luminaries that have a large luminous area.

The problem of providing suitable lighting is much simplified if it can be arranged that all occupants of the office face one way, and the office layout is limited to fixed rows of work positions. Rows of fluorescent luminaries can then be mounted parallel to the direction of view on both sides of the drawing boards. With this arrangement the absence of any luminaire directly above a given work position serves to keep glare and ceiling reflections to a minimum, while the lighting coming from both sides of a worker effectively eliminates hard shadows.

4.5 Lighting for VDU Work-Stations

In general, the visual requirements for office lighting listed above are equally valid, for video-display-unit (VDU) work-stations for both word processors and CAD systems. However, there are certain additional features that have to be taken into account when planning the light if visual performance and comfort are not to be impaired

4.5.1 Reflections

In the first place, the screen of the VDU constitutes an important, additional part of the task area and light sources such as luminaries and windows that reflect in the screen can produce a considerable deterioration in the legibility of the characters.

Such reflection can best be minimized by taking into account the position of VDU workstations and light sources in relation to one another at the initial planning stage. But care in the choice of the lighting installation can also help to obviate this problem.

Both indirect and direct lighting systems can be used, the best choice depending on the height of the room, the type of VDU and the sort of luminaire screening

4.5.2 Indirect Lighting

Good indirect lighting employing up-lighters creates more or less equal brightness on walls, ceiling and furniture. There will therefore, be no bright spots to cause reflections in the screens of the monitors or VDUs. This means that, at least as far as the artificial lighting is concerned, these can be moved about at will.

But indirect lighting does have certain disadvantages'

- i. The luminaries and ceiling become dirty sooner. Some of the dust collecting in the luminaire is carried upward by the warm air currents to settle on the ceiling. The lighting level is thereby reduced, as is the efficiency of the installation.
- ii. In low-ceilinged areas, the ceiling brightness will be uneven, creating reflectors in the VDU

- iii. The very uniform lighting is devoid of shadows, which is not natural

4.5.3 Direct Lighting

Generally speaking, direct lighting is more efficient and does not get dirty so quickly as indirect lighting. Moreover, the heat from the (recessed) luminaires can be drawn away via the ceiling, keeping the heat loading in the room to a minimum.

The degree of freedom allowed in the sitting of the VDUs with direct lighting will depend on the type of screen involved-where dark-screen (positive screen) monitors are in use. Strict requirements are placed on the luminaire screening employed. This should be such as to give a very directional downward light distribution, so lessening the chance of the luminaire causing reflections in the screen. But this also means that they produce quite high contrasts (highlights and deep shadows) on the objects illuminated whilst leaving the walls in relative darkness and such illumination creates a rather somber impression.

Where coated, light-screened VDUs are employed, on the other hand (which is generally the case), minor or prismatic luminaires giving a broader light distribution can be chosen without the risk of producing disturbing reflections. Such lighting is more acceptable in terms of the modelling effect produced.

Where high ceilinged areas are concerned (3.5m and above), pendant luminaires providing a combination of direct and indirect lighting offer a suitable alternative for both types of screens. However, especially with dark screens, it is still necessary to ensure that the ceiling does not exhibit great differences in brightness. And the “screening” of the direct component of lighting should also be critically examined.

4.5.4 Illuminance Level

The choice of the correct illuminance at the workstation is very important. If it is: too low, it will reduce visual performance for conventional work, while if it is too high it can result in a reduction in character contrast on the VDU screen. Excessive jumps in luminance between the documents and the screen must also be avoided if adaptation problems are to be avoided.

Research and experience indicate that the optimum illuminance will lie somewhere between 400 lux for light screens and 250 lux for dark screens.

4.6 Educational Buildings

The visual environment in an educational building, apart from providing the comfortable seeing conditions needed for the performance of a wide variety of work tasks, must also satisfy the psychological and emotional needs of learners. Good lighting can enhance pleasant and attractive surroundings, stimulate learning and influence behaviour in a positive way.

Educational buildings are usually designed to be lit by day light. Whenever and wherever possible, lighting controls should therefore ensure that the artificial lighting can be easily adjusted to suit the prevailing daylight conditions

4.6.1 Class-Rooms

In a conventional class-room the window wall will be parallel to the direction of view (ideally to the left of the students). Good, glare-free lighting can then be provided by employing low-brightness or well screened ceiling luminaires arranged in parallel rows running parallel to the window wall. The rows should be spaced sufficiently far apart to allow the rows of desks to be positioned between the rows. This last precaution serves especially to reduce reflected glare from the work surface.

The Black board should be “provided with its own lighting system in which both direct glare and

ceiling reflections in board are eliminated. The simplest arrangement is to have one or more fluorescent luminaries mounted on the ceiling and screened from the students so as to light the board at an angle of not less than 60° from the normal to any part of its surface.

Where necessary window blinds can be employed to prevent reflected glare from windows occurring in the Black board and to eliminate sun on desks. These same blinds, perhaps, in conjunction with a dimming device for the artificial lighting, will in any case be needed if it is planned to use the class-room for slide /film shows.

Depending on the depth of the class-room it may be necessary to arrange that the luminaires remote from the window wall can be switched on independently of the remainder of the installation to compensate for fading day light

4.6.2 Lecture Halls

In lecture halls and auditorium day light is often shut out altogether and there is complete dependence on artificial lighting. The following points may be mentioned as being of importance in such areas.

- i. Reading and writing require an illuminance of more than 300 lux, preferably 500 lux
- ii. Special care has to be taken to prevent glare.
- iii. Equipment for dimming the lighting during demonstrations, film and slide shows has to be provided.
- iv. Local lighting is required near the chalk board.

Ideally a control panel should be installed at the lecturer's position to enable him to switch the various groups of lights on and off, operate the dimming equipment, and possibly control also an automatic projection system.

It is important that careful attention be paid to the provision of emergency and exit lighting. Steps and stairs should, also be equipped with local orientation lighting.

4.7 Lighting for Houses

In the past, the approach to home lighting was to accept the traditional control pendant light- point, and then ask where the supplementary lighting, if any, should be located. Today, the reverse is more likely to be true: first we meet the local requirements, and then ask whether anything more is desirable.

Although it is accepted that home lighting will always remain a sector in which personal taste plays a dominant role, there are nevertheless certain points on which useful guidance can be given.

i. Indoor Areas

ii. The living-room

There is no other room in the home to compare with the living-room as regards the number and diversity of the activities taking place there. Talking, reading, and watching television are the main ones, but writing and, of course, eating can also take place in the same room. In fact the living-room is the very heart of the home, which is sufficient reason to light it well

Because of its many different uses, the keynotes of the lighting must be flexibility combined with aesthetics. There should be light fittings for all occasions, and it should be possible to use them all, or only a few at a time, at any chosen brightness and intensity according to the needs of the moment.

(a) Orientation (Ambient) Lighting

A single ceiling mounted luminaire can provide the ambient lighting. But this should not be the only lighting in the room. This is because the eye is always attracted to the highest brightness, and if

this is found in the center of the room, the space will be perceived as being ‘around this center’, and thus smaller. Also since all walls will be of very similar brightness, the volume of the room will be weakly rendered by the lighting.

(b) Reading

Reading demands a relatively high illuminance, the correct amount depending upon the age of the reader.

The traditional floor or standard lamp in all its simplicity is excellent. It provides an abundance of light upwards (ambient lighting) and permits comfortable, close-up reading. But energy-saving lamps can also be used: for example a suitable CFL lamp, or the new generation LED pin type lamps can give excellent results.

Work like knitting and embroidery calls for more or less identical lighting to that outlined above, although if anything it should be slightly more intense.

(c) Writing

Writing, whether in the living-room or elsewhere, demands adequate local lighting. But here also, some form of ambient lighting should be present. The luminaire providing the local lighting should be relatively large: the shadows will then be smaller, with softer contours.

(d) Conversation (sitting corner)

Conversation is one of the main activities in the living room. The lighting should therefore facilitate eye-contact and model faces in a pleasant way.

Good ambient lighting is usually sufficient to provide eye-contact. But the need for modelling means that the light should come from more than one direction. A couple of floor or table lamps or pendent luminaires with large, diffusing screens will provide the required lighting harmony in a sitting corner.

With dimmers, the general lighting level can easily be adjusted to create the required mood or atmosphere.

(e) Watching Television

Watching television in the dark is very strenuous on the eyes. A luminaire should therefore be placed on or close to the TV set, or else the surrounding wall area should be lighted by, say, a spot aimed at a painting.

A. Dining room/Dining area

Many (if not the vast majority) of homes do not have a separate dining room, but a dining-area that forms part of the living room. The approach to the lighting is the same in both cases.

A feeling of intimacy can be emphasized by concentrating the light on the dining table instead of uniformly lighting the entire area or room. However, the faces of the diners should be included as well. A single luminaire suspended above the table is the usual solution, although with bigger tables, two or three small, matching luminaires might be used. Suitably screened Luminaires with a glass or fabric shade providing some direct lighting on the faces are to be preferred. However care must be taken to avoid glare.

The provision of a dimmer is useful in enabling the lighting level to be adjusted to suit the occasion or task, or simply to leave the table corner lighted when not in use, as a part of the living-room ‘landscape’.

B. Kitchen

The kitchen is in fact a sort of work-shop and therefore needs virtually shadow-free general lighting. This should reach all surfaces, not only the horizontal work surfaces, but also the vertical ones to facilitate the task of finding things in the cupboards.

Additional local lighting may be needed to fill in the shadows cast by cup-boards and/ or by the occupant(s) of the kitchen standing at the work surfaces.

The lighting, both general and local, must be such as to make it easy to discern even slight colour differences in the food. This means, of course, that all the lamps should have a high colour rendering index ($R_a > 80$). At the same time, the colour appearance created by the lighting should be in accord with that in the rest of the house.

For the breakfast bar or corner, now customary in many larger kitchens, an attractive luminaire on a separate switch would be appropriate.

C. Bedroom

(a) Main Bedroom

Besides general lighting, local lighting will be required to provide adequate illumination for the dressing-table and for reading in bed.

The dressing-table can perhaps best be lighted using two vertically mounted low- brightness luminous panels, one on each side of the mirror.

Good bed-head lighting is provided by twin wall-mounted luminaries having a medium-spread light distribution and individually adjustable and switched to suit individual requirements.

(b) Children's Bedrooms

Children prefer to have more lighting. Dim light often preferred by older people for relaxation, might well prove frightening for young children. But long harsh shadows and glaring, unscreened lamps must be avoided.

For the teenager's room, adjustable spotlights on a power track in combination with adjustable clip-on spots that can be placed anywhere in the room offer good lighting flexibility.

(c) Guest room

Although a more straightforward approach may be adopted to the lighting, the guest-room is in principle similar to the main bedroom. Pleasant and well-thought-out lighting will be appreciated by the guests and help make themselves feel 'at home'.

D. Bathroom

The main needs in the bathroom, as in the kitchen, are for good general lighting of the interior as a whole, and local lighting.

The general lighting should be strong enough to penetrate the shower curtain or screen. It can be provided by a separate ceiling mounted luminaire (out of reach of anyone standing in the bath), but adequate general illumination is usually provided by the local lighting at the mirror above the wash-basin. This should direct light toward the person and not into the mirror. It should be as shadow-free as possible, which means using large-surface luminaires, preferably mounted vertically on both sides of the mirror.

E. Safety regulations

- i. A wall mounted on/off switch must be positioned outside the room.
- ii. Any switch in the bath-room must be of the pull-cord type.
- iii. No socket outlets other than shaver-sockets designed for use in the bath-room
- iv. Light fittings must be enclosed, steam/condensation-proof and positioned (fixed) where they are unlikely to be splashed.

F. Secondary Indoor Areas

The other spaces and rooms in a home - the loft, the cellar, the hobby room, the shed and the garage - call for functional lighting (providing good seeing conditions), with longer burning hours and a higher efficiency than the decorative lighting found elsewhere in the home.

G. Hobby room

The hobby room, preferably decorated in light tones, should be equipped with general lighting giving good colour rendition (i.e. $R_a - 80$)

The luminaries can be mounted in the center of the ceiling, but it is often better to have localized lighting (500-1000 lux) concentrated over the work-bench or table. For very difficult tasks (small details), an adjustable table lamp giving more light or light from several directions is a convenient solution.

A power-track in the hobby room can be very handy, not only as a means of obtaining a flexible lighting system, but also to serve as a power-supply outlet to allow various electrical tools to be used wherever needed.

H. Garage

A well-lighted approach to the garage will make it easier to avoid unexpected obstacles in the drive, such as bicycles and carelessly abandoned toys.

The basic need inside the garage is for orientation lighting, but this should be positioned with the size of the car in mind so as to allow inspection of the engine when the car bonnet is raised as well as illuminating the open boot.

If the garage is equipped with a work-bench, this should have its own lighting.

4.8 Lighting for Hospitals

Lighting requirements in hospitals vary in the different areas of the hospital and depend also on a wide range of visual conditions needed by the various users; patients, doctors, nurses and cleaners. In some cases, the requirements of the medical staff predominate, in others, comfortable lighting for the patients is of greater importance.

Colour, both that produced by the light sources and that reflected by the surroundings, is particularly important. Firstly, it can help ensure the best conditions are created for treatment and examination purposes - for instance, where the diagnosis of a patient's condition may be related to the colour, or change in colour, of the patient's skin. Secondly, it is a factor of psychological significance in reducing the clinical appearance of the hospital and suggesting a more friendly atmosphere, which will contribute towards the recovery of the patient.

Interference free lighting should be provided in those areas where the use of radiation - sensitive electronic equipment is anticipated.

Emergency lighting should be installed in all internal traffic areas and exits and all other areas where life and safety would be endangered by the absence of lighting

A. Hospital Wards

In ward areas the visual needs of the patients themselves and the medical and cleaning staff have all to be considered. Patients should be able to read and do handiwork in or next to their beds, to rest or sleep without being disturbed by any discomfort glare, and to safely move around the room by night as well as by day

Where LED lamps are concerned, the colour of the light should be selected with care. In those areas where a homely atmosphere is wanted, and where medical examination is not critical, perfect colour rendering is not needed and a lamp colour appropriate to the climate can be chosen: warm-white colour 83 for hospitals in colder climates and cool-white colour 84 for hospitals in the tropics. In those wards where medical examinations are performed and better colour rendering is needed, colour 93 and 94 respectively are to be preferred.

The ward lighting should be installed in such a way as not to cause any discomfort glare to the patients-especially those whose field of view may include only the ceiling and the direction of the medical staff

B. General Lighting In Wards

The general lighting in the ward should be sufficient to allow routine medical and domestic duties to be properly performed. The indirect lighting is preferred for this purpose, which is often incorporated in the bed-head luminaires should provide an illuminance of between 100 and 200 lux. There should be a light switch located at the door-way.

C. Local Lighting Over The Bed

This should be sufficient to provide good illumination for reading, handiwork etc. Illuminance at the bed-head should be between 100 and 300 lux over the full width of the bed. The luminance of the luminaires as seen by both patients and medical staff should not exceed 350 cd/m², and heat radiated by the source should be as low as possible. There should be a light switch located within easy reach of the patient. This should be sufficient to provide good illumination for reading, handiwork etc. Illuminance at the bed-head should be between 100 and 300 lux over the full width of the bed. The luminance of the luminaires as seen by both patients and medical staff should not exceed 350 cd/m², and heat radiated by the source should be as low as possible. There should be a light switch located within easy reach of the patient.

D. Examination Lighting

If examination or treatment of the patient cannot be carried out in an appropriate room, supplementary luminaires may be used in the ward. The lamps, which should be so screened that only the bed is illuminated, should give a minimum illuminance of 1000 lux. The light source should also have the desired colour rendering properties.

E. Night Lighting

Night lighting should be sufficient to provide the minimum amount of light necessary for nurses and patients to find their way about during the hours of darkness. This corresponds to an illuminance of 1.0 lux at floor level. It requires that the lamp be adequately screened.

F. Night Observation Lighting

Night lighting intended for the observation of patients should cause the minimum disturbance to other patients in the ward. An illuminance of 5 to 20 lux, restricted to the bed-head, is recommended. The light switch, located at the bed, should not be within reach of the patient.

G. Corridors

The lighting in corridors should be related to the lighting in adjacent rooms so that there is no difference in illuminance when passing from one to the other. This often means that provision must be made for reducing the illuminance in the corridor at night-time.

In those cases where the corridor does not receive sufficient natural light during the day time, the artificial lighting in the corridor should facilitate visual adaptation by providing a rather high luminance on the wall opposite the door of a room that is illuminated by day light.

An asymmetrical lay-out of luminaires along corridors is less disturbing to patients who are being wheeled along the corridors on trolleys. The day time illuminance should be 200-300 lux. This can be reduced during night time to 5-10 lux in corridors open to bed-bays and 10-50 lux in all other corridors.

H. Examination Rooms

Examination lighting should be planned to accommodate a wide variety of possible visual tasks. This is normally achieved using a combined system of general and local lighting. The general lighting and the local lighting should be matched, as closely as possible, for colour temperature. The illuminance of the former type of lighting should be between 500 and 1000 lux.

I. Theatre - Suite Lighting

The lighting of the operating theatre calls for a delicate balance between the very special lighting used to light the centrally placed operating table and that providing the illumination in the remainder of the theatre.

The operating luminaire is designed to give shadow-free lighting of very high illuminance on the table variable in intensity between certain prescribed limits. The illuminance provided by the general lighting should be in the order of 1000 lux in order to always keep luminance differences within the theatre to an acceptable maximum.

The colour of the general illumination in an operating theatre should also be compatible with the illumination from the operating light, that is to say the colour temperature of the two sources should match as closely as possible. The preferred source for the general theatre lighting is the tubular fluorescent lamp having a colour temperature of around 4000 K and the best possible colour rendering. Luminaires should be of the multi-lamp recessed type, equipped with mirror reflectors to give maximum light output and low source luminance.

The illuminance level given by the general lighting in the other rooms comprising the theatre suite, viz. surgeons' and nurses' changing rooms, scrub room, sterilizing room and necessary room, should be at least 50% of that given by the general lighting in the theatre itself in order to facilitate visual adaptation when passing from one to the other. Colour rendering should be the same throughout the suite.

J. Intensive-Care Unit Rooms

The illumination here must be suitable for a wide variety of visual tasks. Furthermore, the lighting system should include provision for changing the illuminance level quickly in order to satisfy emergency conditions.

General illuminance should be variable from 300 lux down to almost zero. The preference is for 'TL' colour 84 or 94. Supplementary luminaires are needed to provide the localized lighting used for examination and treatment purposes portable surgical luminaries (operating lights) should also be available.

Curtains are needed to protect adjacent patients from illuminances that are disturbingly high.

For psychological reasons, the lighting in the intensive care unit should be as similar as possible to that in the ward.

K. X-Ray Rooms

Rooms where x-ray examinations have to be carried out must be lighted according to the examination method adapted. For normal x-ray photography, no special demands are placed on the lighting, but where image intensifiers or television systems are in use it should be possible to reduce the general lighting to between 10 and 30 lux. Where direct observation of the screen is involved, orientation lighting giving no more than about 10 lux should be provided.

For the positioning of patients and for the purposes of room cleaning, a dimmer- controlled general lighting installation that gives an illuminance of 100 lux will suffice. Other tasks e.g. the giving of injections, will require localized lighting.

A pleasant, restful environment can be created by adding some decorative lighting for example a wall luminaire giving a low, comfortable level of lighting.

4.9 Marshalling Yard Lighting

Marshalling yard covers a huge area in thousands of square meters and comprises hundreds of meters length of rail tracks and innumerable junction points. During the hours of darkness, the men who keep things going in this extensive area are busy at various tasks. They can only work efficiently and safely if adequate lighting for visual tasks are available even after sunset.

4.9.1 About Mechanism of Marshalling Yard

To gain an insight into the lighting problem involved in shunting of railway wagons, one must have some idea of how this is done and how a marshalling yard is equipped.

A marshalling yard acts as clearing house for the wagons which have to be distributed over different tracks. In this way, trains are made up of wagons having the same destination. Thus, in principle, every marshalling yard consists of a main feed line which spreads out fan-wise in a number of tracks on which the various trains are made up for number of destinations.

There are two types of marshalling yards - one with flat switching and the other with hump switching.

On a flat marshalling yard the wagons for a certain track are pushed off by the shunting engine accelerating for a moment and then suddenly braking. For pushing off of each wagon or cut off wagon, the engine has to make a short run again and again.

On a yard with a high shoulder of grounds, also called the hump, the cut off wagon is pushed with constant speed against the crest of the hump. Just before reaching the crest the wagons are uncoupled by a shunter with the aid of the hook. The wagon thus released, drops down by their own weight on to the track, being switched on the correct line for which the wagons are destined.

In smaller shunting yards the switches are mostly operated on the spot by the shunter; while the modern marshalling yards with hump are equipped with marshalling cabins having operation panels

representing the entire grid of tracks, on which every wagon in motion is indicated. The switching operation is done from the cabin for directing the wagons as per the desired destination track. On being pushed away and also being released from the hump the wagons often gather too much speed. Marshalling yard with a shunting hump is usually equipped with a braking bridge for the braking of the wagons, which is operated from the marshalling cabin.

4.9.2 Visual Tasks & Illuminance Requirement

More and more work in marshalling yard is concentrated in a few key-points like top of the shunting hump, around the braking bridge and around the area where the switches are located.

However, to facilitate the intensive scale shunting and assembling of trains, to improve productivity by speedy movement, to reduce accidents, to allow safe movement of wagons and railway personnel and to have better security and reduction in personnel and reduction in theft, it is essential to light up the entire marshalling yard having glare free general lighting. The recommended average illuminance in a marshalling yard varies from 10 to 20 lux. Of much more importance than the illuminance in marshalling yards, is the creation of bright images by reflection of the light sources in the surface of the railway tracks. These gleaming tracks afford a clear contrast between the rails and the surroundings; an interruption in gleaming tracks indicate the presence of the wagons and other obstacles and movement of wagons is also much more easily observed in this way. The obstacles are observed as silhouette without details.

4.9.3 Hump Area

Special attention should be given to the lighting of the hump area. Operation must have a clear view in both directions without glare so that the chalk numbers on approaching wagons, the setting of the points and the amount of clear track left in each of the train sidings etc. can be seen easily. Viewing from the hump area, vertical plane illuminance also becomes important in assisting the identification of wagon markings or judging the speed of approaching or receding wagons.

The recommended value of illuminance in the vertical plane is 30 to 50 lux. This can be achieved by low or medium height installations”, where broad beam asymmetric floodlights are most appropriate.

4.9.4 Design Criteria

The performance of all above activities and achievements of quantitative and qualitative requirements of lighting call for various illumination engineering techniques like choice of type of installations, luminaries and light sources, aiming of luminaires, maintenance, etc.

4.9.5 System of Marshalling Yard Lighting

Different railways have adopted lighting system depending upon the size and complexity of yard, which can be divided broadly into the following types.

- i. High Tower lighting system
- ii. Distributed lighting system
- iii. Gantry lighting in main areas
- iv. Combination of the three to cover different areas.

There are no simple thumb rules for deciding the use of a particular type of installation. A careful analysis of many factors is necessary in the context of the specific requirements and the particular local conditions. However, the major requirement of high tower installation is the high efficacy light source and narrow beam floodlight luminaire.

4.9.6 High Mast Tower Lighting System

The recent experiments have indicated that there are many advantages in extra height of tower.

Some of the advantages of high tower installations may be listed as follows:

- i. Large areas can be illuminated from relatively few positions, thus minimizing the amount of obstruction in the working area.
- ii. Cabling costs are lower as supply is required at only a few points.
- iii. The glare is reduced.
- iv. The whole of the light appears to come from the sky, or the uniformity at ground level is very good and the lighting is shadow free.
- v. Maintenance is facilitated as the floodlights are concentrated in batteries on tower platforms and in turn it results into reliability.
- vi. Since there is a considerable overlapping of beams on a large installation, failure of one lamp does not result in an area of darkness.

Some of the disadvantages of high tower installations may be listed as follows:

- (a) In the proximity of air ports, the permissible height is restricted.
- (b) Access to flood light projectors is hazardous, particularly in bad weather.
- (c) More space is required between the railway tracks.
- (d) Shadows become inevitable and lighting between lines cannot be fully arranged.

4.9.7 Light sources

This higher mounting height and their advantages now can be utilized in our country mainly due to the availability of indigenous high efficacy LED lights. These LED light sources can be used in better optically designed floodlight luminaries.

The optical characteristics of the luminaries are such that it gives comparatively narrow beamlight distribution. This is achieved by the scientific design of the reflectors and the highly specific mirror like finish of the reflectors

For marshalling yard lighting the floodlight luminaries should be heavy duty type and weather proof. The housing should be of cast aluminium alloy so that the same can withstand the normal seasonal weather conditions at that height. The reflector should be of anodized aluminium and mirror like finish for better optical control. The luminaries should be provided with heat resistant toughened glass cover in the front along with poly-chloroprene gasket to make the luminaire completely weather proof. The luminaries should have the earthing terminal for the safety requirements.

The design of the luminaries should be such that replacement of the lamp and other maintenance is easy. The electrical accessories required for the operation of the light sources should be designed and manufactured for optimum efficiency and life.

4.9.8 Aiming of Floodlight

Having selected the tower height, light source and luminaries, the quantity requirement of the floodlight luminaries to achieve the illuminance desired is a matter of simple mathematics. However, in practice it is important to achieve the desired illuminance in horizontal and vertical planes, the desired uniformity ratio and glare free lighting in illumination of the marshalling yard. In the absence of the guidelines from the designer with regard to the aiming, this task is difficult. Usually in such cases it is customary to employ methods of trial and error involving a number of people working late and thereby incurring wasteful expenditure. Instead of this it is possible to prepare a detailed aiming diagram which

gives accurate results of illuminance. uniformity or glare free lighting. Having obtained this diagram the use of 'Night Time Visual Method' or 'Daylight Aiming Methods' can be employed. The latter method also makes use of specially designed azimuth device and elevation angle device to set the horizontal and vertical angles of each of the floodlight luminaire.

4.9.9 Safety measures

Whatever type of installation is employed, safety requirements from both operational and maintenance points of view must be fully considered.

Towers or poles can be sited only where ample clearance between the lighting structures and the overhead electrical equipment is available.

4.9.10 Distributed lighting system

Advantages

- i. Lower mounting height.
- ii. Less of directional beam.
- iii. More uniform illumination and effective utilization of lights.
- iv. Reduction of shadows.
- v. Reduced loss due to atmospheric absorption and scattering.

Disadvantages

- i. Large number of physical obstructions.
- ii. Elaborate distribution network,
- iii. Maintenance over large number of points.
- iv. Failure of lamps cause dark spots.
- v. Special care is to be taken for ensuring visibility and sighting of signals

4.9.11 Gantry Lighting

This consists of erection of gantries over the spread of railway tracks across the yard and providing illumination between tracks by separate lights.

Advantages

- (a) Gives excellent illumination for working.
- (b) Eliminates shadows.
- (c) Easy maintenance and acceptability.

4.9.12 Disadvantages

- (a) Very expensive in first cost.
- (b) Can be used only in the main central portion of receipt,
- (c) Classification and, dispatch yards.

4.9.13 Design criteria

While designing the marshalling yard lighting system, the following factors shall be considered individually as well as together as a whole:

- (a) Obstruction clearance

The location of the floodlighting towers shall be such that ample clearance between the lighting

structure and overhead electrical equipment is available. The location of the floodlighting towers shall not cause any obstruction of view either to the control cabin personnel or to the railway shunting staff,

(b) Illuminance levels

The illumination design shall be such that an average horizontal illuminance of 10 lux is provided on the surface level of the marshalling yard and the vertical illuminance is 10 lux and 15 lux when looked along the direction of track or perpendicular to the track respectively.

(c) Illuminance Uniformity

Uniformity of illuminance shall be maintained throughout the body of the marshalling yard where uniformity ratio ($E_{\min} / E_{\text{avg}}$) shall not be less than 0.2 and in hump area the uniformity ratio ($E_{\min} / E_{\text{avg}}$) shall not be less than 0.35.

4.9.14 Glare control

The mounting height, the light distribution and the aiming of the luminaries shall be such that minimum glare is caused to the shunting staff or to the operating staff in the control cabin. Low mounting luminaries shall be avoided to prevent glare to the shunting staff. If necessary, suitable screening louvres shall be fixed on the luminaries to prevent glare.

4.10 Lighting of Railway Stations

4.10.1 Platforms

Good platform lighting on small stations as well as large is essential for the safety and comfort of passengers as well as railway staff. Low built platform roofs offer better possibility for mounting the luminaries with proper distribution to provide optimum lighting conditions from the light incidence and distribution points of view.

- i. Illumination level at Railway Stations of IRs is being defined vide Rly Bd letter no. (i) 2008/Elect (G) / 172/1 dated 08.03.19 as per airport standard for 58 no (27+31) selective stations; (ii) 2008/Elect(G)/172/1 dated 14.02.19 for 155 no (119+36) selective stations ; (iii) no. 2008/Elect (G) / 172/1 dated 28.11.18 for 35 no selective stations; and (iv) for remaining stations the illumination level has to be maintained as per Rly Bd letter no. 2004/Elect(G)/109/1 dated 18.05.2007. (Appendix 17A, 17B, 17C & 17D respectively)

4.10.2 Goods Depots

Normally, goods depots consist of siding for loading and unloading and standing or berthing sidings. The usual attention has to be paid to lighting the switch points and capstans and should be well lit to ensure their safe operation. The luminaires using LED lamp fittings are recommended. The main concern is the loading and unloading area with its associated traffic space. Motor road systems within the yard should have average 30 lux for group A1 road lighting as per IS: 1944- 1970. (National lighting code 2010 page no 241 Table 3 Lighting Recommendations for Different Road Types - IS Classification)

The illumination of the loading area has to be raised to facilitate the reading of labels, schedules, etc. The illuminance value of 100 lux should be provided in the loading area. Low or medium height installations using broad beam asymmetric floodlight luminaires are most appropriate for these areas. The layout of towers/masts should be such that the system must give sufficient clearance for maneuvering of vehicles and movements of cranes, and high enough for light penetration into open wagons.



4.10.3 Carriage Cleaning Siding

Cleaning sidings are normally provided with narrow platforms between the lines of coaches to facilitate access by the cleaners while the electricity and water supply, points are installed at approximate 'coach length' intervals along the middle of the staging.

The task involved requires good vertical illuminance and shadow free lighting. The general illumination on the narrow platform should be good enough for safe movement of the personnel. The luminaires should have the wide beam optical characteristics and also should be splash-proof type to have the protection against the water coming from any direction. The luminaires should be mounted on the poles closely placed along the tracks.

4.11 Street Lighting

Safety and comfort are the prime requirements of any street lighting. Streetlights are expected to be bright enough to enable drivers to see clearly without the use of dipper or driving headlights, and help locate traffic signs and obstacles on the road easily.

These should also help the pedestrian to distinguish edges of footpaths, and see vehicles and obstacles. There are very few municipalities in the country with metering facilities for street lighting consumption. Street lighting load is estimated on the basis of lamp wattage and the number of fittings, irrespective of choke losses. In most places, streetlights are supplied from the local distribution transformers where there is a mix of load. The main issues involved in the design of street lighting systems in any unit are listed here.

- i. Scope for selection of energy-efficient equipment/systems
- ii. Use of better design practices
- iii. External factor of grid, such as power quality

Group A: Main roads, subdivided into two categories

Group-1: Important routes with rapid and dense traffic where safety, traffic speed, and driving comfort are the main considerations

Group-2: Main roads with considerable volume of mixed traffic, such as main city streets, arterial roads, and thorough fares.

Group-B: Secondary roads, which do not require lighting of Group A standard, sub-divided into two categories

Group-1: Secondary roads with considerable traffic, such as the main local traffic routes, shopping streets, etc.

Group-2 : Secondary roads, with light traffic

Group-C: Lighting for residential and unclassified roads not included in the previous groups.

Group-D: Lighting for bridges and flyovers

Group-E: Lighting for town and city centers

Group-F : Lighting for roads with special requirements, such as roads near airfields, railways, and dock

4.11.1 Measurement of Lighting Load and Light Levels

After selecting the streets, lighting load, and lux level, assessment of the following should be carried out.

- i. Type of lamps installed on the street
- ii. Pole-to-pole distance
- iii. Road width
- iv. Mounting height
- v. Angle of tilt

4.12 Illumination System Controls

4.12.1 Importance of Controls

Controls are switching devices which may manually “or automatically activate the lighting system. These may take the form of “on-off” control or controls which vary the power input to the system in accordance with actual needs. Controls cover a broad range of devices, each suited to a particular system’s requirements. These requirements must be established prior to selecting any control device.

To save energy, two factors may be varied:

- (a) Power allocated to the lighting system
- (b) Length of time that power is used.

The length of time that power is ‘ON’ is dependent upon the needs of the occupants and the effective use of controls, Which Lights Should Be Controlled?

When the building operation requires round-the-clock use of lighting (such as a computer center which operates 24 hours a day) extensive controls will be of little value. However, should the function of a building permit all or part of the lights in any particular space to be turned ‘OFF’ at times, an opportunity may exist to save electricity through controls?

When lamps are switched ‘on’ and ‘off’ their life may be reduced slightly so that in the past when electricity was cheap, lamps were never turned off. Now, lamp replacement costs are generally much less than the value of the electricity saved so that such replacement costs are no longer considered in energy studies

4.12.2 Selection of a Control System

A control system must be based upon the use of the space. Where it is intended that the occupants will control their own lighting, the control devices must be located conveniently. Some of the examples are given below

- (a) To obtain a greater degree of control in large rooms, individual work areas may be switched separately, This would permit some people to keep lights in their area ‘ON’ while adjacent unoccupied areas may have the lights ‘OFF’.
- (b) In rooms with more than one exit, it may be desirable to locate a control device at each entrance. This may increase the use of the control devices since the occupants can turn the lights off, when leaving from either exit.

4.12.3 Types Control Systems

The following are the some of the types of controls employed to save electricity.

1. Circuit breaker control

The most common ‘ON-OFF’ control of lighting is by branch circuit breaker. This circuit breaker function, however, is not to work as a switch but to protect the circuit against overload. The wear and tear of repeated use is not intended by the manufacturer. Moreover, the building panel board is often inaccessible to the occupants of the space being served, depriving them of control over their own use of the lighting.

2. A.C. Snap Switch

The A.C. Snap Switch is wired directly into the power Circuit supplying the lighting fixtures. The switch provides manual ‘ON-OFF’ control by closing or breaking the power circuit which supplies electrical energy to the fixtures. The switch is rated for operation at the power line voltage and to carry and interrupt maximum branch circuit current.



The A.C. snap switch is a low cost, simple device that may be installed in any location, where manual 'ON-OFF' operation is desired. Its usefulness in retrofitting will depend upon the extent of rewiring involved. Since the A.C. snap switch is manually controlled, it depends entirely on the occupants of the space to realize electricity savings.

3. Low Voltage Remote Control

The low voltage switch is not designed to directly switch the power to the fixture, rather it does so indirectly via control of a relay.

A power supply transformer is needed to provide control power to operate the relays. Relays can be controlled automatically by time clocks, photocells or computers.

Low voltage remote control permits greater flexibility than AC Snap Switches. It provides the ability to control loads from great distances, a number of different loads from one location and one load from multiple locations. When controlled automatically, local manual overrides may be provided to allow for overtime use.

For application in existing buildings, the higher equipment costs of the low voltage systems may be offset by lower wiring costs.

4. Time clock

Time clocks are automatic controls which may turn lights 'ON-OFF' at a preset time according to a predetermined schedule (usually a seven day schedule).

Time clocks may also be utilized to turn exterior lights 'ON' and 'OFF'. They may also be used in conjunction with other control systems, such as low voltage control, to control lights throughout the building. Although the 'ON-OFF' schedule may be changed, the time clock is not generally intended for use when requiring frequent schedule changes.

5. Timed switches

Timed switches may be used manually to turn lights 'ON' and will then automatically turn the lights 'off' after a predetermined time interval (available from 5 minutes to 12 hours).

Timed switches are useful in all rooms which are not in continuous use (such as toilets) and in which occupants may neglect to turn lights 'OFF'. Timed switches are installed in a manner similar to the A.C. snap switch.

6. Photo cell controls

Photo cells are devices used to sense light. Based upon the level of light, the photo cell will open or close a relay or automatically adjust a dimmer setting.

Photo cells can be useful for control of lighting systems based upon quantity of available light. The photocell, however, must be cleaned periodically to assure proper operation. A common application of photocells is with exterior lighting systems. In this application, the photocells senses sunset and turns the lights 'ON' and then senses sunrise to turn the lights 'OFF'.

The photocell may be also used with other control devices such as the dimmer control.

4.12.4 Dimmers

Dimmers are used to vary the quantity of illumination. Their operation may either be manual or automatic. Dimmers may be useful electricity conservation devices. A photocell can sense any available natural light and automatically reduce the output of electric lighting system, while constantly maintaining adequate lighting.

CHAPTER-5

AIR-CONDITIONING & VENTILATION

5.1 Introduction

Air-conditioning is the science of maintaining the atmosphere of any enclosure at any required temperature and humidity. In addition to the factors of temperature and humidity, the factors of air motion, air distribution and air purification are also taken into consideration.

Air-conditioning essentially involves the following.

- i. Supply of sufficient quantity of fresh air continuously after filtering it to make it dust free and to keep body odours, smoke and carbon-dioxide within low limits.
- ii. Cooling the air in hot weather and heating it in winter to maintain the inside temperature at the right value.
- iii. Humidifying or dehumidifying the air so as to keep the relative humidity of the atmosphere inside at the required level.
- iv. Securing sufficient air movement without producing draughts.

5.2 Principle of Operation of Vapour Compression System of Air-Conditioning

There are various methods by which cooling of air can be achieved in air-conditioning systems. The most commonly used method is vapour compression system. This is an electro-mechanical system which makes use of the temperature, pressure and latent heat of a suitable refrigerant for pumping heat from a lower to a higher temperature level. Thus, in an air-conditioning system heat is absorbed by the refrigerant at a low temperature, thereby cooling the surrounding space and it is discharged at a high temperature level into the atmosphere thereby heating the space around. The refrigerant is usually a gas at normal temperature with boiling point below 0°C at normal atmospheric pressure. Another important property required for a refrigerant is that it should be possible to liquefy the gas at ordinary temperatures by the application of moderately high pressure by a compressor. Fig. 1 explains the line diagram of a typical air conditioning system.

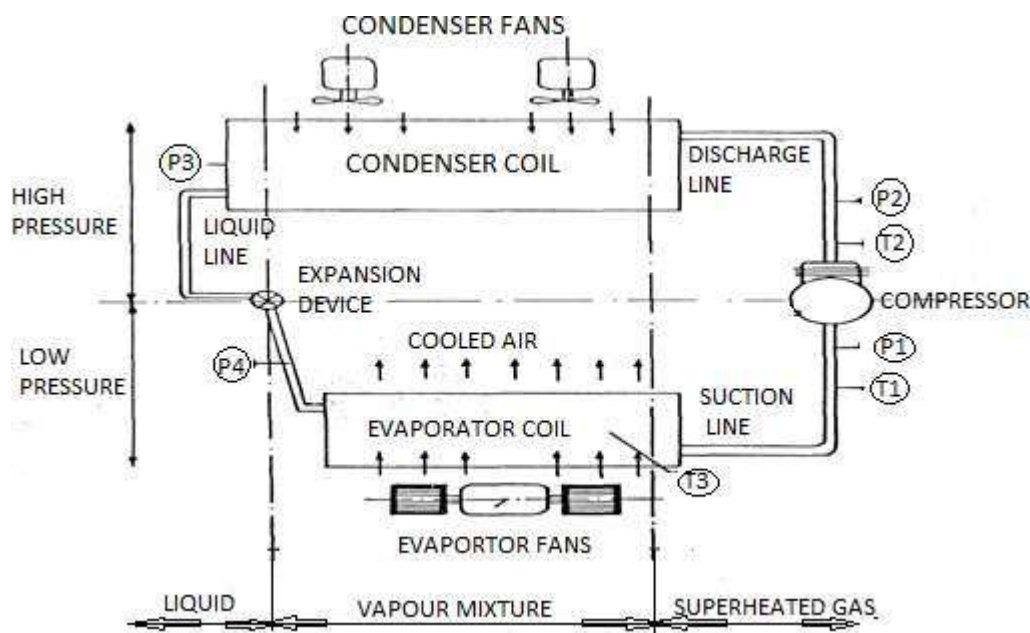


Fig.1 – Air Conditioning System

5.3 Parts of vapour compression system

- i. Compressor
- ii. Condenser
- iii. Expansion valve
- iv. Evaporator
- v. Liquid Receiver
- vi. Dehydrator-cum-filter

5.3.1 Compressor

It has a two function. It removes vapour from the evaporator at a rate, which will permit steady state conditions of temperature and pressure in the evaporator. It compresses and discharges the vapour at a pressure and temperature high enough to permit heat rejection along a descending temperature gradient to the cooling water or air of the condenser.

5.3.2 Condenser

It is intended for cooling the hot gas and liquefying it under pressure. It may be air cooled or water cooled.

5.3.3 Expansion valve

Its function is to control and regulate the rate of flow of liquid Freon under high pressure and allow it into the evaporator under low pressure. The heat load on an evaporator varies over a wide range. The expansion valve admits more refrigerant when air-conditioning load is high and, reduces it to the minimum when load is low. All this is accomplished automatically.

Expansion valve (Fig. 2) comprises of a spring-loaded valve pin which bears against sealed diaphragm. The space above the diaphragm is connected through a capillary tube to a temperature sensitive thermal bulb. The thermal bulb is kept clamped in intimate contact with the suction line to the compressor. The thermal bulb and capillary are charged with a volatile fluid, which is often the same as the refrigerant used in the system. The thermal bulb, the capillary and the diaphragm make the expansion valve

responsive to changes in the temperature of the gas emerging out of the evaporator.

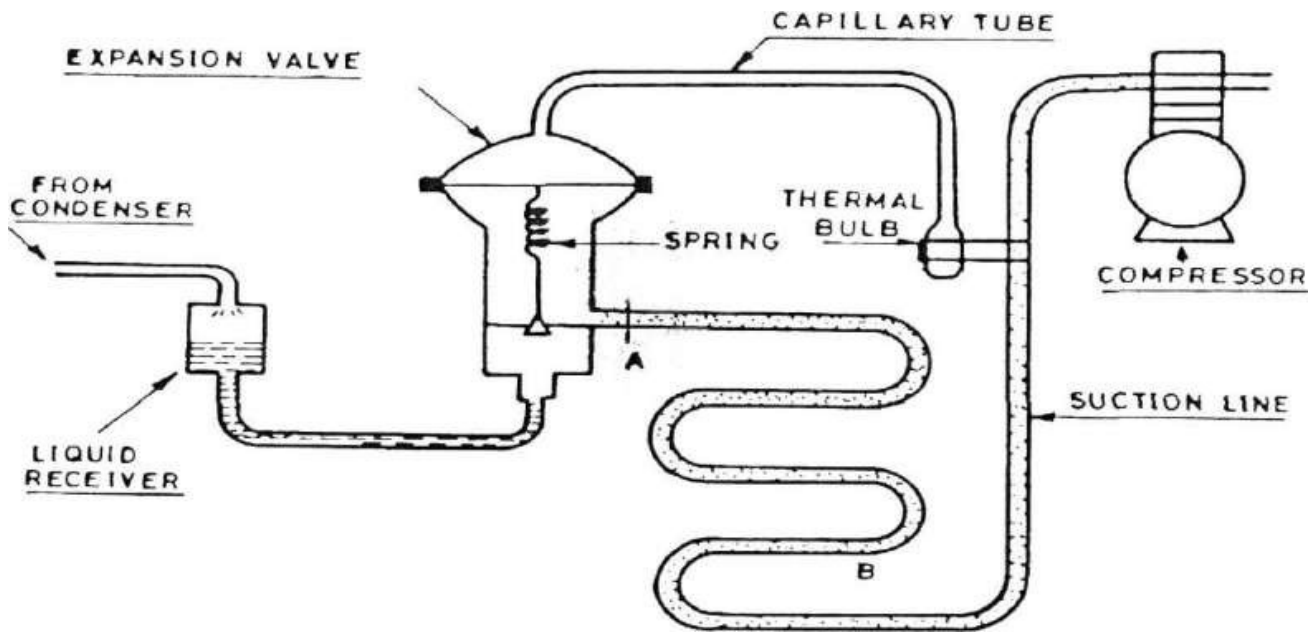


Fig. 2 Schematic diagram of Expansion Valve

5.3.4 Evaporator

This constitutes the cooling unit, in which the liquid Freon under low pressure evaporates and in doing so, it takes away its quota of latent heat, thereby cooling the medium surrounding the cooling coil.

5.3.5 Liquid Receiver

The refrigerant liquid leaving the condenser is led into the liquid receiver, from where it proceeds to the expansion valve on the evaporator. The liquid receiver is a cylindrical container which contains a reserve of the liquid refrigerant.

5.3.6 Dehydrator-cum-filter

The moisture may freeze and block the expansion valve orifice and also cause corrosion in working parts. The dehydrator is a drying device containing silica gel or other similar drying agent inserted in the refrigerant line for removing moisture from the refrigerant while in operation. A filter is also usually incorporated, to prevent small particles or scales in pipes blocking the fine orifice in the expansion valve.

5.4 Refrigerants

Mechanical cooling is based on the use of certain low-boiling point substances, called refrigerants, as heat transfer media. They accomplish energy transfer by means of a cyclical thermodynamic process which involves two changes of state. Refrigerants absorb heat as they evaporate at a low temperature and pressure and they surrender this heat (and also the heat equivalent of compressor work) as they condense at higher temperature and pressure.

5.4.1 Desirable Properties of a Refrigerant

- i. The refrigerant shall be non-poisonous
- ii. It shall be non-inflammable
- iii. It shall be non-corrosive

- iv. It shall be non-irritating
- v. It shall have no harmful effect on the taste, colour or, aroma of food and drinking water
- vi. It shall be cheap and readily available in the market
- vii. It shall have high latent heat of vaporization
- viii. It shall have low boiling point
- ix. It shall have low volume per Kg when in gaseous state
- x. It shall have high coefficient of performance
- xi. Easy detection of refrigerant leakage.

5.5 Efficiency of Refrigerating Machine

A refrigerating machine is a reversed heat engine and similar principles of efficiency are involved in both. The efficiency of a heat engine operating on Carnot cycle between temperature limits T_1 and T_2 is given by the following formula-

$$\text{Efficiency}_{cu} = \frac{T_1 - T_2}{T_1}$$

Where, T_s are in ° kelvin.

Since the refrigerating machine is a reversed heat engine theoretical Carnot efficiency for a refrigerating machine is given by the following formula-

$$\text{Efficiency}_c = \frac{T_2}{T_1 - T_2}$$

Where, T_1 is the condenser temperature (absolute) T_2 is the evaporator temperature (absolute)

5.5.1 Co-Efficient of Performance (C.O.P.)

The co-efficient of performance of a refrigerating cycle is an expression of the cycle efficiency and is stated as the ratio of the heat absorbed in the refrigerated space to the equivalent heat energy supplied to the compressor.

$$\text{C.O.P.} = \frac{\text{Heat absorbed from the refrigerated space}}{\text{Equivalent heat energy supplied to the compressor}}$$

5.5.2 Energy Efficiency Ratio (EER)

A recently popular measure of efficiency, especially for unitary conditioners of small to medium capacity is the ratio Kcal per hour per watt (Kcal/hr/W). This measure is called the “Energy efficiency ratio” (E.E.R.). The average cooling capacity of the unit is determined by a test run under standard conditions. The average power input to the condensing units in watts is measured. From this data the E.E.R. can be calculated by using the following formula:

$$\text{E.E.R.} = \frac{\text{Kcal/Hr. cooling rate}}{\text{Power Input in Watts}}$$

5.5.3 Indian Seasonal Energy Efficiency Ratio (ISEER)

Watts input ISEER rating is the total cooling load (amount of heat removed) to the total amount of energy consumed by the air conditioner. This means, ISEER = Cooling seasonal total load (CSTL)



/ Cooling seasonal energy consumption (CSEC). The ratio calculated is then used to select the correct star ratings.

5.6 Air-Conditioning System

An air-conditioning system is a means of cooling/ heating, dehumidification/ humidification, filtration and its distribution to the various conditioned spaces, maintaining indoor air quality, energy efficiency and other resources. Various types of air-conditioning systems commonly used are:

- (a) Unit type equipment, which may be a window type room air- conditioner or a split type air-conditioner.
- (b) Packaged type units, which may be fully self-contained (factory assembled), or split type units.
- (c) VRV/ VRF system
- (d) Central plants, which are of two types:
 - i. Central DX-Plants with AHUs etc.
 - ii. Central chilled water plants with AHUs, Fan Coil Units, Chilled Beams, Embedded chilled water pipes in slabs & walls, etc.

For each application, there will specifically be only one system, which will be just right for it.

5.6.1 Window A.C

Window A.Cs are available in standard rating of 1, 1.5, 2 TR with BEE star ratings.

A. Features-

- i. Sound level of up to 50 dB inside the room is acceptable.
- ii. These types of A.C.s are efficient & easy to maintain as compared to split A.C.
- iii. BEE star rated WTACs are available. As far as possible 5 star rated A.C. may be provided in all new installation for conserving electrical energy.

B. Installation-

- i. While installing the A.C, care should be taken that the AC is not provided at back of sitting/ chair in room.
- ii. Standard A.C are provided with control plate and wire at right side of A.C (as seen from front), hence power outlet points should be provided at right side of window etc.
- iii. Standard installation procedures, as given by the manufacturers, may be followed.

5.6.2 Split A.C

A. Applications:

- i. Where window for installation of window AC is not available, these ACs are provided.
- ii. Almost Silent (Low dB level) operation of A.C is important, considering VIP rooms, conference rooms, etc.

B. Installation:

- i. Wherever split A.C. are planned in the new buildings, necessary openings in wall may be provided by with use of 75 mm PVC pipe sleeves at suitable locations for taking refrigerant pipes and cable to outdoor unit, so as to avoid unnecessary cutting/ damage to walls at a later stage. The slope of sleeve of PVC pipe should be towards exterior to avoid seepage of water into the room. This opening should be sealed properly after installation to avoid entry of vermin and rainwater.

- ii. For condensate drain, 40 mm PVC/ HDPE pipe be also provided and taken to nearest drain or up to the stack for collection & disposal of condensate. The slope of such pipe also should be downwards. As far as possible, joints should be avoided in this pipe.
- iii. The length of connecting refrigerant pipes between outdoor and indoor unit be kept to minimum feasible at site. However, it should not exceed 10m, as the efficiency of the unit gets severely affected on increase of distance. The refrigerant pipes should be taken along the walls/ columns etc. duly clamped to their surface by saddles. If walls etc. are not available, use tray to support the refrigerant pipes. Where bending of refrigerant pipes is required, proper pipe bending tool should be used to avoid pinching of pipes.
- iv. The refrigerant pipes should be properly insulated as per the recommendations of the manufacturer of split type AC units. The insulation over refrigerant pipes be examined once in a year and in case of any deficiency/ defect the same may be replaced.

5.6.3 VRV/ VRF AC System

Variable Volume (VRV)/Variable Refrigerant Flow (VRF) can be explained as a multiple Split Air-conditioning system using principle of control of flow/ quantity of refrigerant through the Indoor Unit to control the cooling/ heating effect. VRF system uses refrigerant as the cooling and heating medium. This refrigerant is compressed and liquefied by a single outdoor condensing unit (ODU), and is circulated within the building through copper refrigerant pipes to multiple fan-coil units (FCUs) called the IDUs (Indoor Units) or cassette.

VRF, ODUs are typically provided with rectifier-inverter power system, which provided a Variable Voltage & Variable Frequency (VVVF) supply to compressor motor, in order to support variable speed. This in turn provides variable refrigerant flow through the refrigerant lines meeting the demand of cooling/ heating. The speed of the motor is controlled through a feedback system sensing the refrigeration demand from the IDUs.

VRFs come in two system format, two pipe and three pipe systems. In a 2-pipe system, all of the zones must be either all in cooling or all in heating. A three pipe Heat Recovery (HR) systems has the ability to heat certain zones while others require cooling. In this case, the heat extracted from the zone requiring cooling is put to use in the zone requiring heating. This is made possible because the heating units are functioning as a condenser.

Applications-

These systems are basically extensions of split type A.C's and are much less efficient as compared to central A.C. plant but more efficient as compared to Window or Split ACs, hence should not be provided except in following cases:

- i. In the existing building, requiring central AC but the space for providing AC plant, height of ceiling for ducting, water supply for chilled water based AC plant, is not available.
- ii. It is not possible to provide central A.C. plant and run the chilled water lines up to cool the rooms with fan coil units to cool the rooms.

Such system is normally provided where high diversity in demand is available i.e. small guesthouses, small hotels, small offices, art galleries, etc.

5.6.4 Packaged Type AC Units

Application-

These are best suited for air conditioning of areas up to about 450 sq.m. (about 30 TR A/C load) located adjacent to each other. Beyond this central plant is generally more economical. These are

generally available in 5 TR, 7.5 TR, 10 TR, 15 TR and 20 TR capacities. The components are housed in a vertical cabinet. These units can be used singly or in multiples of two/ three units.

- i. A packaged unit can be either water-cooled or air-cooled.
- ii. System components
1. A water-cooled packaged type unit includes the following basic components.
 - i. Refrigeration compressor
 - ii. Condenser (water cooled)
 - iii. Evaporator
 - iv. Expansion Valve
 - v. Refrigerant piping along with controls
 - vi. Supply air blower
 - vii. Filters

Condenser in this system is cooled by a system of cooling tower(s), condenser water pumps & connecting condenser water piping.

- i. An air-cooled packaged unit is in two portions- Indoor unit and outdoor unit. Compressor, Evaporator, Expansion Valve, SA blower & filters are in indoor unit & condenser along with condenser fan is in outdoor unit. Here, condenser is cooled by a propeller fan.

5.6.5 Central AC Plants

For capacities larger than 100 TR, it is generally economical to go for central plants. A central air-conditioning system may comprise of following basic components:

- i. Refrigeration unit (Central plant) comprising of compressor, condenser, expansion valve, evaporator & interconnecting refrigerant piping.
- ii. Hot water generators.
- iii. Cooling towers.
- iv. Condenser water pumps
- v. Chilled / Hot water pumps (Primary and Secondary System as applicable)
- vi. Chilled / Hot water piping (required in central chilled water system).
- vii. Condenser water piping.
- viii. Air handling units (AHUs) comprising of supply air blower, cooling coil and/ or heating coil, humidification system (wherever specified), & filters (room in which AHU is installed is called weather maker room).
- ix. Air distribution system comprising of ducting, variable air volume (VAV) valves, fire control dampers, grilles & diffusers.
- x. Treated fresh air system (TFA), Free Cooling System,
- xi. Demand Control Ventilation System.
- xii. Heat Recovery Wheel / Heat recovery pipe/any other measure for energy conservation for areas, requiring high fresh air intake.
- xiii. Electric power supply & distribution.
- xiv. Controls & control wiring.

A. Types of Central plants

Refrigeration unit (Central plants) as mentioned under para above may be of DX type or chilled water type as per following details:

- i. DX (Direct Expansion) type central plant

In this type of central plant the evaporator(s) component of the central plant is located in the air handling unit(s) & works there as DX-type cooling coil. The components such as chiller, chilled water



pumps & chilled water piping are, therefore, not required in this type of plant. This type of plant is commonly installed under following situations. When the air conditioning load is not very large say up to 100 TR & space for plant room is available adjacent to AHU room(s). When the temperature to be maintained in air conditioning space is below 21°C, the use of DX type plant becomes technically essential due to the limiting factors of evaporation temperature of the refrigerant & the temperature difference between the primary & secondary cooling medium. Chilled water type central plant

The chilled water type central plant becomes necessary when a number of smaller zones require air-conditioning. In this case, the chilled water is generated in a centrally located plant room and is piped to various AHUs, which in turn are individually located near the space which are air-conditioned. The BHP per tonne of refrigeration in the case of chilled water system is high compared to the direct expansion system.

Depending upon the type of compressor used, central air conditioning plants are of three types described below.

a. Reciprocating type central air conditioning plant.

These plants use reciprocating compressor. These are available in capacities ranging from 30 TR to 110 TR. However, these are slowly being discontinued due to poor compressor efficiency and being replaced with scroll & screw type compressors.

b. Screw type central air conditioning plant.

These plants use screw type compressors. These are generally used in capacities ranging from 80 TR and up to 400 TR at present.

c. Centrifugal type central air conditioning plant.

These plants use centrifugal compressors. Centrifugal compressors are not suitable for circulating and expanding the liquid refrigerant in remote heat exchange surface. They are, therefore, used only to chill water/ brine for circulation through remote heat exchanger surface (AHU coils).

B. System Design & plant selection

The system design shall be done after detailed heat load calculations considering the outside and inside design conditions, ventilation requirements and internal loads. The plant selection shall be made based on the calculated peak load, load diversity, partial load requirements and standby capacity. Normally the size of chillers is so chosen that at least two chillers, each of 50% of full load requirement are provided. In case of very large requirements, sometimes the architectural & structural limitations may dictate the compulsions to limit the size of individual chillers to smaller capacity. The standby capacity in turn will depend upon the number of hours of operation of the plant per day, relative importance of the installation and functional requirements. Normally for 12 hrs. Operation of plant one number additional unit of the same capacity as standby may be provided. For 24 hrs. Operation of plant, 100% standby may be provided.

- i. The type, capacity and quantities of the various components of the system shall then have to be worked out and specified.
- ii. It is also a good practice to simulate cost of operation of the plant by considering different capacity of chillers for the type of applications. It is established that by properly selecting the chiller size we can save up to 10 % in operational cost.
- iii. The various components of the system shall be so selected as to match each other under operating conditions of full load as well as anticipated partial loads.
- iv. Having selecting the size of chillers it may be decided whether single circuit or dual circuit chiller be provided.

- v. The overall dimensions of various equipments in the system shall be suitable for installation in the available space. The permissible loading of the building structure, acceptable noise level and aesthetics should also be considered.
- vi. Areas with different requirements of fresh air, degree of filtration and/ or operating hours shall need different and independent AHUs.
- vii. From the fire safety point of view, storage areas of combustible articles such as film stores and explosives shall not be served by the AHUs, which are serving other areas. Other fire precautions as per National Building Code, local municipal bye-laws and other statutory requirements shall be complied with.
- viii. For 24 hrs. A/C areas & where the secondary chilled water pumps are provided, to save energy, the secondary pumps may be provided with variable speed drive (VSD) to regulate water flow as per load requirement.
- ix. For 100% (Fresh air), AHUs requiring 24 hrs. operation, variable speed drive (VSD) may be provided to regulate the flow of dehumidified air as per load requirement.
- x. In case the cooling is done by positioning Fan Coil Units (FCUs) within the conditioned spaces and circulated chilled water through them, it should also be supplemented by circulating conditioned air through 100 % FA AHU (Treated Fresh Air AHU) by a network of ducting, grills and diffusers to the conditioned spaces for better comfort conditions in terms of ventilation, & humidity control and Oxygen requirements.
- xi. For areas like operation theatre, animal house and where specifically required functionally, AHUs with 100% fresh air shall be used. The return/used air in such cases shall be exhausted to atmosphere by installing a suitable exhaust air system. This exhaust air system shall consist of single skin blower section and a filter section. This exhaust air system may be ceiling suspended/ floor mounted as per the site availability.
- xii. In 100% fresh air areas and areas having high occupancy such as lecture theatres & auditorium etc., requiring high volume of fresh air, pre-cooling of fresh air be done by providing heat recovery wheel.
- xiii. In addition to controlling the inside temperature it is necessary to control the concentration limit of various pollutants as per ISHRAE handbook table no. 29, which are listed below. This is done by providing Demand Control Ventilation System using sensors for detecting the concentration and varying the Fresh Air Supply through motorized dampers. The permissible limits of various gases are as follows:

Contaminant	Concentration	PPM	Exposure time
Carbon dioxide*	1.8 g/cum.	1000	Continuous
Carbon Monoxide	55 mg/cum.	50	8 hr
Chlordane	55 µg/cum.	0.0003	Continuous
Ozone	100µg/cum.	0.05	Continuous
Radon**	0.027/WL	-	Annual Average
Nitrogen dioxide	9 mg/cum.	5	Continuous
Sulphur dioxide	13 mg/cum.	5	Sulphur dioxide
Total Suspended Particulates = 100 µg/m/cum. 1 hrs.			
* Threshold value - 600ppm (NIOSH)			
** 3200 picocuries			



5.7 Mechanical Ventilation (For Non-Air-Conditioned Areas)

Ventilation

Ventilation is the process of changing air in an enclosed space. A proportion of the air in the space should be continuously withdrawn and replaced by fresh air drawn from outside to maintain the required level of air purity. Ventilation is required to control the following:

- Oxygen Content — Prevent depletion of the oxygen content of the air
- Carbon dioxide and Moisture — Prevent undue accumulation
- Contaminants — Prevent undue rise in concentration of body odours and other contaminants such as tobacco smoke
- Bacteria — Oxidize colonies of bacteria and fungus to prevent their proliferation.
- Heat — Remove body heat, heat generated by electrical & mechanical equipment, solar heat gains through walls & glass etc.

Mechanical ventilation is one of several forms of ventilation options available. It usually consists of fans, filters, ducts, air diffusers and outlets for air distribution within the building. It may include either mechanical exhaust system or exhaust can occur through natural means.

Natural ventilation and natural exhaust are also the options. The scope of this section is therefore restricted to mechanical ventilation.

5.7.1 Design considerations for ventilation

Following considerations provide details regarding the various parameters that affect the type of ventilation system selected for a particular application and the sizing of the ventilation plant.

- National Building Code of India 2016, Part-8 Section-3 specifies the Ventilation requirement for various areas in different types of buildings as per following table

Application	Air Change per hour
Assembly Rooms	4-8
Bank/building societies	4-8
Bathrooms	6-10
Bedrooms	2-4
Canteens	8-12
Cinemas and theatres	10-15
Club rooms	12 Min
Conference rooms	8-12
Corridors	5-10
Dance halls	12 Min
Entrance halls	3-5
Garages	6-8
Glass Houses	25-60
Gymnasium	6 Min
Hospital –sterilizing	15-25
Hospital –ward	6-8
Hospital domestic	15-20
Laboratories	6-15
Laundries	10-30
Lavatories	6-15
Lecture theatres	5-8
Libraries	3-5
Living rooms	3-6
Offices	6-10
Photo and X- ray dark room	10-15

Note: The ventilation rates may be increased by 50 percent where heavy smoking occurs or if the room is below ground.

- ii. Cubic meter per minute (CMM) required for ventilation system is thus calculated based on the volume of the room and from the above table as-

$$\text{CMM} = \frac{(\text{no. of air changes/ hour}) \times (\text{volume in cu. m of space to be ventilated})}{60}$$

- iii. CMM required for Pressurization of lifts lobby, lift shaft, stair case shaft is calculated from closed door as well as opened door area as-

- (a) Leakage area = total nos. of doors x gap in doors (normally taken as 2 mm) x perimeter of doors.
- (b) Leakage from closed door = $0.821 \times \text{leakage area} \times \text{pressure difference}$.
- (c) Opened door leakage = door area x no. of opened door (normally considered 1 door) x velocity (normally considered as 0.76 m / sec) of air.
- (d) Total air leakage = closed door + opened door leakage.
- (e) Add 10% safety factor/ duct leakage etc., which will give CMM required.

- iv. CMM required for Basement Parking Ventilation

- (a) Divide the basement in zones of area not exceeding 3000 sq.m in case sprinkler system is provided in basement, if not, then not exceeding else 750 sq.m
- (b) For each zone separate set of supply air fans and exhaust air fans shall be provided. Supply air fans shall not be required in areas in zone near Ramps or zone with natural ventilation, however sufficiency may be examined.
- (c) Minimum 12 air changes/hrs. are required to be provided.
- (d) Calculate the CMM required for each Zone as per (b).
- (e) The recommended ventilation rate will ensure that the CO level will be maintained within 29 mg/m³ with peak level not to exceed 137 mg/m³.

- v. Calculation of Fan Static

- (a) Pressurization system for lifts lobby, lift shaft, stair case shaft -

As per NBC Part – 5 fire and light safety the following pressure are to be maintained for various shafts in high-rise building more than 25 mtr. in height. Guidelines are as follows.

Building Height	Pressure Difference	
	Reduce Operation (Stage 1 of a 2 Stage system) (Pa)	Emergency operation (Stage 2 of a 2 stage or single stage system) (Pa)
Less than 15 m	8	50
15 m or above	15	50

- (b) If possible, the same levels shall be used for lobbies and corridors, but level slightly lower may be used for these spaces if desired. The difference in pressurization levels between staircase and lobbies (for corridors) shall not be greater than 5 Pa.
- (c) For Basement Parking Ventilation the static can be calculated by duct friction method using a ductulator.

- vi Selection & Installation of Fans

Having defined the fan CMM & static to be developed, the fan is selected on basis of following criteria,



- (a) Pressurization system for lifts lobby, lift shaft, stair case shaft.
- (b) Fans are normally installed at terrace and are to be enclosed in GI housing.
- (c) Some ductwork is required for connecting up to the shaft.
- (d) These fans shall be operated automatically in case of fire on signal from IBMS or directly from Fire Control Panel of AFAS. Panels for these fans can be provided in lifts machine rooms. Auto manual switch is required to be provided to facilitate local testing.

vii Basement car parking ventilation.

- (a) Normally centrifugal fans are provided in fan room in basement. In case fan room is not available, ceiling mounted axial fans may be provided.
- (b) All exhaust fan provided for the scheme, shall be fire rated for 900°C for 2 hrs.
- (c) Normal ventilation fans for min. 12 air change/hrs. are kept on during working hours. However, CO₂ sensor may be provided which will continuously monitor the air quality and operate the normal fans only when required and there by conserve energy.
- (d) For each zone, zonal electrical panel is required to be provided which shall get the signal from fire alarm panel to activate the fans in case of fire to achieve 30 air changes per hr.
- (e) While selecting the fans noise level of fans may be kept under consideration to make sure that the noise level is kept below 80 decibel at all times except in case of fire.
- (f) Selection of Fan type for Ventilation System

5.7.2 General Description of System

- i. The air in the ventilated space is exhausted into the atmosphere. This air is made up by injecting fresh air from outside. In a simple ventilation system, this fresh air (makeup air) is supplied untreated with the help of blower and duct network. However, in ETAC system, most suitable in a dry climate, this fresh air (make up air) is treated in an air washer before its supply to the ventilated space for providing better comfort conditions.
- ii. The air washer is basically a spray chamber where the air and the cooling medium are brought into contact with each other. The air is drawn through the spray chamber by means of a fan and water is sprayed by means of a water pump & piping network. Such a spray chamber, complete with water collecting tank, eliminator plates, inlet louvers and other auxiliary equipment are known as air washers. During the course of flow through the air washer, the air may get cooled & humidified or cooled & dehumidified or heated & humidified depending on the temperature of spray water as is given hereunder.
 - (a) When the water used in the spray is simply re-circulated, the air passing through air washer will get cooled & humidified.
 - (b) When the water used in the spray is chilled (by some external device) & its temperature is higher than the dew point temperature of entering air, the air on passing through air washer will get cooled & humidified.
 - (c) When the water used in the spray is chilled (by some external device) & its temperature is lower than the dew point temperature of entering air, the air on passing through air washer will get cooled & dehumidified.
 - (d) When the water used in the spray is heated (by some external device), the air on passing through air washer will get heated & humidified.
- iii. The air washers are usually constructed in two different lengths of 2.75 mtrs long and 4.25 mtrs long. The 2.75 mtrs long air washers are equipped with two banks of spray opposing each other.



These air washers are used for humidification or dehumidification purpose. The 4.25 mtrs long air washers are usually with three banks of sprays. These air washers are generally used for certain special applications where high percentage of saturation of air is required.

- iv. Where ex-filtration of air from the ventilated space is to be prevented from reaching the other areas, a slight negative pressure is to be maintained in the ventilated space. This can be achieved by keeping the exhaust air quantity slightly higher than supply air (make up air) quantity. This is especially necessary where odors and fumes are required to be prevented from reaching other areas.

5.7.3 System Components

- i. A complete mechanical ventilation system with air washers includes the following components.
 - (a) Means of exhausting and / or injecting the air
 - (b) Air filters
 - (c) Air distribution
 - (d) Air washer
 - (e) Water spray pump, nozzles & piping network
 - (f) Controls and control wiring and
 - (g) Power supply and distribution arrangement.
- ii. Depending upon the application and design requirements, which the mechanical ventilation / ETAC system must meet, some or all of the above components shall have to be arranged in a certain sequence to condition the air.

5.7.4 System Design

- i. The system design shall be done by first deciding upon the number of air changes per hour required to be maintained in the space. The capacity of the exhausting and/or the injecting equipment can then be worked out on the basis of the volume of the space and the number of air changes required per hour.
- ii. The recommended number of air changes per hour for various applications are as given in the table at item number 5.7.1
- iii. A brief system design for some of the applications is given below
 - a. Kitchens

The exhaust system should take care of all the heat, smoke and odours produced during the cooking process and also maintain a hygienic atmosphere within the kitchen. The exhaust of air should be done through hoods equipped with grease filters, duct network and an exhaust blower. The hood should be of such a size as to capture, as nearly as possible, all the above pollutants produced in the cooking process and to contain them until the fan can exhaust them. Grease filters are used with the hood to protect the exhaust system. The exhaust air is made up by using fresh air from outside with the help of a blower and a duct network. The makeup air can be supplied untreated, or treated in an air washer so that slight negative pressure is maintained in the kitchen to prevent exfiltration of the pollutants to the public areas. This is achieved by exhausting approximately 10% more air than the supply air quantity. Air curtains can also be used at entry / exit points of the kitchen to prevent the kitchen pollutants from going into the public areas.

- b. Toilets

Where the toilets are scattered and located at different places, a local exhaust system with propeller type exhaust fans mounted on the toilet walls exposed to the atmosphere is recommended. However, in multi-storied buildings, where the toilets are generally located one above the other in the various

floors, the toilet shaft can be used for exhausting the air through sheet metal ducts with a centrifugal fan installed on the rooftop.

c. Car Parks

In the case of basement floor parking areas, a push-pull arrangement of ventilation can be used. One set of axial flow fans can push fresh air into the basement area and another similar set can evacuate the fume-laden air.

d. Mechanical Plant Rooms

In the case of air conditioning plant rooms, generator rooms, substation, boiler room etc., located in the building basement, a push-pull arrangement of ventilation as mentioned at(c) above may be used.

e. Designated Smoking Rooms

To curb any movement of contaminated air from the smoking zone to non- smoking areas, it should be ensured that the smoking zone operates at a negative pressure in comparison with the surrounding non-smoking areas. Ventilation system of the smoking zone should be separate from that of the non-smoking areas. To maintain the required indoor air quality standards in the smoking zones, the smoking zones should have higher ventilation rates than non-smoking areas and should be designed for at least 60 cubic feet per minute per person. The contaminated air from the smoking zone should be exhausted directly to the outdoors. It should be ensured that there is no recirculation of this air contaminated with tobacco smoke, to the non-smoking zones of the building. If the smoking zone is mechanically ventilated, it should have an air circulation rate of not less than 30 air changes per hour.

5.8 Ducting

This portion covers the general requirements for sheet metal ductwork for air distribution with associated items such as air outlets and inlets, fresh air intake and fire dampers.

5.8.1 Material

- i. All ducts shall be fabricated either from galvanized Sheet Steel (GSS) conforming to IS: 277 or aluminium sheets conforming to IS:737. The steel sheets shall be hot dip galvanized with MAT finish with coating of minimum 120 grams per square meter (GSM) of Zinc, GI sheets shall be lead free, eco-friendly and RoHS compliant.
- ii. The thickness of sheets for fabrication of rectangular ductwork shall be as under. The thickness required corresponding to the longest side of the rectangular section shall be applicable for all the four sides of the ductwork.
- iii.

Longest side (mm)	Minimum sheet thickness for Aluminium
750 mm and below	0.80
751 mm to 1500 mm	1.00
1501 mm to 2250 mm	1.50
2251 mm & above	1.80

Diameter of duct, mm	Thickness of Sheet, mm	
	GI sheets	Aluminium Sheets
150 to 500	0.63	0.80
501 to 750	0.80	0.80
751 to 1000	0.80	1.00
1001 to 1250	1.00	1.50
1251 and above	1.25	1.80

iv. Thickness of sheet for Round Ducts

- v. All sheet metal connections, partitions and plenums required for flow of air through the filters, fans etc. shall be at least 1.25 mm thick galvanised steel sheets, in case of G.I. sheet ducting or 1.8 mm thick aluminium sheet, in case of aluminium sheet ducting and shall be stiffened with 25 mm x 25 mm x 3 mm angle iron braces.
- vi. Circular ducts, where provided shall be of thickness as specified in IS: 655 as amended upto date.
- vii. Aluminium ducting shall normally be used for clean room applications, hospitals works and wherever high cleanliness standards are functional requirements.

5.8.2 Associated Items

- i. Supply/ return air outlets, F.A. grilles and accessories shall be constructed from extruded aluminium sections.

Application	Duct Width	Angle Size
Flanges	Upto 1000 mm	35 mm x 35 mm x 3 mm
-do-	1001 mm to 2250 mm	40 mm x 40 mm x 3 mm
-do-	More than 2250 mm	50 mm x 50 mm x 3 mm
Bracings	Upto 1000 mm	25 mm x 25 mm x 3 mm
-do-	More than 1000 mm	40 mm x 40 mm x 3 mm
Support angles	Upto 1000 mm	40 mm x 40 mm x 3 mm
-do-	1001 mm to 2250 mm	40 mm x 40 mm x 3 mm
-do-	More than 2250 mm	Size and type of RS section shall be decided in individual cases

- ii. Flanges for matching duct sections, stiffening angles (braces) and supporting angles shall be of rolled steel sections, and shall be of the following sizes.
- iii. Hanger rods shall be of mild steel and of at least 10 mm diameter for ducts upto 2250 mm size, and 12 mm diameter for larger sizes.
- iv. All nuts, bolts and washers shall be zinc plated steel. All rivets shall be galvanised or shall be made of magnesium - aluminium alloy. Self-tapping screws shall not be used.
- v. Construction
- vi. Duct
 - i. Ducts shall be fabricated at site or factory fabricated and shall be generally as per IS: 655 “Specifications for metal air ducts”.
 - ii. The interior surfaces of the ducting shall be smooth.
 - iii. All the ducts upto 600 mm longest side shall be cross broken between flanges by a single continuous breaking. Ducts of size 600 mm and above shall be cross broken by single continuous breaking between flanges and bracings. Alternatively, beading at 300 mm centers for ducts upto 600 mm longest side, and 300 mm centers for ducts above 600 mm size shall be provided for stiffening.
 - iv. As far as possible, long radius elbows and gradual changes in shape shall be used to maintain uniform velocity accompanied by decreased turbulence, lower resistance and minimum noise. The ratio of the size of the duct to the radius of the elbow shall be normally not less than 1:1.5.
 - v. Flanged joints shall be used at intervals not exceeding 2500 mm. Flanges shall be welded at corners first and then riveted to the duct.
 - vi. Stiffening angles shall be fixed to the sides of the ducts by riveting at 1.25 meters from joints for ducts of size 600 mm to 1500 mm, and 0.6 mm from joints for ducts of size larger than 1500 mm. Bracings for ducts larger than 1500 mm can alternatively be by diagonal angles.
 - vii. Plenums for filters shall be complete with suitable access door of size 450 mm x 450 mm.
 - viii. All factory fabricated duct shall be supplied in L sections, the length of any piece shall not be



more than 1800 mm for duct with longest side of cross section as 600 mm and above and 3000 mm for rest.

5.8.3 Air Outlet and Inlets (Supply and Return)

- i. All air outlets and intakes shall be made of extruded aluminium sections & shall present a neat appearance and shall be rigid with mechanical joints.
- ii. Square and rectangular wall outlets shall have a flanged frame with the outside edges returned or curved 5 to 7 mm and fitted with a suitable flexible gasket between the concealed face of the flanges and the finished wall face. The core of supply air register shall have adjustable front louvers parallel to the longer side to give upto 22.5 degrees vertical deflection and adjustable back louvers parallel to the shorter side to achieve a horizontal spread air pattern to at least 45 degrees. Return air grilles shall have only front louvers. The outer framework of the grilles shall be made of not less than 1.6 mm thick aluminium sheet. The louvers shall be of aerofoil design of extruded aluminium section with minimum thickness of 0.8 mm at front and shall be made of 0.8 mm thick aluminium sheet. Louvers may be spaced 18 mm apart.
- iii. Square and rectangular ceiling outlets/intakes shall have a flange flush with the ceiling into which it is fitted or shall be of anti-smudge type. The outlets shall comprise an outer shell with duct collar and removable diffusing assembly. These shall be suitable for discharge in one or more directions as required. The outer shell shall not be less than 1.6 mm thick extruded section aluminium sheet. The diffuser assembly shall not be less than 0.80 mm thick extruded aluminium section.
- iv. Circular ceiling outlets/intakes shall have either flush or anti smudge outer cone as specified in the tender specifications. Flush outer cones shall have the lower edge of the cone not more than 5 mm below the underside of the finished ceiling into which it is fitted. Anti-smudge cones shall have the outer cone profile designed to reduce dirt deposit on the ceiling adjacent to the air outlet. The metal sheet used for construction of these shall be minimum 1.6 mm thick extruded aluminium sheet.
- v. Linear diffusers shall have a flanged frame with the outside edges returned 3.5 mm and shall have one to four slots as required. The air quantity through each slot shall be adjustable. The metal sheet used for the construction of these shall be minimum 1.6 mm thick extruded aluminium sheet.
- vi. Grilles and diffusers constructed of extruded aluminium sections shall have grille bars set straight, or deflected as required. These shall be assembled by mechanical interlocking of components to prevent distortion. These grilles and diffusers shall have a rear set of adjustable blades, perpendicular to the face blades for deflection purposes.
- vii. All supply air outlets shall be fitted with a volume control device, made of extruded aluminium gate section. The blades of the device shall be mill finish/ block shade pivoted on nylon brushes to avoid rusting & rattling noise, which shall be located immediately behind the outlet and shall be fully adjustable from within the occupied space without removing any access panel. The volume control device for circular outlets shall be opposed blade radial /shutter type dampers, or two or more butterfly dampers in conjunction with equalizing grid. Opposed blade dampers shall be used for square and rectangular ceiling/wall outlets and intakes.
- viii. Laminar supply air diffusers shall be made of 2 mm thick powder coated aluminium sheet duly insulated with 5 mm thick closed cell polyethylene foam insulation having factory laminated aluminium foil and joints covered with self adhesive aluminium tape and having holes 2/3 mm diameter including frame work.

5.8.4 Fresh Air Intakes

- i. Fresh air intake grilles shall be made of extruded aluminium sections.

- ii. A flanged frame using RS sections shall be provided on front face to conceal the gap between the louvers and the adjoining wall face. Corners of frame shall be welded. The frame shall be made structurally rigid.
- iii. Louvers made from extruded aluminium section shall be in modular panel form for ease of handling. These shall be free from waves and buckles. Vertical blades shall be truly vertical and horizontal blades shall be truly horizontal. Butt joints in blades shall not be accepted.
- iv. Additional intermediate equally spaced supports and stiffeners shall be provided to prevent sagging/vibrating of the louvers, at not more than 750 mm centres where the louver's length is longer than 750 mm.
- v. A bird wire screen made of 12 mm mesh in 1.6 mm steel wire held in angle or channel frame shall be fixed to the rear face of the louver frame by screens.

5.8.5 Fire Dampers

- i. Fire dampers shall be provided in all the supply air ducts and return air ducts (where provided), return air passage in the air-handling unit room and at all floor crossings. Access door will be provided in the duct before each set of fire dampers.
- ii. Fire dampers shall be multi blade louvers type. The blade should remain in the air stream in open position & shall allow maximum free area to reduce pressure drop & noise in the air passage. The blades and frame shall be constructed with minimum 1.6 mm thick galvanised sheet & shall be factory fitted in a sleeve made out of 1.6 mm galvanised sheet of minimum 400 mm long. It shall be complete with locking device, motorised actuator & control panel.
- iii. Fire dampers shall be motorised smoke & fire dampers type. It shall be supplied with spring loaded UL stamped fusible link to close fire damper in the event of rise in duct temperature. Fire damper shall also close on receipt of fire alarm signal to cut off air supply instantaneously. An electric limit switch shall also be operated by the closing of fire damper, which in turn shall switch off power supply to AHU blower motor as well as strip heaters.
- iv. Fire dampers shall be CBRI tested & certified for 90 minutes rating against collapse & flame penetration as per UL 555-1995 (Under writers laboratories).
- v. Fire dampers shall be compatible with the fire detection system of building & shall be capable of operating automatically through an electric motor on receiving signal from fire alarm panel.
- vi. Necessary wiring from fire alarm panel up to AHU electric panel shall be provided by the department & further from AHU electric panel to fire damper shall be provided by air conditioning contractor.

5.8.6 Acoustic Lining and Insulation This shall be done as per latest standards.

5.8.7 Acoustic Lining and Insulation

Flexible Duct is a round, flexible, light weight duct having following benefits.

- i. Speedy completion of project
- ii. Offers a high degree of flexibility, which allows it to be easily connected to any desired position.
- iii. A quick and economical means of correcting misalignment between system components. Allows ducting around obstacles where fabricated and fitted ducts would be difficult and costly to install.
- iv. An uninsulated flexible duct shall be made of double lamination of metalized polyester film permanently bonded to a coated spring steel wire helix. Duct shall be in tear & puncture resistant construction.
- v. For insulated flexible duct where specified, inner core for the same should be made of double



lamination of metalized polyester film permanently bonded to a coated spring steel wire helix. Fiberglass insulation of minimum 14 kg/cu.m density, 25 mm thickness shall be wrapped over the inner core & covered with strong outer jacket cum vapour barrier made of fibre glass reinforced metalized polyester film laminate.

- vi. Care must be taken to install all the flexible duct in fully extended position & bends made with adequate radius as per manufacturer recommended practices.

5.8.8 Installation of Metallic Duct

A. Ducting

- i. The fabrication and installation shall be in a workman like manner. Duct work shall be rigid and straight without kinks.
- ii. All exposed ducts within the conditioned space shall have slip joints. Flanged joints shall not be used.
- iii. All joints shall be airtight.
- iv. Ducts shall be supported independently from the building structure and adequately, to keep the ducts true to shape. The support spacing shall be not more than 2 m. Where ducts cannot be suspended from ceiling, wall brackets or other suitable arrangements, as approved by the engineer-in-charge shall be adopted. Neoprene or other vibration isolation packing of minimum 6 mm thickness shall be provided between the ducts and the angle iron supports/brackets. Vertical duct work shall be suitably supported at each floor by steel structural members.
- v. Where metal ducts or sleeves terminate in woodwork, tight joints shall be made by means of closely fitting heavy flanged collars. Where ducts pass through brick or masonry openings, wooden frame work shall be provided within the openings and the crossing ducts shall be provided with heavy flanged collars on either side of the wooden frame work, so that duct crossing is made leak-proof.
- vi. Duct connections to the air-handling unit shall be made by inserting a double canvas sleeve 100 mm long. The sleeve shall be securely bonded and bolted to the duct and unit casing.
- vii. Dampers shall be provided in branch duct connections for proper volume control and balancing the air quantities in the system, whether indicated in the drawings or not. Suitable links, levers and quadrants shall be provided for proper operation, control and setting of the dampers. Every damper shall have an indicating device clearly showing the position of the dampers at all times.
- viii. Where electrical heaters are mounted in the duct, these shall be of low temperature totally enclosed type fitted with radiation fins. A removable panel for access to the heaters shall be provided in the duct. Any hole in the duct for electrical wiring must be provided with suitable bushes to avoid leakage. 6 mm thick asbestos board lining shall be provided all around the inside of the duct for a distance of 30 cms. On either side of the electrical heaters. A manually reset thermostatic safety switch shall be provided near the duct section having heaters. In addition, the heaters must be interlocked with the connected fan motor of the AHU.

B. Air Outlets and Inlets

- i. The locations of the air outlets and intakes shall be shown in the tender drawings and necessary openings and the wooden framework for fixing the grilles shall be provided by the air conditioning contractor. The location of these outlets/ inlets is subject to change and the approval of the Engineer-in-Charge shall be obtained before finally fixing the grilles/diffusers in position.
- ii. In installing fresh air intakes, no fixing device shall be visible from the face of the frame. Where louvers are to be fixed in masonry or concrete, fixing shall be with either expanding plugs or raw plugs. Where the louvers are to be fixed in steel or wood, non-ferrous screws or bolts shall be used.

- iii. Supply air outlets and return air intakes shall be anodized/ powder coated aluminium to the desired colour to match the surroundings wall/ceiling. The fresh air intakes shall be anodized/ powder coated aluminium as approved by the Engineer-in-Charge. The paint colour shall be approved by the Engineer-in-Charge.
- iv. All damages to the finish of the structure during the installation work shall be made good by the air-conditioning contractor before handing over the installation to the Department.

5.9 Balancing

Air systems shall be balanced in a manner to minimize throttling losses. The entire air distribution system shall be balanced with the help of an anemometer. The measured air quantities at fan discharge and at the various outlets shall be within + 5 percent of those specified/quoted. For fans greater than 0.75 KW (1.0 HP), fans must then be adjusted to meet design flow conditions. Branch duct adjustments shall be permanently marked after the air balancing is completed so that these can be restored to their correct position if disturbed at any time.

5.10 Measurement

Duct measurements (for insulated ducts) shall be taken before application of insulation.

- i. Duct work shall be measured section wise on the basis of external surface area by multiplying the axial length from flange face to flange face for each section by the corresponding duct perimeter in the centre of that section length.
- ii. Uniformly tapering straight sections shall also be measured as in (i) above. However, for special pieces like tees, bends etc. area computations for surface areas shall be done as per the shape of such pieces.
- iii. The quoted unit rate for external surfaces of ducts shall include all wastage allowances, flanges, gaskets for joints, vibration isolators, bracings, hangers and supports, inspection chambers/ access panels, splitter dampers with quadrants and levers for position indication, turning vanes, straightening vanes, and all other accessories required to complete the duct installation as per the specifications. These accessories shall not be separately measured.
- iv. Grilles and diffusers (except linear diffusers) shall be measured by the cross-sectional areas, perpendicular to the airflow, and excluding the flanges. Volume control dampers, where provided shall not be separately accounted for.
- v. Linear diffusers shall be measured by linear measurements only, and not by cross-sectional areas, and shall exclude flanges for mounting of the linear diffusers. The supply air plenum for linear diffusers shall be measured as described above for ducting.
- vi. Fire dampers shall be measured by their cross-sectional area perpendicular to the direction of the airflow. Quoted rates shall include the necessary collars and flanges for mounting, inspection pieces with access door, fusible link/solenoid with wiring, but excluding the fire detectors, etc.

5.11 Insulation Work

This portion covers the requirements of thermal insulation for chilled water / hot water piping, pumps and tanks, duct work and acoustic lining in duct work and weather maker rooms. This does not cover exposed roof insulation and under deck insulation work.

5.11.1 Material

The insulation material to be used for various applications shall be any of the following, as required

- i. For insulation of water piping, pumps and tanks: -



- (a) Expanded polystyrene (T.F.Quality): shall be used for pipe insulation like inside the A.C. plant room, exposed to outside or buried in ground. In the case of expanded polystyrene (TF quality), Resin bonded glass wool the pipe insulation should be in rigid sections in two halves and preformed to fit snugly on to pipes (upto pipe sizes for which the preformed sections are manufactured by the manufacturer of insulation). For higher pipe sizes insulation slabs shall be used.
- (b) Resin bonded glass wool: is to be used for piping inside the building due to its fire-retardant properties, for considerations of fire safety.
- (c) Polyvinyl Nitrile (Closed cell rubber foam): is available in tube shapes for sliding on to the small dia. pipes can be used if successfully tested for fire retardant properties.
- (d) XLPE (Closed cell cross linked polyolefin foam. However, all shall need to be covered with vapour barrier and cladding with aluminium sheet

ii. For Insulation of duct work: -

- (a) Resin bonded glass wool.
- (b) Polyvinyl Nitrile (Closed cell rubber foam)

iii. For acoustic lining of duct work and AHU rooms: -

- (a) Resin bonded glass wool.
- (b) Resin bonded mineral wool.

iv. For suction line, Chilled water pipe and Chiller insulation: -

- (a) Expanded Polysterene (T.F.Quality)
- (b) Polyvinyl Nitrile (Closed cell rubber foam)

v. For double skin AHUs:

- (a) Polyurethane foam (PUF insulation)

5.11.2 Material Specifications

The insulation material shall satisfy the following requirements: -

i. For thermal application on pipes.

Material	Minimum Density (Kg/cu.m)	Maximum Thermal conductivity (K.cal/ hr. degree C/m at 10 Deg C mean temp.)
Resin bonded glass wool	32	0.031
Expanded polystyrene (TF)	20	0.035
Polyvinyl Nitrile foam	55	0.034

ii For thermal insulation of ducts:

Material	Minimum Density (Kg/cu.m)
Resin bonded glass wool	24
Polyvinyl Nitrile foam	40

- (a) Fibre Glass Insulation used for duct insulation shall be factory faced with aluminium foil on one side reinforced with kraft paper & fused to the insulation material.
- (b) Polyvinyl Nitrile foam Insulation used for duct insulation shall be factory faced with aluminium foil on one side.

iii. For acoustic lining

Application	Thickness (mm)	Material	Minimum Density (Kg./Cu.M)
Duct	25	Resin bonded glass wool	32
AHU room	50	Resin bonded glass wool/ Mineral wool	32/48

iv. The specification for resin bonded glass wool insulation & resin bonded mineral wool insulation shall conform to IS 8183 as amended upto date. The specification for expanded polystyrene shall conform to IS-4671 as amended upto date.

v. Expansion tank Insulation

Expanded polystyrene insulation of density not less than 20kg per cu.m. shall be used.

5.11.3 Insulation Thickness

The thickness of insulation shall be as indicated below unless specified otherwise

i. For pipe insulation (for chilled water as well as hot water application)

Pipe Size (mm)	Glass fibre /Exp. Polystyrene (mm)
150 & below	50
Above 150	75

ii. For Duct insulation:

Application	Fibre glass (mm)
Thermal for AC area	12.5
Thermal for Non-AC area	25
Acoustic	25

iii. For room acoustic lining

Application	Fibre glass (mm)
Resin bonded glass wool	50
Resin bonded mineral wool.	50

iv. For pumps

Application	Fibre glass (mm)
Expanded polystyrene TF quality	50

v. Chiller Insulation:

Thickness of polyvinyl rubber insulation used for chiller insulation shall not be less than 19 mm.

vi. Expansion tank:

Thickness of expanded polystyrene (TF quality) insulation used shall not be less than 50 mm.

5.11.4 Application of Insulation on Pipes (Including Suction Line Insulation)

- The surface to be insulated shall be first cleaned and a coat of zinc chromate primer shall be given. The insulation shall be fixed tightly to the surface with cold setting adhesive CPRX compound. All joints shall be staggered and sealed. The second layer of insulation wherever required shall be similarly applied over the first layer.
- Pipes shall be preferably pre-insulated at factory, meeting the requirement or the insulation shall be finished at site as under:

- iii. For pipes laid inside the building, the insulation over the pipe work shall be finished with 0.63 mm thick aluminium sheet cladding over a vapour barrier of 120 gm/ sq.m. polythene sheet with 50 mm overlap and tied down with lacing wire and complete with type 3, grade-I roofing felt strip (as per IS 1322 as amended upto date) at the joints.
- iv. For pipes outside the building laid above ground the finishing over the pipe insulation shall be finished with 0.63 mm G S sheet cladding over a vapour barrier of 120 gm/sq.m polythene sheet with 50mm overlap and tied down with lacing wire and complete with type 3 grade I roofing felt strip applied by means of cold setting CPRX compound.
- v. For pipes outside the building laid underground the insulation shall be covered with 500 gauge polythene faced hessian, (the polythene facing outwards), with 50 mm overlap. All joints shall be sealed with bitumen. A layer of 0.50 mm x 20 mm G.I. wire mesh netting shall be provided over it butting all joints and it shall be laced down with GI wire, sand cement plaster (1:4) 20 mm. thick shall be provided in 2 layers of each 10mm and shall be water proofed by applying hot bitumen & fixing tar felt over the plaster. It shall be finally finished with a coat of hot bitumen.) In case of factory pre-insulated pipes, buried underground, a water leakage sensing wire shall also be provided, to detect the location of water leakage at later date.
- vi. In case of factory pre-insulated pipes, all joints shall be properly insulated at site as per recommendation of manufacturer
- vii. All valves, fittings, strainers etc. shall be insulated to the same thickness and in the same manner as for the respective piping, taking care to allow operation of valves without damaging the insulation.

5.11.5 Application of insulation on pumps

Expanded polystyrene (TF quality) 50mm thickness shall be sandwiched between two aluminium sheets of 0.5mm thickness and properly clamped to pump in two semicircular sections.

5.11.6 Application of insulation on expansion tank

Insulation of expansion tank shall be expanded polystyrene (T.F. Quality) of thickness not less than 50mm. It shall be applied as mentioned underneath:

- i. Surface shall be thoroughly cleaned with wire brush and rendered free from all dust & grease.
- ii. The two layers of hot bitumen shall be applied.
- iii. The insulation slabs will then be fixed in one layer and joints shall be sealed with hot bitumen.
- iv. The insulation slab then shall be covered with 0.63 mm x 19mm G.I. wire mesh netting which shall be fixed to insulation with brass / G.I. nails.
- v. The insulation shall then finally be finished with aluminium cladding of thickness not less than 0.5mm.

5.11.7 Application of insulation (thermal) on duct

- i. The surface of duct on which the external thermal insulation is to be provided shall be thoroughly cleaned with wire brush and rendered free from all dust and grease.
- ii. Two coats of cold compound adhesive (CPRX compound) shall be applied over the duct. (Any other adhesive recommended by the manufacturers may also be used with the approval of the Engineer-in-Application of Duct Lining (Acoustic Insulation))
- iii. Where specified in the tender specifications, ducts shall be lined internally with acoustic insulation as detailed below:
- iv. The Inside surface of duct on which the acoustic lining is to be provided shall be thoroughly



cleaned with wire brush and rendered free from all dust and grease.

- v. Then 25 x 25 sq.mm section of minimum 1.25 mm thick G.I. sheet shall be fixed on both ends of the duct piece.
- vi. The insulation slabs shall then be fixed between these sections of ducts using CPRX adhesive compound and stickpins.
- vii. The insulation shall then be covered with Reinforced plastic/ fibre glass tissue with proper overlap, sealing all joints so that no fibre is visible.
- viii. The insulation shall finally be covered with minimum 0.5 mm thick perforated aluminium sheet having perforations between 20-40%.

5.11.8 Application of Acoustic Lining in AHU Rooms

- i. The wall/ roof surface should be thoroughly cleaned with wire brush.
- ii. A 610x610 mm frame work of 25mm x50mm x50mm x50mm x25mm shape channel made of 0.6mm thick G.S.S. shall be fixed to walls leaving 610mm from floor by means of raw plugs in walls and dash fasteners in ceiling. Similar frame work shall also be fixed on ceiling by means of dash fasteners.
- iii. Resin bonded glass wool/ mineral wool as specified cut to size will be friction fitted in the frame work and covered with tissue paper.
- iv. Aluminium perforated sheet having perforation between 20-40% of thickness not less than 0.8mm shall be fixed over the entire surface neatly without causing sag/ depression in between and held with screws. Sheet joints should overlap minimum 10mm.
- v. Aluminium beading of 25mm wide and thickness not less than 1.00 mm shall be fixed on all horizontal/ vertical joints by means of screws.

5.11.8.1 Measurement of Insulation

- i. Pipe insulation shall be measured in units of length along the centre line of the insulated pipe. The linear measurements shall be taken before the application of the insulation. For piping measurements, all valves, orifice plates and strainers shall be considered strictly by linear measurement along the centre line of the pipes, and no special rate shall be applicable for insulation of any accessories, fixtures or fittings whatsoever.
- ii. Duct insulation and acoustic lining shall be measured on the basis of surface area along the outer surface (ref IS14164 of 2008) of insulation thickness. Thus, the surface area of externally thermal insulated or acoustically lined duct shall be based on the perimeter at the centre of thickness of insulation, multiplied by the centre-line length of ducting including tapered pieces, bends, tees, branches etc. as measured for bare ducting. In the case of tapering pieces, their average perimeter shall be considered.

6.1 Introduction of Lift & Escalators

Lifts and escalators are nowadays significant part of almost every major building construction or refurbishment project. With the increasing footfall at railway stations of IR, and with the intention to provide best passenger amenities, Lifts and Escalators are being installed at many stations of Indian railways. IR is further planning to provide it at many more railway stations. Also, lifts are being provided in big offices as per the requirement.

A lift is vertical transport equipment that efficiently moves people between floors of a building. It is generally powered by an electric motor that drive a traction cable and counterweight systems like hoist or hydraulic pump is used.

Escalators are moving stairs – a conveyer transport device where the treads moves on a track at an incline or decline to transport people from one floor to another.

Since at railway stations we deal with lot of public, installing a machine like lifts & escalators, needs to be done with extra care. The maintenance of these machines should be proper inorder to safely carry passengers.

6.1.1 Lifts/Elevators:

- i. lift is a mechanical device powered by electrical supply to transport Goods or People vertically from one height to another.
- ii. Generally used for group of people accumulated at a time to reach another floor of a building.
- iii. Essential for multistory building.
- iv. Use full to the extent possible for continuous flowing traffic of people.
- v. Useful for office buildings, multistory colony buildings and Railway stations in Indian Railways.
- vi. Lift is a mechanical device to transport Goods or People vertically from one height to another
- vii. Generally used for group of people accumulated at a time to reach another floor of a building
- viii. Essential for multistory building
- ix. Useful for office buildings, multistory colony buildings in Indian Railways

6.1.2 Escalators

- i. An escalator is a conveyor transport device for transporting people, consisting of individual, linked steps that move up or down on tracks, which keep the steps horizontal.
- ii. Takes the form of stairs which move up or down at an angle of 30° from horizontal level. Continuous Moving Stairway.
- iii. Individual Linked Steps, that move up or down on tracks, which keep the tread horizontal.

6.2 Types of -Lifts/Elevators

- i. Passenger elevators
- ii. Freight elevators
- iii. Vehicle elevators
- iv. Boat elevators
- v. Aircraft elevators

6.2.1 Means of Moving -Lifts/Elevator

- i. Traction Elevator-Gearred or Gearless
- ii. Hydraulic Elevator
- iii. Climbing elevators

6.2.1.1 General Requirements:

The construction of all Elevators generally conform to latest editions of IS-14665, IS 15785, IS-15330, and EN 81-1.

Each Elevator generally have its own driving machine.

The method of Drive generally be Electric Traction with gearless motor having a provision of VVVF Control; regenerative drive may be provided as per manufacturer.

6.2.1.2 Illumination of Cars and Lighting Fixtures:

LED light fittings are provided to achieve a minimum illumination level of 150 lux at the floor of Elevator car.

6.2.1.3 The number of fittings should be two or more.

Emergency Lighting:

For emergency lighting, a subset of lighting fixtures for normal lighting, shall be backed up by a UPS. With emergency lighting, the operating panel shall be 100 lux.

6.2.2 Safety Devices/Features:

Safety gear should comply with the provisions mentioned in EN 81-1.

In addition to the elevator safety devices/ features mentioned, the following shall also be provided.

- i. Anti-man-trap Features.
- ii. Water sensors shall be provided in the Elevator pits.
- iii. An inspection control panel shall be fitted on the top of the Elevator car for maintenance purpose.
- iv. The Elevator shall be provided with a floor-levelling device, which shall automatically bring the Elevator car to stop within ± 5 mm of the level of the floor for which a stop has been initiated regardless of the load or direction of travel.
- v. An automatic re-levelling device shall be provided which returns the Elevator to the floor automatically should the Elevator creep down or move up from floor level due to rope stretch for any distance more than 15 mm. This device shall be operative at all floors served, whether the landing and car doors are opened or closed.
- vi. Each Elevator car shall be provided with Progressive type safety gear mounted on the lower member of the car frame structure.
- vii. A mechanical device and electrical device shall be provided to prevent the car movement resulting from maintenance/ inspection that can be dangerous to persons carrying out maintenance/ inspection works from inside the car or car roof.
- viii. A phase protection device and 3 phase as well as single phase earth leakage protection device shall be provided in the main control cubicle of each Elevator to prevent the Elevator car from moving in the event that there is a phase failure, or the phase of the power supply being reversed due to

any reason whatsoever. These devices, when activated, shall cause a visual indicator to illuminate on the main control cubicle, until the fault has been rectified.

- ix. As in the case of Power failure (including single phasing / unbalanced phase) Elevator should operate in the Emergency Rescue mode.
- x. Each Elevator is provided with overload device .
- xi. An over speed governor also is provided in a Elevator.
- xii. Two stop switches generally provided to prevent any movement of the Elevator car during inspection/test operation.
- xiii. A safety switch to prevent the car from moving when the governor rope tension weight is out of position, shall be provided.
- xiv. Terminal and Limit switches shall be provided as per IS 14665 (Part 3/ Sec 1).

6.2.2.1 Design Criteria for life of items

Elevator Component	Design Life (Years)
Safety Gear Rope	8
Governor	20
Anti creep device, wherever provided	20
Hoisting chain/hoisting rope	8
Contactors/relays*	10
Traction machine/motor	20
Hall and Car buttons	15

* Frequently operating contactors/relays may have lesser life of five years

6.2.2.2 Photographs of Lift Items:

LIFT with Machine Room:-

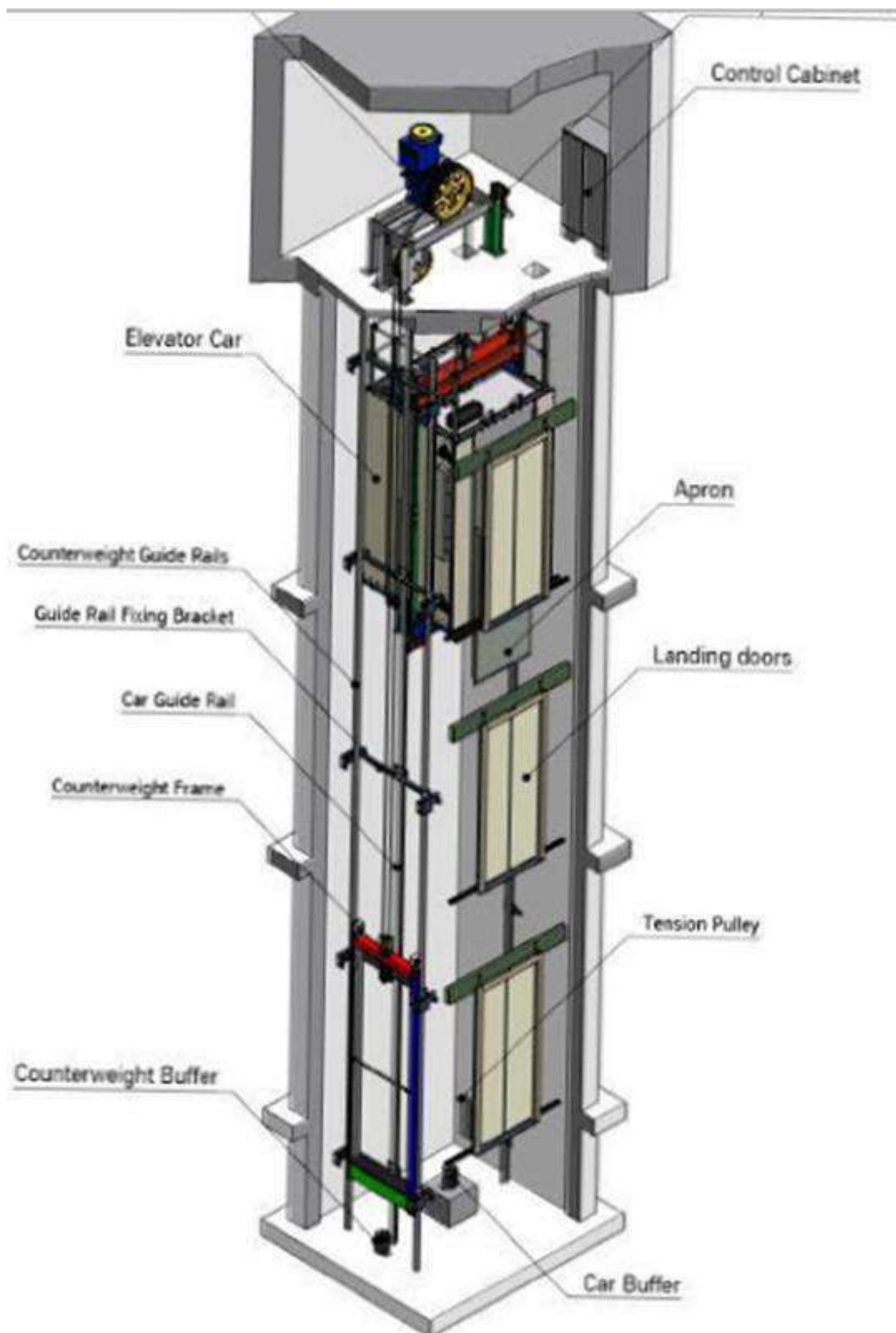


Fig 6.1 LIFT with Machine Room:-

1-Hoistway



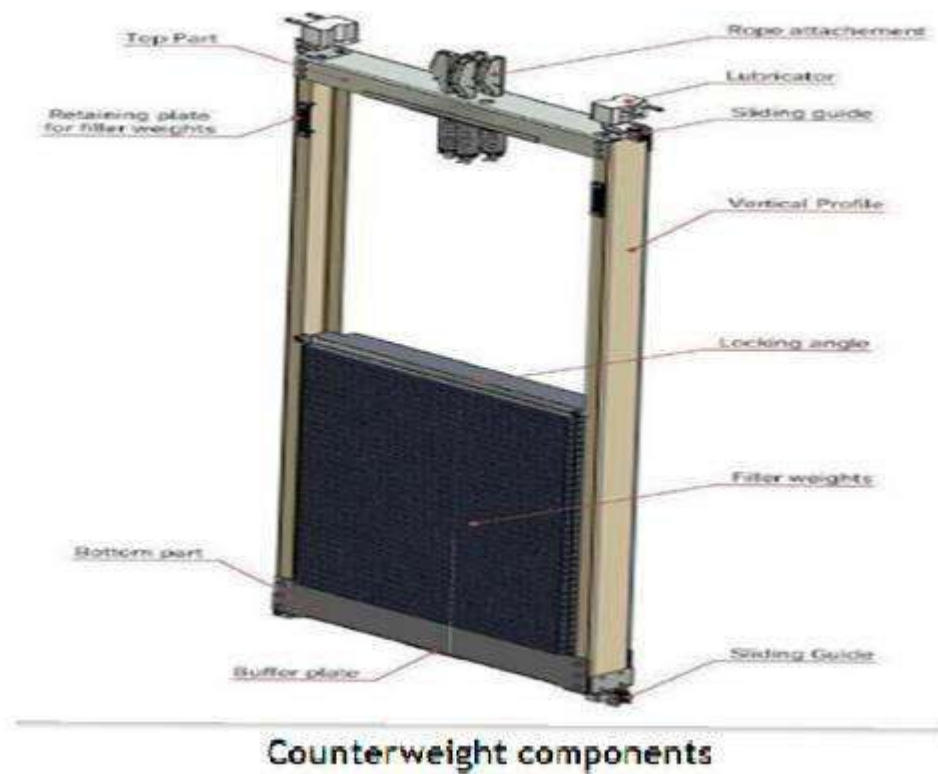
Hoistway

2-Counter weight



Counterweight

Counter weight component

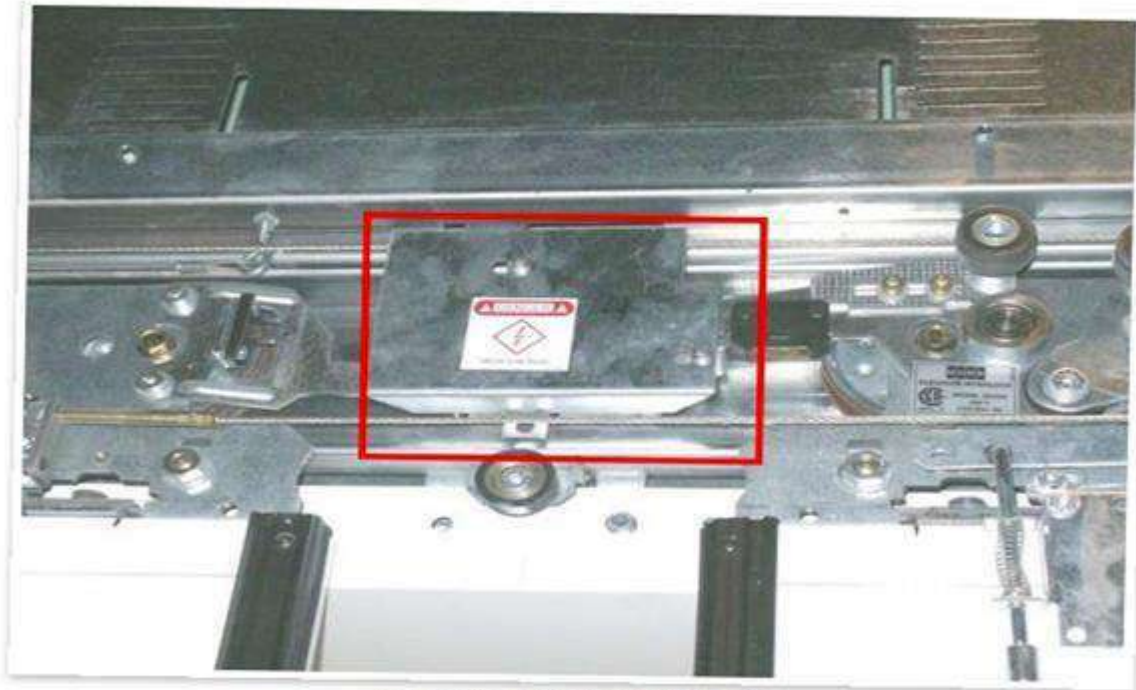


3.Suspension (Hoisting)Ropes(cables)



Suspension Ropes

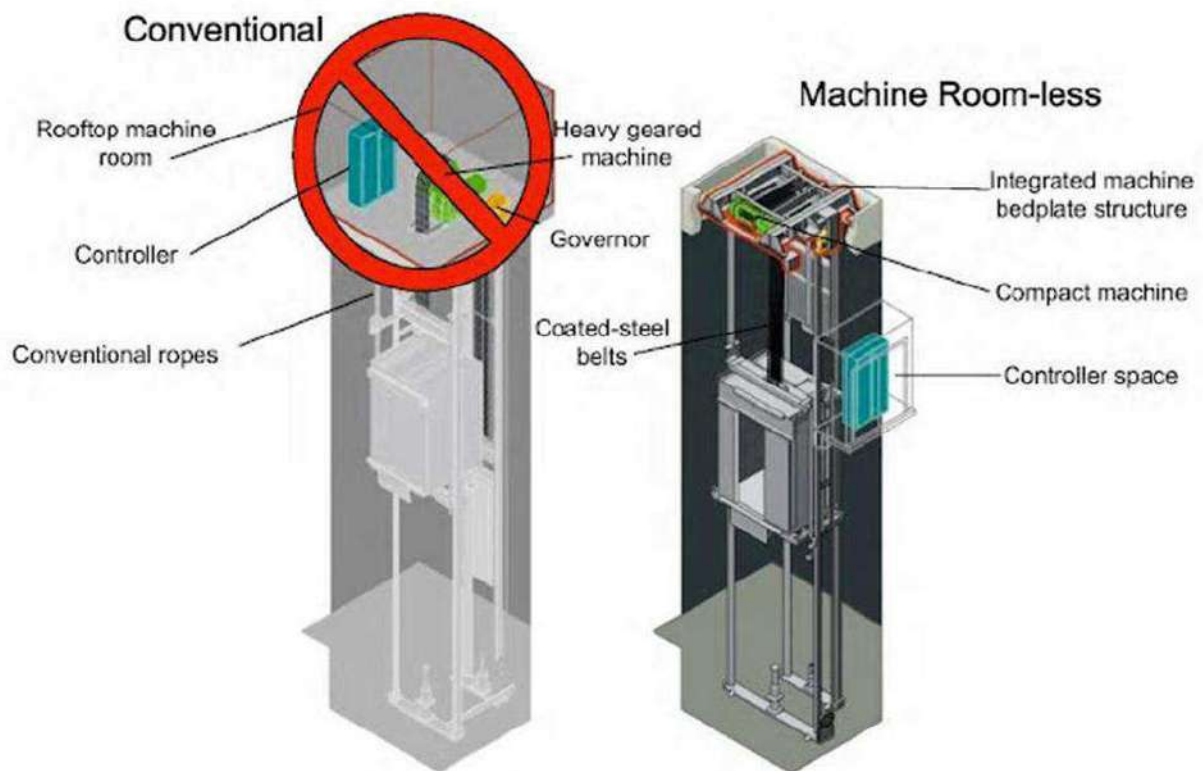
Hoistway Door Interlock



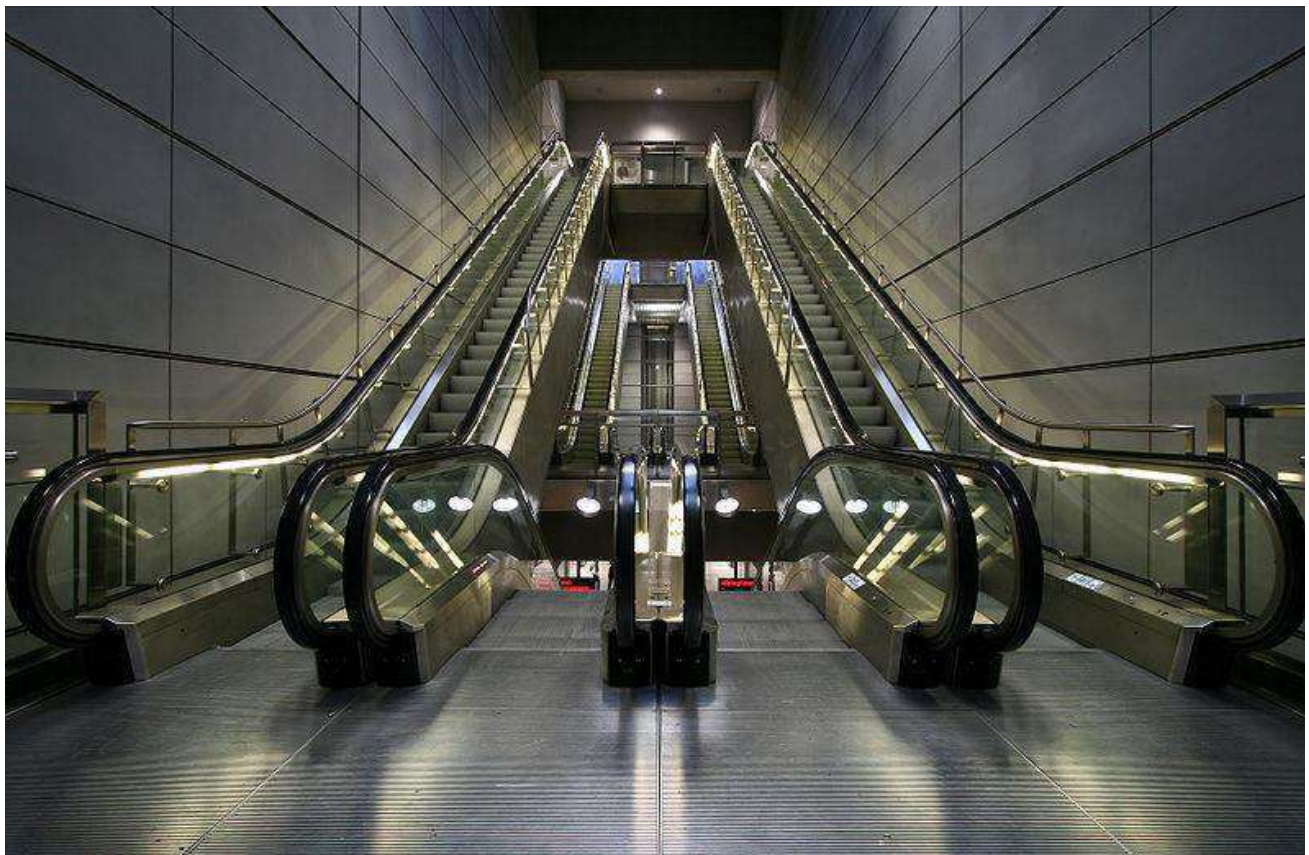
Hoistway Door Interlock

6.2.2.3 Machine-Room-Less Elevators:

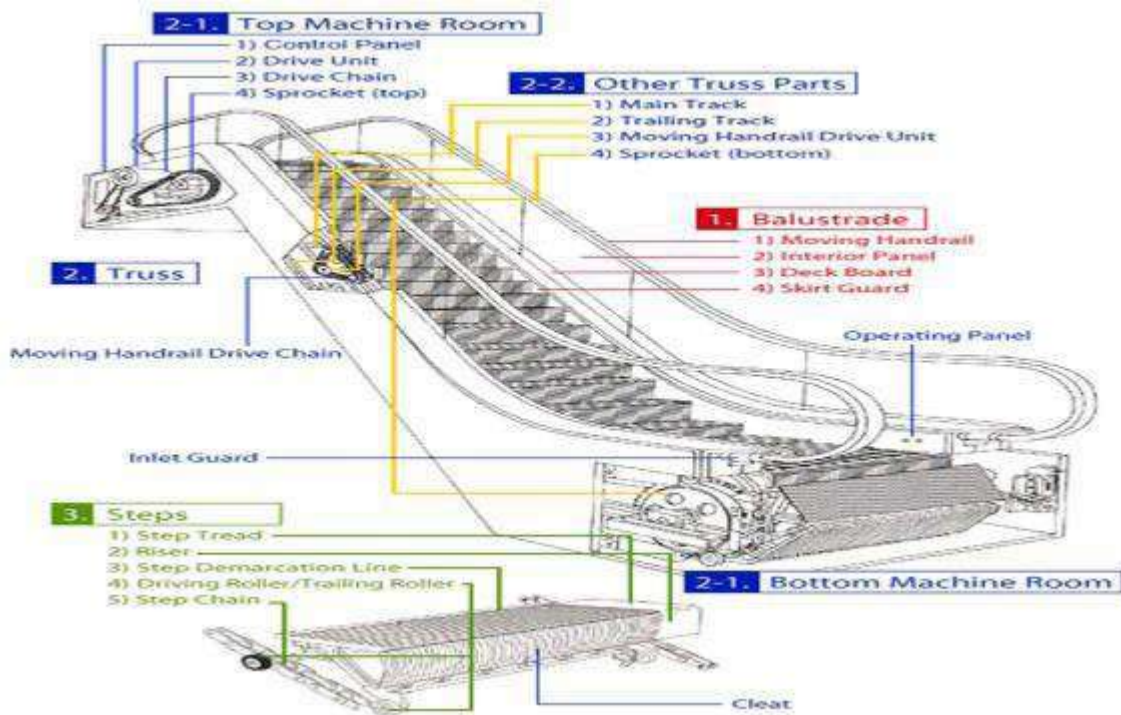
They are typically traction elevators that do not have a dedicated machine room above the elevator shaft. The machine sits in the override space and the controls sit above the ceiling adjacent to the elevator shaft. Machine-room-less elevators are becoming more common; however, many maintenance departments do not like them due to the hassle of working on a ladder as opposed to within a room.



6.3 Escalator / Moving Stair way



An escalator is a Conveyor transport device for transporting people, consisting of individual, linked steps that move up or down on tracks, which keep the treads horizontal.



DEFINITIONS

The following words and phrases used in this specification shall bear the meanings given below.

A. Part I- Technical Terms:

- (a) **Angle of inclination-** The angle at which a passenger travels with respect to the horizontal.
- (b) **Anti slide device-** A device to be installed on the decking between the handrails of the adjacent escalators, or on the decking between the handrail and the adjacent wall, to prevent people or objects from sliding down on the decking.
- (c) **Balustrade-** The enclosure at each side of the moving steps, consisting of decking, inner and outer panels and skirts.
- (d) **Ceiling intersection guard-** A guard provided at the intersection of escalator decking and ceiling or soffit.
- (e) **Comb** – The pronged portion of the comb plate at the landing which meshes with the step thread grooves.
- (f) **Comb plate-** The plate supporting the combs at the landings.
- (g) **Control equipment-** the components by means of which motion, direction of travel, speed and stopping are controlled.
- (h) **Deck, Decking and decking extension-** The position of the balustrade outside the moving handrail that is transversely horizontal. This shall include anti slide devices where applicable.
- (i) **Driving Machinery-** The motorized power unit for driving the escalator.
- (j) **Electro-mechanical Brake-** A brake consisting of friction shoe(s) applied to a brake drum or disc by means of springs that are electrically released.
- (k) **Handrail-** A power driven moving rail for passengers to grip whilst using the escalator.
- (l) **Handrail Guard-** A guard for the moving handrail at the point where the handrail enters or leaves the balustrade.
- (m) **Landing** – The stationary areas at the entrance to or exit from an escalator.
- (n) **Landing Plate / Floor Plate-** The portion of floor plate next to the comb plate at the landing.

- (o) **Newel**- The portion of the balustrade on the landing at the end where the moving handrail changes direction.
- (p) **Number of Horizontal / Flat steps**- Horizontal / Flat steps shall be measured from the point at which the first step emerges from under the comb plate in a horizontal direction to the first exposure of the riser of n adjacent step, both at the upper and lower landings.
- (q) **Panel**- The portion of the balustrade immediately adjacent to the moving stairway, occupying the vertical space between the steps and the deck or inner panel.
- (r) **Skirt**- The portion of the balustrade immediately adjacent to the moving stairway, occupying the vertical space between the steps and the deck or inner panel.
- (s) **Step**- The unit which forms the moving stairway.
- (t) **Step chain**- The main chain to which the steps are attached. **Step roller track**- the track on which the step roller runs.
- (u) **Step chain**- The main chain to which the steps are attached.
- (v) **Step roller**- The rollers attached to the step and supporting the step.
- (w) **Truss**- The supporting structure on which the various components are mounted.
- (x) **Working point**- The intersection of the escalator step nose line and the projection of the escalator floor plate level.
- (y) **Constant length**- The horizontal distance between the escalator working point and the end of escalator support.

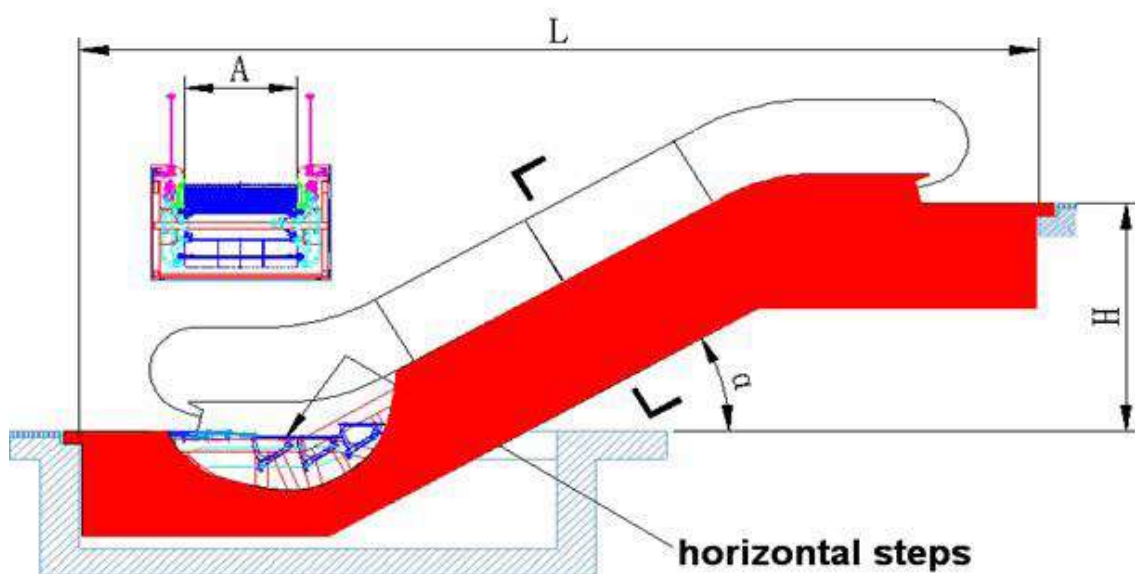
B. Major Details for Erection:

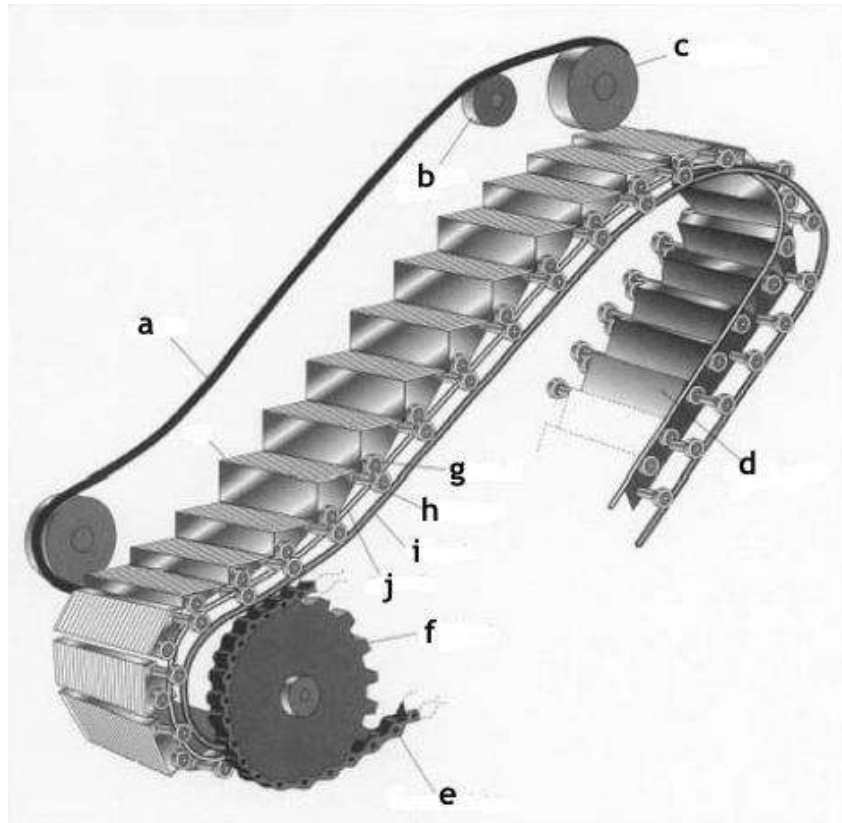
- Vertical Rise (H): The distance between two floors, drawing icon 'H'.
- Inclination Angle (α): The angle between working sect to sea level, drawing icon a (30 degree).30° inclination.

This inclination provides the highest traveling comfort and maximum safety for the user

Step Width (A): The width of nominal width, drawing icon 'A' (1000mm).

- Horizontal span/Installation Length (L): The level distance between up pivot and down pivot, drawing icon 'L' also called installation length of the Escalator.





Escalator components in the figure are as follows:-

a: Handrail, **b:** Tensioning Pulley, **c:** Handrail Pulley, **d:** Returning Stairs
e: Continuous Chain, **f:** Drive Wheel, **g:** Front Wheel, **h:** Back Wheel,
i: Outer Rail **j:** Inner Rail

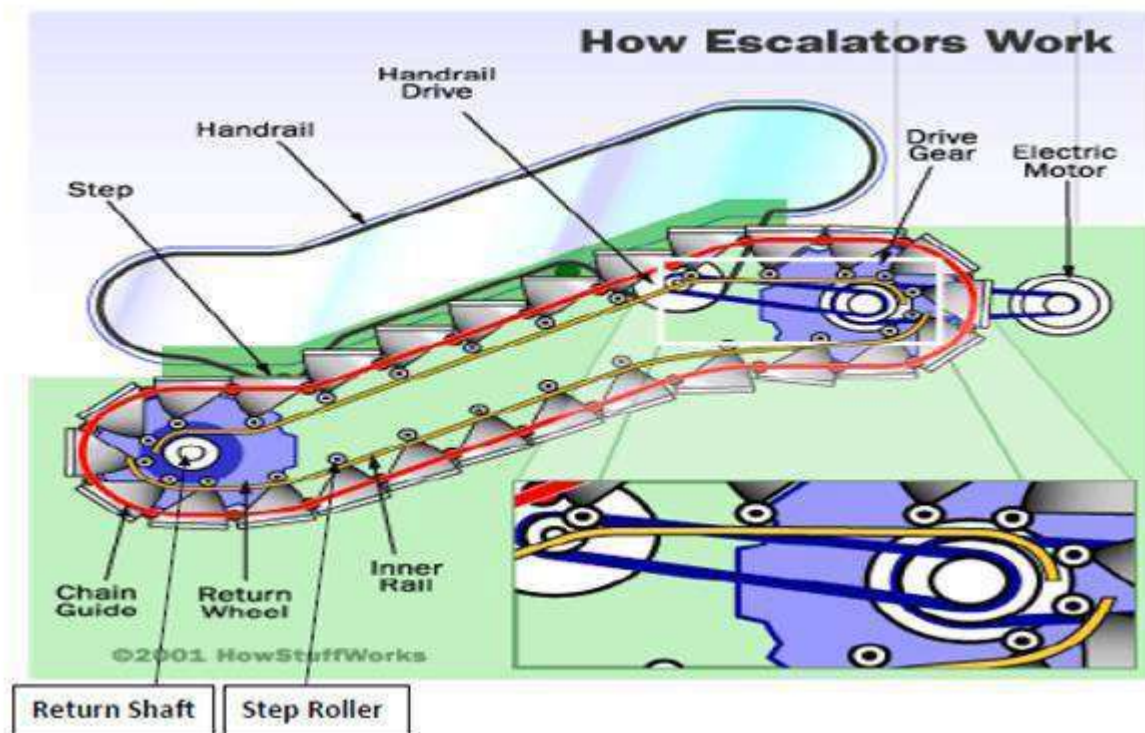
C. TRAV-O-LATOR MOVING WALKS:



Moving walk way is a slow moving conveyor mechanism that transports people across a horizontal or inclined plane over a short to medium distance. Moving walkways can be used by standing or walking on them.

Step width	Theoretical transportation capacity	Effective transportation capacity at a rated speed of				
		$v = 0.5 \text{ m/s}$	$v = 0.5 \text{ m/s}$	$v = 0.5 \text{ m/s}$	$v = 0.5 \text{ m/s}$	$v = 0.65 \text{ m/s}$
			uncrowded	convenient	crowded	crowded
600 mm	4500 pers./h	1800 pers./h	2700 pers./h	3600 pers./h	4400 pers./h	
800 mm	6750 pers./h	2400 pers./h	3600 pers./h	4800 pers./h	5850 pers./h	
1000 mm	9000 pers./h	3000 pers./h	6750 pers./h	3000 pers./h	7300 pers./h	

Working of Escalator



Step

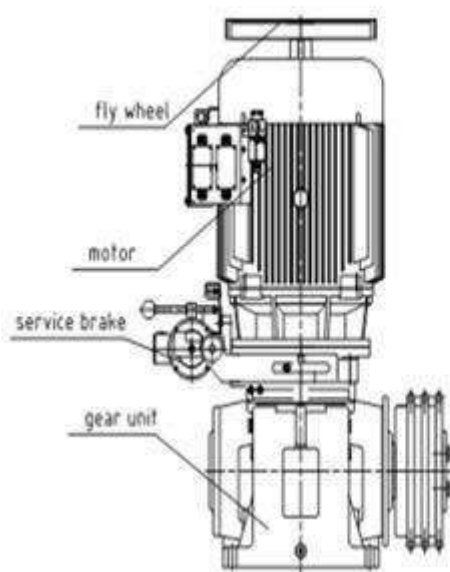
Each step in the escalator has two sets of wheels, which roll along two separate tracks. The upper set (the wheels near the top of the step) are connected to the rotating chains, and so are pulled by the drive gear at the top of the escalator. The other set of wheels simply glides along its track, following behind the first set.



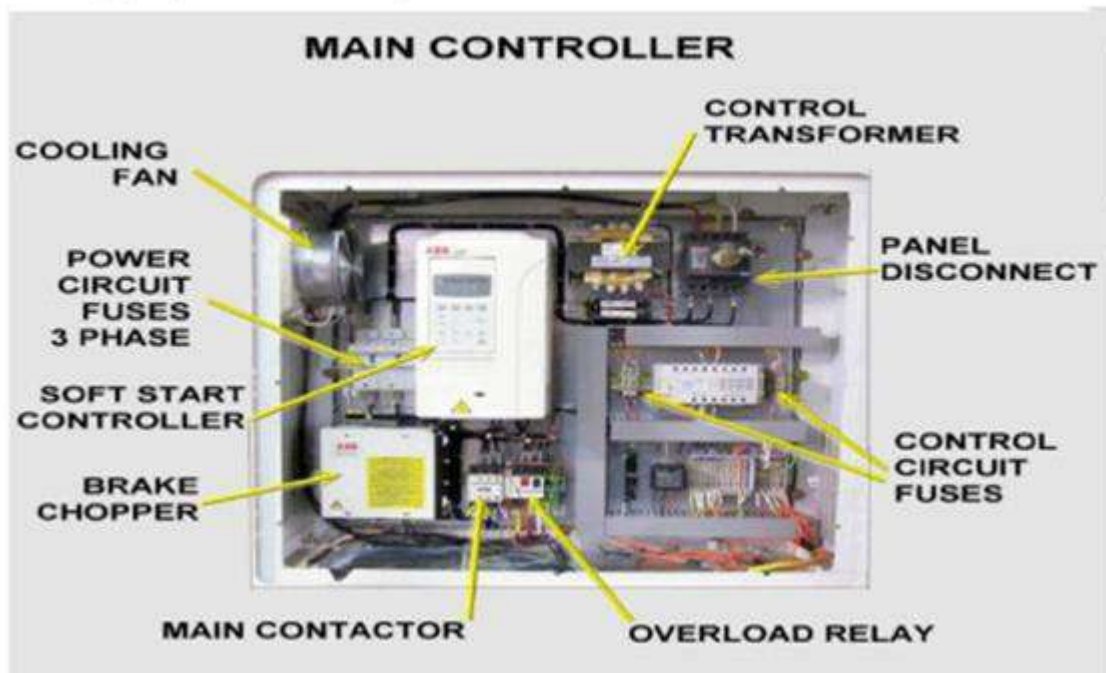
- 2-component plastic roller
- Tire : Hydrolysis resistant PUR 95°Sh(A)
- Core : PA
- Bearing: 6203 - 2RSR - 60% grease fill.
(lifetime lubricated)

Each step in the escalator has two sets of wheels. Which roll along two separate tracks. The upper set (the wheels near the top of the step) are connected to the rotating chains and so are pulled by the drive gear at the top of the escalator. The other set or wheels simply glides along its track, following behind

Drive unit



Supply control system



D. Protection provide for drive unit:

- 1 Protection to the escalator from sun and rain.
2. The 3-phase Induction Motor shall be totally enclosed with external cooling fins having minimum IP-55 Protection and class F Insulation level.
3. All electrical equipment supplied and installed shall at least have the following class of protection for dust and water:
 - i. Machine : IP 55
 - ii. Controller : IP 55
 - iii. Isolating switches : IP 55
 - iv. All safety switches : IP 55
 - v. Control switchgear protection :IP 55
 - vi. Protection class of motor :
 - vii. Fire and smoke protection (provision of smoke detectors, etc.).
5. Motor Overload & Thermal Protection Device:
 - * Built in type thermal protection, if offered, shall conform to BS 4999 Part 72.
6. Emergency Stop Switch: The switch provided at the incline portion shall have protection from the dust ingress.
7. Phase Protection Device .
8. Interface with Fire Protection Systems .
9. Water Flooding Detection Device .
10. Monitoring and Fault Diagnostic System.

E. Electrical Works / Items

- i. All electrical works and switchgear for the escalator installation shall conform to CEAR-2010 (with latest amendments).
- ii. All cables and wiring for open/elevated stations shall be fire retardant. For cables to be used in underground stations, the additional requirement is that they shall be made from low smoke and halogen free materials.
- iii. No bare Conductor shall be used in any escalator as it may cause electrocution danger to the personnel.
- iv. All cables except those within the enclosed controller shall comply the following requirements
 - i. Power and control cables shall be rated for 1100V and 600V grade respectively.
 - ii. The conductor shall be of stranded conductor composed of plain annealed copper wire complying with IEC 228, Class 2.
 - iii. The insulation shall consist of an extruded layer of cross-linked polyethylene complying with IEC 502.
- v. Fire retardant, low smoke, halogen free materials shall meet the following requirements:
 - a. London Transport Executive Three metre Cube Smoke Emission Test, using optical measuring instruments. The maximum value of absorbance AO (ON), AO (OFF) shall be 0.8 & 1.2 respectively.
 - b. The US National Bureau of Standard Smoke Chamber Test, used to evaluate plaque samples of materials of constant thickness. (NFPA-258 Smoke Generation of Solid Materials 1982). The maximum specific optical density shall be 170 under the non-polluted condition.
 - c. The flame propagating criteria of US IEEE Standard 383, with a
 - d. Minimum test short circuit time of five minutes, in the IEEE Standard 383 test. IEC 332 Parts 1 and 3, Category B, tests on single and bunched cables under fire conditions.
 - e. Limiting Oxygen Index of at least 30, to ASTM D 2863.
 - f. A temperature index (TI) of 260°C to ASTM D 2863.
 - g. All insulation is to be moisture and heat resistant, with temperature ratings appropriate to the application conditions, and in no case lower than 120°C.
 - h. When a sample of the cable is subjected to a combustion test for the determination of the amount of halogen acid gases (other than hydrofluoric acid) as set out in IEC 754 - Part 1, the halogen acid evolved shall not exceed a maximum of 0.5%.

Note: Fire retardant materials shall meet the requirements of item c, d, e, f and g only.

- i. All electrical equipment supplied and installed shall at least have the following class of protection for dust and water:
- ii. Machine : IP 55
- iii. Controller : IP 55
- iv. Isolating switches : IP 55
- v. All safety switches : IP 55

F. Simple Safety Precautions –I

- i. Always step out at the end of the stairs to prevent from falling.
- ii. Carry dogs up or down (or use the elevator)
- iii. Check for loose garments. These may include: long dresses, scarves, trench coats, or loose belts. Also, loose shoelaces are particularly notorious for getting caught in escalator machinery, so make sure that shoes are tied

G. Simple Safety Precautions-II

Children under the age of 7 should be accompanied by an adult when riding. Adults should hold a child's hand.

- Do not ride barefoot.
- Face forward.
- Hold the handrail.
- Keep footwear away from the side panels especially shoes with traction.
- Keep walking after exiting the escalator to prevent a pile-up.

H. Simple Safety Precautions-III

- Do not use the escalator when transporting any large package or when pushing a device with wheels (moving sidewalks and ramps usually excepted look for signs). This includes: baby strollers, baggage carts, hand trucks, or shopping carts. Also, the escalator should not be used by someone with a walker or on crutches.
- Do not use the escalator if it is not in motion. ("Escalator steps are not the correct height for normal walking and should not be used in that manner. The risk of tripping and falling is greatly increased.")
- Stand to one side of the escalator to allow others to pass you on wider escalators.
- Provide the operator staff for the working of lifts & escalators to avoid accidents.
- Safety instructions (Do & Don't) and emergency telephone numbers should be displayed inside & in front of the lifts in case of lifts, top & bottom side in case of escalators.

I. Generic Technical Specifications for Escalators used in railways for indicative purpose only

Application	:	At Railway stations – semi-outdoor application. Railway shall provide adequate shade on the top and extended on the sides of the escalators.
Nominal speed	:	0.5 m/sec in normal operation.
Angle of inclination	:	30°
Vertical rise	:	Between 4.5 meter and 8.0 meter (To be exactly specified by user railways in Annexure 1). In exceptional cases, escalator rise may be even more than 8m.
Horizontal span	:	Shall be based on the Contractor's design and other parameters, namely vertical rise, number of horizontal steps, inclination and transition radius, etc.
Truss Design	:	For vertical rise up to 5m, no intermediate support shall be required.
Maximum passenger carrying capacity	:	100 passengers/ min at nominal speed of 0.5 m/sec.
Applicable Standards	:	EN-115; IS-4591 (latest versions)
Power supply	:	AC 3ø, 415V±10%, 50Hz±3%
Lighting supply	:	AC 1ø, 220V±10%, 50Hz±3%
Step Chain strength	:	200KN for escalator rise up to 10m; 300KN for rise above 10m and up to 18m
Chain rollers	:	Inside/ Outside (see Annex 1 item 5)
Handrail guide at newels	:	Guide rollers
Horizontal steps	:	Number of horizontal steps at both the upper and lower landings shall be 4.
Landing plate	:	Etched stainless steel ASTM (or equivalent) SS316 grade with anti-slip pattern
Nominal step's width	:	Minimum 1000 mm
Balustrade panel material	:	ASTM (or equivalent)- SS304 hairline finish
Start function	:	Key operated switch
Control switchgear protection	:	IP 55

J. Safety Devices/ Features Required

- i. Operating and Safety Devices
- ii. Motor Overload & Thermal Protection Device
- iii. Starting switch
- iv. Service Stop Switch
- v. Emergency Stop Switch
- vi. Speed control device
- vii. Broken step chain safety device
- viii. Broken drive device
- ix. Non Reversing Device
- x. Handrail Finger Guard Safety Device
- xi. Step and Skirt Safety Devices
- xii. Comb plate safety device
- xiii. Step Lowering Device
- xiv. Inspection Control
- xv. Missing step detection device
- xvi. Handrail Speed Detection Device
- xvii. Broken Handrail Device
- xviii. Floor plate safety device
- xix. Step up-thrust device
- xx. Dress Guard
- xxi. Brake Lining Safety device
- xxii. Phase Protection Device
- xxiii. Earth leakage protective device
- xxiv. Low Oil Level Detecting Device
- xxv. Interface with Fire Protection Systems
- xxvi. Water Flooding Detection Device
- xxvii. Public announcement system
- xxviii. CCTV system:

Following is a summarized list of critical safety features. All of these will be supplied and installed by the contractor.

Sl. No.	Safety devices/ features required	Description
1.	Emergency stop device	In an emergency, it stops escalator immediately, if pressed
2.	Comb plate safety device	It stops escalator, if objects are caught between comb plate and step treads
3.	Handrail entry safety device	It stops escalator, if human-finger or any Foreign-object is pulled into the hand-Rail entry/Inlet
4.	Phase monitoring device	It stops escalator, if there is a missing phase or a wrong phase sequence.
5.	Over-speed detector	It stops escalator, if the movement is above the normal speed
6.	Non-reversal safety device	It stops escalator, if the direction of movement is suddenly reversed
7.	Main driving chain safety device	It stops escalator, if the main driving chain loosens excessively or breaks
8.	Step chain safety device	It stops escalator, if the step chain breaks or becomes excessively loose
9.	Step sag protection device	It stops escalator, if the Steps start sagging after getting fractured or otherwise
10.	Static electricity prevention device	Eliminates static electricity created by running of the escalator steps and/or handrails
11.	Skirting panel safety device	It stops escalator, if objects are caught between any step and skirting Panel
12.	Skirting panel safety brush (special heavy duty)	It prevents stray objects, clothes such as saree and chunni, etc. being caught between Step and Skirting Panel

Sl. No.	Safety devices/ features required	Description
13.	Step's three-sides yellow demarcation	It demarcates the two horizontal-ends and one inner end of the steps and the safe foot-hold area for passengers
14.	Step gap green illumination	The green light illuminates the riding edge of the steps from below, ensuring safe ride of passengers
15.	Comb plate light	The lights at skirting level on both sides of the comb plate ensure safe ride of passengers
16.	Handrail broken safety device	It stops escalator, if handrail stops or breaks
17.	Handrail speed detection device	It stops escalator, if handrail movement is above/ below the normal speed
18.	Auxiliary brake	It stops escalator, if the Driving Chain breaks and/ or escalator over-speeds
19.	Motor overload & overheat Protection	It stops escalator, when the motor current/temperature is exceeded abnormally
20.	Brake monitoring device	It stops escalator, before a brake-fail situation can occur (due to excess brake lining wear)
21.	Step missing device	It stops escalator, if the Step is missing
22.	“START” Buzzer device	It alerts the passengers when escalator starts working/ moving
23.	“WRONG-ENTRY” alarm Device	It alerts the passengers, if they approach to enter the escalator from a Wrong entry-point/ opposite- direction to its movement- direction, by sounding the warning-buzzer and beginning the escalator movement in its pre-set, correct direction.
24.	“AUTO-START” on passenger-approach device	It ensures the stopped-escalator to start operating/ moving after detecting the approaching passengers by a 3-D scan.
25.	Oil-water separator & drainage system	It ensures separate collection & disposal of the loose/ falling oil/ grease and accumulated water and thus preventing a potential hazard.
26.	Grounding of escalator (limited to making earth connections to escalator)	As per IS 3043:1987
27.	Smoke Detector	It stops escalator, if smoke generates under pit, machine room and controller.
28.	Sprinkler System	An optional item (see Cl. 9.1.24)
29.	Low Oil Level Detecting Device	See Cl. 9.1.23
30.	Float switch	It stops the escalator if the lower pit is flooded

K. Generic Escalator Maintenance Check List – Monthly

Escalator serial No:

Location:

Sl. No.	Description	OK/NOT OK/NA	Remark
A.	VISUAL CHECK BEFORE SHUTDOWN		
1	Check the ride performance of Escalator		
2	Check for any screw , washers etc. on steps		
3	Check the condition of steps		
4	Check the condition of comb teeth		
5	Check the Steps are centrally entering into the combs		
6	Check the condition of Comb carriage & Floor plate sheet on top & bottom (Riveted Or Pasted)		
7	Comb plate to Floor plate actuating gap is clean and Clearance should be 6 – 8 mm		
8	Check the condition of balustrade		
9	Check the handrail moving speed at the same speed as the steps (Handrail & step speed LH & RH should be equal Marking method can be adopted)		
10	Check for any visible damages on handrail		
11	Check the handrail tension& Handrail heat		
12	Check for any handrail powder at four corners (Near handrail entry cover)		



Sl. No.	Description	OK/NOT OK/NA	Remark
13.	Check there is any signs of step misalignment – scraping marks on the sides of the steps		
14.	Check the distance of Brake slip distance (It shall be 275 mm for 0.5m/sec) Slippage distance:		
15.	Check the condition of Entry cover or boot (Both LH & RH in Top and bottom)		
16.	Check for defects on inner & Outer decking covers (scratches , dents & fixing screws etc.)		
17.	Check for cladding condition		
18.	Check for skirt panels (scratches, dents etc.)		
19.	Check the condition and function of Traffic lights		
20.	Check the condition and function of comb lights		
21.	Check the condition and function of Handrail lights		
22.	Check the condition and function of skirt lights		
23.	Check for condition and function of step gap illumination Lights		
24.	Check for Pillar sensor / Radar sensor / Contact mat Sensor		
25.	Check the function of Sensor (wrong entry for both UP & DN)		
26.	Check for skirt brush condition and availability		
27.	Check the function of Auto / Manual Key (Top &Bottom)		
28.	Check the function of Up & Down key switch (Top & Bottom)		
29.	Check the function of Emergency stop button (Top & Bottom)		
30.	Availability of safety sign stickers		
B.	BOTTOM PIT INSPECTION		
31.	Condition and Function of Floor plate switch		
32.	Safety step guard condition and availability		
33.	Function of pit maintenance stop switch		
34.	Function of Inspection pendant (UP , DOWN & STOP Button)		
35.	Step chain tension in LH mm & RH Mm		
36.	Carriage movement Gap LH mm & RH mm		
37.	Function of Step chain broken / tension switch in bottom (LH & RH)		
38.	Rigid fixing of Floor plate L angle bolt & nuts		
39.	Check the availability of FLOOR PLATE STOPPER in LH & RH (OR) ALUMINIUM FLOOR PLATE LOCK		
40.	Check the condition of CHAIN ROLLERS		
41.	Check the condition of ALL STEP ROLLERS		
42.	Check the condition of ALL STEP SLIDER STRIP		
43.	Check the condition of ALL STEP BUSH		
44.	Check the condition of ALL STEP LOCKING CLAMP		
45.	Check the condition of ALL STEP SHAFT LOCKING PIN		
46.	Check the condition and tightness of STEP LOCKALLEN KEYS		
47.	Function of Handrail entry switch in bottom LH & RH		
48.	Condition of BOTTOM CONTROLLER		
49.	Function of bottom pit light		
C.	TOP PIT / MACHINE ROOM AREA INSPECTION		
50.	Condition and Function of Floor plate switch		
51.	Function of pit maintenance stop switch		
52.	Safety step guard condition and availability		
53.	Function of Inspection pendant (UP , DOWN & STOP Button)		
54.	Rigid fixing of Floor plate L angle bolt & nuts		
55.	Check the availability of FLOOR PLATE STOPPER in LH & RH(OR) ALUMINIUM FLOOR PLATE LOCK		
56.	Function of Top pit light		
57.	Function of Main switch and condition (MCB or ELCB provided by customer)		
58.	Function and condition of controller main switch		
59.	Check the Unusual noise & Temperature in MOTOR & GEAR BOX		
60.	Check the brake liner thickness & condition		
61.	Check the condition and function of brake wear monitor		

Sl. No.	Description	OK/NOT OK/NA	Remark
62.	Check for Gear box oil leaks		
63.	MAIN DRIVE CHAIN condition and slack (Slack should be 10 mm to 15 mm) Actual mm		
64.	Function of main drive chain switch		
65.	Condition of RED PIECE SLIDER in Broken drive chain contact assembly		
66.	Condition of Main drive shaft bearings & Marking positions (LH&RH side)		
67.	Check the function of automatic lubrication system and lubrication oil brush		
68.	Check the oil level in automatic lubrication system		
69.	Check the manual function of AUTOMATIC LUBRICATION SYSTEM		
70.	Function of Handrail entry boot switch in Top LH & RH		
D.	HORIZONTAL AND INCLINED AREA INSPECTION		
71.	Horizontal Function of the COMB PLATE IMPACT DEVICE & SWITCH in Top		
72.	Vertical Function of the COMB PLATE IMPACT DEVICE & SWITCH in Top		
73.	Condition and Function of STEP JUMPING SWITCH in top		
74.	Condition and Function of Step missing sensor in TOP		
75.	Condition and Function of Skirt switch in Top LH & RH		
76.	Check the Handrail drive shaft chain tension (Slack should be 10 mm + 5mm) Actual mm		
77.	Condition of handrail shaft bearing in plumber block / pedestal block (Marking should be INLINE)		
78.	Check and maintain uniform gap between the handrail and Friction wheel		
79.	Skirt to Step gap (distance max.2.5 to 3.5 mm in one side / Gap should be equal in both LH & RH side)		
80.	Condition and function of STEP SAG SWITCH in top curve		
81.	Check the condition of anti static brush and proper contact with step shafts		
82.	Check the availability & contact of anti static roller with handrail.		
83.	Condition and Function of Step missing sensor in BOTTOM		
84.	Condition and Function of Handrail speed sensor		
85.	Check the gap between the chain roller and skirt bottom (It should be 0.5 to 1 mm) Actual mm		
86.	Condition and function of STEP SAG SWITCH in bottom curve		
87.	Horizontal Function of the COMB PLATE IMPACT DEVICE & SWITCH in bottom		
88.	Vertical Function of the COMB PLATE IMPACT DEVICE & SWITCH in bottom		
89.	Check Comb compression spring length in bottom side (It should be 60 mm)		
90.	Comb to Step gap (It should be 5 mm + 1mm) Actual mm		
91.	Condition and Function of Skirt switch in bottom LH & RH		
92.	Condition and Function of STEP JUMPING SWITCH in bottom		
E.	CLEANING CHECKS		
93.	Pit cleaning (Bottom pit & Top pit)		
94.	Cleaning of STEPS		
95.	Cleaning of Tracks (Step roller track & Chain roller track)		
96.	Check oil in handrail drive chain guard bottom (clean immediately)		
97.	Cleaning of Balustrade		
98.	Cleaning of laying wires		
99.	Cleaning of Oil in Bottom pit and Machine room top pit		
100.	Cleaning of Handrail pressure rollers		
101.	Cleaning of Floor plate (Top& Bottom)		
102.	Cleaning of Controller panel box and etc		
103.	Cleaning of bottom junction box		
104.	Cleaning of inner and outer decking		
105.	Cleaning of Handrail (using by wet cloth)		
106.	Cleaning of Handrail drive chain cover		
107.	Cleaning of main drive sprocket and assembly		
F.	PARTS TO BE LUBRICATED		
108.	Grease to be applied on step bush & between clamp rings on step fixing shaft		

Sl. No.	Description	OK/NOT OK/NA	Remark
109.	Grease to applied on nylon pad of steps		
110.	Grease to be applied on bearings on main drive shaft & handrail drive shaft (As per lubrication procedure from HO)		
111.	Oil to be lubricated on main drive chain & handrail drive chain		
112.	Oil to be applied on brake levers (Not Liner)		
113.	Oil to be applied on step chain links / Step roller bearings		

Railway Employee name:

Service Engineer Name:

Signature:

Signature:

L. Generic Escalator Maintenance Check List – Quarterly

Escalator serial No:

Location:

Sl. No.	Description	OK/NOT OK/NA	Remark
A.	TOP PIT / MACHINE ROOM AREA INSPECTION		
1.	Check the tightening of drive unit base mounting bolts (gear box base mounting bolts)		
B.	HORIZONTAL AND INCLINED AREA INSPECTION		
2.	Handrail drive chain tension adjustment bolt length should be equal in both LH & RH side (Check parallelness of the handrail drive shaft with main drive shaft)		
3.	Check the Length of the handrail pressure roller Spring tension. (Should be 55 mm) mm		
4.	Check the Condition & thickness of handrail drive wheel liner (Friction wheel liner) Thickness should be more than 8mm		
5.	Check the condition of SUB ROLLERS / Step guide rollers in TOP (It should not touch with steps, minimum 0.5 mm clearance is required)		
6.	Check the flushness of Skirt joint (Top of the chain roller & Step white bush side)		
7.	Check the condition of SUB ROLLERS / Step guide rollers in Bottom (It should not touch with steps, minimum 0.5 mm clearance is required)		
C.	CLEANING CHECKS		
8.	Cleaning of handrail support rollers inside the inner decking's		
D.	SAFETY CHECK OF CUSTOMER INTERFACING WORKS		
9.	Customer Safety Handrail – ENTRY & EXIT of the escalator Landings		
10.	Floor plate / Platform to customer floor level (FFL) at both Landings in Top and Bottom		
11.	Customer main earthing		
12.	3 phase main switch marked nearer to the Entrance		
13.	Water entry protection throughout the escalator Surroundings		
14.	Head guard provision for escalator inclined area		

Railway Employee Name:

Service Engineer Name:

Signature:

Signature:

Note: This Quarterly checklist should be used along with Monthly checklist

M. Generic Escalator Maintenance Check List – Half Yearly**Escalator serial No:****Location:**

Sl. No.	Description	OK/NOT OK/NA	Remark
A.	BOTTOM PIT INSPECTION		
1.	Condition of INSPECTION PENDANT		
2.	Rigid fixing of half round ' C ' track (Rivet & Screws)		
3.	Condition of half round “ C “ Track in Bottom LH & RH		
B.	TOP PIT / MACHINE ROOM AREA INSPECTION		
4.	Check the tightening of drive unit base mounting bolts (GEAR BOX BASE mounting bolts)		
5.	Check the clearance between FLY WHEEL and FLY WHEEL COVER		
6.	Check the Gear box oil level and condition Gear Oil changed date		
7.	Rigid fixing of half round ' C ' track in TOP (Rivet & Screws)		
8.	Condition of Half round “ C “ Track in Top LH & RH		
9.	Rigid fixing of TANGENT track		
10.	Check the clearance between Tangent track and step chain roller in 4 areas (It should be min. 0.5mm) LH top: mm, LH bottom : mm, RH top: mm, RH Bottom : mm		
C.	HORIZONTAL AND INCLINED AREA INSPECTION		
11.	Handrail drive chain tension adjustment bolt length should be equal in both LH & RH side (Check parallelness of the handrail drive shaft with main drive shaft)		
12.	Check the Length of the handrail pressure roller Spring tension. (Should be 55 mm) mm		
13.	Check the Condition & thickness of handrail drive wheel liner (Friction wheel liner), Thickness should be more than 8mm		
14.	Check the condition of sub rollers / Step guide rollers in TOP (It should not touch with steps, minimum 0.5 mm clearance is required)		
15.	Check the Handrail Plumber block / pedestal bearing housing mounting bolt tightness		
16.	Check the tightness of Friction wheel fixed bolts		
17.	Check the flushness of Skirt joint (Top of the chain roller & Step white bush side)		
18.	Check the Gap between Step sag trip poles and Step – 4 Nos. Gap :mm (It should be 5mm) in bottom curve		
19.	Check the condition of handrail guide bush		
20.	Check the Gap between Step sag trip poles and Step – 4 Nos. Gap :mm (It should be 5mm) in top curve		
21.	Check the condition of SUB ROLLERS / Step guide rollers in Bottom (It should not touch with steps, minimum 0.5 mm clearance is required)		
22.	Check gap between step to step meshing treads on horizontal & inclined portion. It should be max. 6mm Actual : mm		
D.	CLEANING CHECKS		
23.	Cleaning of handrail support rollers inside the inner deckings		
24.	Cleaning of Handrail guide and End reversing chain		
25.	Cleaning of Main drive unit and drive chain		
26.	Cleaning of Handrail drive chain		
E.	PARTS TO BE LUBRICATED		
27.	Grease to be applied on bearings on main drive shaft & handrail drive shaft (As per lubrication procedure from HO)		
F.	SAFETY CHECK OF CUSTOMER INTERFACING WORKS		
28.	Customer Safety Handrail – ENTRY & EXIT of the escalator landings		
29.	Floor plate / Platform to customer floor level (FFL) at both Landings in Top and Bottom		
30.	Customer main earthing		



Sl. No.	Description	OK/NOT OK/NA	Remark
31.	3 phase main switch marked nearer to the Entrance		
32.	Water entry protection throughout the escalator surroundings		
33.	Head guard provision for escalator inclined area		

Railway Employee Name:

Service Engineer Name:

Signature:

Signature:

Note: This Half Yearly checklist should be used along with Quarterly and Monthly Checklist.

N. Generic Escalator Maintenance Check List – Yearly

DATE: Escalator serial No:

Location:

Sl. No.	Description	OK/NOT OK/NA	Remark
A.	BOTTOM PIT INSPECTION		
1.	Condition of INSPECTION PENDANT		
2.	Rigid fixing of half round ' C ' track (Rivet& Screws)		
3.	Condition of half round “ C “ Track in Bottom LH & RH		
4.	Check the availability and condition of chain link circlips.		
B.	TOP PIT / MACHINE ROOM AREA INSPECTION		
1.	Check the tightening of drive unit base mounting bolts (GEAR BOX BASE mounting bolts)		
2.	Check the clearance between FLY WHEEL and FLY WHEEL COVER		
3.	Check the Gear box oil level and condition Gear Oil changed date		
4.	Rigid fixing of half round ' C ' track in TOP (Rivet& Screws)		
5.	Condition of Half round “ C “ Track in Top LH & RH		
6.	Rigid fixing of TANGENT track		
7.	Check the clearance between Tangent track and step chain roller in 4 areas (It should be min. 0.5mm) LH top: mm, LH bottom : mm , RH top: mm, RH Bottom : mm		
8.	Condition & tightening of MAIN DRIVE SPROCKET BOLT & TEETH		
C.	HORIZONTAL AND INCLINED AREA INSPECTION		
9.	Handrail drive chain tension adjustment bolt length should be equal in both LH & RH side (Check parallelness of the handrail drive shaft with main drive shaft)		
10.	Check the Length of the handrail pressure roller Spring tension.(Should be 55 mm) mm		
11.	Check the Condition & thickness of handrail drive wheel liner (Friction wheel liner), Thickness should be more than 8mm		
12.	Check the condition of SUB ROLLERS / Step guide rollers in TOP (It should not touch with steps, minimum 0.5 mm clearance is required)		
13.	Check the Handrail Plumber block / pedestal bearing housing mounting bolt tightness		
14.	Check the tightness of Friction wheel fixed bolts		
15.	Check the flushness of Skirt joint (Top of the chain roller & Step white bush side)		
16.	Check the Gap between Step sag trip poles and Step – 4 Nos Gap : mm (It should be 5mm) in BOTTOM CURVE		
17.	Check the condition of HANDRAIL GUIDE BUSH		

Sl. No.	Description	OK/NOT OK/NA	Remark
18.	Check the Gap between Step sag trip poles and Step – 4 Nos Gap : mm (It should be 5mm) in TOP CURVE		
19.	All fasteners are tightened properly (comb plate locknuts , skirt panels, balustrade brackets, Drive unit , Track to rail support , Tension rod on bottom, pressure roller fixing cleats etc)		
20.	Check the flush between the Step chain track and step chain in bottom curve area		
21.	Check the track joint & Flushness		
22.	Check the condition of SUB ROLLERS / Step guide rollers in Bottom (It should not touch with steps, minimum 0.5 mm clearance is required)		
23.	Check for gap between step to step meshing treads on horizontal & inclined portion. It should be max. 6Mm Actual : mm		
24.	Check the Leveling of STEPS (Using by 1 feet spirit level)		
D.	CLEANING CHECKS		
25.	Cleaning of handrail support rollers inside the inner deckings.		
26.	Cleaning of Handrail guide and End reversing chain		
27.	Cleaning of Main drive unit and drive chain		
28.	Cleaning of Handrail drive chain		
29.	Cleaning of Step chain LH & RH		
E.	PARTS TO BE LUBRICATED		
30.	Grease to be applied on bearings on main drive shaft & handrail drive shaft (As per lubrication procedure from HO)		
F.	SAFETY CHECK OF CUSTOMER INTERFACING WORKS		
31.	Customer Safety Handrail – ENTRY & EXIT of the escalator landings		
32.	Floor plate / Platform to customer floor level (FFL) at both Landings in Top and Bottom		
33.	Customer main earthing		
34.	3 phase main switch marked nearer to the Entrance		
35.	Water entry protection throughout the escalator surroundings		
36.	Head guard provision for escalator inclined area		
G.	GENERAL INSPECTION		
37.	Operational instruction given to Customer		
38.	Training for escalator operation to customer representatives		
39.	Cables routing inside the escalator from top to bottom		
40.	Availability of circuit stickers inside the controller cover		
41.	Passenger circulation should be available in around the escalator		
H.	KEY AREA POINTS FOR NOISE INSPECTION		
42.	All track joint noise		
43.	step bush noise		
44.	End reversal chain noise		
45.	Motor & Gear box noise		
46.	Roller noise on steps		
47.	Handrail noise		
48.	Step chain rollers on return track section on top & bottom at four corners		
49.	Drive chain noise		
50.	Skirt to step noise		
51.	Bearing noise on main drive shaft & handrail drive shaft		
52.	C-section of skirt panel to step chain rollers		
53.	Step chain noise		

Railway Employee Name:

Service Engineer Name:

Signature

Signature:

Note: This Yearly checklist should be used along with Half Yearly, Quarterly and Monthly Checklist.



लिफ्ट/ एलिवेटर के उपयोगकर्ताओं के लिए सुरक्षा निर्देश INSTRUCTIONS WHILE USING LIFT/ ELEVATOR

DO's/ करें



UP या DOWN बटन दबाने से पहले अपने गंतव्य को जानें।
KNOW YOUR DESTINATION BEFORE PRESSING UP OR DOWN BUTTON.



एक तरफ खड़े होकर पहले अन्दर के यात्रियों को बाहर निकलने दें।
STAND ASIDE LET THE PASSENGER EXIT FIRST.



बच्चों का हाथ हमेशा पकड़ कर रखें।
HOLD CHILDREN FIRMLY



जरूरतमंद जैसे कि वृद्ध, विकलांग आदि को वरीयता दें।
GIVE PREFERENCE TO NEEDY i.e. Sr.CITIZENS, HANDICAPPED etc.



प्रवेश अथवा निकास के समय अपने कदमों का ध्यान रखें।
WATCH YOUR STEPS CAREFULLY BEFORE ENTER AND EXIT.



फ्लोर इंडिकेटर पर ध्यान रखें।
PAY ATTENTION TO THE FLOOR INDICATORS.



सहायता के लिए अलार्म/ हेल्प बटन को दबाएँ या टेलीफोन/ इंटरकॉम का उपयोग करें
USE THE ALARM/HELP BUTTON, OR TELEPHONE/ INTERCOM TO CALL FOR ASSISTANCE.

DON'Ts/ न करें

बंद होते दरवाजे को रोकने का प्रयास न करें।
DON'T TRY TO STOP A CLOSING DOOR.



यदि लिफ्ट भरी हो तो प्रवेश न करें, कृपया प्रतीक्षा करें।
DON'T ENTER IF THE LIFT IS FULL, WAIT FOR THE NEXT.



लिफ्ट के अंदर या आसपास बच्चों को न खेलने दें।
DON'T ALLOW CHILDREN TO PLAY IN OR AROUND THE LIFT.



जब लिफ्ट दो तलों के बीच रुक जाए तब घबराएं नहीं, धैर्य रखें।
DON'T PANIC, REMAIN PATIENT WHEN LIFT STOPS BETWEEN THE FLOORS.



दरवाजों को जबरदस्ती खोलने की कोशिश न करें एवं न ही लिफ्ट को छोड़ने का प्रयास करें
DON'T ATTEMPT TO FORCE OPEN THE DOORS AND TRY TO LEAVE THE LIFT.



इमारत में आग लगने पर लिफ्ट का उपयोग न करें। सीढ़ियों या आपात निकास का ही उपयोग करें।



DON'T USE LIFT IN CASE OF FIRE IN THE BUILDING. USE THE STAIRS OR EMERGENCY EXIT.



INDIAN RAILWAYS
Centre for Advanced Maintenance Technology
MAHARAJPURA, GWALIOR, M.P. - 474005



स्वचालित सीढ़ियों के उपयोग कर्ताओं के लिए सुरक्षा निर्देश SAFETY INSTRUCTIONS WHILE USING ESCALATOR

DO's/ करें



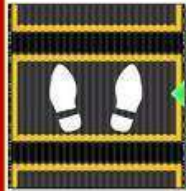
हैंडरेल (रेलिंग) को पकड़ें
HOLD THE HANDRAIL



एस्केलेटर के निकास क्षेत्र
से तुरंत निकलें।
KEEP WALKING
AFTER YOU STEP OFF



बच्चों का हाथ हमेशा
पकड़ कर रखें।
HOLD CHILDREN
FIRMLY



सीढ़ियों पर पीली लाइनों
के अंदर खड़े हों।
STAND WITHIN THE
YELLOW LINES



यात्रा की दिशा की ओर मुंह
रखें
FACE TOWARDS
DIRECTION OF TRAVEL



आपातकालीन स्थिति में "आपातकालीन लाल स्टॉप बटन" दबाएं।

IN CASE OF EMERGENCY PRESS "RED EMERGENCY STOP BUTTON"



INDIAN RAILWAYS
Centre for Advanced Maintenance Technology
MAHARAJPURA, GWALIOR, M.P. - 474005



DON'Ts/ न करें

एस्केलेटर पर न दौड़ें।

DO NOT RUN ON
ESCALATOR



भारी सामान या व्हील चेयर
ना ले जायें।

DO NOT CARRY HEAVY
LUGGAGE OR WHEEL
CHAIR



एस्केलेटर की सीढ़ियों पर कभी
न बैठें चाहे वो चालू हो या बंद।
NEVER SIT ON THE
ESCALATOR STEP EITHER
MOVING OR NOT.



मोबाइल फोन का प्रयोग न
करें।

DO NOT USE MOBILE
PHONE



बंद एस्केलेटर का प्रयोग
सीढ़ियों के तौर पर न करें।

DON'T USE AN
INOPERATIVE ESCALATOR
AS A STAIRWAY.



CHAPTER-7

GREEN BUILDING CONCEPTS & CERTIFICATION

7.1 Introduction

Green building (also known as green construction or sustainable building) refers to both a structure and the application of processes that are environmentally responsible and resource-efficient throughout a building's life cycle: from planning to design, construction, operation, maintenance, renovation, and demolition.



7.2 Translating energy use to savings and environment by way of Green Buildings

Incorporating Active and Passive Strategies in the home can yield energy savings. These savings lead to reduction in energy bills. Due to low operating costs, these savings can accrue overtime to provide homeowners additional benefit. With improved efficiency, your home can see appreciation of real estate value as well. In addition to direct monetary benefits, the energy saving strategies can provide you a comfortable environment. This can lead to a positive impact on the physical and mental well-being thereby improving productivity and reducing health related costs.

Eco Niwas calculates annual energy and cost savings for the building. It compares the energy use of the home to a typical home and applies the cost of energy (in Rs/unit) to show financial savings. Use Eco Niwas to find out which strategy can yield highest savings!

The electricity we receive at our homes uses coal. This coal is burnt at thermal power stations to generate electricity. The process releases harmful emissions into the air. Therefore, when we use electrical appliances or other electrical equipment we are indirectly releasing emissions and affecting our environment.

The energy we save goes a long way in protecting the environment. Firstly, we avoid the unnecessary emissions linked to electricity generation. Secondly, we are preserving natural resources like forests and wildlife that are affected due to mining activities. Finally, the released emissions and receding forests have health impacts on communities residing close to these mining areas.



Eco Niwas calculates the potential of avoiding emissions through energy efficiency strategies. It uses emission factor to calculate avoided emissions. Emission factor is a metric used to calculate amount of carbon-di-oxide equivalent (CO₂) emissions for every unit of electricity generated. Use Eco Niwas to find out which strategy is most helpful in avoiding emissions.

7.3 Passive strategies in Building Design

Heat flow, in and out of the building through its walls and roofs is faster when the temperature difference between the outdoor and indoor is greater and when wall and roof area exposed to outside is more and the wall, roof or floor material itself are good conductors of heat

Various cost effective passive design methods described below can be inculcated in the design of your homes to bring down the electricity consumption and to increase the comfort-level.

7.3.1 Building Envelope

The “building envelope” of the house includes the outside walls, windows, doors, roof, skylights, etc. of the home. It is the skin of the house and helps protect everything inside it. The kind of building envelope chosen will determine how comfortable the home remains at different times of the day, night and during the year. This is because a well-designed building envelope keeps the home as warm, cool, or lit as we want for longer, so that we do not have to use heaters, air-conditioners or indoor lighting as often.

Understanding how heat flows helps us understand how our houses’ building envelope will function. Heat moves from a warm to a cool space. This flow of heat occurs if the building envelope is not designed to suit the climate in which we live, and can cause discomfort especially during peak summer or winter, when the difference in temperature inside and outside your home is significant (Fig. 1).

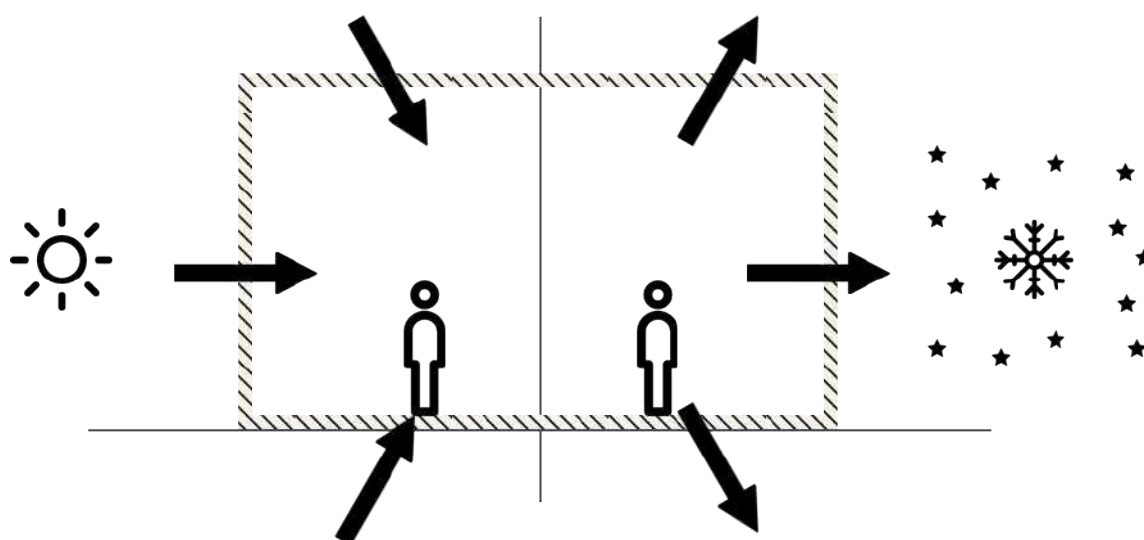


Fig. 1 – Building Envelope and Energy Exchange

7.3.2 Orientation

Orientation is the direction the home faces. It is usually preferred that homes are oriented towards gardens, green spaces and beautiful views. Sometimes the need for comfort also dictates how rooms are arranged, where windows are placed and when spaces are used (Fig. 2).

Orienting the building, its spaces and windows can help to achieve naturally lit, ventilated and comfortable rooms through the day and around the year.

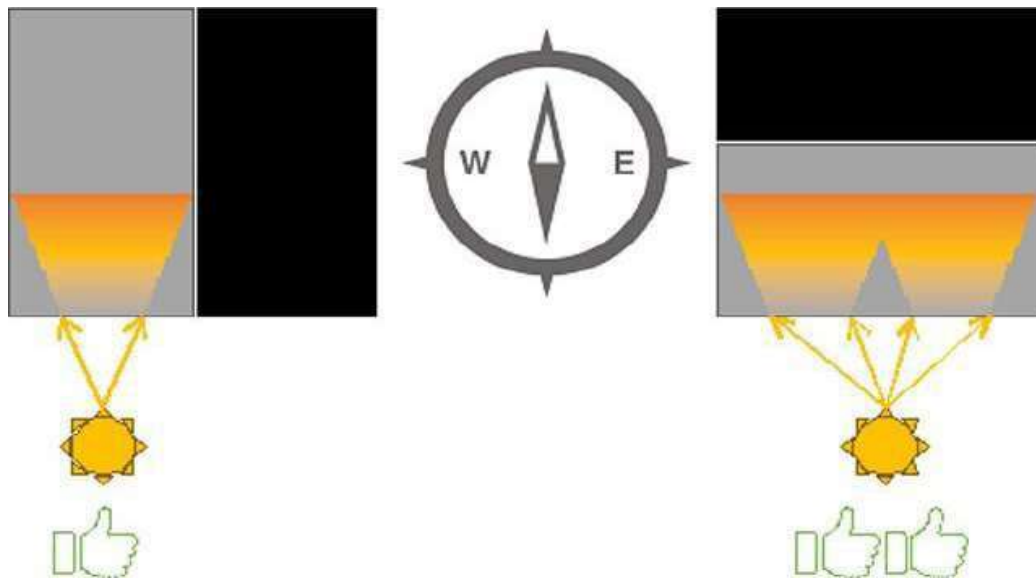


Fig. 2 – Impact of layout arrangements and orientation

7.3.3 Orientation for Daylight

Frequently used spaces that must be well lit, such as living rooms, should face North-South. Window that face the North provide comfortable, glare free light. South facing windows also provide ample sunlight, but they will also heat up your rooms, and are especially helpful in colder climates. East and West facing windows bring in both heat and glare and should be avoided (Fig. 3).

While windows help in bringing daylight, shading is required to get maximum benefit.

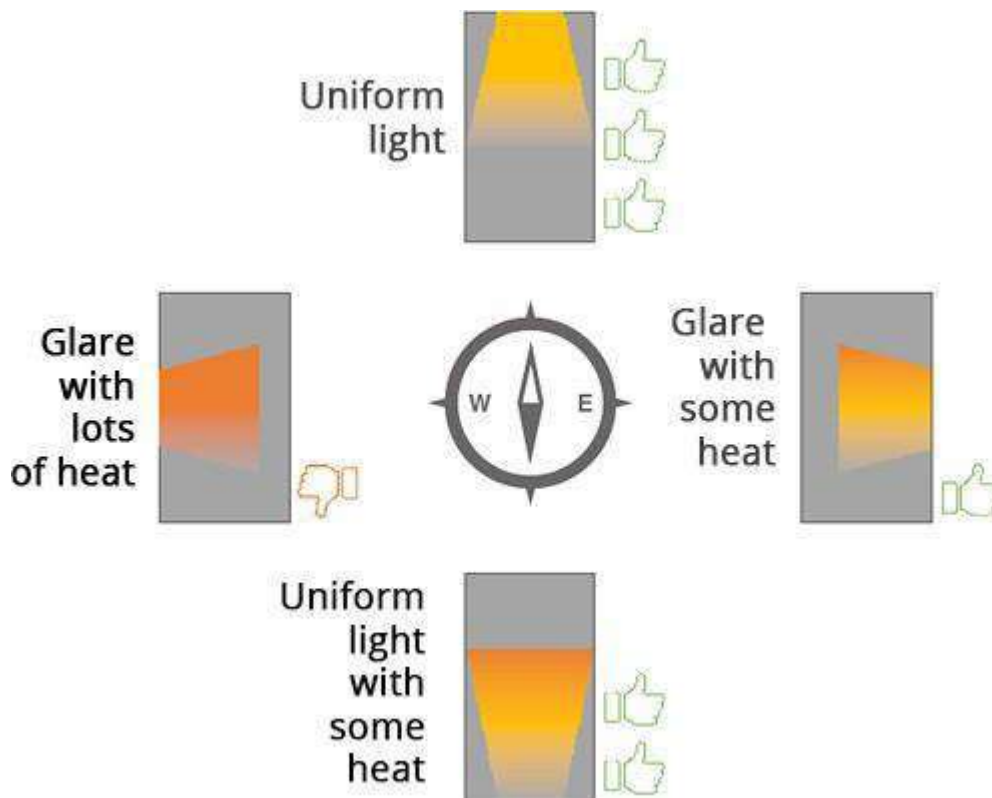


Fig. 3 – Impact of orientation on heat and light coming into the building

7.3.4 Orientation for Thermal Comfort

The weather can often be harsh, either too hot or too cold. The home can mitigate the effects of weather and orientation of the home has an important role to play. This is because the direction your house faces has affects how much heat and light it takes in.

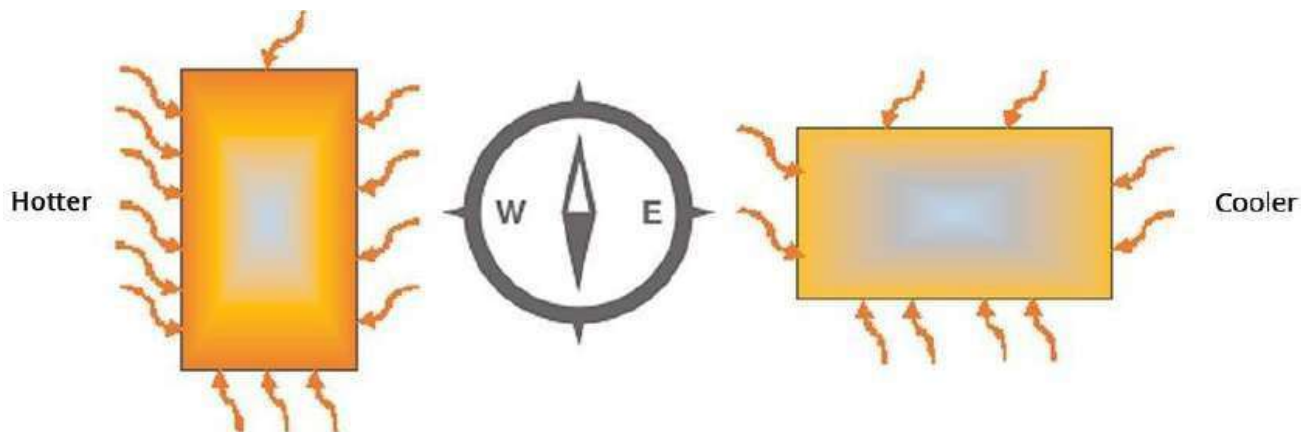


Fig. 4 – Impact of orientation on heat flowing into a building

The rooms which family uses frequently should preferably face away from the rising and the setting sun (East and the West directions respectively as shown in Fig. 4). This would reduce the heat of the sun falling over the building. Only rooms not meant for longer periods of occupancy, such as storerooms, staircases, bathrooms, and etcetera may face the setting sun.

7.3.5 Shading

Shades protect the home from direct sunlight and rain. Shades are temporary or permanent structures such as horizontal or vertical projections around the window, which protect the home from direct sunlight and rain. Even a verandah or projected roof acts as a shade.

7.3.6 External Shading Devices

The most effective solution for shading your home is to add an external shading device such as an overhang or a fin that would stop the sunrays from falling onto the glass surface altogether. An overhang is a horizontal projection above the window, while a fin is a vertical projection on the window sides (Fig. 5). Both are shades that protect your windows from direct sunlight. These features must be carefully designed considering what time of the year and between what hours of the day shading is necessary for your home.

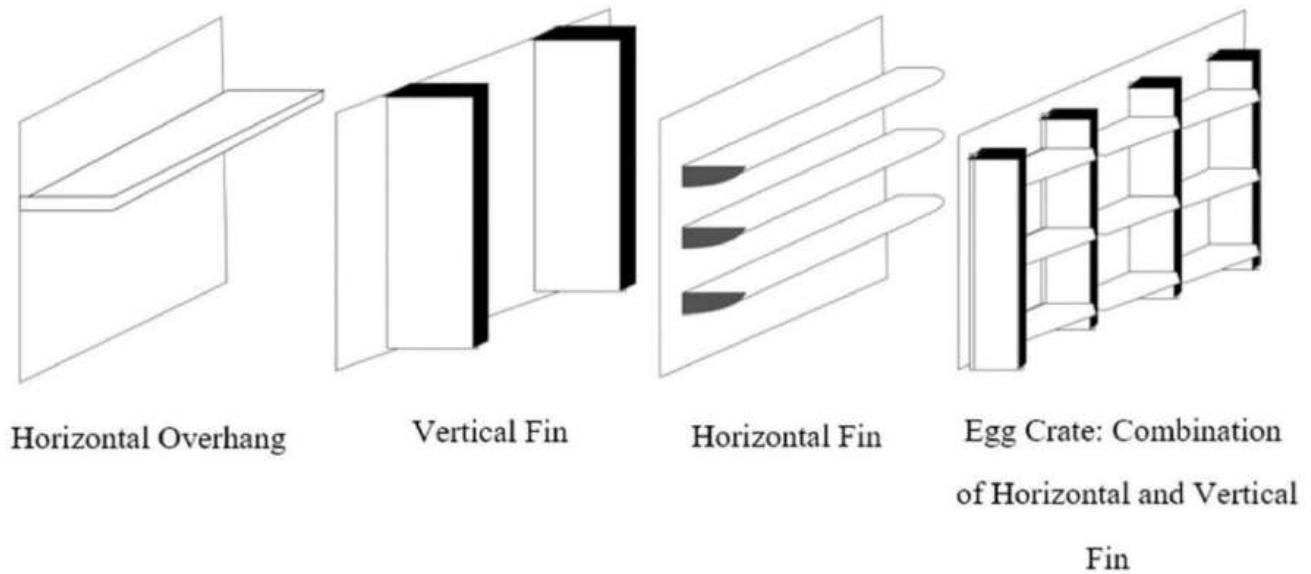


Fig. 5 – Shading Devices

Extended roof, horizontal overhangs over the windows are effective in shading the overhead afternoon sun (beaming in from south and south-west). Combination of fins and overhangs, and plants can be used for protection from rising and the setting sun (beaming in from east and west). These devices can be designed to be fixed or moveable, so that it can be adjusted according to the home's shading requirements. North facing windows require minimal shading, as they do not receive direct sun for most part of the year (Fig. 6). In cold places, windows can be unshaded to receive the sun.

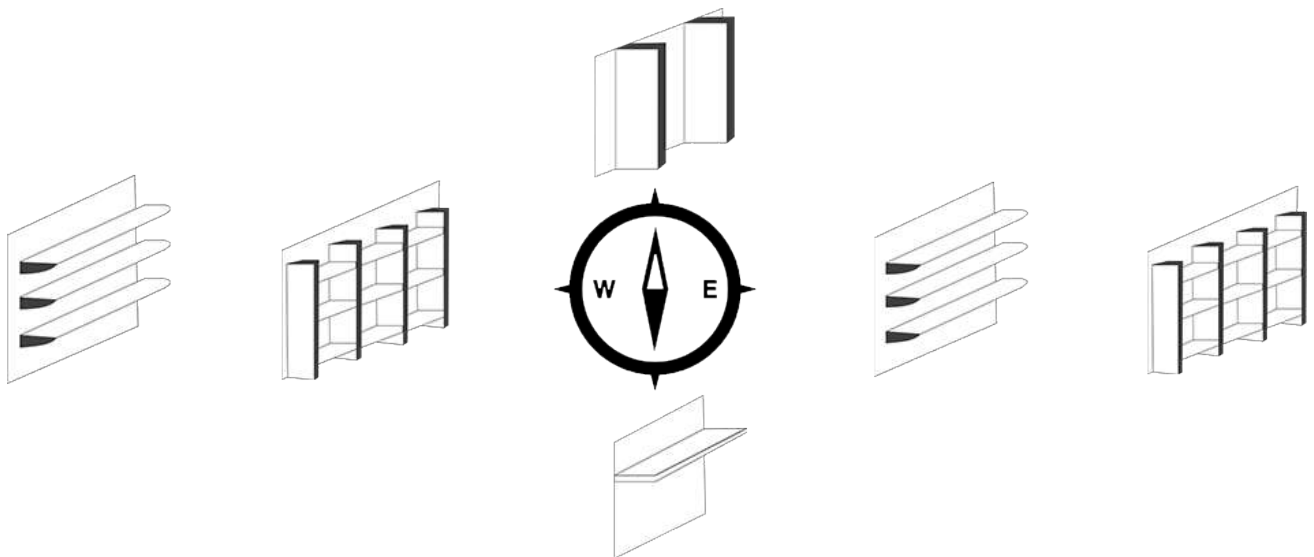


Fig. 6 – External Shading Devices and their Applicability as per Orientations

7.3.7 Internal Blinds and Curtains

Curtains and blinds help make the home more welcoming and beautiful and can help to control the space to meet the requirements. For example, one could pull the blinds when there is need an afternoon nap, but draw them away when one would like to study. However fundamentally, the external shade is the first line of defense against direct sun and heat, while the internal blinds can help in exercising finer control over how much heat and light one wants to allow into the room.

7.3.8 Insulation

Insulation is a bad conductor of heat, i.e. it is difficult for heat to travel through it. It is applied in buildings to regulate temperature inside the home, irrespective of outside conditions. For example, in hot climates, insulation helps in limiting heat from entering the building, while in cold climates, insulation helps in keeping the heat inside the building (Fig. 7).

When the building is not insulated, we usually use room heaters/coolers to keep our homes at comfortable temperature with respect to the outside conditions. This essentially means that there is an exchange of heat energy between the home and the outside environment. The building envelope of the home acts as a medium for this exchange. Obstructing this exchange, especially during harsh weather (summers or winters), can help to reduce the reliance over these mechanical heaters/coolers, while also reducing the electricity bills. Insulating the building envelope can help in obstructing heat exchange.

Building with Poor Insulation or No Insulation



Building Insulation with Fiberglass Insulation



Fig. 7 – Impact of insulation. (Insulated vs Uninsulated home)

Insulating materials can be applied on walls, roofs, windows and sometimes even the floor of the home.

For walls and roofs, insulation can be achieved by:

choice of appropriate material,

adding commercially available insulation products, or,

constructing roof and wall with air cavities in them. This is because air is a bad conductor and therefore building air pockets into the walls and roof of the home will help insulate it.



Fig. 8 – Insulation Products Available for Roof and Wall Assemblies

For windows, insulation can be achieved by selecting the right material for frames and insulated glass.

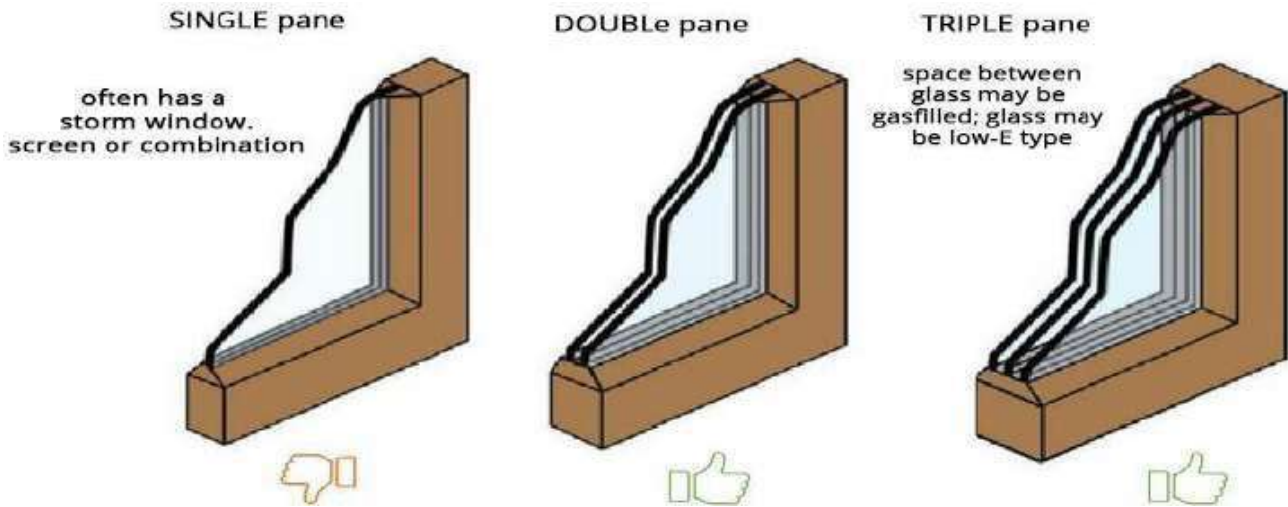


Fig. 9 – Different Glazing Types. Insulated Glazing is preferred (double or triple)

Glass traps some of the Sun's heat that enters through it leading to high temperature indoor. This is the reason spaces enclosed by glass in a hot climate need increased air conditioning. Heat gain through windows can also be reduced by using special glass. With technological advancements, new varieties of glass that reduce the incoming heat have been developed such as – heat reflecting glass, tinted glass, glass filled glazing etc. However, you may wish to consider proper shading for your home first as that will effectively reduce the need for more expensive options such as these glasses. Such glasses will come to your aid in case shading is not an option for your home.

Finally, while constructing your house, you must ensure that there are no air-gaps between the wall, roof and windows. This is because air-gaps will allow air to enter your home from outside, or allow it to leave from inside your home.

7.3.9 Day Light

Daylight is essentially sunlight. Daylight has the potential of naturally lighting our spaces during the daytime to avoid use of artificial light sources like bulbs, tube-lights, etcetera. This can help in reducing energy use, and therefore electricity bills for lighting during daytime. In addition to financial savings in electricity bills, daylight also promotes physical and mental well-being and its impact on productivity has been well established.

Daylight enters the space through windows. Mindfully placed windows, shades and room arrangements can improve the quality of daylight entering your home. You can adopt the following strategies to improve the quality of daylight in your home:

- i. Frequently used spaces in your home should have windows opening to the outside, and you must take care to provide necessary shading to screen your home from excessive daylight in case you live in a warm climate.

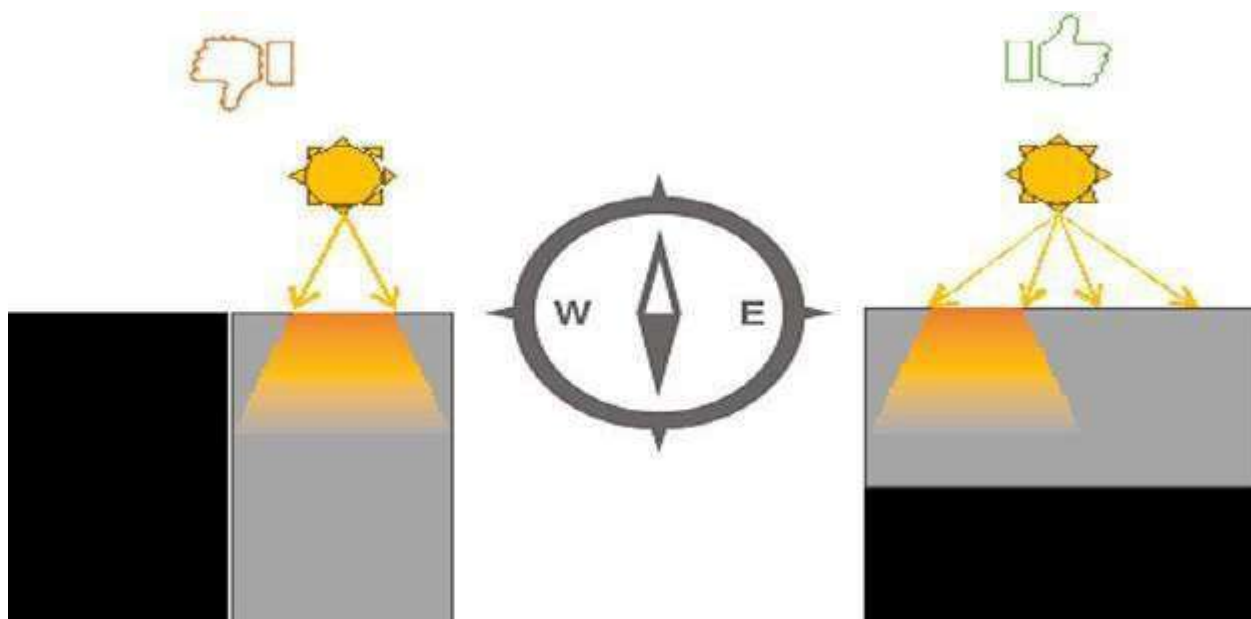


Fig. 10 – Frequently used rooms should face outside, preferably North/South

- ii. Areas of your home that are used often should face North/South. North facing windows provide uniform, glare-free light and require minimal shading.

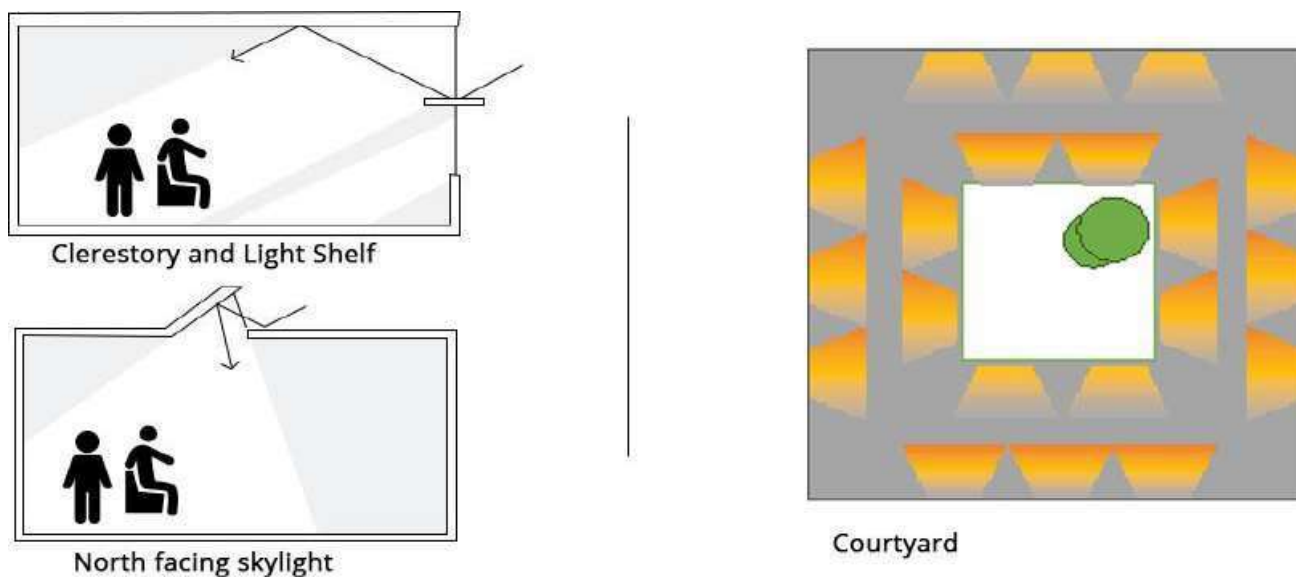


Fig. 11 – North-South facing rooms have better daylight quality

- ii. While designing your home, you must avoid very large rooms because brightness of light diminishes as we go away from the window.

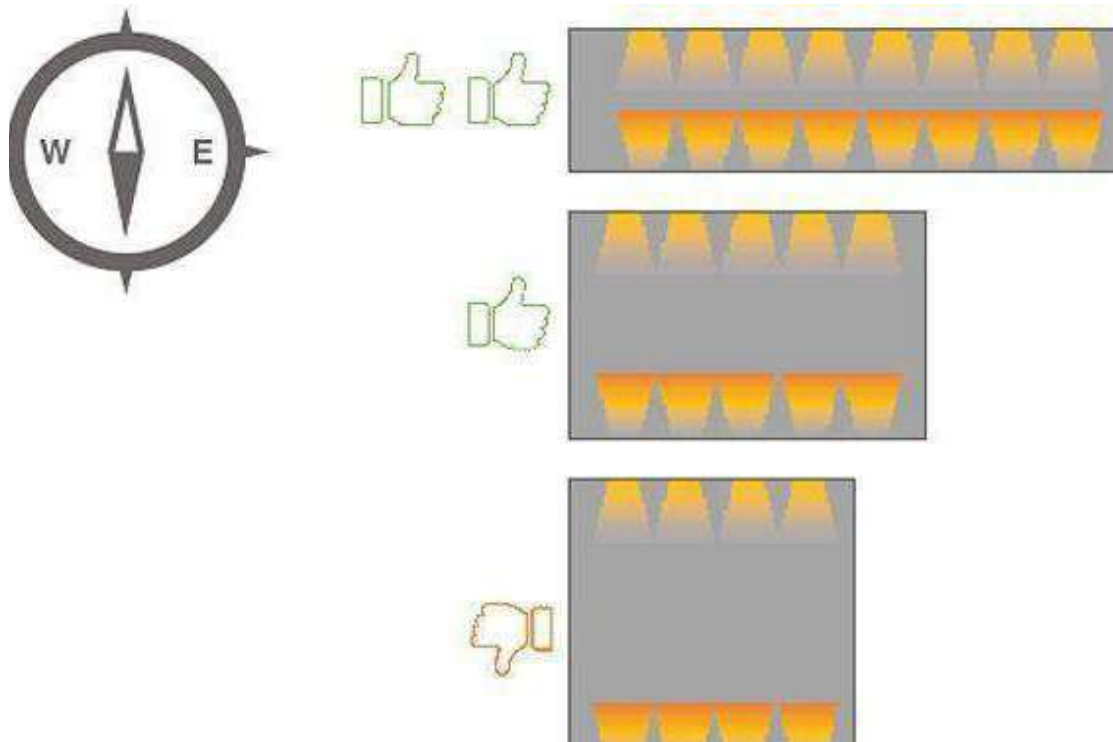


Fig. 12 – Area being naturally lit reduces as we build deep spaces

- iv. Use of high windows (clerestory), north facing windows (north lights), reflective shades and proper arrangement of windows and integrating courtyards can improve the quality of daylight.

Fig. 13 – High windows, courtyards, etcetera are few strategies that assist in improving natural light

- v. Use of reflective and light-colored surfaces inside your home can help enhance the quality of daylight. Walls and ceilings which are light colored scatter light better and allow for more uniform distribution of light, which will make your home brighter and more comfortable.

The window area needs to be designed so as to strike a balance between natural light and the possible incoming heat through glass. Shading devices discussed earlier, along with obstructing heat from directly falling on the windows also reduce the occurrence of harsh light inside the rooms, and thus are an important aspect of climate responsive design.

7.3.10 Natural Ventilation

We inhale oxygen and exhale carbon-di-oxide (CO_2), this is called the respiration process. When we are indoors, the level of CO_2 in the air increases due to the respiration cycle. Along with CO_2 , body odor, moisture and other pollutants within the house make the air inside stale. Breathing stale air is unhealthy. To maintain freshness in space, the stale air must be replaced by fresh air regularly. Fresh outdoor air, is taken from the external environment, and the replaced indoor air in turn carries away with it the pollutants from inside your home. This process of replacing stale air inside your home with fresh air from the environment outside through windows and door openings, without the use of fans is Natural Ventilation.

In hotter places natural ventilation also help bring the room temperature down. This cooling effect can help reduce use of fans, coolers and avoid air-conditioners to significantly bring down your energy bills. You can employ the following strategies to improve the natural ventilation in your home:

- i. You can design openings (such as windows) in your home's building envelope so that they are in the path of wind flows from outside.

- ii. These openings must be placed at a suitable height in the direction of the natural breeze outside your home to allow air to flow through your rooms at body level to help make you feel more comfortable.

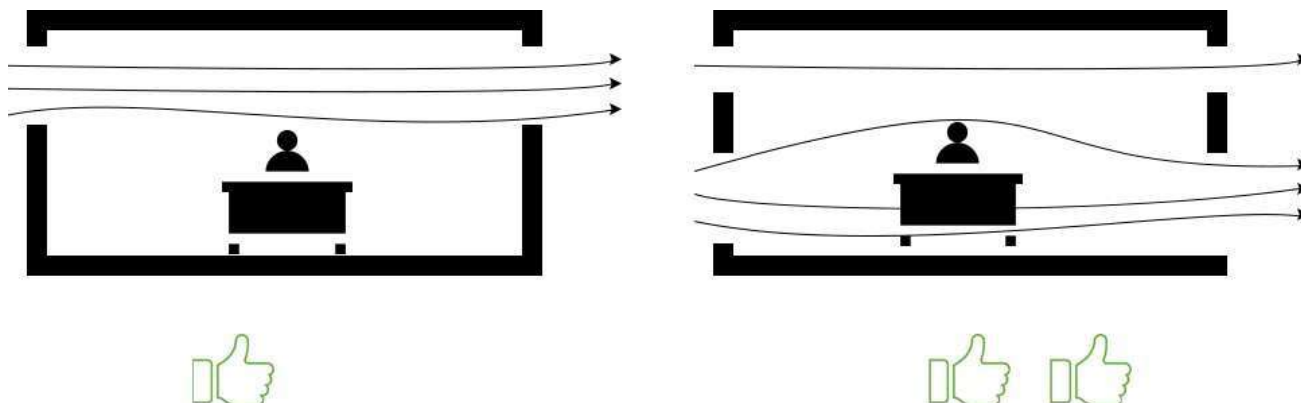


Fig. 14 – Winds flowing at suitable height improve comfort

- iii. Place windows to facilitate wind circulation throughout the space. When wind flows in from one side, circulates through the space and exits from an opposite side, it is called Cross Ventilation. Cross Ventilation improves ventilation by distributing the flow of air throughout the space.

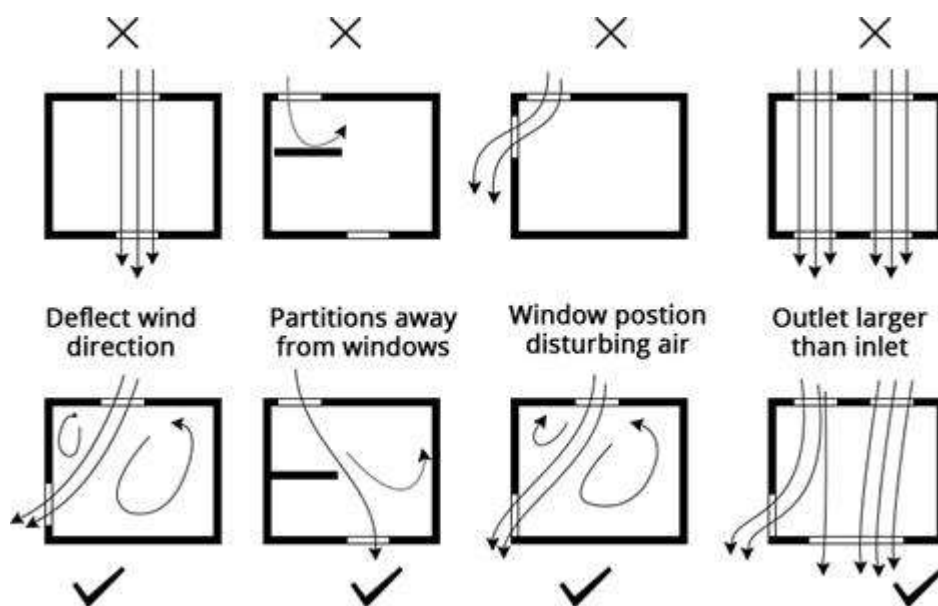


Fig. 15 – Strategies to improve ventilation through appropriate window placement

- iv. You can enhance the flow of air inside your home by using 'jaalis' (lattice wall) and ventilators. Smaller windows funnel air into your home. Air passing through these small windows speeds up towards a larger opening in the opposite wall that serves as an exit. This engineered wind flow makes your home cooler. Traditionally, this was practiced in hot climates with 'jaalis'. 'jaalis' are small apertures, that aid in accelerating passing wind passing to enhance ventilation.

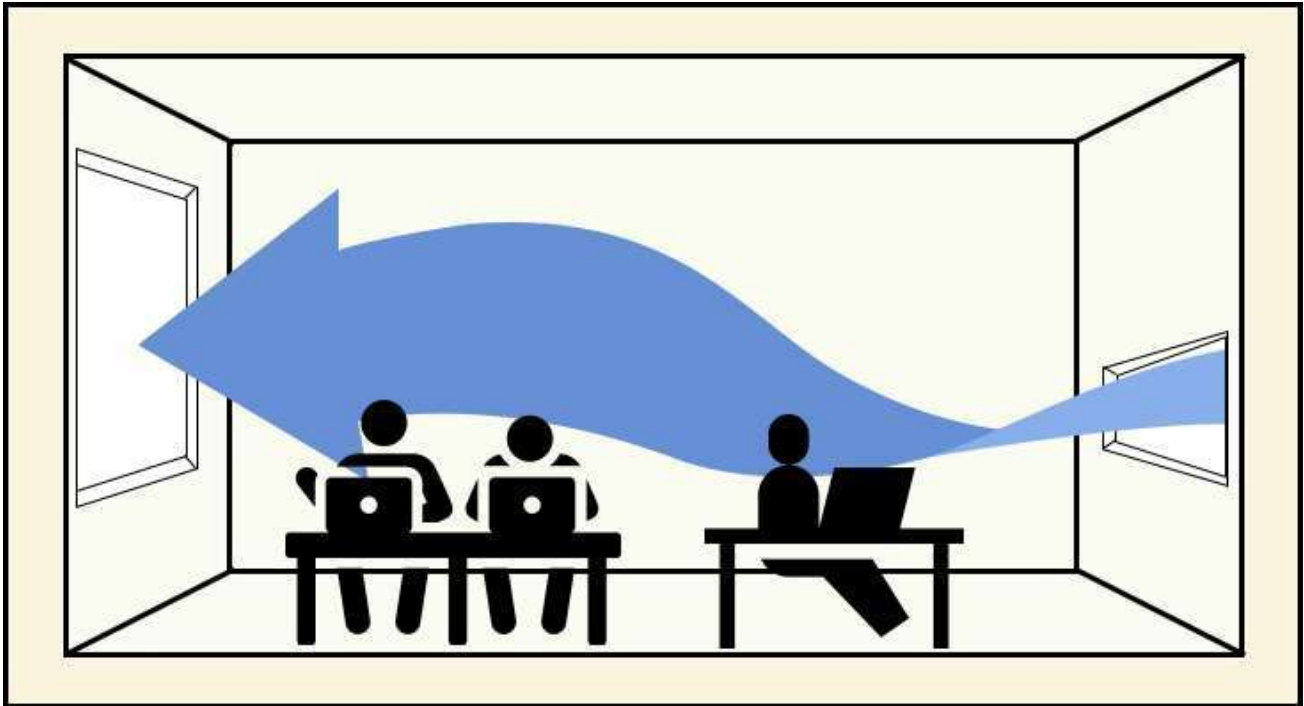


Fig. 16 – Winds speed up as they pass from smaller to larger windows.

- v. High openings such as clerestory windows and ventilators act as effective exhausts for the hot air that accumulates near the ceiling of your home. Warmer air is lighter than cooler air, and therefore it rises up. This concept of rising hot air is called the Stack effect.

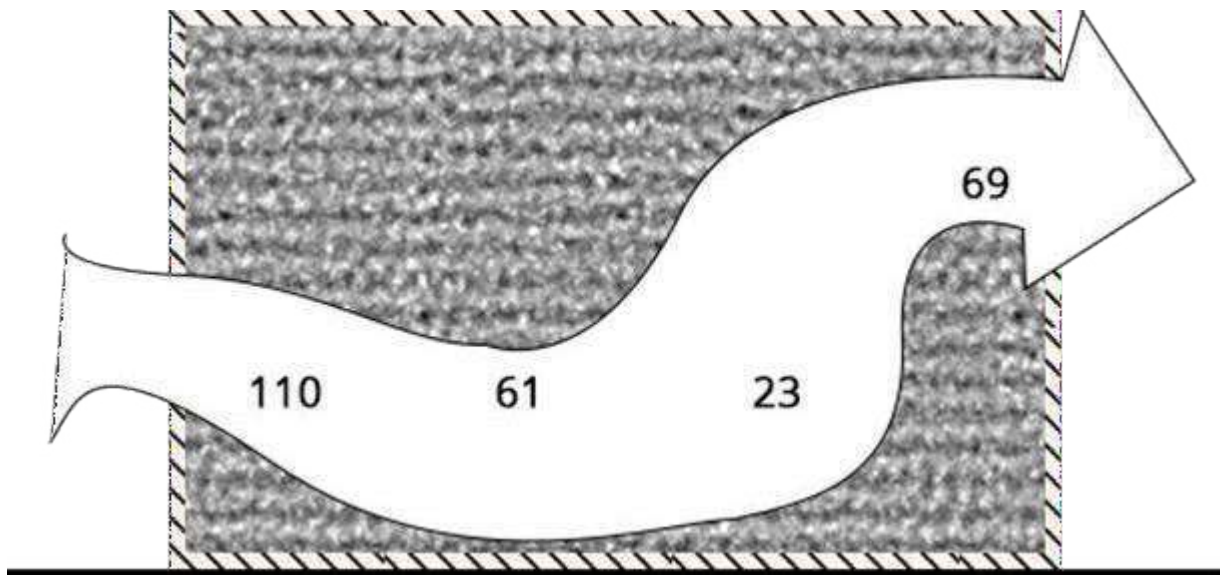


Fig. 17 – Windows near the ceiling aid in removing accumulated hot air.

In humid climates such as in Coastal regions, ventilation can bring in much needed relief, because cool breeze replaces moist warm air faster away from our bodies causing the sensation of comfort. In desert like climates, natural ventilation can bring in unwanted heat as well which can cause discomfort. Wind passing over water bodies or through ‘khus’ pads, like in desert coolers, can provide cooler air. In colder areas, cold winds can cause discomfort. Obstructions around the house may be used to slow the cold winds. In the plains, which see both hot summers and cool winters, the in-between period is especially suited for natural ventilation when ‘Natural cooling’ can help avoid use of air-conditioners.

7.3.11 Cool Roof

‘Cool’ roofs are used in hotter climates. As the name suggests they prevent heat from entering your home. The roof is exposed to sun throughout the day, it heats up during the day and passes this heat inside. As the name suggests, cool roofs keep the heat out. In case you live in a warmer climate, in addition to shading and providing insulation, selecting the right roof finish can significantly reduce the need for cooling your home. Cool roofs reflect most of the solar radiation falling on the rooftops. These can be implemented in three ways.

7.3.12 Green Roofs

Green roofs are gardens cultivated on terraces. The soil and the plants will help in insulating your roof, which will reduce your home’s overall heating and cooling costs. These roofs can reduce “urbanheat island” effect – An urban heat island (UHI) is an urban area that is much warmer than its surrounding rural areas due to human activities. A green roof reduces the level of heat absorbed by a building, and helps reduce the UHI effect for your home. In increasingly urbanized spaces, Green roofs also provide you with easily accessible green spaces.

7.3.13 Reflective Surface

Your roof can be transformed into a cool roof by painting it with white reflective paint and overlaying the surface with white ceramic broken tiles etc.

Thus, installing a cool roof will reduce the need for air conditioning and make buildings more comfortable for your family.

7.4 Active strategies in Building Design

7.4.1 Air Conditioning

We often use heating and/or cooling equipment in our homes to provide a comfortable living environment for our families. In a carefully designed building, the walls, roofs, windows and interiorsurfaces alone can maintain comfortable interior temperatures for a large part of the year. Sometimes, however we also require a certain level of moisture (humidity), air speeds and air qualityto feel comfortable and these can be achieved by mechanical systems.

Air conditioning systems transport heat, that is, they move it from one place to another. Heat is removed from a space such as your bedroom to provide cooling and released outside. Mechanical cooling permits to move heat from a place with lower temperature (inside the building) to a place with higher temperature (outside the building), which would otherwise be impossible.

Air conditioning systems consume large amounts of energy for operation leading to high electricity bills and contain refrigerants which are greenhouse gases responsible for climate change. We should aim to reduce if not eliminate our dependency on these mechanical systems. While purchasing these systems you can choose the most appropriate options for your requirements and help enhance the comfort of your home.

7.4.2 Most commonly used air conditioning systems for homes are:

Unitary Air-Conditioners

Unitary Air-Conditioners or Window Air-Conditioners are normally used for cooling individual rooms and provide cooling only when needed. Room air-conditioners house all the components of an air conditioning system in one box. As the name suggests they are installed in the windows.

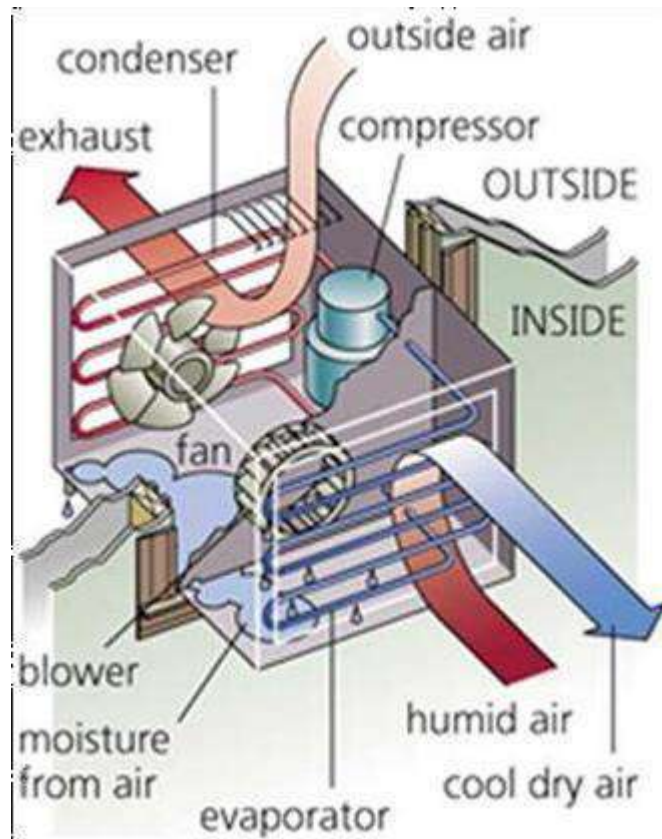


Fig. 18 – Room air-conditioner

7.4.3 Split-System Air-Conditioners

A split AC system has two parts, one placed outside the room which contains the cooling equipment and another part which is placed inside the room, which contains a fan to take in heat from the room, and supply cool air.

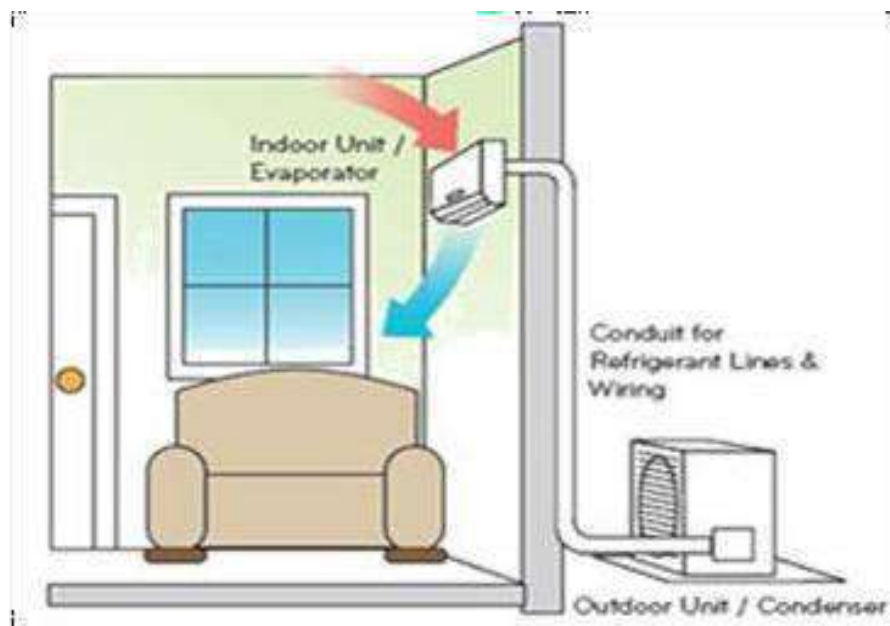


Fig. 19 – Split air-conditioner

7.4.4 Packaged Air-Conditioners

A packaged air-conditioner is a bigger version of the window air-conditioner. An outdoor unit which usually is placed on a roof or on a concrete slab adjacent to the building performs the cooling functions. Conditioned Air is supplied from and warm air returned to the outdoor unit by connecting ducts through building's exterior wall or roof.

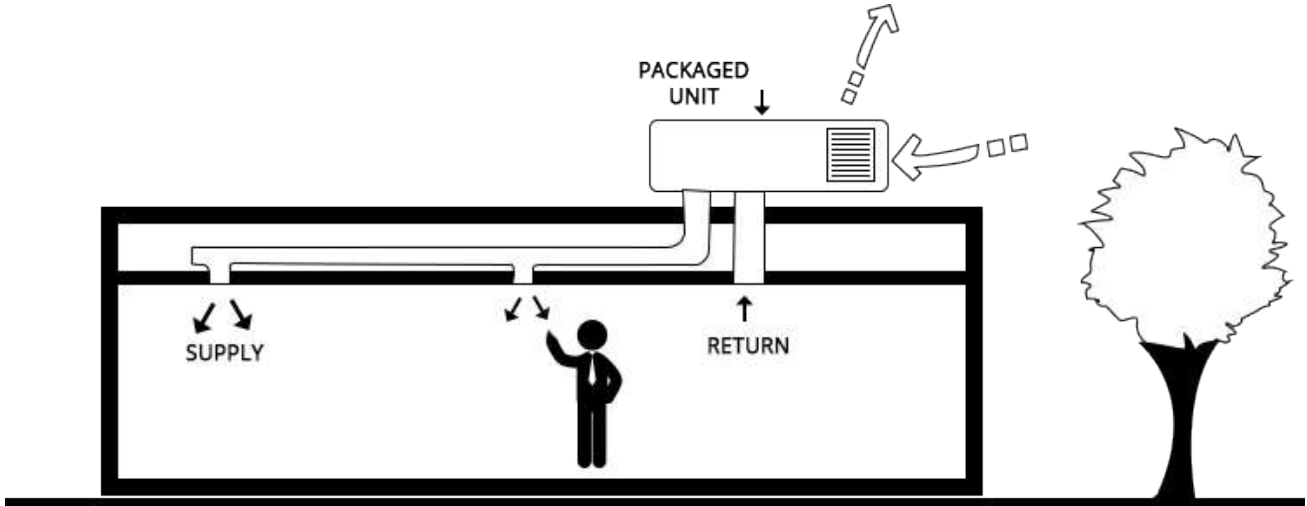


Fig. 20 – Packaged Air-Conditioner

HVAC systems are expensive, and it is therefore important that the most optimal one be selected for your home so that it provides your family with the most comfortable living conditions. It is also important that such equipment be installed properly.

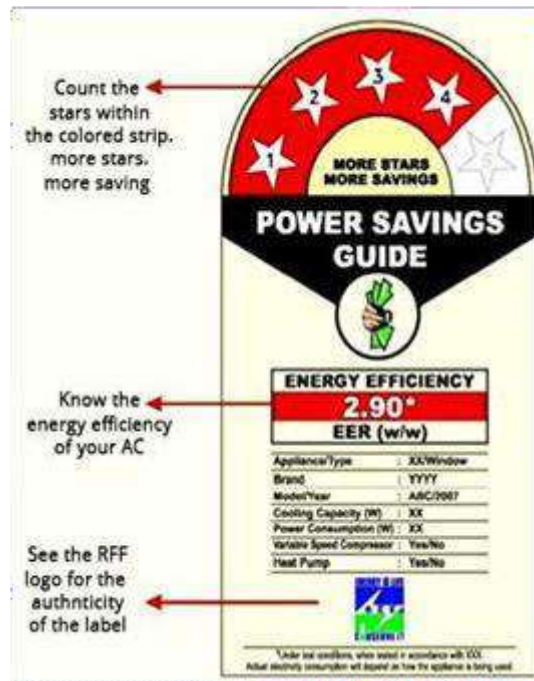


Fig. 21 – BEE's Star Label for Room Air-Conditioner

You can still reduce your electricity bill by using Air-conditioners that have more BEE stars. The label on the air-conditioner has stars on a scale of 1 to 5. Any machine which has a star rating of 1 on this

scale is the least efficient machine. A five-star AC is the most efficient AC possible, and if you purchase this air-conditioner and install it as per instructions, it should consume the least amount of electricity in comparison to any other air-conditioner. Thus, the more the stars, the less electricity such equipment should consume because it is more energy efficient.

While selecting a place to install your air-conditioners, you must make sure it is away from direct sunlight and heat, and in a shaded space. You must also always keep the filters of your air-conditioners clean to ensure that it continues to run efficiently and maintains good quality of indoor air.

Air-conditioners take the same amount of time until they reach a given temperature no matter how low their cooling temperature is set to. For example, if on a hot day you wish to make the temperature of the room more comfortable, and want your AC to help cool the room to 24°C, setting the AC temperature to 18°C will not help make the AC run faster. This is because the machine will cool your room to 18°C only after it first cools it to 24°C, and therefore will make your AC work harder for a longer period of time and consume more electricity than when set at the temperature you feel comfortable at.

Another way to ensure that your AC is running at the optimum level is to make sure you are not setting the temperature uncomfortably low, for example we set our ACs at an uncomfortably low temperature of 16-19°C for the AC and cover ourselves to keep us warm. Instead we must dress up according to the persisting weather conditions. We should make it a practice to wear light, less layered clothes at home during the summers and set the AC to a higher temperature, so that the energy consumed by the AC is reduced. People feel most naturally comfortable between the temperatures of 24- 26°C. Setting a lower temperature on your AC would also feel uncomfortable because when you step out of the conditioned room, the temperature outside would feel even warmer than it otherwise would. A third danger is that if you spend a lot of time in such low temperatures, your body will get used to living in such conditions. This means that a space which you may earlier have felt was warm, will now feel very hot to you. All these issues will lead to an over use of your air-conditioners, making them less efficient and leading to them developing mechanical faults earlier.

If we continue to set our ACs at a lower temperature, overtime our body gets accustomed to such low temperatures. A space which in the past would have been judged by us as warm will now be perceived as very hot. Our preferences would shift to having lower room temperatures leading to higher usage of AC.

7.4.5 Forced Ventilation

Your homes can be ventilated, to circulate cool air throughout the room and avoid still hot air by using an electric fan. By using fans, the air is forced to move across our bodies faster, taking away air filled with sweat and this makes us feel cooler.

Since ceiling fans are widely used in most houses, they consume major share of energy among our electric home appliances. Energy consumed by fans is much more than that consumed by artificial lighting. Also, artificial light is used for shorter duration of time, generally when it gets dark to the time we sleep, whereas fans are used mostly throughout the day and night for ventilation. To reduce the electricity consumed by fans, BEE rated fans, which have more stars should be used. BEE star rated fans with more number of stars, may cost you a little more than a regular fan on purchase, but they will give you the benefit of reduced electricity bills over its lifetime, making it a good buy for your house.

With advancements in technology like BLDC (Brushless DC Motor) technology efficiency of fans have improved. These are capable of saving 50% of the electricity, by consuming only 30-35 watts of electricity, against conventional fans which consume 70-80 Watts of electricity.

7.4.6 Lighting

Conventional incandescent bulbs produce light when electricity passes through its filament to heat it enough to produce light. In this process, the bulbs convert electricity to large amounts of heat and not as much useful light. Only about 5% of the electrical energy supplied is converted to light and the rest is released as heat and warms up your home.



Fig. 22 – Efficiency comparative for lighting technologies

Of the various types of lights available in market, CFL and LEDs lamps are much more energy efficient than the regular yellow light bulbs or halogen lamps because they produce less heat while producing the same amount of useful light. The major benefits of installing CFL or LED lights in your home are that they have last longer, and they do not heat up the rooms, reducing the need for repeated replacement of your light fixtures and for air-conditioning bringing down your costs.

Significant energy savings can be achieved by a combination of automatic operations and manual switching which allow you to turn down or switch off lights when they are not needed. Oftentimes, large amounts of energy are wasted when only manual switching is resorted to for turn off lights as they are not prudently controlled. Various automatic lighting control systems that use timers and sensors can be used to turn on and off lights when needed. They are convenient, and reduce payback time period for the investment you have made in installing them through the cost of electricity saved and longer life of lamps due to reduced use by dimming or turning off lights.

7.4.7 Solar Photo Voltaic

Powering your home through renewable energy such as Sunlight can significantly reduce the costs of owning and living in it. Many renewable energy technologies such as photovoltaic panels, biomass, wind turbines are available for use in the residential context which can help reduce your home's dependence on electricity supplied by the electricity grid and various power distribution companies at high prices. This will also make your home independent of the impacts of power cuts and shortages, and provide you with as much power as you require whenever you need it at a much lower cost than what you will experience with the conventional electricity grid connection.

Solar energy is free and abundant in most places in India. It also offers immense scope of applicability, adaptability (versatility over other renewable sources of energy) and ease of operations and maintenance over other sources of renewable energy. If you decide to take advantage of this resource for providing electricity for your home fully or in part, you must take the following information into account:

Solar or Photovoltaic rooftop system consists of a solar panel installed on the roof of the house. They generate power during daytime by converting sunlight directly to electricity. They can be of two types-

1. Provided with battery to store the solar electricity to be used whenever the sun is not available
2. Connected to the electrical power grid to draw power when solar power is insufficient due to cloudy sky conditions.

A 1 kW grid connected rooftop solar system can be set up over a shade free area of 10 sq m. Photovoltaic system provide the following benefits –

- i. Reduce electricity bill, while utilizing existing roof space of a building.
- ii. No movable parts, so they are quiet and depreciate slowly. They do not generate pollution while producing electricity at your home, which is a health advantage for your family.
- iii. Can be used even in remote areas of the country where other renewable systems may not be available.



Fig. 23 – Generation of Photo voltaic energy

With advancements in technology, Building Integrated Photovoltaics (BIPV) made from thin film solar cells are available in the market. They are photovoltaic materials that are used to replace conventional building materials in parts of your home such as skylight, window shades etcetera. They generate electricity while performing other functions as a building element. The initial cost of BIPV is offset by reducing your money spent on the conventional building materials and labour required to normally construct that part of your home, as well as the much reduced electricity costs over the lifetime of your home.

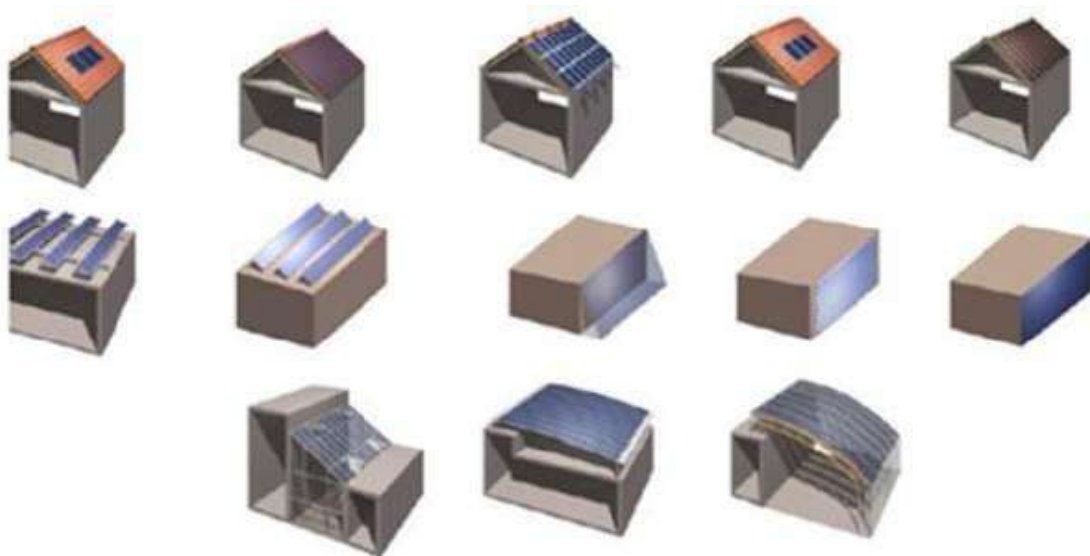


Fig. 24 – Building Integrated Photo-voltaic applications

7.4.8 Solar Water Heater

The energy from sunlight can be used to heat water in homes. A solar hot water heater does the same. It consists of several solar collectors installed in open spaces, roofs which get sunlight. Water which is heated is stored in a tank capable of retaining the heat, to be used for various daily activities like washing, bathing etc.

For homes, the solar heater system without a pump shall suffice. The system can run efficiently unless cloudy conditions do not persist for over a day or two. Under such weather conditions, an electric system integrated with the solar hot water system shall serve as a backup.

A solar water heater for a family of 3- 4 shall be of 100 litres per day capacity, taking up 1.5-2 sq.m of space on the terrace/open space. It can save up to 1,500 units of electricity a year for you.

Depending on various factors like weather conditions, location of your city, system efficiency, etc. the soft water running through the system can attain a temperature of upto 60-80 °C . Solar hot water heater can supply hot water even when electricity is not available and does not produce pollution as in case of heating water with firewood or other fuels.

7.4.9 Energy Metering & Monitoring

It is useful to keep track of your home's energy use. Energy use can be tracked by periodically monitoring the information on your energy meters. Monitoring your energy use can influence conscious decisions on purchase and use of appliances and other energy consuming equipment. Nowadays, smart meters are available for home-owners. These devices can connect to your smartphones and give almost real-time updates on energy use.

Other than knowing your overall energy use, you can also benefit from knowing your energy use by components. Like each household is metered separately, each circuit within the house maybe metered separately as well. This is known as sub-metering.

7.5 Facts about Buildings

Buildings are the third largest consumers of energy after industry and agriculture. Buildings consume about 31 % of global energy. This figure is likely to go up to 38 % by 2050. A green building may cost 20 % to 50 % more than the conventional buildings, depending on green features being incorporated in the design and construction, but annual energy cost would go down substantially.

Benefits of a Green Building:

- i. Reduced energy consumption without sacrificing the comfort levels
- ii. Reduced destruction of natural areas, habitats, and biodiversity, and reduced soil loss from erosion etc.
- iii. Reduced air and water pollution (with direct health benefits)
- iv. Reduced Water Consumption
- v. Limited Waste Generation due to Recycling and Reuse
- vi. Reduced Pollution Loads
- vii. Increased User Productivity
- viii. Enhanced Image and Marketability

7.6 Green Rating for Integrated Habitat Assessment (GRIHA)

7.6.1 Role of GRIHA To Minimize

- i. Building's Resource Consumption
- ii. Waste Generation
- iii. Overall Ecological Impact
- iv. Evaluates Environmental Performance of a Building Holistically over its Entire Life Cycle



7.6.2 GRIHA Variants

- i. SVAGRIHA
- ii. GRIHA V2015(Latest since Jan 2015)
- iii. GRIHA Version 3(Open till Dec.2017)

7.6.3 SVAGRIHA

Salient features

- i. SVAGRIHA (Simple Versatile Affordable GRIHA) was jointly developed by GRIHA Council and TERI
- ii. It is a significantly simplified, faster, easier and more affordable rating system.
- iii. Applicable for projects with built-up area less than 2500 sq. mtr.
- iv. For individual residences, small offices, schools, motels, commercial buildings etc. The rating comprises 14 criteria.
- v. The criteria are divided into 5 broad sub-groups-namely:
 - o Energy
 - o Water and waste
 - o Materials
 - o Landscape
 - o Others.
- vi. The total points that a project can achieve are 50.
- vii. The rating will be done on a 1-5 star scale

7.6.4 Process

- i. Registration
- ii. Submission of drawings and other documents as required (quantity estimates) to GRIHA Council
- iii. Assessment/review as per SVAGRIHA
- iv. Feedback to project team
- v. Site visit and due diligence check post construction
- vi. Evaluation by a GRIHA Evaluator
- vii. Award of rating
- viii. Award of letter and certificate

Points achieved	SVAGRIHA Precertification Rating
25-30	
31-35	
36-40	
41-45	
45-50	

Certification fee

Pre-certification Fees – Rs 30,000/-

Criterion number	Criterion name	Points
1	Reduce exposed, hard paved surface on site and maintain native vegetation cover on site	6
2	Passive architectural design and systems	4
3	Good fenestration design for reducing direct heat gain and glare while maximizing daylight penetration	6
4	Efficient artificial lighting system	2
5	Thermal efficiency of building envelope	2
6	Use of energy efficient appliances	3
7	Use of renewable energy on site	4
8	Reduction in building and landscape water demand	5
9	Rainwater harvesting	4
10	Generate resource from waste	2
11	Reduce embodied energy of building	4
12	Use of low-energy materials in interiors	4
13	Adoption of green lifestyle	4
14	Innovation	2

7.6.5 GRIHA V2015 & 3.0 GRIHA Version 3

Most of items in both the variants of these GRIHA are common, which are discussed below:

7.6.6 Pre-Certification

In accordance with the Office Memorandum by the Ministry of Environment and Forest (MoEF), Government of India, GRIHA Council has proposed a procedure that will enable fast track environmental clearance through GRIHA pre-certification.

Built-up Area (sqm)	Fees
≤299	Rs 30,000/-
300 - 799	Rs 60,000/-
800 -1499	Rs 80,000/-
1500 - 2499	Rs 1,00,000/-

Eligibility

Except for industrial complexes, all buildings - offices, retail malls, institutions, hotels, hospitals, health-care facilities, residences and multifamily high rise buildings - in the pre-design/ design stage are eligible for pre - certification under GRIHA.

i. For built up area greater than 20,000 sq .mtr Projects applying for Environmental Clearance

from MoEF are eligible to apply under this category. Please note that it is mandatory to register the project under GRIHA rating after precertification has been awarded.

- ii. **For built up area less than 20,000 sq. mtr** Projects can register for GRIHA pre-certification and GRIHA rating at the same time. The registration- cum- rating fee for both the processes must be submitted upfront by the project proponent to complete the registration process.

7.6.7 Process

- i. **Registration:** On submitting the online Expression of Interest, the project team must submit a proposed development plan for the registered project with a recent date stamped site photographs. GRIHA Council shall then review the feasibility of registering the project for GRIHA pre-certification. Once approved by GRIHA Council, the project can proceed with the payment of registration cum rating fee and pre-certification process.
- ii. **Certification fee:** GRIHA pre-certification fee is calculated on the built-up area (excluding basement area for parking)

Built-up Area (sqm)	Fees
≤1,50,000	Rs 1,00,000
1,50,000 – 3,00,000	Rs 2,00,000
>3,00,000	Rs 3,00,000

- iii. **Online submission of documents:** All compliance documents are submitted through the online portal on the GRIHA website. The documents must be uploaded under the categories mentioned in the “Document checklist V 3 “ | “Document checklist V 2015”
 - Narratives
 - Declaration/certificates
 - Drawings
 - Test reports
 - Other documentation
 - GRIHA checklist
 - Presentation for GRIHA pre-certification (summary of the project)

7.6.8 GRIHA Version 2015 Self-evaluation Checklist

Eligibility

All buildings, which are in the design stage and have built up area more than 2,500 m², are eligible for certification under GRIHA. Building types include, but are not limited to offices, retail spaces, institutional buildings, hotels, hospital buildings, healthcare facilities, residences, and multi-family high-rise buildings.

7.6.9 Criteria and their weightage

GRIHA is a performance-oriented system where points are earned for meeting the design and performance intent of the criteria. Each criterion has certain points assigned to it. It means that a project demonstrating compliance with a criterion would achieve the associated points. GRIHA is a 100-point system consisting of some core points, which are mandatory, while the rest are optional. Different levels of certification (one star to five stars) are awarded based on the number of points earned. The minimum points required for certification are 25. The scores for achieving GRIHA rating have been revised. The new thresholds for achieving GRIHA rating are mentioned below:

GRIHA V 2015 Rating Thresholds	GRIHA Rating
25-40	
41-55	
56-70	
71-85	
86 or more	

Criterion 1	Site Selection
Criterion 2	Low-impact design
Criterion 3	Design to mitigate UHIE
Criterion 4	Site Imperviousness Factor
Criterion 5	Air and water pollution control
Criterion 6	Preserve and protect landscape during construction
Criterion 7	Construction Management Practices
Criterion 8	Energy efficiency
Criterion 9	Renewable energy utilization
Criterion 10	Zero ODP materials
Criterion 11	Achieving indoor comfort requirements (visual/thermal/acoustic)
Criterion 12	Maintaining good IAQ
Criterion 13	Use of low-VOC paints and other compounds in building interiors
Criterion 14	Use of low-flow fixtures and systems
Criterion 15	Reducing landscape water demand
Criterion 16	Water Quality
Criterion 17	On-site water reuse
Criterion 18	Rainwater Recharge
Criterion 19	Utilization of BIS recommended waste materials in building structure
Criterion 20	Reduction in embodied energy of building structure
Criterion 21	Use of low-environmental impact materials in building interiors
Criterion 22	Avoided post-construction landfill
Criterion 23	Treat organic waste on site
Criterion 24	Labour safety and sanitation
Criterion 25	Design for Universal Accessibility
Criterion 26	Dedicated facilities for service staff
Criterion 27	Increase in environmental awareness
Criterion 28	Smart metering and monitoring
Criterion 29	Operation, Maintenance Protocols
Criterion 30	Performance Assessment for Final Rating
Criterion 31	Innovation

7.7 Energy Conservation Building Code (ECBC)

To improve the energy efficiency in the new commercial buildings, the Energy Conservation Building Code (ECBC) was created. ECBC was launched by Ministry of Power (MoP), Government of India, in May 2007, as the first step towards promoting energy efficiency in the commercial building sector. The said code has been revised in 2017.

The Energy Conservation Building Code (ECBC) sets minimum energy standards for new commercial buildings having a connected load of 100 kW or contract demand of 120 kVA or more. The effective implementation of code provides comfort to occupants by adopting passive design strategies & day

light Integration. It is technologically neutral, promotes renewable energy and also emphasises on life cycle cost of building.

There are three levels of energy performance standards in the Energy Conservation Building Code (ECBC) i.e. ECBC, ECBC Plus, Super ECBC. In ascending order of efficiency, ECBC compliant buildings shall demonstrate approximately 25% savings, ECBC+ building 35% savings and Super ECBC building will show 50% or more energy savings as compared to conventional building.

7.7.1 Energy Efficiency Performance levels

The code prescribes the following three levels of energy efficiency:

(a) Energy Conservation Building Code Compliant Building (ECBC Building)

ECBC Buildings shall demonstrate compliance by adopting the mandatory and prescriptive requirements listed under ECBC Compliant Building requirements, or by following the provisions of the Whole Building Performance (WBP) Method.

(b) Energy Conservation Building Code Plus Building (ECBC+ Building)

ECBC+ Buildings shall demonstrate compliance by adopting the mandatory and prescriptive requirements listed under ECBC+ Compliant Building requirements, or by following the provisions of the Whole Building Performance (WBP).

(c) Super Energy Conservation Building Code Building (Super ECBC Building)

Super ECBC Buildings shall demonstrate compliance by adopting the mandatory and prescriptive requirements listed under Super ECBC Compliant Building requirements, or by following the provisions of the Whole Building Performance (WBP) Method.

7.7.2 Building Systems

The provisions of this code apply to:

- (a) Building envelope,
- (b) Mechanical systems and equipment, including heating, ventilating, and air conditioning, service hot water heating,
- (c) Interior and exterior lighting, and
- (d) Electrical power and motors, and renewable energy systems.

The provisions of this code do not apply to plug loads, and equipment and parts of buildings that use energy for manufacturing processes, unless otherwise specified in the Code.

7.7.3 Energy Performance for Buildings

In order to assess energy performance of a building, its Energy Performance Index (EPI) is evaluated as following,

$$\text{EPI} = \frac{\text{Annual Energy consumption in kWh}}{\text{Total builtup area}}$$

EPI for a building represents annual energy consumption in kilowatt-hours per square meter of the building. While calculating the EPI of a building, the area of unconditioned basements shall not be included.

Further, EPI ratio of a building is defined as,

$$\text{EPI ratio} = \frac{\text{EPI of Proposed Building}}{\text{EPI of Standard Building}}$$

Proposed Building is consistent with the actual design of the building, and complies with all the mandatory requirements of ECBC.

Standard Building is a standardized building that has the same building floor area, gross wall area and gross roof area as the Proposed Building which complies with the mandatory requirements of ECBC buildings and minimally complies with prescriptive requirements for ECBC Buildings.

7.7.4 ECBC Compliance Approaches for buildings

For ECBC compliance, EPI ratio of the Proposed Building shall be established through any one of the following two methods,

- (a) Prescriptive Method
- (b) Whole Building Performance Method

After that, building must meet with the mandatory requirements and any of the above mentioned compliance methods (a) or (b).

Mandatory Requirements: Buildings shall comply with all mandatory requirements mentioned under the heads,

- i. Building Envelope
- ii. Comfort Systems and Controls
- iii. Lighting and Controls
- iv. Electrical and Renewable Energy Systems

Depending upon the parameters attained by a building pertaining to mandatory and prescriptive requirements, it is graded as ECBC, ECBC+ or Super ECBC. For a better understanding of mandatory and perspective requirements, section on Lighting and Controls has been described in following sections as per provisions of ECBC Code-2017. The said code may be consulted for other requirements pertaining to Building Envelope, Comfort Systems and Controls and Electrical and Renewable Energy Systems.

7.7.5 Lighting and Controls

7.7.5.1 General

Lighting systems and equipment shall comply with the mandatory provisions of § 7.7.5.2 and the prescriptive criteria of § 7.7.5.3. The lighting requirements in this section shall apply to:

- (a) Interior spaces of buildings,
- (b) Exterior building features, including facades, illuminated roofs, architectural features, entrances, exits, loading docks, and illuminated canopies, and,
- (c) Exterior building grounds lighting that is provided through the building's electrical service.

Exceptions to §7.7.5.1: Emergency or security lighting that is automatically off during normal building operations.

7.7.5.2 Mandatory Requirements

7.7.5.2.1 Lighting Control

A. Automatic Lighting Shutoff

(a) 90% of interior lighting fittings by wattage, in building or space of building larger than 300 m² shall be equipped with automatic control device. (b) Automatic control device shall function on either:

- i. A scheduled basis at specific programmed times. An independent program schedule shall be provided for areas of no more than 2,500 m² and not more than one floor, or,
- ii. Occupancy sensors that shall turn off the lighting fixtures within 15 minutes of an occupant leaving the space. Light fixtures controlled by occupancy sensors shall have a wall-mounted, manual switch capable of turning off lights when the space is occupied.
- iii. Additionally, occupancy sensors shall be provided in
 - a. All building types greater than 20,000 m² BUA, in
 - b. All habitable spaces less than 30 m², enclosed by walls or ceiling height partitions.
 - c. All storage or utility spaces more than 15 m².

Public toilets more than 25 m², controlling at least 80 % of lighting by wattage, fitted in the toilet. The lighting fixtures, not controlled by automatic lighting shutoff, shall be uniformly spread in the area.

- iv. Corridors of all Hospitality greater than 20,000 m² BUA, controlling minimum 70% and maximum 80% of lighting by wattage, fitted in the public corridor. The lighting fixtures, not controlled by automatic lighting shut off, shall be uniformly spread in the area.
- v. All conference or meeting rooms.

Exception to §7.7.5.2.1(A) Lighting systems designed for emergency and firefighting purposes.

B. Space Control

Each space enclosed by ceiling-height partitions shall have at least one control device to independently control the general lighting within the space. Each control device shall be activated either manually by an occupant or automatically by sensing an occupant. Each control device shall

- (a) control a maximum of 250 m² for a space less than or equal to 1,000 m², and a maximum of 1,000 m² for a space greater than 1,000 m².
- (b) have the capability to override the shutoff control required in § 7.7.5.2.1(A) for no more than 2 hours, and
- (c) be readily accessible and located so the occupants can see the control.

Exception to § 7.7.5.2.1(B) (c): The required control device may be remotely installed if required for reasons of safety or security. A remotely located device shall have a pilot light indicator as part of or next to the control device and shall be clearly labeled to identify the controlled lighting.

C. Control in Daylight Areas

- (a) Luminaires, installed within day lighting extent from the window as calculated, shall be equipped with either a manual control device to shut off luminaires, installed within day lit area, during potential day lit time of a day or automatic control device that:
 - i. Has a delay of minimum 5 minutes, and,
 - ii. Can dim or step down to 50% of total power.
- (b) Overrides to the daylight controls shall not be allowed.

D. Exterior Lighting Control

- (a) Lighting for all exterior applications shall be controlled by a photo sensor or astronomical time

switch that is capable of automatically turning off the exterior lighting when daylight is available or the lighting is not required.

- (b) Lighting for all exterior applications, shall have lamp efficacy not less than 80 lumens per watt for ECBC, unless the luminaire is controlled by a motion sensor or exempt under §7.7.5.1.
- (c) Façade lighting and façade non-emergency signage of Shopping Complexes shall have separate time switches.

Exemption to §7.7.5.2(D): Exterior Lighting systems designed for emergency and firefighting purposes.

E. Additional Control

The following lighting applications shall be equipped with a control device to control such lighting independently of general lighting:

- (a) Display/Accent Lighting. Display or accent lighting greater than 300m² area shall have a separate control device.
- (b) Hotel Guest Room Lighting. Guest rooms and guest suites in a hotel shall have a master control device at the main room entry that controls all permanently installed luminaires and switched receptacles.
- (c) Task Lighting. Supplemental task lighting including permanently installed under shelf or under cabinet lighting shall have a control device integral to the luminaires or be controlled by a wall-mounted control device provided the control device complies with §7.7.5.2(B).
- (d) Nonvisual Lighting. Lighting for nonvisual applications, such as plant growth and food-warming, shall be equipped with a separate control device.
- (e) Demonstration Lighting. Lighting equipment that is for sale or for demonstrations in lighting education shall be equipped with a separate control device accessible only to authorized personnel.

F. Exit Signs

Internally-illuminated exit signs shall not exceed 5 Watts per face.

7.7.5.3 Prescriptive Requirements

A. Interior Lighting Power

The installed interior lighting power for a building or a separately metered or permitted portion of a building shall be calculated in accordance with §7.7.5.3(D) and shall not exceed the interior lighting power allowance determined in accordance with either §7.7.5.3(B) or §7.7.5.3(C).

Exception to §7.7.5.3: The following lighting equipment and applications shall not be considered when determining the interior lighting power allowance, nor shall the wattage for such lighting be included in the installed interior lighting power. However, any such lighting shall not be exempt unless it is an addition to general lighting and is controlled by an independent control device.

- (a) Display or accent lighting that is an essential element for the function performed in galleries, museums, and monuments,
- (b) Lighting that is integral to equipment or instrumentation and is installed by its manufacturer,
- (c) Lighting specifically designed for medical or dental procedures and lighting integral to medical equipment,
- (d) Lighting integral to food warming and food preparation equipment,
- (e) Lighting for plant growth or maintenance,
- (f) Lighting in spaces specifically designed for use by the visually impaired,

- (g) Lighting in retail display windows, provided the display area is enclosed by ceiling height partitions,
- (h) Lighting in interior spaces that have been specifically designated as a registered interior historic landmark,
- (i) Lighting that is an integral part of advertising or directional signage,
- (j) Exit signs,
- (k) Lighting that is for sale or lighting educational demonstration systems,
- (l) Lighting for theatrical purposes, including performance, stage, and film or video production, and
- (m) Athletic playing areas with permanent facilities for television broadcasting.

B. Building Area Method

Determination of interior lighting power allowance (watts) by the building area method shall be in accordance with the following:

- (a) Determine the allowed lighting power density for each appropriate building area type from Table 7-1 for ECBC Buildings, from Table 7-2 for ECBC+ Buildings and from Table 7-3 for Super ECBC Buildings.
- (b) Calculate the gross lighted area for each building area type.
- (c) The interior lighting power allowance is the sum of the products of the gross lighted floor area of each building area times the allowed lighting power density for that building area type.

Table 7-1 Interior Lighting Power for ECBC Buildings – Building Area Method

Building Type	LPD (W/m ²)	Building Area Type	LPD (W/m ²)
Office Building	9.5	Motion picture theater	9.43
Hospitals	9.7	Museum	10.2
Hotels	9.5	Post office	10.5
Shopping Mall	14.1	Religious building	12.0
University and Schools	11.2	Sports arena	9.7
Library	12.2	Transportation	9.2
Dining: bar lounge/ leisure	12.2	Warehouse	7.08
Dining: cafeteria/fast food	11.5	Performing arts theater	16.3
Dining: family	10.9	Police station	9.9
Dormitory	9.1	Workshop	14.1
Fire station	9.7	Automotive facility	9.0
Gymnasium	10.0	Convention center	12.5
Manufacturing facility	12.0	Parking garage	3.0

In cases where both a general building area type and a specific building area type are listed, the specific building area type shall apply.

Table 7-2 Interior Lighting Power for ECBC+ Buildings – Building Area Method

Building Area Type	LPD (W/m ²)	Building Area Type	LPD (W/m ²)
Office Building	7.6	Motion picture theater	7.5
Hospitals	7.8	Museum	8.2
Hotels	7.6	Post office	8.4
Shopping Mall	11.3	Religious building	9.6
University and Schools	9.0	Sports arena	7.8
Library	9.8	Transportation	7.4
Dining: bar lounge/ leisure	9.8	Warehouse	5.7
Dining: cafeteria/fast food	9.2	Performing arts theater	13.0
Dining: family	8.7	Police station	7.9

Building Area Type	LPD (W/m ²)	Building Area Type	LPD (W/m ²)
Dormitory	7.3	Workshop	11.3
Fire station	7.8	Automotive facility	7.2
Gymnasium	8.0	Convention center	10.0
Manufacturing facility	9.6	Parking garage	2.4

In cases where both a general building area type and a specific building area type are listed, the specific building area type shall apply.

Table 7-3 Interior Lighting Power for Super ECBC Buildings – Building Area Method

Building Area Type	LPD (W/m ²)	Building Area Type	LPD (W/m ²)
Office Building	5.0	Motion picture theater	4.7
Hospitals	4.9	Museum	5.1
Hotels	4.8	Post office	5.3
Shopping Mall	7.0	Religious building	6.0
University and Schools	6.0	Sports arena	4.9
Library	6.1	Transportation	4.6
Dining: bar lounge/leisure	6.1	Warehouse	3.5
Dining: cafeteria/fast food	5.8	Performing arts theater	8.2
Dining: family	5.5	Police station	5.0
Dormitory	4.6	Workshop	7.1
Fire station	4.9	Automotive facility	4.5
Gymnasium	5.0	Convention center	6.3
Manufacturing facility	6.0	Parking garage	1.5

In cases where both a general building area type and a specific building area type are listed, the specific building area type shall apply.

C. Space Function Method

Determination of interior lighting power allowance (watts) by the space function method shall be in accordance with the following:

- Determine the appropriate building type and the allowed lighting power density from Table 7-4 for ECBC Buildings, Table 7-5 for ECBC+ Buildings and, Table 7-6 for Super ECBC Buildings. In cases where both a common space type and building specific space type are listed, building specific space type LPD shall apply.
- For each space, enclosed by partitions 80% or greater than ceiling height, determine the gross lighted floor area by measuring to the center of the partition wall. Include the area of balconies or other projections. Retail spaces do not have to comply with the 80% partition height requirements.
- The interior lighting power allowance is the sum of the lighting power allowances for all spaces. The lighting power allowance for a space is the product of the gross lighted floor area of the space times the allowed lighting power density for that space.

Table 7-4 Interior Lighting Power for ECBC Buildings – Space Function Method

Category	LPD (W/m ²)	Lamp category	LPD (W/m ²)
Common Space Types			
Restroom	7.7	Stairway	5.5
Storage	6.8	Corridor/Transition	7.1
Conference/ Meeting	11.5	Lobby	9.1
Parking Bays (covered/ basement)	2.2	Parking Driveways (covered/ basement)	3.0
Electrical/Mechanical	7.1	Workshop	17.1
Business			

Category	LPD (W/m ²)	Lamp category	LPD (W/m ²)
Enclosed	10.0	Open Plan	10.0
Banking Activity Area	12.6	Service/Repair	6.8
Healthcare			
Emergency	22.8	Recovery	8.6
Exam/Treatment	13.7	Storage	5.5
Nurses' Station	9.4	Laundry/Washing	7.5
Operating Room			
Patient Room	7.7	Medical Supply	13.7
Pharmacy	10.7	Nursery	5.7
Physical Therapy	9.7	Corridor/Transition	9.1
Radiology/Imaging	9.1		
Hospitality			
Hotel Dining	9.1	Hotel Lobby	10.9
For Bar Lounge/ Dining	14.1	Motel Dining	9.1
For food preparation	12.1	Motel Guest Rooms	7.7
Hotel Guest Rooms	9.1		
Shopping Complex			
Mall Concourse	12.8	For Family Dining	10.9
Sales Area	18.3	For food preparation	12.1
Motion Picture Theatre	9.6	Bar Lounge/ Dining	14.1
Educational			
Classroom/Lecture	13.7	Card File and Cataloguing	9.1
For Classrooms	13.8	Stacks (Lib)	18.3
Laboratory	15.1	Reading Area (Library)	10.0
Assembly			
Dressing Room	9.1	Seating Area – Performing Arts Theatre	22.6
Exhibit Space - Convention Centre	14.0	Lobby – Performing Arts Theatre	21.5
Seating Area - Gymnasium	4.6	Seating Area – Convention Centre	6.4
Fitness Area - Gymnasium	13.7	Seating Religious Building	16.4
Museum - General Exhibition	16.4	Playing Area - Gymnasium	18.8
Museum - Restoration	18.3		

Table 7-5 Interior Lighting Power for ECBC+ Buildings – Space Function Method

Category	LPD (W/m ²)	Lamp category	LPD (W/m ²)
Common Space Types			
Restroom	6.1	Stairway	4.4
Storage	5.4	Corridor/Transition	3.6
Conference/ Meeting	9.2	Lobby	7.3
Parking Bay(covered/ basement)	1.8	Parking Driveways (covered/ basement)	2.5
Electrical/Mechanical	5.7	Workshop	13.7
Business			
Enclosed	8.6	Open Plan	8.6
Banking Activity Area	9.3	Service/Repair	5.5
Healthcare			
Emergency	18.2	Recovery	7.0
Exam/Treatment	10.9	Storage	4.4
Nurses' Station	7.5	Laundry/Washing	6.0
Operating Room	17.5	Lounge/Recreation	6.4
Patient Room	6.1	Medical Supply	10.9
Pharmacy	8.5	Nursery	4.6
Physical Therapy	7.8	Corridor/Transition	7.3

Category	LPD (W/m ²)	Lamp category	LPD (W/m ²)
Radiology/Imaging	7.3		
Hospitality			
Hotel Dining	7.3	Hotel Lobby	8.8
For Bar Lounge/ Dining	11.3	Motel Dining	7.3
For food preparation	12.1	Motel Guest Rooms	6.1
Hotel Guest Rooms	7.3		
Shopping Complex			
Mall Concourse	10.2	For Family Dining	8.8
Sales Area	14.6	For food preparation	12.1
Motion Picture Theatre	10.3	Bar Lounge/ Dining	11.3
Educational			
Classroom/Lecture	10.9	Card File and Cataloguing	7.3
For Classrooms	11.0	Stacks (Library)	14.6
Laboratory	12.1	Reading Area (Library)	9.2
Assembly			
Dressing Room	7.3	Seating Area - Performing Arts Theatre	18.1
Exhibit Space - Convention Centre	11.2	Lobby - Performing Arts Theatre	17.2
Seating Area - Gymnasium	3.6	Seating Area – Convention Centre	5.1
Fitness Area - Gymnasium	7.9	Seating Religious Building	13.1
Museum - General Exhibition	11.3	Playing Area - Gymnasium	12.9
Museum - Restoration	11.0		

Table 7-6 Interior Lighting Power for Super ECBC Buildings – Space Function Method

Category	LPD (W/m ²)	Lamp category	LPD (W/m ²)
Common Space Types			
Restrooms	3.8	Stairway	2.7
Storage	3.4	Corridor/Transition	2.3
Conference/ Meeting	5.7	Lobby	4.6
Parking Bays(covered/ basement)	1.1	Driveways (covered/ basement)	1.5
Electrical/Mechanical	3.5	Workshop	8.6
Business			
Enclosed	5.4	Open Plan	5.4
Banking Activity Area	5.8	Service/Repair	3.4
Healthcare			
Emergency	11.4	Recovery	4.4
Exam/Treatment	6.8	Storage	2.7
Nurses' Station	5.0	Laundry/Washing	3.8
Operating Room	10.9	Lounge/Recreation	4.6
Patient Room	3.8	Medical Supply	6.8
Pharmacy	5.3	Nursery	2.9
Physical Therapy	4.9	Corridor/Transition	4.6
Radiology/Imaging	4.6		
Hospitality			
Hotel Dining	4.6	Hotel Lobby	5.5
For Bar Lounge/ Dining	7.0	Motel Dining	4.6
For food preparation	7.5	Motel Guest Rooms	3.8
Hotel Guest Rooms	4.6		
Shopping Complex			
Mall Concourse	6.4	For Family Dining	5.5
Sales Area	9.2	For food preparation	7.5
Motion Picture Theatre	6.5	Bar Lounge/ Dining	7.0
Educational			
Classroom/Lecture	6.8	Card File and Cataloguing	4.6

Category	LPD (W/m ²)	Lamp category	LPD (W/m ²)
For Classrooms	6.9	Stacks (Library)	9.2
Laboratory	7.5	Reading Area (Library)	5.7
Assembly			
Dressing Room	4.6	Seating Area - Performing Arts Theatre	11.3
Exhibit Space – Convention Centre	7.0	Lobby - Performing Arts Theatre	10.8
Seating Area - Gymnasium	3.4	Seating Area – Convention Centre	3.2
Fitness Area - Gymnasium	3.9	Seating Religious Building	8.2
Museum – General Exhibition	5.7	Playing Area - Gymnasium	6.5
Museum – Restoration	5.5		

Note 7-1 Calculating Interior Lighting Power – Space Function Method



A four-story building has retail on the ground floor and offices on the top three floors. Area is 3,598 m². Space types and their respective areas are mentioned below. Steps for calculating interior lighting power allowance using the space function method for a ECBC building is described below.

For each of the space type, corresponding Lighting Power Density (LPD) values for Business and Shopping complex building type from Table 7-4 are used. Area is multiplied with the LPD values to estimate the lighting power allowance for the whole building. It is 40,242W.

Table Space Types, Areas and Corresponding LPDs

Space Function	LPD (W/ m ²)	Area (m ²)	Lighting Power Allowance (W)
Office			
Office - enclosed	10.0	720	7,200
Office – open plan	10.0	1,485	14,850
Meeting Rooms	11.5	120	1,380
Lobbies	9.1	93	846
Restrooms	7.7	51	393
Corridors	7.1	125	888
Electrical/ Mechanical	7.1	14	99
Staircase	5.5	84	462
Total			26,118
Retail			
General sales area	18.3	669	12,243
Offices - enclosed	10.0	28	280
Restrooms	7.7	9	69
Corridors	7.1	79	561
Storage	6.8	93	632
Food preparation	12.1	28	339
Total			14,124
Building Total			40,242 W

D. Installed Interior Lighting Power

The installed interior lighting power calculated for compliance with §7.7.5.3 shall include all power used by the luminaires, including lamps, ballasts, current regulators, and control devices except as specifically exempted in §7.7.5.1.

Exception to §7.7.5.3(D): If two or more independently operating lighting systems in a space are controlled to prevent simultaneous user operation, the installed interior lighting power shall be based solely on the lighting system with the highest power.

Luminaire Wattage

Light output ratio shall be 0.7 or above. Luminaire wattage incorporated into the installed interior lighting power shall be determined in accordance with the following:

- (a) The wattage of incandescent luminaires with medium base sockets and not containing permanently installed ballasts shall be the maximum labeled wattage of the luminaires.
- (b) The wattage of luminaires containing permanently installed ballasts shall be the operating input wattage of the specified lamp/ballast combination. Operating input wattage can be either values from manufacturers' catalogs or values from independent testing laboratory reports.
- (c) The wattage of all other miscellaneous luminaire types not described in (a) or (b) shall be the specified wattage of the luminaires.

The wattage of lighting track, plug-in bus-way, and flexible-lighting systems that allow the addition and/or relocation of luminaires without altering the wiring of the system shall be the larger of the specified wattage of the luminaires included in the system or 135 Watt per meter. Systems with integral overload protection, such as fuses or circuit breakers, shall be rated at 100% of the maximum rated load of the limiting device.

E. Exterior Lighting Power

Connected lighting power of exterior lighting applications shall not exceed the lighting power limits specified in Table 7-7 for ECBC Buildings, Table 7-8 for ECBC+ Buildings and Table 7-9 for Super ECBC Buildings. Trade-offs between applications are not permitted.

Table 7-7 Exterior Building Lighting Power for ECBC Buildings

Exterior lighting application	Power limits
Building entrance (with canopy)	10 W/m ² of canopied area
Building entrance (w/o canopy)	90 W/ linear m of door width
Building exit	60 W/lin m of door width
Building façade	5.0 W/m ² of vertical façade area
Emergency signs, ATM kiosks, Security areas façade	1.0 W/m ²
Driveways and parking (open/ external)	1.6 W/m ²
Pedestrian walkways	2.0 W/m ²
Stairways	10.0 W/m ²
Landscaping	0.5 W/m ²
Outdoor sales area	9.0 W/m ²

Table 7-8 Exterior Building Lighting Power for ECBC+ Buildings

Exterior lighting application	Power limits
Building entrance (with canopy)	8.0 W/m ² of canopied area
Building entrance (w/o canopy)	72 W/ linear m of door width
Building exit	48 W/lin m of door width
Building façade	4.0 W/m ² of vertical façade area
Emergency signs, ATM kiosks, Security areas façade	0.8 W/m ²
Driveways and parking (open/ external)	1.3 W/m ²
Pedestrian walkways	1.6 W/m ²
Stairways	8.0 W/m ²
Landscaping	0.4 W/m ²
Outdoor sales area	7.2 W/m ²

Table 7-9 Exterior Building Lighting Power for Super ECBC Buildings

Exterior lighting application	Power limits
Building entrance (with canopy)	5.0 W/m ² of canopied area
Building entrance (w/o canopy)	45 W/ linear m of door width
Building exit	30 W/lin m of door width

Exterior lighting application	Power limits
Building façade	2.5 W/m ² of vertical façade area
Emergency signs, ATM kiosks, Security areas façade	0.5 W/m ²
Driveways and parking (open/ external)	0.8 W/m ²
Pedestrian walkways	1.0 W/m ²
Stairways	5.0 W/m ²
Landscaping	0.25 W/m ²
Outdoor sales area	4.5 W/m ²

F. Controls for ECBC+ and Super ECBC Buildings

ECBC+ and Super ECBC Buildings shall comply with requirements of § 7.7.5.3(F) in addition to complying with requirements of §7.7.5.2.

a) Centralized Controls

ECBC+ and Super ECBC building shall have centralized control system for schedule based automatic lighting shutoff switches.

b) Exterior Lighting Controls

Lighting for all exterior applications, shall have lamp efficacy not less than 80 lumens per watt, 90 lumens per watt, and 100 lumens per watt, for ECBC, ECBC+, and Super ECBC Buildings respectively, unless the luminaries is controlled by a motion sensor or exempt under §7.7.5.1.

7.8 Shunya (Zero) Labelling Programme for Net Zero and Net Positive Energy Buildings

1. Scope:

The programme targets the Net Zero Energy Buildings (NZEB) and Net Positive Energy Buildings (NPEB).

2. Terminology:

- Government Buildings:** The buildings owned/managed by Central/State Govt. or Statutory Body or Indian Railways etc. OR any building used or required for the public service or for any public purpose, which is the property, or in the occupation, of the Central/State Government, or which is to be erected on land which is the property, or in the occupation, of the Central/State Government.
- Net Zero Energy Buildings (NZEB):** A net-zero energy building is one that relies on renewable sources to produce as much energy as it uses, usually as measured over the course of a year.
- Net Positive Energy Buildings (NPEB):** A net-positive energy building is one that relies on renewable sources to produce as much energy as it uses and supplies excess generated electricity to grid, usually as measured over the course of a year.
- User of label:** The owner of building or authorised representative who applies for the 'Shunya' Labelling of his premise/s. The authorised representative must be a person employed with the organisation which owns/manage the building. Any other firm/third party/outside person will not be entertained for the application/renewal process. The building owner has to submit the contact details of the authorised representative and all the correspondences will be sent to that person only. In case the authorised representative/contact person is changed it would be the responsibility of the owner to inform the BEE about the change and to provide updated contact details.

- (e) Energy Performance Index (EPI): Electricity purchased & generated divided by built up area in m². However, the total electricity would not include electricity generated from on-site renewable sources such as solar photovoltaic etc. It is calculated as:

$$\text{EPI} = \frac{\text{Electricity purchased and generated (excl. generated from onsite RE sources)}}{\text{Built up area excluding basement parking, lawn, roads etc. (in m}^2\text{)}}$$

Energy Performance Index (EPI) in kWh/m²/year will be considered for rating the building.

- (f) IAME: It is an abbreviation for Independent Agency for Monitoring and Evaluation. The Bureau will appoint an independent agency to evaluate the program impact and process of application on periodic basis.

3. Scheme Participation Process:

- i. To apply for 'Shunya' Labelling, a standardized format is developed for collection of actual energy consumption. Data required includes building's built-up area, conditioned and non-conditioned area, type of building, hours of operation of the building in a day, climatic zone in which building is located, and other related information of the facility. The format for application and submitting Building Information and Energy Data details is enclosed as Annexure-A and Annexure-I respectively.
- ii. Building owner can register for each building either manually or electronically. Initially the applications would be scrutinized on manual submission. The application for each building shall be accompanied by the non – refundable registration fees. The fees can be submitted either electronically (print of the receipt would be required to be sent with application) or in the form of a crossed bank draft issued in the name of Bureau of Energy Efficiency payable at New Delhi. The fees structure for registration and renewal is provided in Section-5.
- iii. Building owner(s)/ or their authorized representatives will enter into an agreement (as Annexure-B) on a non-judicial stamp paper worth Rs.100/- (rupees one hundred only), with the Bureau of Energy Efficiency (hereinafter called the Bureau) agreeing to abide by the terms and conditions of the scheme. The agreement will be valid for a period of three years from the date of issuance of the certificate for 'Shunya' Labelling.
- vi. After receiving the complete application for the building, the Bureau would scrutinize the application, and seek further information, if require. The Bureau would authorize the use of label after completion of the scrutiny of the application. The Bureau will have the right to conduct an energy audit or any other form of assessment regarding the information provided by the builder whenever there are grounds for the same.

- 4. Renewal Process:** For renewal of the 'Shunya' Labelling, the applicant has to apply for renewal within six months from the date of expiry of validity period (i.e., three years from issuance of Certificate). All the documents as required for registration has to be submitted with latest data/information. Fees for renewal is given in Section-5.

After submitting the documents and requisite fees, BEE will verify the data and after the assessment, appropriate certificate and plaque will be issued.

Note: If the owner fails to apply within three months from date of expiry of the existing 'Shunya' Labelling validity period (i.e., three years from issuance of Certificate) the application will be considered as new application and registration fees for new application will be applicable.

5. Fees

Registration Fees	
New/Fresh Application	Rs. 1 Lakh/project
Renewal (with up-gradation) or only up-gradation (on request of building owner before expiry of validity period)	
For other Buildings	Rs. 25 Thousands
Renewal (without up-gradation) or Downgrading	
For other Buildings	Rs. 10 Thousands

6. EPI Table For Shunya Labelling:

Shunya Label (For Net Zero Energy Buildings)	Shunya+ Label (For Net Positive Energy Buildings)
$10 \leq \text{EPI} \leq 0 \text{ kWh/m}^2/\text{year}$	$\text{EPI} < 0 \text{ kWh/m}^2/\text{year}$

7. **SHUNYA Label/Plaque:** The renewal/registration fees will consist cost of ONE plaque, however, the building owner can request for duplicate plaques by paying Rs.5000 per plaque additionally. Design and colour scheme of the plaque is at Annexure-II.

8. Adherence To Label/Plaque Specification:

- The user of label is solely responsible for the adherence to the specification of the label prescribed by BEE and the authenticity of the documents submitted. However, in case of a new building, the building owner(s)/ or their authorized representatives would be required to submit the detailed information in respect of the building and its energy performance after completion of 1 year of operation with full occupancy of the building.
- Building owner shall be given a time frame of one month after the expiry of each year to file the Building Information and Energy Data for the previous year, failing which BEE shall inform the owner of the lapse and after the expiry of the notice period of one month, the label shall be withdrawn temporarily and owner shall be requested to furnish the information. The entire communication shall take place for a maximum period of six months failing which the label shall be permanently withdrawn for the building and information shall be displayed on BEE's website and in public domain.
- The user of label shall be solely responsible for ensuring:
 - the accuracy of the information displayed on the label or any public claim for label level
 - compliance to the terms and condition of the scheme,
 - directions of the Bureau on the implementation of the scheme
 - Payment of any compensation adjudicated by any court/tribunal to any person for any information displayed on the label.

9. Label Verification Process:

- The Bureau through its authorized representatives would verify the label content and the manner of display on the building.
- The Bureau may conduct sample verification of building for accuracy of the information provided

by the building owner and the EPI either on its own or through a third party. This sample may be conducted without prior notice. The results of the sample check may be put in the public domain, if required.

- iii. The user of the label would agree to make available the drawings of the building/facility and provide access to the building to the authorized representative of the Bureau.
- iv. If it is noticed that the building does not conform to the authorized label specification then a second verification will be done with an authorized representative of the building owner. The date and time for the second check will be decided by the Bureau and the Building owner will be informed at least 48 hours in advance and if no representative is present then the second check results will be binding on the building owner.

Annexure - A

Application Form for Participation and Agreement

(ON THE LETTER HEAD OF THE COMPANY/FIRM)

The Director General
Bureau of Energy Efficiency
4th Floor, Sewa Bhawan,
R. K. Puram, New Delhi-66

Subject: Application for Participation in the BEE Shunya Labelling Programme

I/We are the building owner(s)/authorized representative of (building name and address) owned by (full name of developer/ firm) hereby apply for participation in the scheme “BEE Shunya Labelling Programme”.

I/We have gone through the scheme for the BEE Shunya Labelling Programme, and we agree to abide by the terms and conditions of the scheme. I/We am/are willing to enter into an agreement for participating in the scheme. The duly signed complete agreement is enclosed.

Application Fees Payment Details

(Write N/A if not required, also mention the reason for waiver and enclose copy of the supporting document) –

DD No.: Issue Date:

Issuing Bank and Branch Name:

Online Payment details-

Transaction No.: Date of Transaction:

Amount :

Payment through : (Internet Banking/Credit Card/Debit Card/UPI/Others)

Bank Name :

Dated this Day of....(Year)

Signature

Name

Designation

For and on behalf of

.....

(Name of the firm) Encl:

(i) Copy of Payment Receipt/DD

(ii) Agreement



Annexure- I

Building Information and Energy Data

Name of the Building:

City:

Table 1: Information and Energy Data			Year:
Sl. No.	Primary Data Item		Value
1	Connected Load (kW) or Contract Demand (kVA)		
2	Installed capacity: DG/ GG Sets (kVA or kW)		
3	a) Annual Electricity Consumption, purchased from Grid (kWh)		
	b) Annual Electricity Consumption, through Diesel Generating (DG)/ Gas Generating (GG) Set(s) (kWh)		
	c) Total Annual Electricity Consumption, Utilities + DG/GG Sets (kWh)		
4	a) Annual Cost of Electricity from Grid		
	b) Annual Cost of Electricity generated through DG/GG Sets (Rs.)		
	c) Total Annual Electricity Cost, Utilities + DG/GG Sets (Rs.)		
5	Area of the building (exclude parking, lawn, roads, etc.)	Built Up Area floor wise (m ²) with No. of rooms	
		Conditioned Area (in m ²)	
		Conditioned Area (as % of built-up area)	
6	Working hours (e.g., day working /24 hour working)		
7	Working days/week (e.g., 5/6/7 days per week)		
8	a) Office	Total no. of Employees	
		Average.no. of Persons at any time in building during working hours	
9	a) Installed capacity of Air Conditioning System (TR)		
	b) No. of Window and Split ACs with capacity (TR)		
	c) No. of Water coolers and Air Heaters		
10	Installed lighting load (kW) (if available)		
12	HSD (or any other fuel oil used, specify)/Gas Consumption in DG/GG Sets (liters/cu. meters) in the year		
13	Fuel (e.g., FO, LDO, LPG, NG) used for generating steam/water heating in the year (in appropriate units)		
14	Water Requirement (liters or cu. meters/day) if available		
15	Major Loads in Building e.g., Lighting, cooling tower pump, water pumping motors, Transformer details, present power factor, Boilers, etc. (Insert additional rows if required)		
	Sl. No.	Name	kW Load/KVA/Ton
	1		
	2		
	.		
	.		

Table 2: Details of Major Lighting Inventory

Type and Category wise Building Connected Load					
Category	Type of Fittings	Watts	No of Fittings	Total Load (KW)	Total Load (KW)
Lighting					

Table 3: Details of Diesel Generator sets (One Year Data)

S. No.	Items	Value
1.	DG Set rating (KVA)	
2.	Total Units generated (kWh)	
3.	Diesel Consumption (Ltrs.)	
4.	No. of hours used	
5.	Avg. load (kW)	
6.	Percentage Loading	
7.	Cost of diesel (Rs.)/ltr.	

Table 4: Details of AC Plants

S. No.	Items	Nos. Installed	Individual capacity (TR/kW/hp)	Total Capacity
1.	Chiller			
2.	AHU's			
3.	FCU's			
4.	Cooling Tower			
5.	Primary Chilled water Pump			
6.	Secondary Chilled water Pump			
7.	Condenser Water Pump			
8.	CT fan			

Table 5: Contact Details of the Organization and the Contact Person

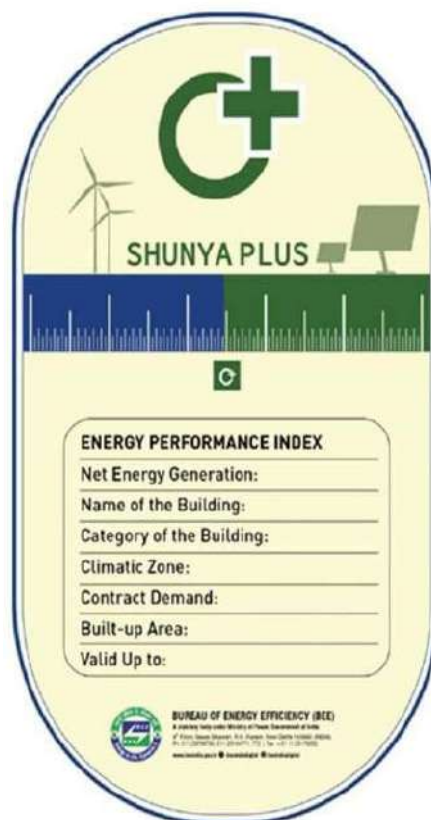
S. No.	Organization	Details
a)	Name of the Organization	
b)	Postal Address	
c)	Phone No.	
	Contact Person	
a)	Name & Designation	
b)	E-mail Address	
c)	Phone Nos.	

Label design with specification



← For Net Zero Energy Building

For Net Positive Energy Building →



Annexure–B

AGREEMENT

(To be printed on non-judicial stamp paper worth Rs.100/- (rupees one hundred only))

Agreement between the Bureau of Energy Efficiency, a statutory body under the Ministry of Power and Building owner(s)/authorized representative under the “Shunya Labelling Programme”.

Whereas the Bureau of Energy Efficiency, Ministry of Power (hereinafter referred to as the Bureau), a statutory body established under the Energy Conservation Act 2001, (52 of 2001) with its office at Bureau of Energy Efficiency 4th Floor, Sewa Bhawan, R. K. Puram, New Delhi-66, Whereas M/s (Building owner(s)/authorized representative Name) having its registered office at (full address) has agreed to participate under the “Shunya Labelling Programme” (herein after referred to as the user of label)

Now therefore, the parties hereto mutually agree as follows:

1. General

1.1 Commencement and duration

1.1.1 The agreement shall be valid for a period of three years commencing from the date it is signed or until Notification under the Energy Conservation Act 2001 issued by the Central Government, whichever is earlier.

1.2 Objective

The main objective of this Agreement is that both the parties to the Agreement shall work together to implement the scheme for “Shunya Labelling Programme” in accordance with the details of the Scheme as attached.

1.3 Use of Shunya label

1.3.1 The label is being promoted by the Bureau. The use of the label is assigned to M/s (Building owner(s)/authorized representative Name) for achieving the objective defined in Article 1.2 of this Agreement.

1.3.2 Format for submitting Building Information and Energy Data details is enclosed as Annexure-I. Energy Performance Index (EPI) in kWh /m²/ year will be considered in rating the buildings.

1.3.3 The user of label is solely responsible for the adherence to the specification of the label prescribed by BEE (as enclosed at Annexure II), and the authenticity of the documents submitted.

2. Taxes and duties

2.1 The User of label shall also bear any taxes, duties, levies, registration fee, etc as applicable from time to time in the use of label under the implementation of the scheme for “Shunya Labelling Programme”.

3. Amendment / Additions

3.1 If both parties to the Agreement form an opinion that any or some provision of the scheme are coming in the way of achievement of the objective of this Agreement defined in Article 1.2; and both BEE and the user of label are satisfied that the adjustment or amendment of such provisions



shall contribute towards the achievement of the objective defined in Article 1.2; BEE may, adjust or amend such provisions of the scheme at any stage during the implementation of the scheme in consultation with other stakeholders

3.2 Any such adjustment or amendment shall be made in writing.

4. Notice

4.1 Any notice given by any of the parties hereunder shall be sent in writing at the address given as follows:

(1) Bureau of Energy Efficiency

(2) User of label

The Director General
Bureau of Energy Efficiency
4th Floor, Sewa Bhawan,
R. K. Puram New Delhi-66

In witness whereof the parties here to have signed this Agreement.

Signature.....

Signature.....

(Place, date)

(Place, date)

Bureau of Energy Efficiency

User of label

Witness: 1

Witness: 1

Witness: 2

Witness: 2

8.1 Introduction

Renewable energy or Green Energy provides reliable power supplies and fuel diversification, which enhance energy security, lower risk of fuel spills, and reduce the need for imported fuels. Renewable energy also helps conserve the nation's natural resources. It is environment friendly. It helps in the following ways-

- i. Reducing CO₂ & other greenhouse gases.
- ii. Reducing Global warming.
- iii. Guarantees Energy security.

8.1.1 What is Green Energy?

- i. Green energy comes from natural sources such as sunlight, wind, rain, tides, plants, algae and geothermal heat.
- ii. These energy resources are renewable, meaning they're naturally replenished. In contrast, fossil fuels are a finite resource that take millions of years to replenish.

8.1.2 Why Green Energy?

- i. Green energy or Renewable energy provides reliable power supplies and fuel diversification, which enhance energy security, lower risk of fuel spills, and reduce the need for imported fuels. Renewable energy also helps conserve the nation's natural resources.
- ii. Do not deplete natural resources.
- iii. Global warming has hit the public conscience.
- iv. Effective method to reduce CO₂ emissions.
- v. Guarantee Energy security for countries deploying it

8.2 Types of Renewable Energy

- i. Solar Energy
- ii. Wind Energy
- iii. Hydroelectric
- iv. Geothermal
- v. Biomass

8.2.1 Solar Energy

Introduction

The sources of conventional and non-renewable energy such as coal, petrol, diesel etc. are diminishing continuously on Earth, the formation of which is a long process. Hence a need for alternative energy sources was felt such as Wind energy, Bio-energy, solar energy. These are called as non-conventional or renewable energy sources. Solar energy, which is abundant in nature and free of cost, is considered to be the best and most popular one.

Solar energy is obtained through the use of Solar cells. The Solar cells convert sunlight into electrical energy, based on the principle of photovoltaic effect. The electricity so obtained can directly be used to charge the batteries used for various appliances.



8.2.2 Advantages and Disadvantages of Solar Panel

Advantages

1. Fuel source for Solar Panel is direct and endless so no external fuels required. Sunlight free of cost.
2. Unlimited life of Solar Modules, fast response and high reliability. Can operate under high temperature and in open.
3. Inherently short circuit protected and safe under any load condition. Pollution free.
4. Minimum Maintenance Independent working
5. Operation is simple and no electrochemical reaction and no liquid medium. Noise-free as there are no moving parts.
6. No AC to DC conversion losses as DC is produced directly. No transmission losses as installed in the vicinity of the load. Suitable for remote, isolated and hilly places.
7. Suitable for moving loads/objects
8. Since it is in modular form, provision of future expansion of capacity is available. It can generate powers from milli-watts to several megawatts.
9. It can be used almost everywhere from small electronic device to large scale MW power generation station.
10. It can be installed and mounted easily with minimum cost.

Disadvantages

1. Initial cost is high.
2. Dependent on sunlight
3. Additional cost for storage battery.
4. Climatic condition, location, latitude, longitude, altitude, tilt angle, ageing, dent, bird dropping, etc. affect the output.
5. It has no self-storage capacity.
6. Manufacturing is very complicated process.
7. To install solar panel large area is required.

8.2.3 Utilization of Solar Power Supply System in the Indian Railways

The efficient running and control of Railway traffic in the country is sometimes seriously hampered by the irregular grid supply (by State Electricity Board) resulting in traffic congestion and other operational equipment failures also. The alternate D.G. sets **pose** considerable problem as it has a high maintenance cost and necessitates the use of additional D.G. sets as stand by. Again diesel oil is prone to pilferage, and moreover transportation and storage costs are involved. It also causes atmospheric pollution. Hence by harnessing the abundantly available and non-polluting by nature solar energy source for power requirements came into action after decades of research and field experience

8.2.4 Photo voltaic effect

Electricity can be generated directly from sunlight, by a process called photovoltaic effect, which is defined as the generation of an electromotive force as a result of the absorption of ionizing radiation. The photo voltaic effect can be observed in almost any junction of material that have different electrical characteristics, but the best performance to date has been from solar cells made of Silicon

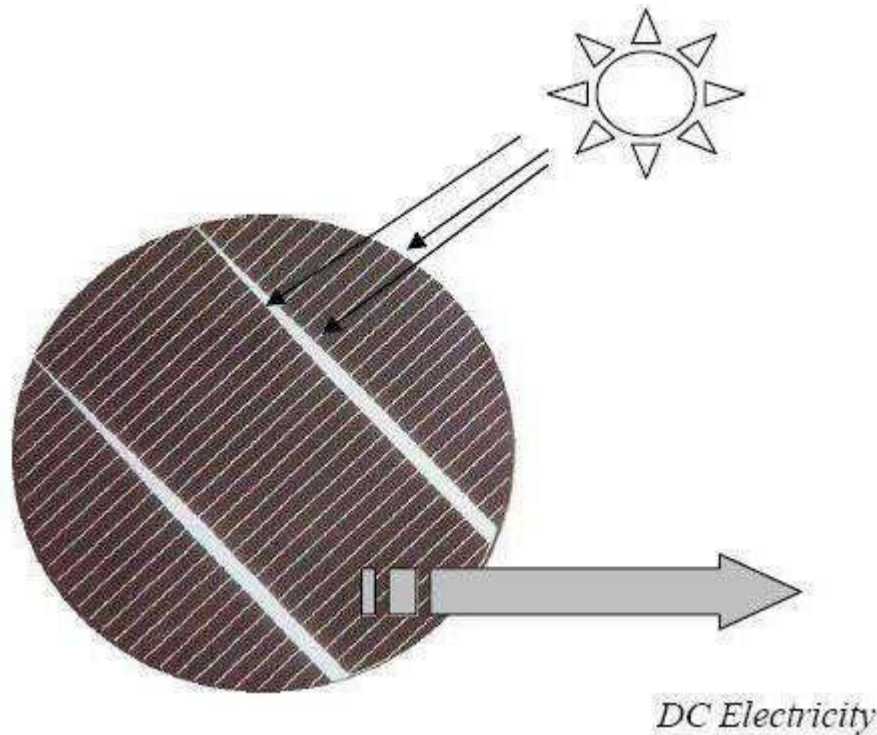


Fig. 8.1 – Photo Voltaic effect

8.2.5 Solar Cell: Construction & Working

The basic building block of a photovoltaic system is the Solar Cell, a semiconductor device having a simple p-n junction and which when exposed to sunlight produces DC electricity. The solar cell is made up of “Semi-Conductor” materials that are processed to make the device photovoltaic. The solar cell is made of single crystal silicon, polycrystalline and amorphous Silicon with an area of a few sq. centimeters to 200 sq. centimeters and even more. A thin p type silicon wafer is taken through phosphorus diffusion process and by screen-printing technology electrodes are made. The P-N junction of the solar cell gives rise to diode characteristics. Hence a solar cell is a PN junction device on which front and back electrical contacts are screen-printed. A sketch of typical psuedo-square solar cell is shown in Fig.1.2 (a) & (b). The side, which has negative polarity, is taken as front side and that which has positive polarity is taken as backside. The front or Negative side is exposed to sunlight for conduction to take place. Two Tinned copper strips work as terminal leads for interconnection to other cells. For collection of charge from the cell and conduction to terminal leads on negative side, Silver Oxide lines are screen printed horizontally and these are joined to terminal leads at close spacing (refer Fig 1.2 a). These lines cover only 5% of the total area of the cell, so that these do not pose any hindrance to the exposure of Sunrays. The back or Positive side is not exposed to sunlight; hence Aluminium is coated on whole surface for better conductivity (refer Fig 1.2 b). Aluminium is coated instead of Silver Oxide as latter is expensive hence not economical. The operation of solar cells involves these major processes:

- i. Absorption of sunlight into semiconductor materials
- ii. Generation of charge carriers.
- iii. Separation of +ve & -ve charges to different regions of the cell to produce e.m.f.

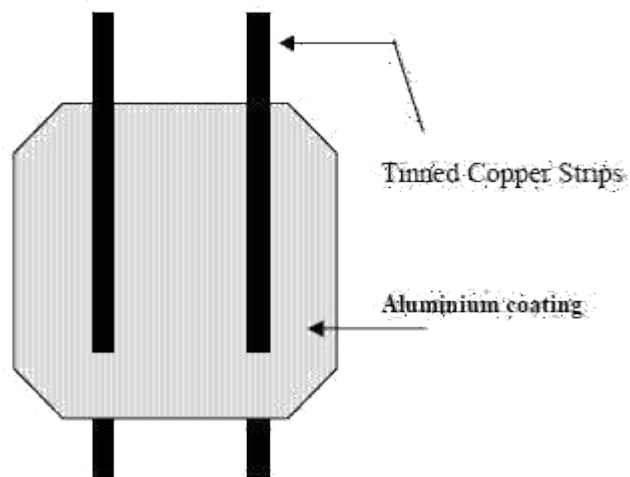


Fig 8.2 – (a) Sketch showing front view of typical pseudo square solar cell

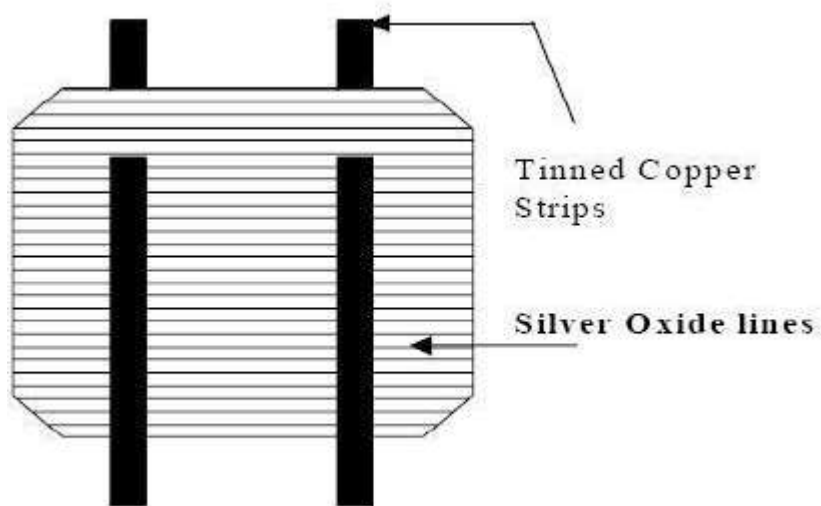


Fig 8.2 – (b) Sketch showing rear view of typical pseudo square solar cel

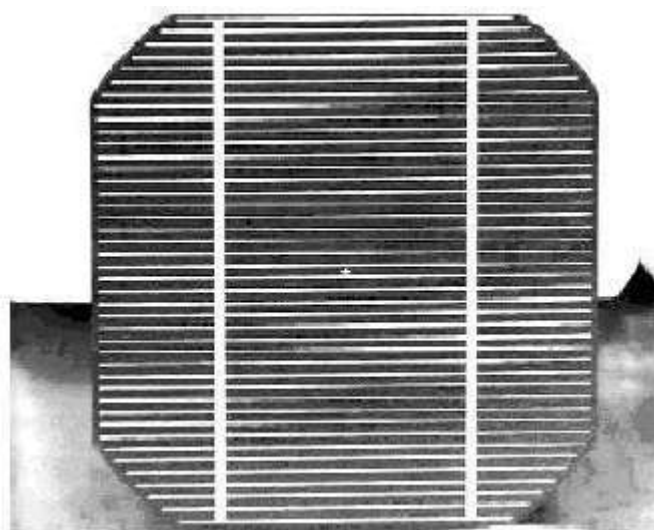


Fig. 8.2 – (c): Solar Cell: Actual view

8.2.6 Solar Photo Voltaic (SPV) Module

The power generated by a single cell is small and therefore several cells are interconnected in series/parallel combination to get the required voltage and current. When a number of solar cells are connected in series to get a specific voltage the unit so formed is called as Solar Module. Charging batteries is the primary use of SPV module. Therefore normally 36 cells are joined in series to form a standard module, which is capable of charging 12 volts battery. A terminal box is provided on the backside of the module for external connections. A Bypass diode is connected across +ve and -ve in the terminal box. Cathode of the diode will be at +ve terminal and Anode will be at -ve terminal of the module. This diode protects the module cells from overheating due to shadowing of the module or any cell breakage generally the rating of bypass diode is 1.52 times of the maximum current of module. The Repetitive Reverse Peak Voltage V_{rrm} of the diode should be double the string open voltage. A typical solar module is shown in Fig 8.3.

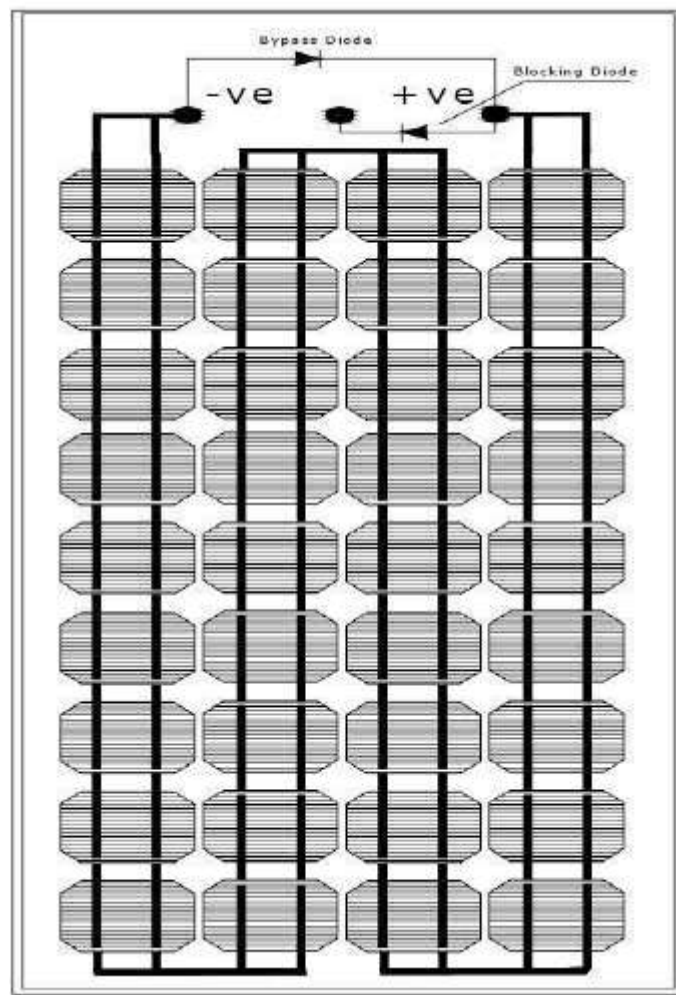


Fig.8.3 – Solar Module

8.2.7 Solar Panel

A Solar panel consists of a number of solar modules, which are connected in series and parallel configuration to provide specific voltage and current to charge a battery. A diode is connected on the +ve terminal of such string in forward bias. This is called Blocking diode. This diode is provided so that in daytime current can flow from module to battery, but at night or in cloudy day current should not flow back from battery to module or from one string to another string. Drawing shown in Fig 8.4

below illustrates a Solar panel

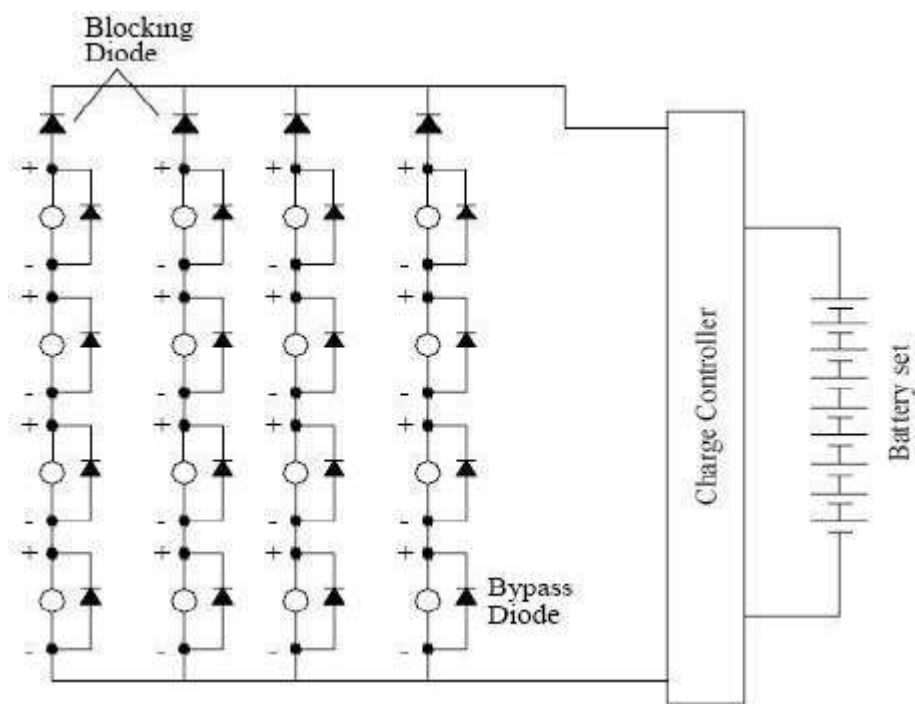


Fig. 8.4 – Structure of a Solar Panel

8.2.8 Main Components of Solar Photo Voltaic System

The solar power system consists of the following components:

- Solar array.
- Battery Bank
- Solar Charge Controller
- Field Junction Box
- Solar Module Mounting Structure
- Earthing kit
- Cables.

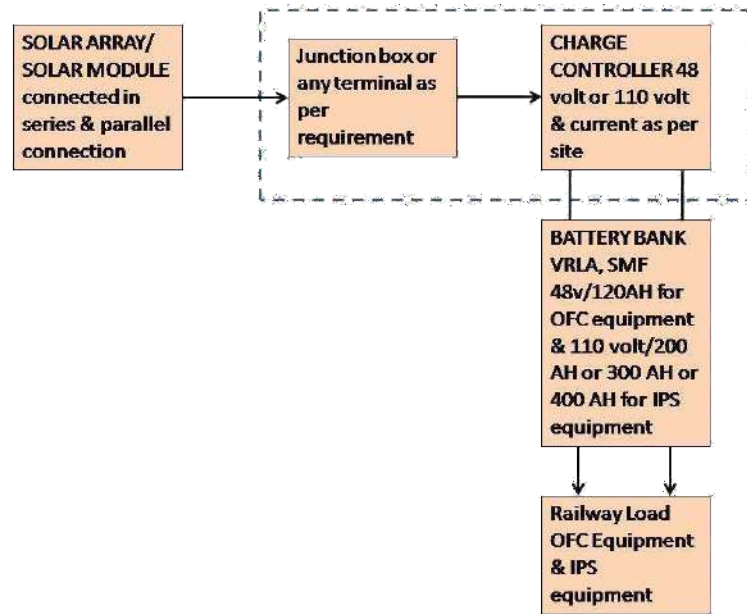


Fig. 8.5 – Block diagram of Solar Photo Voltaic System

8.2.9 Solar Array

Solar array consists of series/parallel combination of modules, which are mounted on the metallic structure in sunny and shadow free area at a fixed angle as recommended by designer. All the modules will face the South in Northern hemisphere. Cables from the array area will come to the control and battery room through junction boxes from panels of modules

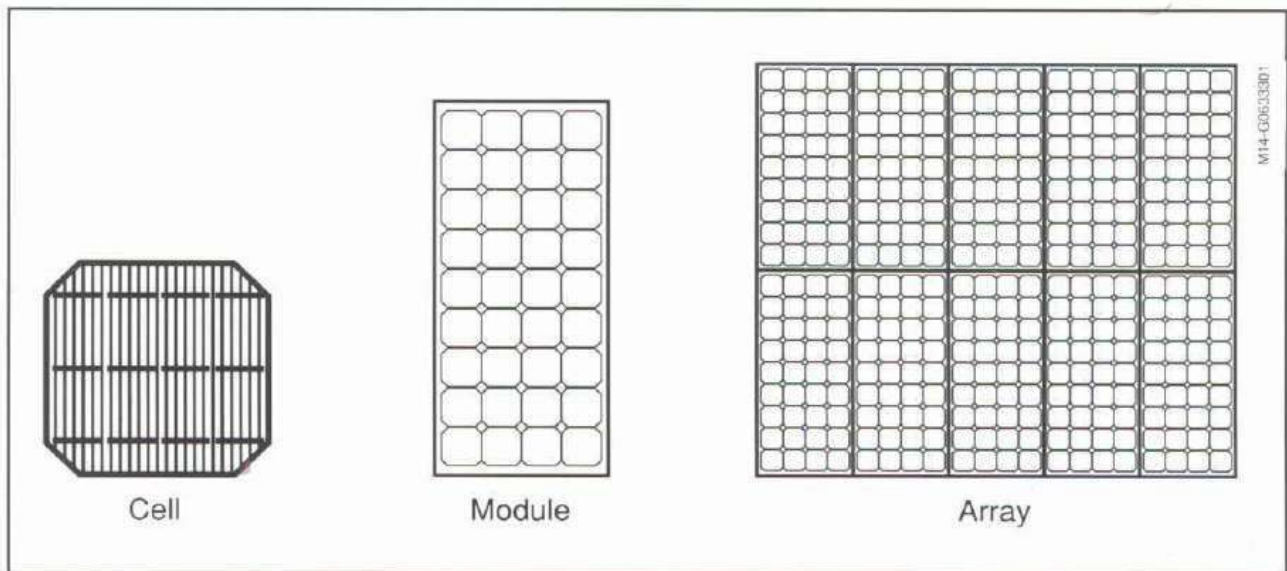


Fig. 8.6 – Sketches showing Cell, Module and Array

8.2.10 Battery Bank

The Sun is not always available and it is not regular. However, loads are to be fed any time of the day. Therefore power should be stored in a battery bank. Low maintenance Lead acid battery as per IRS: S 88/2004 or latest of specified capacity will be provided. The capacity of this battery bank is given in Ampere Hour (AH) and bus bar voltage. The bus-bar voltage is decided by the voltage requirement of the load

8.2.11 Solar Charge Controller

Charge controller is the interface between Array and battery bank. It protects the battery from overcharging and moderate charging at finishing end of charge of battery bank. Therefore it enhances the life of the battery bank. It also indicates the charging status of batteries like battery undercharged, overcharged or deep discharged through LEDs indications. Some switches and MCBs are also provided for manual or accidental cut-off of charging. In some charge controllers load terminals are also provided through a low battery charge cut-off device so that it can protect the battery bank from deep discharge.

The technology adopted nowadays for manufacturing solar charge controller is MOSFET/IGBT technology. With this technology the idle current of the controller is less than 50 mA depending upon the rating of the charge controller and its current. First the controller is connected to battery bank and then it is connected to Solar Array/Solar module for sensing the voltage from the module. When the system is put into operation, the SPV modules start charging the battery bank. Care should be taken that in no case the battery connections are removed from the controller terminals when the system is in operation, otherwise SPV voltage may damage the Charge controller, since the Solar voltage is always higher than the battery voltage

8.2.12 Field Junction Box (FJB):

FJB is the interface between solar panels and the charge controller. All the incoming/outgoing cables / Wires from solar panels to charge controller are terminated at FJB

8.2.13 Solar Module Mounting Structure:

This is made up of galvanized iron frames and angles. In this structure flexibility is provided to change the module-mounting angle seasonally. This structure is grouted by small civil work and modules are mounted subsequently. Also, this mounting structure should be earthed suitably at several places if voltage of the array is more than 50 Volts

8.2.14 Earthing kit

Earthing kit is provided to earth the mounting structure. Provision of earthing shall be done as follows:

The installation shall have proper earth terminals and shall be properly earthed.

The earth resistance shall not be more than 2 ohm. Earth provided shall preferably be maintenance free using earth resistance improvement material

As far as some hardware is concerned the screws and bolts/nuts are of Chrome plated, stainless steel and brass so that rusting should not be take place.

8.2.15 Cables

Different types of cables are required to connect module to module, modules to charge controller, charge controller to battery, connect battery to load. The cable size used for interconnection of SPV module, Charge Controller and battery shall be minimum 2 X 2.5 sq. mm Cu. Cable.

8.2.16 Types of Solar Panels

Solar panels are classified on the basis of the following points:

Crystalline Silicon (Mono/Poly/Amorphous)

Different Size or Area of cells

Type of cells & nos. (Rectangular/Circular/Square/ Pseudo-square/Semi-circular etc.)

Power (High/Mid/Low range)



8.2.17 Mono crystalline solar PV Panels

Mono crystalline or single crystal solar PV panels are one of the oldest, most reliable, and most efficient ways to generate electricity from solar energy. Here, each PV module is fabricated from a single silicon crystal. The silicon is purified, melted, and then crystallized into ingots, which are then cut into thin wafers to produce individual cells. The typical color of mono crystalline PV module is black or iridescent blue.

8.2.18 Pros and Cons of Mono crystalline Solar Panels

The following are the key benefits of the mono crystalline solar PV panels:

- a. Longevity
- b. Efficiency is high in the range of 15-24% as they are fabricated from the highest grade silicon, making them cost effective in the long term
- c. Lower installation costs
- d. Space-efficient
- e. Non-hazardous to environment
- f. Greater heat resistance
- g. More electricity
- h. Embodied energy

High initial cost and fragility are the major drawbacks of mono crystalline solar panels. The mono crystalline silicon is produced using the Czochralski process, which involves significant silicon wastage.

8.2.19 Poly crystalline Panels

Poly crystalline or multi crystalline panels use solar cells that are made from multifaceted silicon crystals. The appearance of polycrystalline cells is not as uniform as the mono crystalline solar cells. They have a surface with a random pattern of crystal borders rather than the solid color of single-crystal cells. Since a low-cost silicon is used to fabricate polycrystalline cells, their efficiency is typically in the range of 12%-14%, a value slightly less than the mono-crystalline cells, but much higher than solar technologies such as thin film

8.2.20 A Pros and Cons of Multi-crystalline Solar Panels

The following are key advantages of the multi-crystalline panels:

- a. The production process is simple, cost-effective, and reduces silicon waste compared to single crystal panels
- b. Heat tolerance is slightly lower than single crystal panels
- c. Temperature co-efficient is higher than single crystal panels, meaning that the panel output will drop with increasing temperature; however these variations are minimal practically

The disadvantages of the polycrystalline panels are as follows:

- a. Lower conversion efficiency compared to mono-crystalline panels due to the use of low purity silicon
- b. Lower space-efficiency
- c. Less aesthetically pleasing compared to single crystal and thin film panels



8.2.21 Criteria for Designing of Solar Photovoltaic System

DEFINITIONS

The following definitions are very important in designing a solar photo voltaic system.

a. Solar Cell:

The basic photovoltaic device, which generates electricity when exposed to sunlight, shall be called a “Solar Cell”.

b. Solar Module

The smallest complete environmentally protected assembly of interconnected solar cells shall be called “Module”.

c. Solar Panel

A group of modules fastened together, pre-assembled and interconnected, designed to serve as an installable unit in an Array shall be called “Panel”.

d. Solar Array

A mechanically integrated assembly of modules or panels together with support structure, but exclusive of foundation, tracking, thermal control and other components, as required to form a dc power producing unit shall be called an “Array”.

e. Solar irradiation

On any given day the solar radiation varies continuously from sunrise to sunset and depends on cloud cover, sun position and content and turbidity of the atmosphere.

The maximum irradiance is available at **solar noon** which is defined as the midpoint, in time, between sunrise and sunset. The total solar radiant power incident upon unit area of an inclined surface (Watt/m^2) is called total solar irradiance.

f. Insolation

Insolation differs from irradiance because of the inclusion of time. Insolation is the amount of solar energy received on a given area over time measured in kilowatt-hours per square meter squared (kW-hrs/m^2) - this value is equivalent to “**peak sun hours**”.

g. Peak Sun Hours

Peak sun hours is defined as the equivalent number of hours per day, with solar irradiance equaling $1,000 \text{ W/m}^2$, that gives the same energy received from sunrise to sunset.

Peak sun hours is of significance because PV panel power output is rated with a radiation level of $1,000 \text{ W/m}^2$.

Many tables of solar data are often presented as an average daily value of peak sun hours (kW-hrs/m^2) for each month.

h. Conversion Efficiency

The ratio of the maximum power to the product of area and irradiance expressed as a percentage.

$$n = \frac{\text{Maximum power}}{\text{Area} \times \text{irradiance}} \times 100\%$$

8.2.22 General & Technical requirements for Solar Photo Voltaic Module

Following are the general and technical requirements of solar photovoltaic module for use in Railway installation for the correctness of its material, design and electrical characteristics as per IRS specification IRS:S 84-92

8.2.23 General Requirements

The solar module for the purpose of this specification shall consist of the following three main components:

- i. Toughened front glass.
- ii. A suitable mounting frame.
- iii. An assembly of suitably interconnected, silicon solar cells working on the principle of photovoltaic conversion of sunlight into electricity.

The silicon wafers cut from the large crystal shall be polished and necessary chemical treatment shall be given to achieve requisite surface characteristics for optimum efficiency of individual cells.

P-N junction on individual wafer shall be made by injecting impurity (phosphorous or any other suitable material) by diffusion process.

The solar cells required to form a module shall be connected in series/ parallel through tinned copper foils. These shall be mounted behind a high transparency, toughened glass front surface. Two thin transparent films of suitable plastic material, preferably (Ethylene Vinyl Acetate) shall be interposed between the solar cell layer and the front glass and the solar cell layer and the back plastic laminate. This assembly shall then be kept in a temperature controlled oven at a suitable temperature, so that the above assembly becomes a solid mass with the cells protected against corrosion, moisture, pollution and weathering.

The transparency of toughened glass used shall not be less than 91%. A certificate to this effect shall be submitted by the supplier. A copy of test results from a recognized test house or their own laboratory shall be submitted at the time of type approval.

The complete solar module shall be sealed in an Anodized Aluminium Frame with RTV silicon rubber compound filling around the edges to give further moisture barrier and shock resistance.

The output terminals of the module shall be provided on the back of the solar PV-module. Terminal block shall be made of Nylon- 6. It shall be housed in a HDPE-UV stable junction box secured physically uniformly to the frame of the PV module. The junction box should have a hinged lid with self-holding fasteners enabling easy handling. The box lid should be secured with a gasket for greater protection against ingress of moisture (conforming to IP-55 of IS: 2147-62). Cable outlets from solar PV module terminal shall be through cable glands to be provided in the junction box (with addl. knockouts provided) to help in series /parallel connection of solar PV modules. The junction box should have common terminals with suitable by pass diodes for prevention of hot spot problem.

If required by the purchaser the module shall be fixed on a mounting bracket, which shall be suitably designed to withstand the weight of the panel. The mounting arrangement shall be suitable for pole mounting, column mounting or flat surface, as desired by the purchaser.

Provision for directional and angular adjustment shall be provided to get maximum utilization of incident sunlight.

The design/drawings of the mounting bracket shall be supplied along with the module to the purchaser.

The supplier shall give information regarding the weight and dimensions of the module, to the purchaser.

The solar photovoltaic module shall be highly reliable, light-weight and shall have a long operational life.

The recommended values of output power from each module are 4, 6, 9, 12, 30, 32, 35, 40, 50, 70, 80 & 100 watts. The purchaser shall, however, specify the output wattage of the module required by him.



The recommended nominal voltages of each module are 4, 6, 9, 12 & 24Volts. The purchaser shall, however, specify the voltage of the module required by him.

8.2.24 Technical Requirement

Some of the important technical requirements as per IRS:S 84-92 are as given below: The following parameters shall be clearly specified by the manufacturer for different type of solar modules manufactured by him:

- a. Peak power output (Pm)
- b. Current at peak power output (Im)
- c. Voltage at peak power output (Vm)
- d. Short circuit current (Isc)
- e. Open circuit voltage (Voc)
- f. Conversion efficiency of the module (n)

The values of parameters from (a) to (f) above shall be specified under standard test conditions of-

- a. Cell junction temperature of $25^{\circ}\text{C} \pm 2^{\circ}\text{C}$.
- b. Irradiance of 1000 Watt/m^2 as measured with a reference solar cell (duly certified by a recognized national/international test house/lab. nominated for this purpose.
- c. Standard Solar spectral energy distribution.
- d. Air Mass of 1.5.

8.2.25 Primary phases of designing an SPV system

The primary phases of designing a Photovoltaic system consists of the following steps:

- a. Planning
- b. Collection of information/data
- c. Load calculation
- d. Sizing Solar Array
- e. Selection of net meter
- f. Deciding Inverter capacity
- g. Structure
- h. Wiring

A. Planning

Before designing a solar photovoltaic system, several considerations are to be kept in mind such as the cost of the system should not be unusually high and at the same time the quality should also not suffer. Initial costs and lifetime costs shall also be taken into consideration. The system should be simple in design as far as possible with high reliability and efficiency

B. Collection of Information/data

Following types of information are to be gathered

i. Load/ Application

- a. Voltage system e.g. AC or DC or both
- b. Operating voltage range of load
- c. Daily consumption

- d. Daily duty cycle
- e. Criticality of loads
- f. Monthly / Weekly load profile

ii. Climatic conditions

- a. Insolation
- b. Latitude, Longitude Temperature
- c. Accessibility to site Terrain
- d. Local Knowledge

iii. User compatibility

- a. Understanding technical issues.
- b. Maintenance schedules and mentality.
- c. Whether the controls are field adjustable.
- d. Budget constraints
- e. Understanding of managing energy budget

C. Load calculation

Obtain the maximum amount of data pertaining to the amount of energy consumed by the load for the last two or three years. This helps to design the System and also helps to forecast any variations of load in future and take that into account at the designing stage only.

D. Sizing Solar Array

For the sizing of solar array back calculations are done. Required energy needed per day is translated to the energy input to inverter based on the efficiency of inverter and wiring system. Then the required solar array is dividing it with efficiency of panel and solar irradiance

E. Selection of Net metering system:

Net metering allows to store energy in electric grid when the solar panels produce excess power, that energy is sent to the grid and in exchange we can import power from the grid when Solar PV system is under generating like in night time.

The Net Meter conforming to the standards specified by the CEA for installation and operation of meters shall be procured and installed by MSEDCL at its own cost in the premises of the Eligible Consumer

F. Deciding Inverter capacity:

Inverter capacity will be decided as per the capacity of solar generating system.

G. Module mounts:

While mounting the modules, following points should be considered for getting maximum output from the solar modules:

- a. Modules should be oriented to face the Sun.
- b. The Modules produce more power when cooler.
- c. The mounting and color of the modules can sometimes be chosen to blend with the architecture.
- d. Tracking the Sun increases the amount of power from an array.



H. Structure:

Select type of structure i.e. Ground Mount, Rooftop Mount, Pole Mount or Tracker.

A group of Modules mounted on single unit of structure and interconnected together is called Panel.

Calculate Number of Structures by following formula

No. of Structures = Total No. of Modules / No. of Modules on single unit of structure.

Group of panels connected through junction box will make Array.

While designing structure provision for future growth should be considered.

I. Wiring:

Selecting the correct size and type of wire will enhance the performance and reliability of PV system. The size of the wire must be large enough to carry the maximum current expected without undue voltage losses.

All wire has a certain amount of resistance to the flow of current. This resistance causes a drop in the voltage from the source to the load. Voltage drops cause inefficiencies, especially in low voltage systems (12V or less).

Typical Values of Module current and voltages are provided by the manufacturer. Based on system voltage and current decide size of wire/cable to be used for module interconnection.

Calculate output current and voltage of the panel and decide specifications of wire/cable for panel interconnection. Always use minimum possible wire lengths. Always use suitable lugs, connectors etc. for connection.

Decide number and type of switches, fuses and circuit breakers as per load, system and user requirement.

8.2.26 Grid Connected System:

In the Grid connected system the flexibility available is that they can install solar panels based on the amount of energy they intend to inject into the system, No separate calculations for calculating the panel ratings based on load are needed as in the case of Off-grid system.

The extra equipment that comes in the Grid connected system is the net meter which will monitor and record the amount of energy imported and exported from the Solar PV system.

Maintenance is comparatively less in grid connected system as battery are not present. So maintenance charges comes down and rate of return improves

8.2.27 Design of Grid connected PV System:

A. Facing of the Panels:

Solar panels should be installed south facing in the Northern hemisphere and north facing in the Southern hemisphere. Since India is in the Northern hemisphere, Solar panels will be installed always- South facing.

Any obstruction (such as tree or building) should be avoided in East, West or South of the place of installation. The following is the criteria:

- i. East or West: The distance between solar panel and obstruction should be more than double the height of obstruction.
- ii. South: The distance should be more than half the height of obstruction.

B. Tilt of the panel:

Solar panels should be installed at an angle of '(LATITUDE of the place + 10) degree'. Nasik is located at the latitude of $19^{\circ}57'$. So, the panels are to be fixed at a tilt of $29^{\circ}57'$.

C. Spacing between the panels

Distance between adjacent rows of structures have to be maintained so that the shadow can be avoided

Distance provides = length of panel * Sin (tilt+10)*U

U value varies based on tilt and it is taken from RDSO handbook

Lalitude	0	10	20	28	30	32	34	36	38	39	40	41
U	0.614	0.885	0.1259	1.699	1.842	2.001	2.195	2.404	2.667	2.818	2.972	3.166

Therefore distance between two rows = $1.984 * 0.499 * 1.259 = 1.2469$ mts.

D. Determining total number of modules needed.

Solar irradiance in Nasik is $5.51 \text{ KWH}/\text{m}^2/\text{Day}$. That means in a day in a sq. meter area available solar energy is 5.51KWH. But in practical the solar panels have a less efficiency of around 12 to 18% and the inverter and wiring circuit also have efficiency of 90% only.

Total number of units required at the output of inverter is 28 units. By considering the inverter and wiring circuit efficiency as 90%. The energy output of solar panels needed is 31.11 units.

Example. As the efficiency of TATA T300 panel has efficiency of 15.1%.

From the data sheet, Module surface area is 1.984 m^2 .

The Module efficiency is 0.151.

Total surface area required to generate 31.11 units daily = $(31.11) / (5.51 * 0.151) = 37.3913 \text{ m}^2$.

Module area of each panel is 1.984 m^2 .

No. of panels required = $37.3913 / 1.984 = 18.81$ panels.

We will round it to 21 as it will be convenient to form the array. The 21 panels will be connected as 7 in series and such three strings will be connected in parallel. Which will give a maximum output voltage of 256.2V and maximum current of 24.6A.

E. Determining the rating of inverter:

The converter should be able to operate at the maximum power output of the PV string

The rating of Inverter = $256.2 * 24.6 = 6302$ Watts

So, 7 KW inverter can be used.

8.2.28 Cost Estimation of Grid connected PV system:

The electrical design of a PV project can be split into the DC and AC systems.

The DC system comprises the following:

- Array(s) of PV modules



- b. DC cabling (module, string and main cable)
- c. DC connectors (plugs and sockets)
- d. Junction boxes/ combiners
- e. Disconnects/ switches
- f. Protection devices
- g. Earthing

The AC system includes:

- a. Inverter
- b. AC cabling
- c. Switchgear
- d. Earthing and surge protection

8.2.29 Illustrative example Total savings in bill for one year

Apart from paying the nominal fixed charges, most of the monthly electrical energy imported from the grid will be compensated by the energy exported to the grid by solar PV system.

The total savings per year= Total electricity bill paid in that year if there is no Solar PV system – Fixed charges paid for whole year.

$$\begin{aligned} &= (\text{average monthly consumption} * 12) - (\text{fixed charges} * 12) \\ &= (16402 * 12) - (220 * 12) \\ &= \text{Rs.1, 94,184.00} \end{aligned}$$

The Grid connected Solar PV system will give savings of Rs.1, 94,814.00

8.2.30 Payback period

The rate of return for the project = Total investment for the project / total savings per year
 $= 7, 51,000 / 194814 = 3.85 \text{ years.}$

Definition

A Grid Tied Solar Rooftop Photo Voltaic (SPV) power plant consists of SPV array, Module Mounting Structure, Power Conditioning Unit (PCU) consisting of Maximum Power Point Tracker (MPPT), Inverter, and Controls & Protections, interconnect cables and switches. PV Array is mounted on a suitable structure. Grid tied SPV system is without battery and should be designed with necessary features to supplement the grid power during day time. Components and parts used in the SPV power plants including the PV modules, metallic structures, cables, junction box, switches, PCUs etc., should conform to the BIS or IEC or international specifications, wherever such specifications are available and applicable. Solar PV system shall consist of following equipments/components.

Solar PV modules consisting of required number of **Crystalline** PV modules. Grid interactive Power Conditioning Unit with Remote Monitoring System Mounting structures

Junction Boxes.

Earthing and lightening protections.

IR/UV protected PVC Cables, pipes and accessories

Solar PV Modules/Panels	
IEC 61215/ IS 14286	Design Qualification and Type Approval for Crystalline Silicon Terrestrial Photovoltaic (PV) Modules
IEC 61701	Salt Mist Corrosion Testing of Photovoltaic (PV) Modules
IEC 61853- Part 1/ IS 16170: Part 1	Photovoltaic (PV) module performance testing and energy rating –: Irradiance and temperature performance measurements, and power rating
IEC 62716	Photovoltaic (PV) Modules – Ammonia (NH ₃) Corrosion Testing (As per the site condition like dairies, toilets)
IEC 61730-1,2	Photovoltaic (PV) Module Safety Qualification – Part 1: Requirements for Construction, Part 2: Requirements for Testing
IEC 62804	Photovoltaic (PV) modules - Test methods for the detection of potential-induced degradation. IEC TS 62804-1: Part 1: Crystalline silicon (mandatory for applications where the system voltage is > 600 VDC and advisory for installations where the system voltage is < 600 VDC)
IEC 62759-1	Photovoltaic (PV) modules – Transportation testing, Part 1: Transportation and shipping of module package units
Solar PV Inverters	
IEC 62109-1, IEC 62109-2	Safety of power converters for use in photovoltaic power systems – Part 1: General requirements, and Safety of power converters for use in photovoltaic power systems Part 2: Particular requirements for inverters. Safety compliance (Protection degree IP 65 for outdoor mounting, IP 54 for indoor mounting)
IEC/IS 61683 (as applicable)	Photovoltaic Systems – Power conditioners: Procedure for Measuring Efficiency (10%, 25%, 50%, 75% & 90-100% Loading Conditions)
BS EN 50530 (as applicable)	Overall efficiency of grid-connected photovoltaic inverters: This European Standard provides a procedure for the measurement of the accuracy of the maximum power point tracking (MPPT) of inverters, which are used in grid-connected photovoltaic systems. In that case the inverter energizes a low voltage grid of stable AC voltage and constant frequency. Both the static and dynamic MPPT efficiency is considered.
IEC 62116/ UL 1741/ IEEE 1547 (as applicable)	Utility-interconnected Photovoltaic Inverters - Test Procedure of Islanding Prevention Measures



IEC 60255-27	Measuring relays and protection equipment – Part 27: Product safety requirements
IEC 60068-2 (1, 2, 14, 27, 30 & 64)	Environmental Testing of PV System – Power Conditioners and Inverters a) IEC 60068-2-1: Environmental testing - Part 2- 1: Tests - Test A: Cold b) IEC 60068-2-2: Environmental testing - Part 2-2: Tests - Test B: Dry heat c) IEC 60068-2-14: Environmental testing - Part 2-14: Tests - Test N: Change of temperature d) IEC 60068-2-27: Environmental testing - Part 2- 27: Tests - Test Ea and guidance: Shock e) IEC 60068-2-30: Environmental testing - Part 2-30: Tests - Test Db: Damp heat, cyclic (12 h + 12 h cycle) f) IEC 60068-2- 64: Environmental testing - Part 2-64: Tests - Test Fh: Vibration, broadband random and guidance
IEC 61000 – 2,3,5 (as applicable)	Electromagnetic Interference (EMI) and Electromagnetic Compatibility (EMC) testing of PV Inverters
Fuses	
General safety requirements for connectors, switches, circuit breakers (AC/DC): a) Low-voltage Switchgear and Control-gear, Part 1: General rules b) Low-Voltage Switchgear and Control-gear, Part 2: Circuit Breakers c) Low-voltage switchgear and Control-gear, Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units d) EN 50521: Connectors for photovoltaic systems – Safety requirements and tests	General safety requirements for connectors, switches, circuit breakers (AC/DC): a) Low-voltage Switchgear and Control-gear, Part 1: General rules b) Low-Voltage Switchgear and Control-gear, Part 2: Circuit Breakers c) Low-voltage switchgear and Control-gear, Part 3: Switches, disconnectors, switch-disconnectors and fuse-combination units d) EN 50521: Connectors for photovoltaic systems – Safety requirements and tests
IEC 60269-6	Low-voltage fuses - Part 6: Supplementary requirements for fuse-links for the protection of solar photovoltaic energy systems
Surge Arrestors	
IEC 62305-4	Lightening Protection Standard
IEC 60364-5-53/ IS 15086-5 (SPD)	Electrical installations of buildings - Part 5- 53: Selection and erection of electrical equipment - Isolation, switching and control
IEC 61643-11:2011	Electrical installations of buildings - Part 5- 53: Selection and erection of electrical equipment - Isolation, switching and control
Cables	
IEC 60227/IS 694, IEC 60502/IS 1554 (Part 1 & 2)/ IEC69947	General test and measuring method for PVC (Polyvinyl chloride) insulated cables (for working voltages up to and including 1100 V, and UV resistant for outdoor installation)
BS EN 50618	Electric cables for photovoltaic systems (BT(DE/ NOT)258), mainly for DC Cables

Earthing /Lightning	
IEC 62561 Series (Chemical earthing)	IEC 62561-1 Lightning protection system components (LPSC) - Part 1: Requirements for connection components IEC 62561-2 Lightning protection system components (LPSC) - Part 2: Requirements for conductors and earth electrodes IEC 62561- 7 Lightning protection system components (LPSC) - Part 7: Requirements for earthing enhancing compounds
Junction Boxes	
IEC 60529	Junction boxes and solar panel terminal boxes shall be of the thermo-plastic type with IP 65 protection for outdoor use, and IP 54 protection for indoor use
Energy Meter	
IS 16444 or as specified by the DISCOMs	A.C. Static direct connected watt-hour Smart Meter Class 1 and 2 — Specification (with Import & Export/ Net energy measurements)
Solar PV Roof Mounting Structure	
IS 2062/IS 4759	Material for the structure mounting

8.3 Wind Energy

- Converts Kinetic energy of wind to electrical energy.
- Broadly serving as the renewable of choice in India.
- Increased size and higher productivity have enabled wind generation to become an
- Increasingly competitive alternative to more traditional methods of power generation to more traditional methods of power generation
- Uncertainty is the main problem with wind production owing to the inherent unpredictability of weather condition



Fig 8.7 – Wind mill

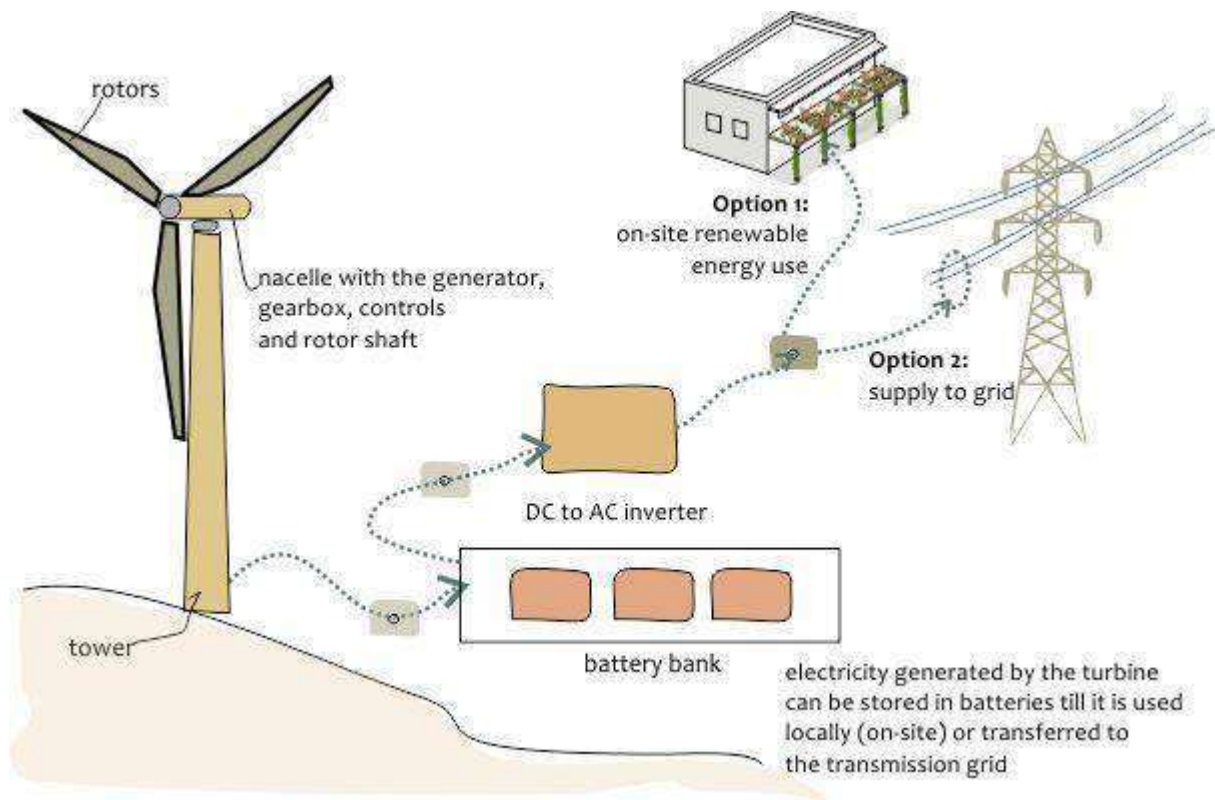


Fig 8.8 – Wind mill single line diagram

8.3.1 Wind Energy Technology

Wind electric generator converts kinetic energy available in wind to electrical energy by using rotor, gear box and generator.

Wind Turbine Configuration

- i. Vertical-axis wind turbines
- ii. Horizontal-axis turbines.

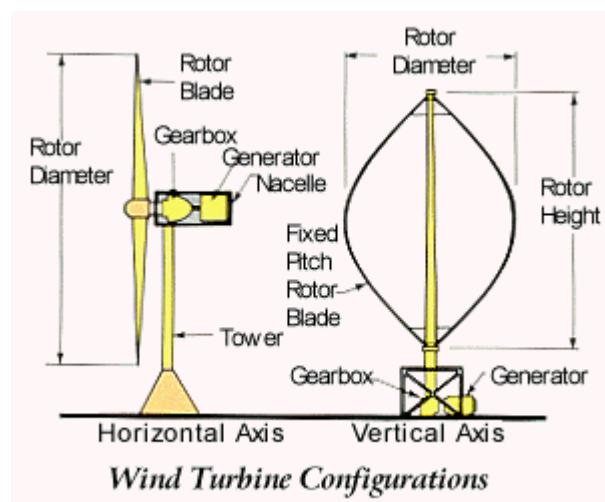


Fig 8.9 – Wind turbine configuration

8.3.2 Wind Turbines

- i. Blades are made of reinforced carbon-fiber plastics or glass plastics.
- ii. Small wind turbines that can power a single home may have a capacity of 10 kW.
- iii. The largest wind turbines in operation have electricity generating capacities of up to 10,000 kW, and larger turbines are in development.

8.3.3 Wind Energy Application

- i. Off-Grid Applications: residential, rural, industrial.
- ii. Wind turbines suitable for residential or village scale range from 500 W to 50 Kw.
- iii. Potential market sectors for remote locations include Rural market sectors Railways, Defence

8.3.4 Wind solar hybrid system

- i. The combination of wind and solar energy sources is called as wind solar hybrid system
- ii. Wind -Solar hybrid Energy System
- iii. Hybrid systems found to be ideal instead of backup diesel generator sets for applications such as homes in remote locations, GSM towers etc



Fig 8.10 – Wind solar hybrid system

8.4 Hydroelectric Energy

Hydroelectric energy is a form of renewable energy that uses the power of moving water to generate electricity

- i. Most mature of renewable energies.
- ii. Largest global contributor amongst all renewable energies.
- iii. Largely utilizes established technology from other sectors.
- iv. Can be “switched on-off” at almost immediately.
- v. Arguably the cheapest where available.

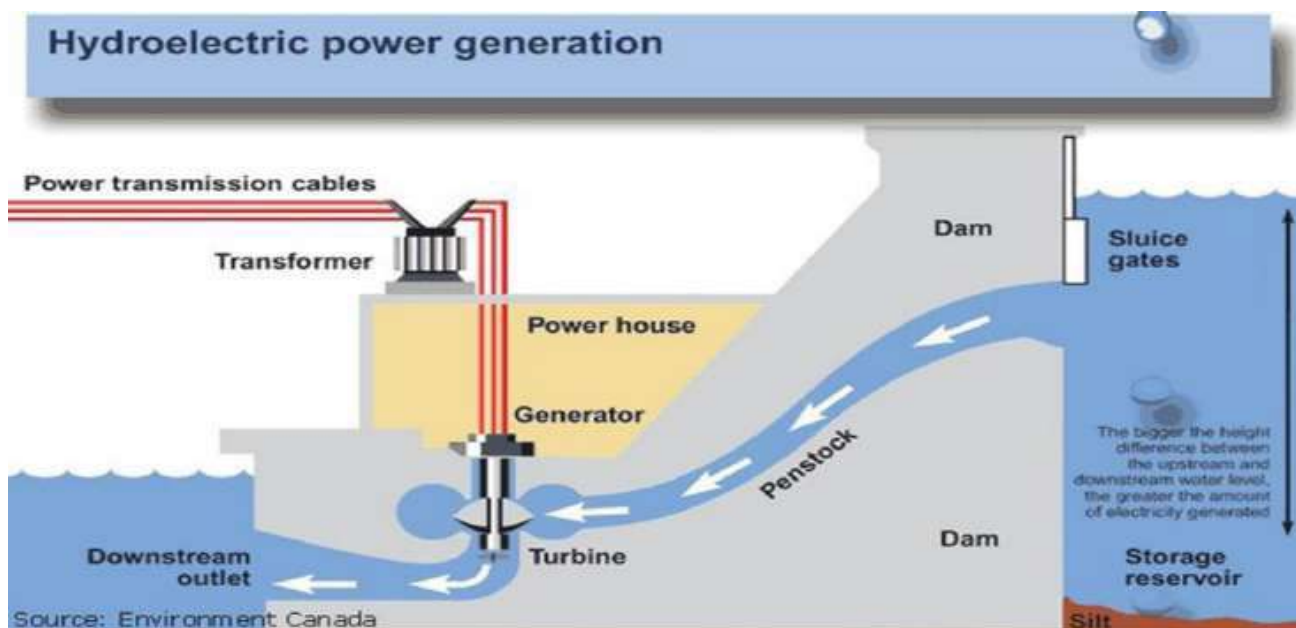


Fig 8.11 – Hydroelectric power generation

8.5 Geothermal Energy

The internal heat energy available at a considerable depth below the surface of earth is called Geothermal energy

- i. Geothermal Energy –Heat contained in underground rocks and fluid that can be tapped for energy.
- ii. Extract dry steam, wet steam or hot water and can be used to heat space or water.
- iii. Potentially renewable resource.
- iv. “22 countries currently use geothermal energy which supplies 1% of world energy. In the USA (44% geothermal energy is produced worldwide) geothermal electricity is produced mostly in Hawaii, California, Nevada and Utah”.

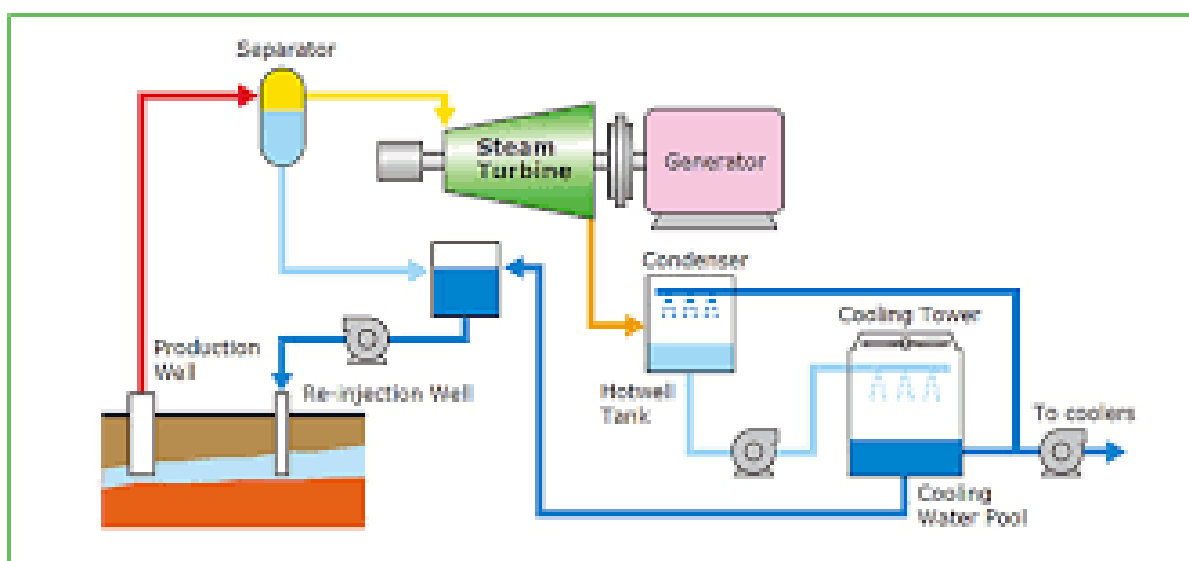


Fig 8.12 – Geothermal energy

8.6 Biomass Energy

Biomass energy is the energy generated or produced by living or once living organisms.

Biomass:– organic matter in plants produced through photosynthesis and can be burned directly as a solid fuel or converted into a gas or liquid fuel.

- i. Burning wood
- ii. Agricultural Waste
- iii. Bagasse (sugar cane residue)
- iv. Straw
- v. Urban Waste (WTE)
- vi. Burning garbage



Fig 8.13 – Bio mass

CHAPTER-9

ENERGY CONSERVATION & ENERGY EFFICIENCY

9.1 Introduction

Energy conservation reduces the need for energy services and can result in increased environmental quality, national security, personal financial security and higher savings. It is at the top of the sustainable energy hierarchy. It also lowers energy costs by preventing future resource depletion. Energy conservation avoids wasteful use of energy without much investment. It can be termed as a new source of energy, which when available, can be readily used without any further loss or gestation period. It is the cheapest source of energy. In fact, it is the easiest solution to bridge the gap between demand and supply.

Energy efficiency simply means using less energy to perform the same task that is, eliminating energy waste. Energy efficiency brings a variety of benefits: reducing greenhouse gas emissions, reducing demand for energy imports, and lowering our costs on a household and economy-wide level.

9.2 Role of Indian Railways as a Designated Consumer

Indian Railways has been identified as one of the designated consumers as specified in Clause (e) of section 14 of the Energy Conservation Act, 2001 which makes it mandatory to comply with the energy consumption norms and standards as prescribed by the Central Government and

- i. To furnish to the designated agency, in such form and manner and within such period, as may be prescribed, the information with regard to the energy consumed and action taken on the recommendation of the accredited energy auditor, and
- ii. To designate or appoint energy manager in charge of activities for efficient use of energy and its conservation and submit a report, in the form and manner as may be prescribed, on the status of energy consumption at the end of every financial year to designated agency.

By virtue of being a Designated Consumer, the following actions are to be taken by the Management.

- 9.2.1 To comply with the provisions of energy conservation building codes for efficient use of energy and its conservation.
- 9.2.2 Take all measures necessary to create awareness and disseminate information for efficient use of energy and its conservation
- 9.2.3 Arrange and organize training of personnel and specialists in the techniques for efficient use of energy and its conservation.
- 9.2.5 Take steps to encourage preferential treatment for use of energy efficient equipment or appliances.

9.3 Energy Audit

An Energy Audit involves evaluating the actual Energy used in a plant/building and compare it with an optimum quantity of energy required to perform that particular function by maintaining the same standards and it necessitates.



- 9.3.1 Appointment of Energy Manager, who is responsible for planning and implementing energy conservation measures as recommended by accredited Energy Auditor.
- 9.3.2 Engagement of Energy Auditor, who will Conduct internal audit of individual equipment/ system once a year and submit copy of reports to Energy Manager with recommendation on action.

9.4 Tips for Energy Conservation & Efficiency

Electricity

- 9.4.1 Optimise the tariff structure with utility supplier.
- 9.4.2 Schedule your operations to maintain a high load factor.
- 9.4.3 Shift loads to off-peak times if possible.
- 9.4.4 Minimise maximum demand by tripping loads through a demand controller.
- 9.4.5 Stagger start-up times for equipment with large starting currents to minimise load peaking.
- 9.4.6 Use standby electric generation equipment for on-peak high load periods.
- 9.4.7 Correct power factor to at least 0.90 under rated load conditions.
- 9.4.8 Relocate transformers close to main loads.
- 9.4.9 Set transformer taps to optimum settings.
- 9.4.10 Disconnect primary power to transformers that do not serve any active loads.
- 9.4.11 Consider on-site electric generation or cogeneration.
- 9.4.12 Export power to grid if you have any surplus in your captive generation.
- 9.4.13 Check utility electric meter with your own meter.
- 9.4.14 Shut off unnecessary computers, printers and copiers at night.

Motors

- 9.4.15 Properly size to the load for optimum efficiency.
- 9.4.16 Use energy-efficient motors where economical.
- 9.4.17 Use synchronous motors to improve power factor.
- 9.4.18 Check alignment.
- 9.4.19 Provide proper ventilation.
- 9.4.20 *(For every 10° increase in motor operating temperature over recommended peak, the motor life is estimated to be halved)*
- 9.4.21 Check for under-voltage and over-voltage conditions.
- 9.4.22 Balance the three-phase power supply.
- 9.4.23 Demand efficiency restoration after motor rewinding.
- 9.4.24 *(If rewinding is not done properly, the efficiency can be reduced by 5 - 8%)*
- 9.4.25 Use BEE star rated brands.
- 9.4.26 Use of VVVF motors wherever possible

Drives

- 9.4.27 Use variable-speed drives for large variable loads.
- 9.4.28 Use high-efficiency gear sets.
- 9.4.29 Use precision alignment.
- 9.4.30 Check belt tension regularly.
- 9.4.31 Eliminate variable-pitch pulleys.
- 9.4.32 Use flat belts as alternatives to v-belts.
- 9.4.33 Use synthetic lubricants for large gearboxes.
- 9.4.34 Eliminate eddy current couplings.
- 9.4.35 Shut them off when not needed.

Fans

- 9.4.36 Use smooth, well-rounded air inlet cones for fan air intakes.
- 9.4.37 Avoid poor flow distribution at the fan inlet.
- 9.4.38 Minimise fan inlet and outlet obstructions.
- 9.4.39 Clean screens, filters and fan blades regularly.
- 9.4.40 Use aerofoil-shaped fan blades.
- 9.4.41 Minimise fan speed.
- 9.4.42 Use low-slip or flat belts.
- 9.4.43 Check belt tension regularly.
- 9.4.44 Eliminate variable pitch pulleys.
- 9.4.45 Use variable speed drives for large variable fan loads.
- 9.4.46 Use energy-efficient motors for continuous or near-continuous operation.
- 9.4.47 Eliminate leaks in ductwork.
- 9.4.48 Minimise bends in duct work.
- 9.4.49 Turn fans off when not needed.
- 9.4.50 Replacement of conventional fan regulator with electronic fan regulator.
- 9.4.51 Install exhaust fan at a higher elevation than ceiling fan.
- 9.4.52 Make sure air vents are not blocked.
- 9.4.53 Use of super energy efficient fan.
- 9.4.54 Use of BEE star rated & ISI marked fans

Blowers

- 9.4.55 Use smooth, well-rounded air inlet ducts or cones for air intakes.
- 9.4.56 Minimise blower inlet and outlet obstructions.
- 9.4.57 Clean screens and filters regularly.
- 9.4.58 Minimise blower speed.
- 9.4.59 Use low-slip or no-slip belts.
- 9.4.60 Check belt tension regularly.
- 9.4.61 Eliminate variable pitch pulleys.
- 9.4.62 Use variable speed drives for large variable blower loads.
- 9.4.63 Use energy-efficient motors for continuous or near-continuous operation.
- 9.4.64 Eliminate ductwork leaks.
- 9.4.65 Turn blowers off when they are not needed.
- 9.4.66 Pumps
- 9.4.67 Operate pumping near best efficiency point.
- 9.4.68 Modify pumping to minimise throttling.
- 9.4.69 Adapt to wide load variation with variable speed drives or sequenced control of smaller units.
- 9.4.70 Stop running both pumps - add an auto-start for an on-line spare or add a booster pump in the problem area.
- 9.4.71 Use booster pumps for small-loads requiring higher pressures.
- 9.4.72 Increase fluid temperature differentials to reduce pumping rates.
- 9.4.73 Repair seals and packing to minimise water waste.
- 9.4.74 Balance the system to minimise flows and reduce pump power requirements.
- 9.4.75 Use siphon effect to advantage: Do not waste pumping head with a free-fall (gravity) return.
- 9.4.76 Use VFD drive.



Compressors

- 9.4.77 Consider variable speed drive for variable load on positive displacement compressors.
- 9.4.78 Use a synthetic lubricant if the compressor manufacturer permits it.
- 9.4.79 Be sure lubricating oil temperature is not too high (oil degradation and lowered viscosity) and not too low (condensation contamination).
- 9.4.80 Change the oil filter regularly.
- 9.4.81 Periodically inspect compressor intercoolers for proper functioning.
- 9.4.82 Use waste heat from a very large compressor to power an absorption chiller or preheat process or utility feeds.
- 9.4.83 Establish a compressor efficiency-maintenance program. Start with an energy audit and follow-up, then make a compressor efficiency-maintenance program a part of your continuous energy management program.
- 9.4.84 Use VFD drives.

Compressed Air

- 9.4.85 Install a control system to coordinate multiple air compressors.
- 9.4.86 Study part-load characteristics and cycling costs to determine the most-efficient mode for operating multiple air compressors.
- 9.4.87 Avoid over sizing match the connected load.
- 9.4.88 Load up modulation controlled air compressors. (They use almost as much power at partial load as at full load.)
- 9.4.89 Turn off the back-up air compressor until it is needed.
- 9.4.90 Reduce air compressor discharge pressure to the lowest acceptable setting. (*Reduction of 1 kg/cm air pressure (8 kg/cm to 7 kg/cm) would result in input power savings. This will also reduce compressed air leakage rates*)
- 9.4.91 Use the highest reasonable dryer dew point settings.
- 9.4.92 Turn off refrigerated and heated air dryers when the air compressors are off.
- 9.4.93 Use a control system to minimise heatless desiccant dryer purging.
- 9.4.94 Minimise purges, leaks, excessive pressure drops and condensation accumulation. (*Compressed air leak from 1 mm hole size at 7 kg/cm pressure would mean power loss equivalent to 0.5 kW*)
- 9.4.95 Use drain controls instead of continuous air bleeds through the drains.
- 9.4.96 Consider engine-driven or steam-driven air compression to reduce electrical demand charges.
- 9.4.97 Replace standard v-belts with high-efficiency flat belts as the old v-belts wear out.
- 9.4.98 Use a small air compressor when major production load is off.
- 9.4.99 Take air compressor intake air from the coolest (but not air-conditioned) location. (*Every 5° reduction in intake air temperature would result in 1% reduction in compressor power consumption*)
- 9.4.100 Use an air-cooled after-cooler to heat building makeup air in winter.
- 9.4.101 Be sure that heat exchangers are not fouled (e.g. with oil).
- 9.4.102 Be sure that air/oil separators are not fouled.
- 9.4.103 Monitor pressure drops across suction and discharge filters and clean or replace filters promptly upon alarm. Use a properly sized compressed air storage receiver.
- 9.4.104 Consider alternatives to compressed air such as blowers for cooling, hydraulic rather than air cylinders, electric rather than air actuators and electronic rather than pneumatic controls.
- 9.4.105 Use nozzles or venture-type devices rather than blowing with open compressed air lines.
- 9.4.106 Check for leaking drain valves on compressed air filter/regulator sets. Certain rubber-type valves may leak continuously after they age and crack.



- 9.4.107 In dusty environments, control packaging lines with high-intensity photocell units instead of standard units with continuous air purging of lenses and reflectors.
- 9.4.108 Establish a compressed air efficiency-maintenance program. Start with an energy audit and follow-up, then make a compressed air efficiency-maintenance program a part of your continuous energy management program.

Chillers

- 9.4.109 Increase the chilled water temperature set point if possible.
- 9.4.110 Use the lowest temperature condenser water available that the chiller can handle. *(Reducing condensing temperature by 5.5 °C, results in a 20 - 25% decrease in compressor power consumption)*
- 9.4.111 Increase the evaporator temperature. *(5.5 °C increase in evaporator temperature reduces compressor power consumption by 20 - 25%)*
- 9.4.112 Clean heat exchangers when fouled.
- 9.4.113 (1 mm scale build-up on condenser tubes can increase energy consumption by 40%)
- 9.4.114 Optimise condenser water flow rate and refrigerated water flow rate.
- 9.4.115 Replace old chillers or compressors with new higher-efficiency models.
- 9.4.116 Use water-cooled rather than air-cooled chiller condensers.
- 9.4.117 Use energy-efficient motors for continuous or near-continuous operation.
- 9.4.118 Specify appropriate fouling factors for condensers.
- 9.4.119 Do not overcharge oil.
- 9.4.120 Install a control system to coordinate multiple chillers.
- 9.4.121 Study part-load characteristics and cycling costs to determine the most-efficient mode for operating multiple chillers.
- 9.4.122 Run the chillers with the lowest operating costs to serve base load.
- 9.4.123 Avoid over sizing - match the connected load.
- 9.4.124 Isolate off-line chillers and cooling towers.
- 9.4.125 Establish a chiller efficiency-maintenance program. Start with an energy audit and follow-up, then make a chiller efficiency-maintenance program a part of your continuous energy management program.

HVAC (Heating Ventilation and Air Conditioning)

- 9.4.126 Tune up the HVAC control system.
- 9.4.127 Consider installing a building automation system (BAS) or energy management system (EMS) or restoring an out-of-service one.
- 9.4.128 Balance the system to minimise flows and reduce blower/fan/pump power requirements.
- 9.4.129 Eliminate or reduce reheat whenever possible.
- 9.4.130 Use appropriate HVAC thermostat setback.
- 9.4.131 Use morning pre-cooling in summer and pre-heating in winter (i.e. before electrical peak hours).
- 9.4.132 Use building thermal lag to minimise HVAC equipment operating time. In winter during unoccupied periods, allow temperatures to fall as low as possible without freezing water lines or damaging stored materials.
- 9.4.133 In summer during unoccupied periods, allow temperatures to rise as high as possible without damaging stored materials.
- 9.4.134 Improve control and utilisation of outside air.
- 9.4.135 Use air-to-air heat exchangers to reduce energy requirements for heating and cooling of outside air.
- 9.4.136 Reduce HVAC system operating hours (e.g. night, weekend).
- 9.4.137 Optimize ventilation.



- 9.4.138 Ventilate only when necessary. To allow some areas to be shut down when unoccupied & install dedicated HVAC systems on continuous loads (e.g. computer rooms).
- 9.4.139 Provide dedicated outside air supply to kitchens, cleaning rooms, combustion equipment, etc. to avoid excessive exhausting of conditioned air.
- 9.4.140 Use evaporative cooling in dry climates.
- 9.4.141 Reduce humidification or dehumidification during unoccupied periods.
- 9.4.142 Use atomization rather than steam for humidification where possible.
- 9.4.143 Clean HVAC unit coils periodically and comb mashed fins.
- 9.4.144 Upgrade filter banks to reduce pressure drop and thus lower fan power requirements.
- 9.4.145 Check HVAC filters on a schedule (at least monthly) and clean/change if appropriate.
- 9.4.146 Check pneumatic controls air compressors for proper operation, cycling, and maintenance.
- 9.4.147 Isolate air conditioned loading dock areas and cool storage areas using high-speed doors or clear PVC strip curtains.
- 9.4.148 Install ceiling fans to minimise thermal stratification in high-bay areas.
- 9.4.149 Relocate air diffusers to optimum heights in areas with high ceilings.
- 9.4.150 Consider reducing ceiling heights.
- 9.4.151 Eliminate obstructions in front of radiators & baseboard heaters etc.
- 9.4.152 Check reflectors on infrared heaters for cleanliness and proper beam direction.
- 9.4.153 Use professionally designed industrial ventilation hoods for dust and vapour control.
- 9.4.154 Use local infrared heat for personnel rather than heating the entire area.
- 9.4.155 Use spot cooling and heating (e.g. use ceiling fans for personnel rather than cooling the entire area).
- 9.4.156 Purchase only high-efficiency models for HVAC window units.
- 9.4.157 Put HVAC window units on timer control.
- 9.4.158 Do not oversize cooling units. (Oversized units will “short cycle” which results in poor humidity control.)
- 9.4.159 Install multi-fuel capability and run with the cheapest fuel available at the time.
- 9.4.160 Consider dedicated make-up air for exhaust hoods.
- 9.4.161 Minimise HVAC fan speeds.
- 9.4.162 Use BEE star rated brands.
- 9.4.163 Consider desiccant drying of outside air to reduce cooling requirements in humid climates.
- 9.4.164 Consider ground source heat pumps.
- 9.4.165 Seal leaky HVAC ductwork.
- 9.4.166 Seal all leaks around coils.
- 9.4.167 Repair loose or damaged flexible connections (including those under air handling units).
- 9.4.168 Eliminate simultaneous heating and cooling during seasonal transition periods.
- 9.4.169 Zone HVAC air and water systems to minimise energy use.
- 9.4.170 Inspect, clean, lubricate, and adjust damper blades and linkages.
- 9.4.171 Establish an HVAC efficiency maintenance program. Start with an energy audit and follow-up, then make an HVAC efficiency maintenance program a part of your continuous energy management program.

Refrigeration

- 9.4.172 Use water-cooled condensers rather than air-cooled condensers.
- 9.4.173 Challenge the need for refrigeration, particularly for old batch processes.
- 9.4.174 Avoid over sizing- match the connected load.
- 9.4.175 Consider gas-powered refrigeration equipment to minimise electrical demand charges.

- 9.4.176 Use “free cooling” to allow chiller shutdown in cold weather.
- 9.4.177 Use refrigerated water loads in series if possible.
- 9.4.178 Convert firewater or other tanks to thermal storage.
- 9.4.179 Do not assume that the old way is still the best particularly for energy-intensive low temperature systems.
- 9.4.180 Correct inappropriate brine or glycol concentration that adversely affects heat transfer and/or pumping energy. If it sweats, insulate it, but if it is corroding, replace it first.
- 9.4.181 Make adjustments to minimise hot gas bypass operation.
- 9.4.182 Inspect moisture/liquid indicators.
- 9.4.183 Consider change of refrigerant type if it will improve efficiency.
- 9.4.184 Check for correct refrigerant charge level.
- 9.4.185 Inspect the purge for air and water leaks.
- 9.4.186 Establish a refrigeration efficiency maintenance program. Start with an energy audit and follow-up, then make a refrigeration efficiency maintenance program a part of your continuous energy management program.
- 9.4.187 Use BEE star rated brands.

Cooling Towers

- 9.4.188 Control cooling tower fans based on leaving water temperatures.
- 9.4.189 Control to the optimum water temperature as determined from cooling tower and chiller performance data.
- 9.4.190 Use two-speed or variable-speed drives for cooling tower fan control if the fans are few. Stage the cooling tower fans with on-off control if there are many.
- 9.4.191 Turn off unnecessary cooling tower fans when loads are reduced.
- 9.4.192 Cover hot water basins (to minimise algae growth that contributes to fouling).
- 9.4.193 Balance flow to cooling tower hot water basins.
- 9.4.194 Periodically clean plugged cooling tower water distribution nozzles.
- 9.4.195 Install new nozzles to obtain a more-uniform water pattern.
- 9.4.196 Replace splash bars with self-extinguishing PVC cellular-film fill.
- 9.4.197 On old counter flow cooling towers, replace old spray-type nozzles with new square-spray ABS practically non clogging nozzles.
- 9.4.198 Replace slat-type drift eliminators with high efficiency, low pressure drop, self-extinguishing & PVC cellular units.
- 9.4.199 If possible, follow manufacturer’s recommended clearances around cooling towers and relocate or modify structures, signs, fences & dumpsters etc. that interfere with air intake or exhaust.
- 9.4.200 Optimise cooling tower fan blade angle on a seasonal and/or load basis.
- 9.4.201 Correct excessive and/or uneven fan blade tip clearance and poor fan balance.
- 9.4.202 Use a velocity pressure recovery fan ring.
- 9.4.203 Divert clean air-conditioned building exhaust to the cooling tower during hot weather.
- 9.4.204 Re-line leaking cooling tower cold water basins.
- 9.4.205 Check water overflow pipes for proper operating level.
- 9.4.206 Optimise chemical use.
- 9.4.207 Consider side stream water treatment.
- 9.4.208 Restrict flows through large loads to design values.
- 9.4.209 Shut off loads that are not in service.
- 9.4.210 Take blow down water from the return water header.
- 9.4.211 Optimise blow down flow rate.
- 9.4.212 Automate blow down to minimise it.



- 9.4.213 Send blow down to other uses (Remember, the blow down does not have to be removed at the cooling tower. It can be removed anywhere in the piping system.)
- 9.4.214 Implement a cooling tower winterisation plan to minimise ice build up.
- 9.4.215 Install interlocks to prevent fan operation when there is no water flow.
- 9.4.216 Establish a cooling tower efficiency maintenance program. Start with an energy audit and follow up, then make a cooling tower efficiency maintenance program a part of your continuous energy management program.

Lighting

- 9.4.217 Reduce excessive illumination levels to standard levels using switching, decamping, etc. (Know the electrical effects before doing decamping.)
- 9.4.218 Aggressively control lighting with clock timers, delay timers, photocells, and/or occupancy sensors.
- 9.4.219 Install efficient alternatives to incandescent lighting & mercury vapour lighting etc. Efficiency (lumens/Watt) of various technologies range from best to worst approximately as follows- low pressure sodium, high pressure sodium, metal halide, fluorescent, mercury vapour & incandescent.
- 9.4.220 Select ballasts and lamps carefully with high power factor and long-term efficiency in mind.
- 9.4.221 Upgrade obsolete fluorescent systems to Compact fluorescents and electronic ballasts.
- 9.4.222 Consider lowering the fixtures to enable using less of them. Consider day lighting & skylights, etc.
- 9.4.223 Consider painting the walls a lighter colour and using less lighting fixtures or
- 9.4.224 Lower wattages.
- 9.4.225 Use task lighting and reduce background illumination.
- 9.4.226 Re-evaluate exterior lighting strategy, type and control. Lighting for exterior applications shall be controlled by a photo sensor or astronomical time switch that is capable of automatically turning off the exterior lighting when daylight is available or the lighting is not required.
- 9.4.227 Change exit signs from incandescent to LED.
- 9.4.228 Consider day light & sky light etc. by using light pipe and transparent roofs wherever applicable.
- 9.4.229 Turn off the light when not in use.

LED	CFL	Incandescent
		
50,000	10,000	750-1000
Vastly longer	long	low
6-18	3-120	3-500

DG Sets

- 9.4.230 Optimise loading.
- 9.4.231 Use waste heat to generate steam/hot water /power an absorption chiller or preheat processor utility feeds.
- 9.4.232 Use jacket and head cooling water for process needs.
- 9.4.233 Clean air filters regularly.
- 9.4.234 Insulate exhaust pipes to reduce DG set room temperatures.
- 9.4.235 Use cheaper heavy fuel oil for capacities more than 1MW.

Buildings

- 9.4.236 Seal exterior cracks/openings/gaps with caulk, gaskets & weather stripping etc.
- 9.4.237 Consider new thermal doors, thermal windows & roofing insulation etc.
- 9.4.238 Install windbreaks near exterior doors.
- 9.4.239 Replace single-pane glass with insulating glass.
- 9.4.240 Consider covering some window and skylight areas with insulated wall panels inside the building.
- 9.4.241 If visibility is not required but light is required, consider replacing exterior windows with insulated glass block.
- 9.4.242 Consider tinted glass, reflective glass, double glass or even filled with Argon gas, coatings, awnings, overhangs, draperies, blinds and shades for sunlit exterior windows.
- 9.4.243 Use landscaping to advantage.
- 9.4.244 Add vestibules or revolving doors to primary exterior personnel doors.
- 9.4.245 Consider automatic doors, air curtains, strip doors, etc. at high-traffic passages between conditioned and non-conditioned spaces. Use self-closing doors if possible.
- 9.4.246 Use intermediate doors in stairways and vertical passages to minimise building stack effect.
- 9.4.247 Use dock seals at shipping and receiving doors.
- 9.4.248 Bring cleaning personnel in during the working day or as soon after as possible to minimise lighting and HVAC costs.

Water & Wastewater

- 9.4.249 Recycle water, particularly for uses with less-critical quality requirements.
- 9.4.250 Recycle water, especially if sewer costs are based on water consumption.
- 9.4.251 Balance closed systems to minimise flows and reduce pump power requirements.
- 9.4.252 Eliminate once-through cooling with water.
- 9.4.253 Use the least expensive type of water that will satisfy the requirement.
- 9.4.254 Fix water leaks.
- 9.4.255 Test for underground water leaks. (It is easy to do over a holiday shutdown.)
- 9.4.256 Check water overflow pipes for proper operating level.
- 9.4.257 Automate blow down to minimise it.
- 9.4.258 Provide proper tools for wash down- especially self-closing nozzles.
- 9.4.259 Install efficient irrigation.
- 9.4.260 Reduce flows at water sampling stations.
- 9.4.261 Eliminate continuous overflow at water tanks.
- 9.4.262 Promptly repair leaking toilets and faucets.
- 9.4.263 Use water restrictors on faucets & showers etc.
- 9.4.264 Use self-closing type faucets in restrooms.
- 9.4.265 Use the lowest possible hot water temperature.
- 9.4.266 Do not use a heating system hot water boiler to provide service hot water during the



cooling season -- install a smaller, more-efficient system for the cooling season service hot water.

- 9.4.267 If water must be heated electrically, consider accumulation in a large insulated storage tank to minimise heating at on-peak electric rates.
- 9.4.268 Use multiple, distributed & small water heaters to minimise thermal losses in large piping systems.
- 9.4.269 Use freeze protection valves rather than manual bleeding of lines.
- 9.4.270 Consider leased and mobile water treatment systems, especially for de-ionised water.
- 9.4.271 Seal sumps to prevent seepage inward from necessitating extra sump pump operation.
- 9.4.272 Install pretreatment to reduce TOC and BOD surcharges.
- 9.4.273 Verify the water meter readings.
- 9.4.274 Verify the sewer flows if the sewer bills are based on them.

Metering

- 9.4.275 Services exceeding 1000 KVA shall have permanently installed electrical metering to record demand (kVA), energy (kWh), and total power factor. The metering shall also display current (in each phase and the neutral), voltage (between phases and between each phase and neutral), and total harmonic distortion (THD) as a percentage of total current.
- 9.4.276 Services not exceeding 100 kVA but over 65 kVA shall have permanently installed electric metering to record demand (kW), energy (kWh), and total power factor (or kVARh).
- 9.4.277 Services not exceeding 65 kVA shall have permanently installed electrical metering to record energy (kWh).
- 9.4.278 Electrical meters shall be installed to measure the energy units generated on site through DG/ GG sets.
- 9.4.279 Separate electrical sub-meters shall be installed to measure energy consumption by
- 9.4.280 HVAC plant, AHU fans and indoor lighting.

Miscellaneous

- 9.4.281 Meter any unmetered utilities. Know what normal efficient use is. Track down causes of deviations.
- 9.4.282 Shut down spare, idling, or unneeded equipment.
- 9.4.283 Make sure that all of the utilities to redundant areas are turned off - including utilities like compressed air and cooling water.
- 9.4.284 Install automatic control to efficiently coordinate multiple air compressors, chillers, Cooling tower cells & boilers, etc.
- 9.4.285 Renegotiate utilities contracts to reflect current loads and variations.
- 9.4.286 Consider buying utilities from neighbours, particularly to handle peaks.
- 9.4.287 Leased space often has low-bid inefficient equipment. Consider upgrades if your Lease will continue for several more years.
- 9.4.288 Adjust fluid temperatures within acceptable limits to minimise undesirable heat transfer in long pipelines.
- 9.4.289 Minimise use of flow bypasses and minimise bypass flow rates.
- 9.4.290 Provide restriction orifices in purges (nitrogen, steam, etc.).
- 9.4.291 Eliminate unnecessary flow measurement orifices.
- 9.4.292 Consider alternatives to high pressure drops across valves.
- 9.4.293 Turn off winter heat tracing that is on in summer.
- 9.4.294 BEE Star Rating Equipments.
- 9.4.295 Energy consumption standards.

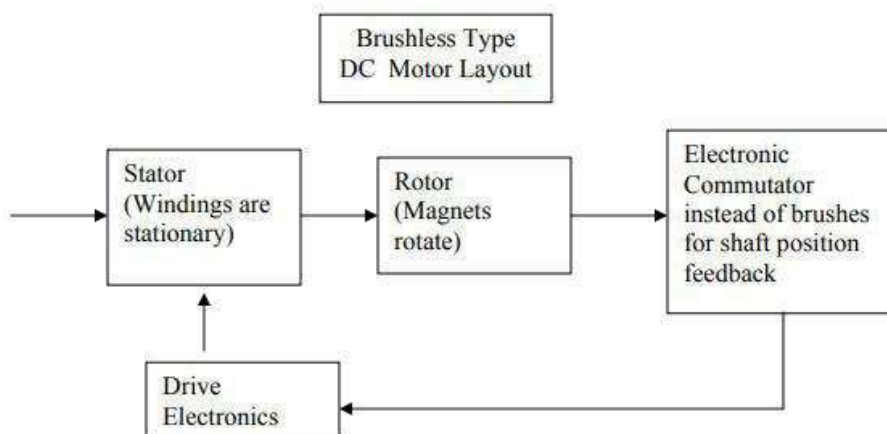
- 9.4.296 Energy saving certificates.
- 9.4.297 Standardization of electrical general power equipment.
- 9.4.298 Demand side management.
- 9.4.299 Energy audit on regular intervals



9.5 BLDC Motor

A Brushless DC Motor is similar to a Brushed DC Motor but as the name suggests, a BLDC doesn't use brushes for commutation but rather they are electronically commutated. In conventional Brushed DC Motors, the brushes are used to transmit the power to the rotor as they turn in a fixed magnetic field.

As mentioned earlier, a BLDC motor used electronic commutation and thus eliminates the mechanically torn brushes.

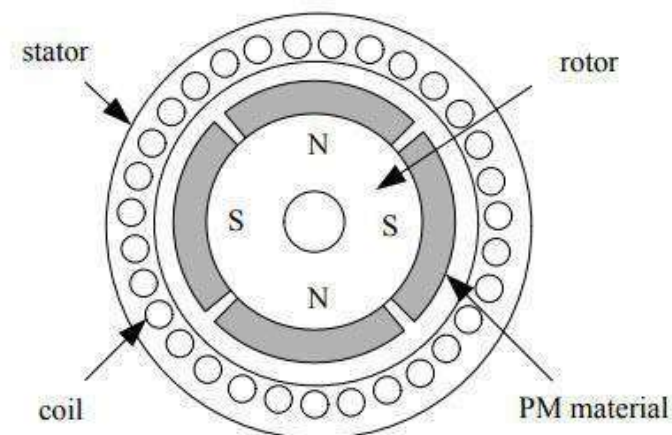


9.5.1 Construction of BLDC Motor

The main design difference between a brushed and brushless motors is the replacement of mechanical commutator with an electric switch circuit. Keeping that in mind, a BLDC Motor is a type of synchronous motor in the sense that the magnetic field generated by the stator and the rotor revolve at the same frequency.

Brushless Motors are available in three configurations: single phase, two phase and three phase. Out of these, the three phase BLDC is the most common one.

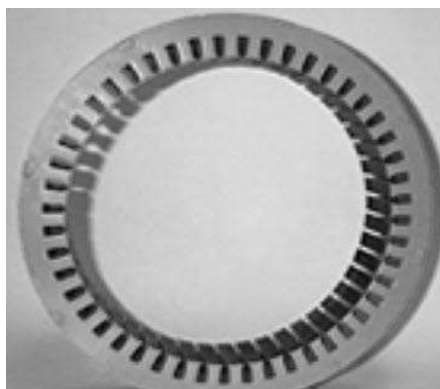
The following image shows the cross-section of a BLDC Motor.



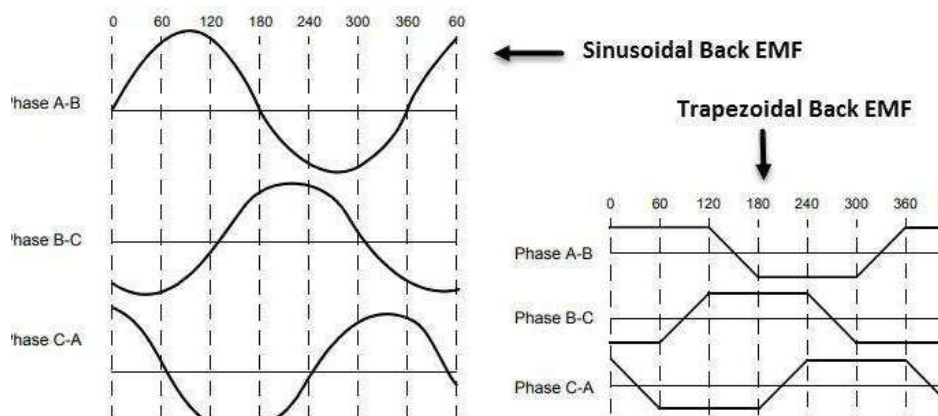
As you can see in the image, a BLDC Motor consists of two main parts: a stator and a rotor.

9.5.2 Stator

The structure of the stator of a BLDC Motor is similar to that of an induction motor. It is made up of stacked steel laminations with axially cut slots for winding. The winding in BLDC are slightly different than that of the traditional induction motor.



Generally, most BLDC motors consists of three stator windings that are connected in star or 'Y' fashion (without a neutral point). Additionally, based on the coil interconnections, the stator windings are further divided into Trapezoidal and Sinusoidal Motors.



In a trapezoidal motor, both the drive current and the back EMF are in the shape of a trapezoid (sinusoidal shape in case of sinusoidal motors). Usually, 48 V (or less) rated motors are used in automotive and robotics (hybrid cars and robotic arms).

9.5.3 Rotor

The rotor part of the BLDC Motor is made up of permanent magnets (usually, rare earth alloy magnets like Neodymium (Nd), Samarium Cobalt (SmCo) and alloy of Neodymium, Ferrite and Boron (NdFeB)).

Based on the application, the number of poles can vary between two and eight with North (N) and South (S) poles placed alternately. The following image shows three different arrangements of the poles. In the first case, the magnets are placed on the outer periphery of the rotor.



The second configuration is called magnetic-embedded rotor, where rectangular permanent magnets are embedded into the core of the rotor. In the third case, the magnets are inserted into the iron core of the rotor.

9.5.4 Position Sensors (Hall Sensors)

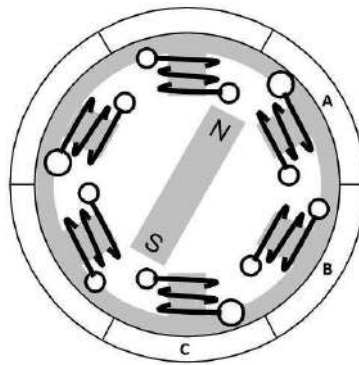
Since there are no brushes in a BLDC Motor, the commutation is controlled electronically. In order to rotate the motor, the windings of the stator must be energized in a sequence and the position of the rotor (i.e. the North and South poles of the rotor) must be known to precisely energize a particular set of stator windings.

A Position Sensor, which is usually a Hall Sensor (that works on the principle of Hall Effect) is generally used to detect the position of the rotor and transform it into an electrical signal. Most BLDC Motors use three Hall Sensors that are embedded into the stator to sense the rotor's position.

The output of the Hall Sensor will be either HIGH or LOW depending on whether the North or South Pole of the rotor passes near it. By combining the results from the three sensors, the exact sequence of energizing can be determined.

9.5.5 Working Principle

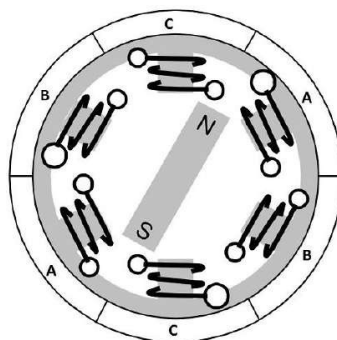
Consider the following setup of three windings in the stator designated A, B and C. For the sake of understanding, let us replace the rotor with a single magnet.



We know that when a current is applied through a coil, a magnetic field is generated and the orientation of the field lines i.e. the poles of the generated magnet will depend on the direction of the current flowing through the coil.

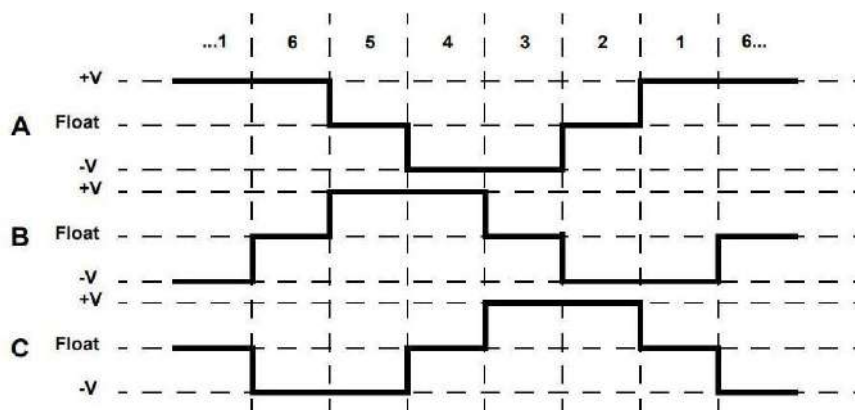
Using this principle, if we supply current to the coil A so that it will generate a magnetic field and attract the rotor magnet. The position of the rotor magnet will shift slightly clockwise and will align with A.

If we now pass current through coils B and C one after the other (in that order), the rotor magnet will rotate in clock wise direction.



To increase efficiency, we can wind the opposite coils using a single coil so that we get double attraction. Further increasing the efficiency, we can energize two coils at the same time so that one coil will attract the magnet and the other coil will repel it. During this time, the third will be idle.

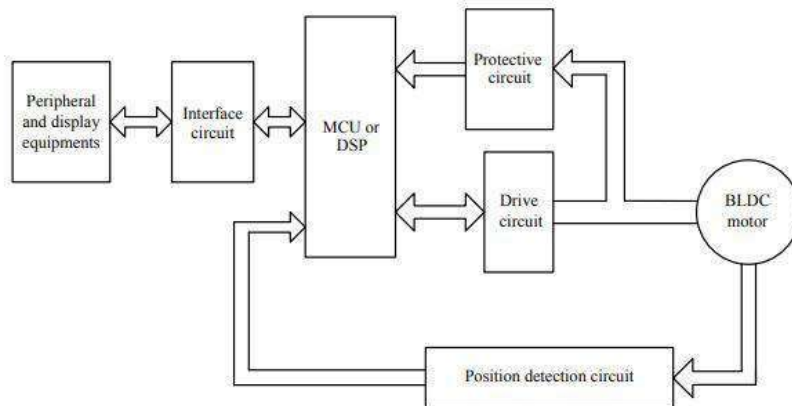
For a complete 360° rotation of the rotor magnet, six possible combinations of the coils A, B and C are applicable and are shown in the following timing diagram.



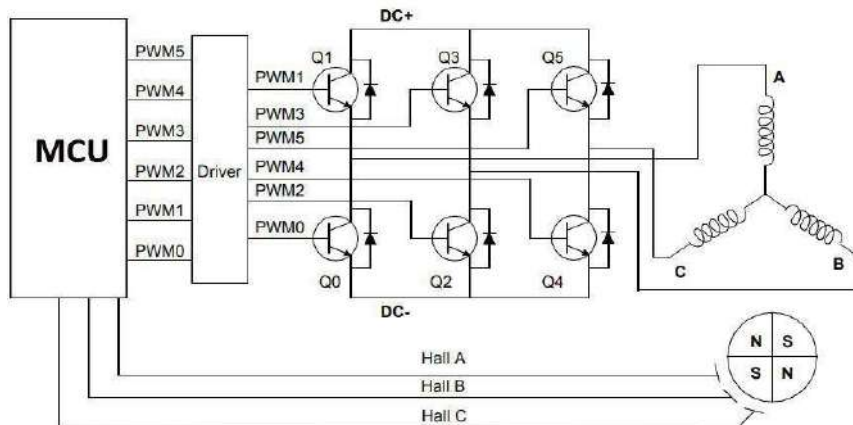
Base on the above diagram, we can confirm that at any time, one phase is positive, one phase is negative and the third phase is idle (or floating). So, based on the inputs from the Hall Sensors, we have two switch the phases as per the above diagram.

9.5.6 Driving Brushless DC Motors

If stator and rotor are essential parts of a BLDC Motor that are integral to it, then the driving electronics are equally essential. Block diagram of a typical Brushless DC Motor control or drive system is shown in the following image.



This drive circuitry is often known as Electronic Speed Controller System or simply an ESC. One common setup is called the Full Bridge Drive Circuit. It consists of an MCU with PWM outputs, six **MOSFETS** for the three phases of the stator windings, feedback from the Hall sensors and some power supply related components.



The MCU can be programmed to appropriately switch the MOSFETS based on the data from the Hall Sensors.

9.5.7 Advantages of BLDC Motors

Since BLDC Motors are electronically commutated, there are several advantages over traditional brushed DC Motors. Some of them are:

- i. No wear and tear (due to absence of brushes)
- ii. High efficiency
- iii. Better speed vs torque characteristics
- iv. Long life
- v. Less noise or noiseless operation
- vi. Significantly higher RPM

9.5.8 Applications of Brushless DC Motors

Some of the areas of applications of BLDC Motors are mentioned below:

- i. Single speed applications
- ii. Adjustable speed applications
- iii. Position control
- iv. Low noise applications
- v. High speed applications

9.6 Certified Energy Managers & Certified Energy Auditors

In order to implement energy conservation measures The *Energy Conservation Act, 2001* incorporated development of pool of Certified Energy Managers (CEM) & Certified Energy Auditors (CEA) through BEE, who has nominated the National Productivity Council (NPC) as the National Certifying Agency, which would conduct the National Level Certification Examination for Certified Energy Managers & Certified Energy Auditors.

9.6.1 Role of Energy Managers

- a. Prepare an annual activity plan and present to management concerning financially attractive investments to reduce energy costs.
- b. Establish an energy conservation cell within the firm with management's consent about the mandate and task of the cell.
- c. Initiate activities to improve monitoring and process control to reduce energy costs.
- d. Analyze equipment performance with respect to energy efficiency.
- e. Ensure proper functioning and calibration of instrumentation required to assess level of energy consumption directly or indirectly.
- f. Prepare information material and conduct internal workshops about the topic for other staff.
- g. Improve disaggregating of energy consumption data down to shop level or profit centre of a firm.
- h. Establish a methodology how to accurately calculate the specific energy consumption of various products/services or activity of the firm.
- i. Develop and manage training programme for energy efficiency at operating levels.
- j. Co-ordinate nomination of management personnel to external programs.
- k. Create knowledge bank on sectoral, national and international development on energy efficiency technology and management system and information denomination.
- l. Develop integrated system of energy efficiency and environmental upgradation, Wide internal & external networking.
- m. Co-ordinate implementation of energy audit/efficiency improvement projects through external agencies.
- n. Establish and/or participate in information exchange with other energy managers of the same sector through association.

9.6.2 Role Energy Auditors

- a. The energy auditor is responsible for preparing the annual plan for the activities and also it is their responsibility as well as duty to present the plan in front of the management that is concerned with the attractive deals for making investments and reducing the energy costs.



- b. Establishment of the energy conservation cell in the firm is also the responsibility of the energy auditor. They have to initiate the activities for improving monitoring as well as process control for bringing reduction in the energy costs.
- c. Along with taking measures for reducing the energy costs, the energy auditors are also given the responsibility of analysing the performance of the equipments in regard to energy efficiency. Preparation of the information material along with conducting of internal workshops is also one of the responsibilities of energy auditor.
- d. The energy auditors have the responsibility of developing and managing the training program at the operational levels for energy efficiency. Along with this, they also have to develop the incorporated system of the energy efficiency as well as environmental up gradation.
- e. One of the responsibilities given to the energy auditor includes conducting internal audit of the individual system or equipments once in a year.
- f. One of the essential duties that have to be performed by the energy auditor includes submitting the copy of the report to energy managers. Also the energy managers must be efficient in keeping a record of the calibration status of all instruments and devices used for energy measurement.
- g. It is essential for them to have the capabilities of maintaining all the portable instruments and tools that are necessary for audit. Efficiency in keeping all the practice codes for testing energy efficiency is also must for the energy auditor.
- h. The energy auditors must have the capability of working in a team with the other members of external audit team.

CHAPTER-10

TARIFF AND METERING

10.1 Introduction

Electrical Tariff represents the basis on which charges are recovered from the consumers for supply of electricity.

The main objectives of the tariff is to distribute equitably the cost of supplying electrical energy among the various classification of use such as lighting, heating, industrial and, bulk supply etc. All types of tariffs must cover the following costs:

- i. Recovery of cost of capital investment in generating plant, transmission and distribution system equipment's and in other forms of the operating equipment.
- ii. Recovery of cost of operation and maintenance of equipments and plant.
- iii. Recovery of cost of auxiliary equipment, metering equipment, billing and collection expenses and miscellaneous services.
- iv. A reasonable return on the total capital investment.

The principle factors involving the formulation of tariff are enumerated below:

- i. Proper return is secured from each consumer of electric energy.
- ii. Consumers are made to make more extended use of electric energy.
- iii. Consumers of electric energy are charged according to what the energy costs.
- iv. The tariff should be simple and cheap and should be easy to understand by the consumers.

10.2 Important Terms

10.2.1 Fixed Cost

This cost is independent of maximum demand and energy output. It is due to annual overhead cost of central organization, interest on the capital cost of land (especially if some land is held for future development) and salaries of officials.

10.2.2 Semi-fixed cost

This cost depends on maximum demand but independent of energy output. The semi-fixed cost is due to annual interest and depreciation on the capital cost of building and equipment, taxes and insurance charges and salaries of management and clerical staff, cost of transmitting and distributing the energy. The semi-fixed cost is approximately proportional to the maximum demand.

10.2.3 Operating cost

This cost depends upon the energy output. This is due to annual cost of fuel, lubricating oil, water, maintenance and repairs, wages and salaries of operating staff etc. The operating cost is approximately proportional to the units generated.

10.3 Types of Tariffs

The different kinds of tariffs in common use are as under



- a. Simple tariff
- b. Flat rate tariff
- c. Two-part tariff
- d. Block rate tariff
- e. Maximum demand tariff
- f. Power factor tariff
- g. Three part tariff
- h. Off peak tariff

10.3.1 Simple Tariff

This is the simplest kind of tariff. Here the cost of energy is charged on the basis of units consumed. The rate per unit can be calculated as,

$$\text{Charges per kWh} = \frac{(\text{Annual Fixed charges} + \text{Annual running charges})}{\text{Total number of units supplied to consumer}}$$

This method has following drawbacks although the procedure for fixing the rates is very simple for the supplier and calculation, verification by the consumer.

- i. The cost per kWh delivered is higher.
- ii. There is no discrimination among the different categories (such as domestic, commercial and industrial) of consumers.
- iii. The simple tariff can be made suitable by having some modifications mentioned below.
- iv. By allowing a discount to the consumer who consumes more electricity than an average consumer.
- v. Special tariff be framed for different categories of consumers such that the domestic consumers may be charged light rates than in case of industrial consumers and commercial consumers.
- vi. By encouraging the consumers of electric energy to use electricity during off peak load period thereby giving them a special discount. Its use is restricted to industrial loads only.

10.3.2 Flat Rate Tariff

This kind of tariff differs from the former (simple tariff) one in the sense that the different categories of consumers are charged at different rates. In this case the flat rate thus is slightly higher for domestic (light and fan) loads than for industrial (power) loads. The rate for each category of consumers is derived by taking into account its load factor and diversity factor.

This method is very popular with the consumers since it can be easily understood by the consumers and the calculations at the supplier's end are very simple. If the energy consumed by an industrial consumer is x units and the flat rate per unit is Rs. a per unit then the total charges of the bill are Rs. ax .

The disadvantage of this tariff is that separate meters are required for different types of supply.

In some public utilities for certain categories of supplies e.g. agricultural loads, flat demand rate based on per kW or BHP connected load is charged. Here the main advantage of this tariff is the elimination of the metering equipment, meter reading, billing and accounting costs. This tariff is known as flat demand rate tariff. The main disadvantage of this tariff is that there is tendency on the part of the consumer to keep their appliances on even when not required. But this tariff can be used where numbers of hours of use are known and energy consumption is readily predictable such as street lighting, sign lighting and signal lighting etc.

10.3.3 Two-Part Tariff

The charges include fixed charges independent of energy consumed and proportional to per kW of maximum demand and the running (operating) charges per kWh of the total energy consumed.

The tariff can be expressed as, $C = Rs. (a. kW + b. kWh)$

Where Rs. a is the charge per kW of maximum demand assessed and Rs. b is the charge per kWh of energy consumed.

This tariff is mostly applicable to the medium industrial consumers.

Here, the charges made on the maximum demand covers the fixed charges such as interest and depreciation on the capital cost of building and equipment, taxes and insurance charges and operating cost which is independent of energy supplied by it. The charge varies with the variation in energy supplied.

There is a disadvantage of this tariff to the consumers because they have to pay also the fixed charges unnecessarily during the month in which their industry is closed.

10.3.4 Block Rate Tariff

The disadvantage of the flat rate tariff is that the charges are made for the total quantity of energy consumed at the same rate irrespective of the magnitude of energy consumed by the different consumers. The fixed charges are spread over a greater number of units generated or consumed thus lowering the rate per unit. This shortcoming is removed in block rate tariff in which a given blocks of energy are charged at progressively increased rates.

10.3.5 Maximum Demand Tariff

This tariff is very similar to the two-part tariff except that in this case the maximum demand is actually measured by a maximum demand indicator instead of merely assessing it on the basis of predetermined value. Thus the drawback of two-part tariff is removed. This tariff is applicable to large industrial consumers and bulk consumers.

10.3.6 Power Factor Tariff

The equipment and plant efficiency depends on the power factor of the load, In order to increase the utility of the plant and equipment to the maximum, the plant must be operated at the most economical power factor. Because of this reason, power factor tariffs are applied. By applying power factor tariffs, the consumers are penalized for keeping poor power factor on their loads.

10.3.7 KWH and KVARH Tariff

In this type of tariff the consumer is charged separately on the basis of kWh and kVarh consumption. With the improvement of power factor the kVarh decreases and thus the consumer tries to improve power factor of his load in order to decrease the charges on account of less kVarh registered by the kVarh meter.

10.3.8 KVA Maximum Demand Tariff

This is a modified form of two part tariff. The consumption is measured in kWh while the maximum demand is measured in kVA. Instead of kW. Because with low power factor of the installation the kVA part of load will be larger, the consumer tries to improve power factor of his installation so as to avoid more demand charges.

10.3.9 Average power factor tariff or sliding scale tariff

In this type of tariff, some reference power factor, say 0.8 lagging, may be taken and for every decrease of 0.01 over the average power factor (0.8), the consumer is levied surcharge. Similarly, a discount



may be allowed for each 0.01 by which the average power factor rises above 0.8. Such types of tariff, are rarely used.

10.3.10 Three-Part Tariff

In this type of tariff, the cost consists of the fixed charges, semi-fixed charges and the running or operating charges. Thus three-part tariff is composed of three elements and is mathematically represented by the equation,

Total cost = $a + b \text{ (kW or kVA)} + c \cdot \text{kWh}$,

Constant charges 'a' are also called consumer charges and are on account of giving service connection and expenses incurred in connection with metering and office establishment. Semi fixed charges 'b' are proportional to kW or kVA maximum demand. These are variable charges and include the initial cost of plant as well as the operating cost which is independent of total energy supplied by it. The charges vary with the maximum demand.

Part 'c' is the variable charge based on energy consumed and recovers the cost of fuels and other operating charges etc. This type of tariff is generally applicable to bulk supplies.

10.3.11 Off Peak Tariff

The load on the power station is very low during night hours (10 P.M. to 6 A.M.), while in the evening peak loads occur. During the off peak period, the plant, the transmission and distribution system and equipment will be lying idle. In order to encourage the consumers to use electric energy during off peak load period, the energy can be supplied without incurring any extra capital investment and thus is profitable.

This tariff is advantageous for processes as water heating by thermal storage, refrigeration and pumps etc.

10.4 Special Tariffs

10.3.1 Availability Based Tariff (ABT)

It is a tariff system which depends on the availability of power. It is a frequency based tariff mechanism which tends to make the power system more stable and reliable. This tariff mechanism also has of 3 parts:

Total Cost = Fixed Charge + Capacity Charge + UI (Unscheduled Interchange)

Where fixed cost independent of the maximum demand and energy consumed. This cost takes into account the cost of land, labor and interest on capital cost, depreciation, etc. The capacity charge is for making the power available to them and depends on the capacity of the plant, and the third one is UI. UI charges are worked out from ABT mechanism.

10.3.2 Mechanism of ABT

- i. The generating stations commit a day ahead of the scheduled power which they can provide to the regional load dispatch center (RLDC).
- ii. The RLDC conveys this information to various SLDC which in turn collects the information from various state DISCOMS about the load demand from various types of consumers.
- iii. The SLDC sends load demand to RLDC, and now RLDC allocates the power accordingly to the various states.

If everything goes well, power demand is equal to power supplied and the system is stable and

frequency is 50 Hz. But practically this rarely happens. One or more state overdraws or one or more GS under supplies and these lead to deviation in frequency and system stability. If demand is more than supply frequency that dips from the normal and vice versa.

UI charges are incentives provided or penalties imposed on the generating stations. If the frequency is less than 50 Hz, implies demand is more than supply, then the GS which supplies more power to the system than committed is given incentives. On the other hand, if the frequency is above 50 Hz, implying supply is more than demand, incentives are provided to GS for backing up the generating power. Hence it tries to maintain the system stable.

10.3.3 Time of Day (ToD)

Time of Day Tariff (ToD), also known as Time of Usage (ToU), involves dividing the day into tariff slots with higher rates at peak load periods and low tariff rates at off-peak load periods. While this can be used to automatically control usage on the part of the customer (resulting in automatic load control), it is often simply the customer's responsibility to control his own usage, or pay accordingly (voluntary load control). In this kind of arrangement, usually during day period the demand for power is very high, and the supply remains the same. Consumers are discouraged to use excess energy by making the cost high. Contrary to that during night time, demand is less compared to supply, and hence consumers are encouraged to consume power by providing it at a cheaper rate.

ToD tariff normally splits rates into an arrangement of multiple segments including on-peak, off-peak, mid-peak and critical peak. A typical arrangement is a peak occurring during the day, such as from 5pm to 11 pm.

10.5 Metering

10.5.1 Domestic Metering

Railway Board vide letter no. 84/Elec.I/150/2, Dt. 21.01.1987 have decided

1. That the Railway employees residing in the Railway colonies should be charged at the same rate as they would have paid if they had taken supply directly i.e. they will pay at the same rate as the residents of adjoining colonies are billed for electricity consumption for domestic purposes from the local supply authorities.
2. Railways should also analyze the problem of taking separate connection from colony to colony and wherever they find that taking of direct connection is feasible from practical and economic considerations, such works should be taken in hand on priority. This should enable the employees to pay directly to the local supply authorities.
3. The efforts to bring round the local supply authorities and State Electricity Boards to agree to charge energy consumed in Railway residential premises at their domestic tariffs should also continue.
4. For new quarters wherever possible and practicable direct service connections from local supply authorities/Electricity Board lines should be arranged in a manner that the occupants can be billed individually and they can clear their electricity charges without coming to the Railway channel.

These instructions should uniformly be followed across the Indian Railways.

10.5.2 Electromechanical Induction Type Energy Meter

It is the popularly known and most common type of age old watt hour meter. It consists of rotating aluminium disc mounted on a spindle between two electro magnets. Speed of rotation of disc is



proportional to the power and this power is integrated by the use of counter mechanism and gear trains. This type of meter is simple in construction and accuracy is somewhat less due to creeping and other external fields. A major problem with these types of meters is their easy prone totampering, leading to a requirement of an electrical energy monitoring system. These are very commonly used in domestic and industrial applications.

10.5.3 Electronic Energy Meter

These are of accurate, high procession and reliable types of measuring instruments as compared to conventional mechanical meters. It consumes less power and starts measuring instantaneously when connected to load. These meters might be analog or digital. In analog meters, power is converted to proportional frequency or pulse rate and it is integrated by counters placed inside it. In digital electric meter power is directly measured by high end processor. The power is integrated by logic circuits to get the energy and also for testing and calibration purpose. It is then converted to frequency or pulse rate.

a. Analog Electronic Energy Meter

In analog type meters, voltage and current values of each phase are obtained by voltage divider and current transformers respectively which are directly connected to the load. Analog to digital converter converts these analog values to digitized samples and it is then converted to corresponding frequency signals by frequency converter. These frequency pulses then drive a counter mechanism where these samples are integrated over a time to produce the electricity consumption.

b. Digital Electronic Energy Meter

Digital signal processor or high performance microprocessors are used in digital electric meters. Similar to the analog meters, voltage and current transducers are connected to a high resolution ADC. Once it converts analog signals to digital samples, voltage and current samples are multiplied and integrated by digital circuits to measure the energy consumed.

Microprocessor also calculates phase angle between voltage and current, so that it also measures and indicates reactive power. It is programmed in such a way that it calculates energy according to the tariff and other parameters like power factor, maximum demand, etc. and stores all these values in a non-volatile memory EEPROM.

It contains real time clock (RTC) for calculating time for power integration, maximum demand calculations and also date and time stamps for particular parameters. Furthermore it interacts with liquid crystal display (LCD), communication devices and other meter outputs. Battery is provided for RTC and other significant peripherals for backup power.

10.5.4 Smart Energy Meter

It is an advanced metering technology involving placing intelligent meters to read, process and feedback the data to customers. It measures energy consumption, remotely switches the supply to customers and remotely controls the maximum electricity consumption. Smart metering system uses the advanced metering infrastructure system technology for better performance.

These are capable of communicating in both directions. They can transmit the data to the utilities like energy consumption, parameter values, alarms, etc and also can receive information from utilities such as automatic meter reading system, reconnect/disconnect instructions, upgrading of meter software's and other important messages. These meters reduce the need to visit while taking or reading monthly bill. Modems are used in these smart meters to facilitate communication systems such as telephone, wireless, fiber cable, power line communications. Another advantage of smart metering is complete

avoidance of tampering of energy meter where there is scope of using power in an illegal way.

10.5.5 Industrial Metering

Trivector Meter

The Trivector meter is a measuring instrument which measures the kW, kVAr, the kVA. These instruments can measure both power as well as energy. Trivector meters are normally used in substations and to measure the power flowing through the feeders. They are used for billing power drawn by industrial customers. The Trivector enables the simultaneous measurement of different electrical parameters which enables accurate assessment of the power consumed.

Trivector is called so as it measures three vectors representing the active, reactive and apparent power of a line. Trivector meters come in two quadrant and four quadrant models. The four quadrant model can measure both the incoming (import) and the outgoing power (export) while the two quadrant trivector meter can measure either imported or exported power.

10.5.6 Trivector Meter with ABT and ToD facilities

This is the most generic meter and is used for metering and billing purposes for HT installations. It is an Electronic HT tri vector meters suitable for ABT (Availability Based Tariff), allowing Four Quadrant, Bi-Directional power flow, solidly earthed system with balanced and un-balanced loads for a power factor range from zero to unity (lagging and leading), with accuracy class 0.2s. This is suitable for being connected directly to voltage transformers (VT)/capacitive voltage transformers (CVT) having a rated secondary line-to-line voltage of 110V and to current transformers (CTS) having a rated secondary current of 1A, 3 element 4 wire.

10.5.7 Governing Standards

The meter shall conform in all respects including performance and testing thereof to the following Indian/ International Standards to be read with up-to-date and latest amendments/ revisions thereof

Sl No.	Standard No.	Title
1	IS:14697/1999 Reaffirmed 2004	AC static transformer operated watt-hour and VAR-Hour meters, class 0.2s, 0.5 S and 1.0 S.
2	CBIP publication No 304, July 2008.	Manual on Standardization of Ac static electrical energy meters
3	IEC 62052-11	Electricity metering equipment (AC) – General requirements, tests and test conditions
4	IEC 62053-22	Static meters for active energy (class 0.2 S and 0.5 s)
5	IEC 62056	The standard for Electricity metering – Data exchange for meter reading, tariff and load control.

10.5.8 Energy measurements

The active energy (Wh) and reactive energy (Varh) measurement shall be carried out on 3-phase, 4-wire principle, with an accuracy as per class 0.2 S of IS: 14697, the energy shall be computed directly in CT and VT secondary quantities, and indicated in watt-hours/varh. The harmonics shall be filtered out while measuring Wh, Var and VARh, and only fundamental frequency quantities shall be measured/computed.

10.5.9 Instantaneous Parameters

The meters shall display the following parameters on demand (by pressing the push button) and automatically. In automatic display each parameter shall be displayed for at least 10 sec. Both forward and backward scroll provision shall be available in on demand display.



1. Parameters:
2. Unique identification number of the meter
3. Date
4. Time
5. Current – IR
6. Current – IY
7. Current – IB
8. Voltage - VRN for 3 Φ / 4W
9. Voltage – VYN for 3 Φ / 4W
10. Voltage – VBN for 3 Φ / 4W
11. Signed Power Factor – R phase
12. Signed Power Factor – Y phase
13. Signed Power Factor – B phase
14. System Power Factor – PF
15. Frequency
16. Signed Active Power – kW (+ Forward, - backward)
17. Signed Reactive Power – kVAr (+ Lag, - Lead)
18. Apparent Power – kVA
19. Cumulative Energy export – kWh
20. Cumulative Energy Import – kWh
21. Cumulative Energy – kVAh – export
22. Cumulative Energy – kVAh – import
23. KVARh – Quadrant 1
24. KVARh – Quadrant 2
25. KVARh – Quadrant 3
26. KVARh – Quadrant 4
27. Maximum demand – (kVA)export
28. Maximum demand – (kVA)import
29. Cumulative MD (MVA)export
30. Cumulative MD (MVA)import
31. Date and Time of Last MD reset
32. Cumulative MD reset count
33. Raising demand(KVA) and elapsed time
34. Average frequency of the previous 15-minute block
35. Net Wh transmittal in the previous 15-minute block, with +/-sign
36. Average percentage voltage
37. Voltage-high VARh register reading
38. Voltage-low VARh register reading.
39. Cumulative Power Down Time in DD:HH:MM
40. Total Voltage Harmonic Distortion VTHD
41. Total Current Harmonic Distortion ITHD

42. Cumulative tamper count
43. Cumulative programming count
44. Demand Integration Period
45. Programmed external CT and PT ratios set in the meter

10.5.10 Load Survey Parameters

The following parameters for load survey purpose and shall be logged with a block period of 15 minutes. The data storage required for the load survey parameters shall be 45 days in nonvolatile memory with life time of the meter.

1. Average Frequency (Coded 00-99 for 49.00-51.00 Hz)
2. Average Power factor (Export)
3. Average Power factor (Import)
4. Net active energy
5. Active Energy (kW/kWh) Import
6. Active Energy (kW/kWh) Export
7. Apparent Energy (kVA/kVAh) import
8. Apparent Energy (kVA/kVAh) export
9. kVAr/ kVArh Lag Export
10. kVAr/ kVArh Lead Export
11. kVAr/ kVArh Lag Import
12. kVAr/ kVArh Lead Import
13. Percentage Voltage unbalance
14. Total harmonic distortion of voltage in percentage of fundamental
15. Total harmonic distortion of current in percentage of fundamental
16. Phase wise voltages and currents also shall be made available.
17. Date and time shall also be included

10.5.11 Billing Parameters

The parameters listed below for billing purpose and are logged at each day midnight (00.00Hrs) and stored in non-volatile memory for 45 days.

1. Cumulative Active Energy (kWh) – Import up to two decimal
2. Cumulative Active Energy (kWh) – Export up to two decimal
3. Cumulative Apparent Energy (kVAh) – Import
4. Cumulative Apparent Energy (kVAh) – Export
5. Cumulative Reactive Energy (kVArh) (Lag/Lead) - While kW is Import
6. Cumulative Reactive Energy (kVArh) (Lag/Lead) - While kW is Export
7. kVArh during low voltage <97%
8. kVArh during high voltage >103%
9. T.o.D Parameters:
 - i. kWh and kVAh- Export
 - ii. kWh and kVAh – Import
 - iii. MD in kVA



iv. Power Factor for programmed periods.

10. Power Down Time or Power Off Data (DD:HH:MM)

Historical Data Recording: Meter shall be capable of recording in its Non-Volatile (NVM) historical data consisting of billing energy, demand, ToD registers, minimum of six such data sets shall be stored and it should be possible to retrieve these data through communication port on common meter reading instrument (CMRI) or RMR.

10.5.12 Programmable Parameters

1. Real time clock
2. Demand integration Period
3. Block Capture Time
4. Billing Date/MD reset date
5. Time Zones (1 to 8)
6. External CT/PT ratios.
7. Events/tampers

Provisions shall be made to program the above parameters at sight using CMRI, Laptop or using Base computer software from remote station with proper security system. Logging of programmable parameter changed event (date & time) along with display of the same under On Demand Display Parameters & snapping of billing data at that time shall be stored and can be retrievable with CMRI and RMR and Laptop.

10.5.13 Maximum Demand Recording

The maximum demand is to be monitored during each demand interval set with 30/15 minutes integration and the maximum of these in a month shall be stored. Whenever MD is reset the maximum demand value so registered shall be stored along with date and time. Under the current integration period, the rising demand should be displayed continuously along with the elapsed time. The registered demand and the number of times the MD is reset up to 10 shall be stored in the memory.

MD Reset:

The meter shall have the following provisions regarding MD reset.

- a. Manually by operation of a button, which is to be covered and sealing provision available for such, cover.
- b. Resetting shall also be possible through a hand held common meter reading instrument (CMRI), Windows based Laptop capable of communicating with the meter.
- c. Provision for automatic resetting at the end of certain period may be made available and it should be possible to invoke this through CMRI, Windows based Laptop with date and time.

10.5.14 Time of Day Tariff (ToD)/Time of Use (ToU)

The meter shall contain provisions for differential pricing of energy and/or maximum demand. The meter shall be capable of being set in to minimum of 6 time zones (00:00 to 06:00 Hrs., 06:00 to 10:00 Hrs., 10:00 to 14:00 Hrs., 14:00 to 18:00 Hrs., 18:00 to 22:00 Hrs., 22:00 to 24:00 Hrs.).

Optionally more time zones can be offered. The entire hours of one day or seven days of one week or 365 days of one year shall be grouped in specific time slots, each slot being associated with specific metered register(s). The meter shall have a real time clock based on a quartz crystal with a battery totally independent of power supply.



It should be possible to change the time period for the ToD recording through a CMRI, Laptop/ remote communication using a proper security system. Meter shall be capable to log such changes with date and time stamping. The main control for this change shall be available in the basecomputer system.

10.5.15 Communication Capability

The meter may be provided with two ports for communication of the measured / collected data, i.e. hardware ports. The meter shall have a galvanically isolated optical communication port as per IEC 1107/ANSI and additional communication port RS 232/RS 485 should be provided for remote meter reading purpose with open standard protocols. Both the ports shall communicate simultaneously. Both the ports shall be of universal type conforming to relevant standard so that these can be easily connected to a DCD, CMRI, MODEM (e.g. GSM, GPRS, CDMA, PLCC, Microwave, Radio, VSAT, Leased Line, PSTN, VPN, Ethernet etc.), Laptop, PC, GPS Time device for data communication/ time synchronization etc. The ports shall be integral part of body and sealable. All of the parameters available in the register of the meter shall be user selectable through CMRI and also with laptop.

10.5.16 Gross Metering and Net Metering

Drastic price decline in the last decade, combined with policy incentives for rooftop systems, have allowed consumers to install solar system on their rooftop. However, given that it is expensive to store electricity, systems are often connected to the grid so that surplus can be exported to the grid and deficit can be imported from the grid. Two arrangements are often defined by governments when designing the regulations for solar rooftop system –Gross and Net metering.

Gross metering is an arrangement in which a consumer is compensated at a fixed feed-in- tariff for the total number of units of solar energy generated and exported to the grid (accounted by a unidirectional ‘gross meter’) and has to pay the electricity distribution company (Discom.) at retail supply tariff for the electricity consumed from the grid. The feed-in-tariff and retail supply tariff are typically different rates.

Net metering is an arrangement in which electricity exports are adjusted against imports, lowering the electricity bill, such that, electricity produced is deducted from the total electricity consumed over a fixed period of time. The adjustment may be done either on a monthly, half-yearly or annual basis. Typically, a bidirectional ‘net meter’ accounts for both import and export of power. If the exported electricity is higher than the imported electricity, a consumer may or may not be compensated for the excess electricity being fed into the grid (depending up a state’s net metering policy).

With increasing awareness and availability of new business models, more and more consumers are adopting rooftop solar systems. In the current context while many distribution companies are inclined to discourage rooftop installations due to potential revenue loss, few have proposed to shift from net metering to gross metering. This is because under the gross metering arrangement, compensation to consumers is typically lower than the retail supply tariff (at which they buy electricity from Distribution Companies). While, under net metering since import of power is adjusted against the export, the compensation is effectively at retail supply tariff. Therefore, as a revenue protection measure, they are inclined to adopt gross metering instead of net metering. However, there may be exceptions and consumers should understand the benefit and impact before choosing net or gross metering for their solar rooftop system (if distribution company provides the option).



11.1 Introduction

The chapter describes details of tests to be conducted before commissioning of an electrical installation as per norms & the role of Electrical Inspector to the Government of India. The purpose of the electrical installation condition report and testing is for the safety of persons and livestock. Protection against damage by fire and heat. Confirmation that the installation is not damaged or deteriorated. It verify proper functioning of the equipment / system after installation i.e. overall purpose is to capture and record performance data of the whole installation as the base line for future operation and maintenance.

11.2 Testing of Electrical Installation

On completion of an installation following tests shall be carried out.

- i. Insulation resistance test.
- ii. Polarity test of switch.
- iii. Earth continuity test.
- iv. Earth electrode resistance test
- v. Continuity of protective conductors including main and supplementary equipotential bonding.

11.2.1 Insulation Resistance

- i. The insulation resistance shall be measured by applying between earth and the whole system of conductors, or any section thereof with all fuses in place, and all switches closed, and except in earthed concentric wiring, all lamps in position, or both poles of the installation otherwise electrically connected together, a direct current pressure of not less than twice the working pressure, provided it need not exceed 500 volts for medium voltage circuits. Where the supply is derived from a three wire D.C., or a polyphase A.C. system, the neutral pole of which is connected to earth either directly or through added resistance, the working pressure shall be deemed to be that which is maintained between the phase conductor and the neutral.
- ii. The insulation resistance shall also be measured between all the conductors connected to one pole, or phase conductor of the supply, and all the conductors connected to the neutral, or to the other pole, or phase conductors of the supply with all the lamps in position and switches in “off” position, and its value shall be not less than that specified.
- iii. The insulation resistance in mega ohms measured as above shall not be less than 12.5 mega ohms for the wiring with PVC insulated cables, subject to a minimum of 1 mega ohm.
- iv. Where a whole installation is being tested, a lower value than that given by the formula, subject to a minimum of 1 mega ohm, is acceptable.
- v. A preliminary and similar test may be made before the lamps etc. are installed, and in this event the insulation resistance to earth should not be less than 25 mega ohms for the wiring with PVC insulated cables, subject to a minimum of 2 mega ohms.
- vi. The term “outlet” includes every point along with every switch, except that a switch combined with a socket outlet, appliance or lighting fitting is regarded as one outlet.



- vii. Control rheostats, heating and power appliances and electric signs may, if required, be disconnected from the circuit during the test, but in that event the insulation resistance between the case or frame work, and all live parts of each rheostat, appliance and electric sign, shall be not less than that specified in the relevant Indian Standard Specifications, or where there is no such specification, shall be not less than one mega ohm.
- viii. Insulation Resistance for one time testing has been mentioned, but due to safety reason, the insulation resistance of Electrical installations should be tested on periodic way. The installations in buildings used for public gatherings must be retested periodically by authorized agents.
- ix. The frequency of testing commonly prescribed according to the kind of installation concerned:

Type of Installation			Testing frequency
Installations which require the protection of employees	i.	Locations at which a risk of degradation, fire or explosion exists.	Annually
	ii.	Temporary installations at work sites.	
	iii.	Location at which MV installations exists.	
	iv.	Restrictive conducting locations where mobile equipment is used.	
Installations in buildings used for public gatherings, where protection against the risk of fire and panic are required.		According to the type of establishments and its capacity for receiving the public.	From one to three years.

11.2.2 Polarity Test of Switch

- i. In a two wire installation, a test shall be made to verify that all the switches in every circuit have been fitted in the same conductor throughout, and such conductor shall be labeled or marked for connection to the phase conductor, or to the non-earthed conductors of the supply.
- ii. In a three wire or a four wire installation, a test shall be made to verify that every non-linked single pole switch is fitted in a conductor which is labeled, or marked for connection to one of the phase conductors of the supply.
- iii. The installation shall be connected to the supply for testing. The terminals of all switches shall be tested by a test lamp, one lead of which is connected to the earth. Glowing of test lamp to its full brilliance, when the switch is in “on” position irrespective of appliance in position or not, shall indicate that the switch is connected to the right polarity.

11.2.3 Testing of Earth Continuity Path

The earth continuity conductor, including metal conduits and metallic envelopes of cables in all cases, shall be tested for electric continuity. The electrical resistance of the same along with the earthing lead, but excluding any added resistance, or earth leakage circuit breaker, measured from the connection with the earth electrode to any point in the earth continuity conductor in the completed installation shall not exceed one ohm.

11.2.4 Measurement of Earth Electrode Resistance

- i. Two auxiliary earth electrodes, besides the test electrode, are placed at suitable distance from the test electrode of the tester. A measured current is passed between the electrode to be tested and an auxiliary current electrode, and the potential difference between the test electrode and auxiliary potential electrode is measured. The resistance of the test electrode is then given by:

$$R = \frac{V}{I}$$



I

where,

R - Resistance of the test electrode in ohms,

V - Reading of the voltmeter in volts,

I - Reading of the ammeter in amps.

- a. Stray currents flowing in the soil may produce serious errors in the measurement of earth resistance. To eliminate this, hand driven generator is used.
- b. If the frequency of the supply of hand driven generator coincides with the frequency of stray current, there will be wandering of instrument pointer. An increase or decrease of generator speed will cause this to disappear.
- iii. At the time of test, the test electrode shall be separated from the earthing system.
- iv. The auxiliary electrodes shall be of 13 mm diameter mild steel rod driven upto 1 m into the ground.
- v. All the three electrodes shall be so placed that they are independent of the resistance area of each other. If the test electrode is in the form of a rod, pipe or plate, the auxiliary current electrode 'C' shall be placed at least 30 m away from it, and the auxiliary potential electrode 'B' shall be placed mid-way between them.
- vi. Unless three consecutive readings of test electrode resistance agree, the test shall be repeated by increasing the distance between electrodes A and C upto 50 m, and each time placing the electrode B midway between them.
- vii. On these principles, "Megger Earth Tester", containing a direct reading ohm-meter, a hand driven generator and auxiliary electrodes are manufactured for direct reading of earth resistance of electrodes.

11.2.5 Continuity of protective conductors including main and supplementary equipotential bonding

Every protective conductor including all conductors and any extraneous conductive parts used for equipotential bonding should be tested for continuity. The test should be made by connecting together the neutral and protective conductors at the main position and checking between earth and neutral at every outlet by a continuity tester, which should share a reading near zero.

11.2.6 Test Certificate

On completion of an electrical installation (or an extension to an installation), a certificate shall be furnished which is countersigned by the certified supervisor under whose direct supervision the installation was carried out. This certificate shall be in the prescribed form as being followed in various zones, in addition to the test certificate required by the local Electric Supply Authorities.

11.3 EIG Sanction

11.3.1 Introduction

This chapter describes the details of reports to be submitted to the Electrical Inspector to Government of India (EIG), in the completed internal electrical installations, before commissioning or before restarting of existing installations which have been under shutdown for more than six months and obtaining the requisite permission to energize the installation.



In exercise of the powers conferred by sub-section (1) of section 162 and Clause (z) of sub-section (2) of section 176 of the Electricity Act, 2003, (36 of 2003), the Central Government has made rules for Qualifications, Powers and Functions of Chief Electrical Inspector and Electrical Inspectors which has been notified vide G.S.R. 481(E) in the Gazette of India, Extraordinary, Part II, Section 3, Sub-Section (i) on 17.08.2006. These rules apply to any works or electric installation belonging to the Central Government or under its control and hence Railways are covered under these rules.

These rules confer powers to the Electrical Inspector to inspect the works and electrical installations in his area in respect of which, such an Inspector has been directed by the Central Government to exercise his powers and perform functions under sub-section (1) of the Section 162 of the Electricity Act, 2003.

In terms of above rules, Principal Chief Electrical Engineer (PCEE) has been designated as Electrical Inspector to Government of India (EIG) on Indian Railways.

11.3.2 Self-Certification

In exercise of powers conferred by Clause (zka) of regulation 2 of the Central Electricity Authority (Measures relating to Safety and Electric Supply) Regulations, 2010, the Central Government has specified that the notified voltage for the purpose of self-certification under regulation 30 and regulation 43 of the said regulations shall be 11 kV. The above notification has been published in the gazette vide S.O.1780(E) dt. 16.05.2016 and is accessible at http://cea.nic.in/reports/others/ps/pce2/cei/notifications/notified_voltage_self%20certification.pdf

As per Reg. 30(2) the periodical inspection and testing of installation of voltage equal to or below the notified voltage (i.e. up to & below 11 kV) and as per Reg. 43(1) (a), Every electrical installation of notified voltage and below (i.e. up to & below 11 kV) shall be inspected, tested and self-certified by the owner or supplier or consumer, as the case may be, before commencement of supply or recommencement after shutdown for six months and above for ensuring observance of safety measures specified under these regulations and such owner or supplier or consumer, as the case may be, shall submit the report of self-certification to the Electrical Inspector in the formats (Form I (upto 250V), Form II (above 250V to 650V) & Form III (above 650V)) as framed and issued by the Authority. These forms are enclosed as Annexures as Form I, Form II and Form III in the last of this chapter.

11.3.3 Periodical Inspection under Regulation 30

Procedure to be followed for inspection and testing and Self Certification of Electrical Installation of Notified Voltage up to and below 11 KV as per CEA (Measures relating to Safety and Electric Supply) regulation 2010 amended on 2015 & amended on 2018 under Regulation 30 For Periodical Inspection of LT Lines, 11 kV lines and Substations (Regulation 30- at least once in a five year)

- i. The Designated Self Certifying Officer for these installations is Senior Section Engineer.
- ii. The Section Engineer will visit the site. Check the working of existing LT Lines, 11 kV lines and Substations as per Railways' Standard construction practices and as per time to time directives/circulars issued by higher offices about construction of LT lines, 11 kV lines and Substations.
- iii. He should check line to line clearance, across and above ground clearance, and clearance from nearby house/building.
- iv. The safety measure like Earthing, use of stay insulator, guarding etc. should be invariably checked.
- v. If irregularity/abnormality found in LT lines, 11 kV lines or substations, get it rectified.



- vi. Senior Section Engineer will prepare the report as per Form-I/II for LT lines or Form-III for 11 kV lines and Substations as the case may be (Formats enclosed), and send the copies along with the certificate to the Electrical Inspector i.e. PCEE through the Sr.DEE.
- vii. If the Electrical Inspector is not satisfied with the compliance report, shall inspect the electrical installation within a period of one year (for reg-30) from the date of submission of self-certification report and intimate the Section Engineer the defects, if any, for rectification within fifteen days.
- viii. The Section Engineer will rectify/clear the discrepancies if any and re-submit the report to the Electrical Inspector.

11.3.4 Periodical Inspection under Regulation 43

Procedure for inspection and testing as per Regulation 43 for every electrical installation before commencement of supply (New Installation) or recommencement after shutdown for six months and above

A. LT lines

1. The Designated Self Certifying Officer for LT lines is Senior Section Engineer.
2. After completion of erection of LT Line (Single phase and Three phase) under any scheme concerned agency/contractor will give intimation in writing to Section Engineer for charging the line.
3. The Section Engineer will visit the site within two days after intimation from the agency. Check the work of newly erected LT line as per Railways' Standard construction practices and as per time to time directives/circulars issued by higher offices about construction of LTlines.
4. He should check line to line clearance, across and above ground clearance, and clearance from nearby house/building as per CEA safety Regulations 2010(Latest).
5. The safety measure like Earthing, use of stay insulator, guarding etc. should be invariably checked.
6. The irregularity/abnormality found in LT Line Construction works, should be conveyed in writing (by email/ register post/ Electronic Media) to concerned agency/contractor on same day of inspection. The same is brought to the notice of ADEE/Sr.DEE.
7. Agency should rectify irregularity/abnormality conveyed to him by the Section Engineer within 3 days and again submit the compliance to Section Engineer.
8. Section Engineer will visit immediately to the said location and inspect the rectified work.
9. After satisfactory report i.e. as per Railways' Standard construction practices, Section Engineer will charge/commission the LT line.
10. Section Engineer will prepare the report as per Form-I/II as the case may be (Format enclosed), and send the copies along with the certificate to the Electrical Inspector, i.e. PCEE through the Sr.DEE.
11. If the Electrical Inspector is not satisfied with the compliance report, shall inspect the electrical installation within a period of ninety days (for reg-43) from the date of submission of self-certification report and intimate the Section Engineer the defects, if any, for rectification within fifteen days.
12. The Section Engineer will get rectify/clear the discrepancies if any and re-submit the report to the Electrical Inspector.



B. Substations and 11 kV lines

1. The Designated Self Certifying Officer for Substations and 11 kV lines is Senior Section Engineer.
2. Senior Section Engineer will visit the site within two days after intimation from the agency. Check the work of existing Substation & 11 kV Lines as per Railways' Standard construction practices and as per time to time directives/circulars issued by higher offices about construction of Substation & 11 kV Lines.
3. He should check line to line clearance, across and above ground clearance, and clearance from nearby house/building.
4. The safety measure like earthing, use of stay insulator, guarding etc. should be invariably checked.
5. Irregularity/abnormality found in substation or 11 kV Lines Construction works should be conveyed in writing (by email/ register post/ electronic Media) to concerned agency/contractor on same day of inspection and get it rectified.
6. After satisfactory report i.e as per Railways' Standard construction practices, Senior Section Engineer will charge the substation & 11 kV Lines.
7. Senior Section Engineer will prepare the report as per Form-III Format enclosed), and send the copies along with the certificate to the Electrical Inspector, i.e. PCEE through the Sr.DEE.
8. If the Electrical Inspector is not satisfied with the compliance report, shall inspect the electrical installation within a period of ninety days (for reg-43) from the date of submission of self-certification report and intimate the Senior Section Engineer about the defects, if any, for rectification within fifteen days.
9. Senior Section Engineer will get rectify/clear the discrepancies if any and re-submit the report to the Electrical Inspector.

11.3.5 Sanction of EIG

The main objectives of EIG is to ensure that all the electrical installations are in general conformity with the provision of I.E Rules 1956 with a specific intention of minimising the danger caused by the electricity to human beings, animal life and to the property.

In the above notified voltage (11 kV) ,every installation shall be inspected and tested by Electrical Inspector for the purpose of said regulations before according sanction for energizing the installation. Once an electrical installation is complete in all aspects, concerned engineer must obtain permission from the Electrical Inspector for commissioning of the installation.

For this purpose, the owner i.e. Senior Section Engineer shall inspect, test and self-certify his electrical installation and submit the details in pro-forma given in Form III to Electrical Inspector through Divisional Officers Sr.DEE/G or DEE/G. Consequently, Electrical Inspector shall inspect the electrical installation within a period of ninety days (for reg-43) from the date of submission of self-certification report and intimate the Senior Section Engineer about the defects, if any, for rectification within fifteen days. Sanction shall be accorded for commissioning the installation once all the observation from Electrical inspector is complied.

FORM OF COMPLETION CERTIFICATE

I/We certify that the installation detailed below has been installed by me/us and tested and that to the best of my/our knowledge and belief it complies with Central Electricity Authority (Measures relating to Safety and Electricity Supply) Regulations, 2010

Electrical installation at

Voltage and system of supply

I. Particulars of work:

(a) Internal Electrical Installation

	No.	Total Load	Type or system of wiring
(i) Light point			
(ii) Fan point			
(iii) Plug Point			
(a) 3 pin 5 Amp.			
(b) 3 pin 15 Amp.			

(b) Others	Description	HP/KW	Type of Starting
------------	-------------	-------	------------------

(a) Motors:

(i)

(ii)

(iii)

(b) Other plants:

(c) If the work involves installation of overhead line and/or underground cable.

(d) (i) Type & description of overhead line.

(ii) Total length and no. of spans.

(iii) No. of street lights and its description.

(e) (i) Total length of underground cable & its size.

- (ii) No. of joints:
- | | |
|--|--------------------|
| | End joint : |
| | Tee joint: |
| | St. through joint: |

II. Earthing

- (i) Description of earthing electrode.
- (ii) No. of earth electrodes.
- (iii) Size of main earth lead.

III. Test results:

- (a) Insulation resistance

- (i) Insulation resistance of the whole system of
Conductors to earth – Mega ohms

- (ii) Insulation between the phase conductor and neutral
- | | | |
|-----------------------------|---|-----------|
| Between Phase R and neutral | – | Mega ohms |
| Between Phase Y and neutral | – | Mega ohms |
| Between Phase B and neutral | – | Mega ohms |

- (iii) Insulation resistance between the phase conductors in case of polyphase supply.

- | | | |
|-----------------------------|---|-----------|
| Between Phase R and Phase Y | – | Mega ohms |
| Between Phase Y and Phase B | – | Mega ohms |
| Between Phase B and Phase R | – | Mega ohms |

- (b) Polarity test

Polarity of linked single pole branch switches.

- (c) Earth continuity test

Maximum resistance between any point in the earth continuity conductor including metal conduits and main earthing lead Ohms

- (d) Earth electrode resistance

Resistance of each earth electrode

- | | |
|-------|------|
| (i) | Ohms |
| (ii) | Ohms |
| (iii) | Ohms |
| (iv) | Ohms |

- (e) Lighting protective system

Resistance of the whole of lightning protective system to earth before any bonding is effected with earth electrode and metal in/on the structure Ohms.

Signature and name of
Senior Section Engineer

Signature and Name of the Contractor



Schedule-IV

Forms for Inspection Report / Self Certification under Regulation 30 / 43**FORM I****(Installations of voltage up to and including 250V)**

Report No. _____

Date of Inspection by Electrical Inspector or self-certification by owner _____

Date of Last inspection or self certification _____

1. Consumer No. _____

2. Voltage and system of supply:

(i) Volts _____

(ii) No. of Phases _____

(iii) AC/DC _____

3. Type of wiring _____

4. Name of the consumer or owner _____

5. Address of the consumer or owner _____

6. Location of the premises _____

7. Particulars of the installations: _____

		Number	Connected Load in KW
(a)	(i) Light Points	_____	_____
	(ii) Fan Points	_____	_____
	(iii) Plug Points	_____	_____

State type of wiring whether casing capping, lead covered of teak wood batten, concealed conduit, Tough Rubber Sheathed and any other type.

(b) Other equipments (complete details to be furnished):

(i) _____

(ii) _____

Total connected load in KW _____

Maximum current demand in Amps _____

(on the basis of total connected load)

(c) Generators details i.e. Make, S. No, KVA rating and Voltage:

(i) _____

(ii) _____

General conditions of the installation:

Sl. No.	Regulation Nos.	Requirements	Report
8.	Regulation-12	(i) Is/Are there any visible sign(s) of overloading in respect of any apparatus wiring? (ii) Condition of flexible cords, sockets, switches, plug-pins, cut-outs and lamp holders and such other fittings. (iii) General condition of wiring. (iv) Whether any unauthorised temporary installation exist? (v) State if sockets are controlled by individual switches. (vi) Whether separate boards / conduits have been provided for power supply and communication purpose? (vii) Any other defect or condition which may be a source of danger. If yes give details.	Yes/No Satisfactory/Not Satisfactory Satisfactory/Not Satisfactory Yes/No Yes/No Yes/No
9.	Regulation-13	Give report on condition of service lines, cables, wires, apparatus and such other fittings placed by the supplier or owner of the premises. If not satisfactory give details.	Satisfactory/Not Satisfactory
10.	Regulation-14	Whether suitable cut-outs / MCBs provided by the supplier at the consumer's premises are within enclosed fire proof / resistant receptacle?	Yes/No
11.	Regulation-15	(i) State if switches are provided on live conductors. (ii) State if indication of a permanent nature is provided as per Regulation so as to distinguish neutral conductor from the live conductor as per IS color code? (iii) Whether a direct line is provided on the neutral in the case of single phase double pole iron clad switches/Isolators/MCBs instead of fuse ?	Yes/No Yes/No Yes/No
12.	Regulation-16	(i) State if earthed terminal is provided by the supplier. (ii) Have three pin plugs been provided for plug points ? (iii) General visible condition of the earthing arrangement. (iv) Whether Green wire is provided at switchboard for earthing?	Yes/No Yes/No Satisfactory/Not Satisfactory Yes/No

13.	Regulation-17	Are the live parts in accessible position?	Yes/No
14.	Regulation-34	Leakage on premises: State insulation resistance between conductors and earth in Mega Ohms.	----- M Ohms
15.	Regulation-35	(i) State if linked switches of requisite capacity are provided near the point of commencement of supply. (ii) State if the wiring is divided in suitable number of circuits and each such circuit is protected by suitable cut-out / MCBs. a). No. of Power Circuits b). No. of Lighting Circuits (iii) State if supply to each motor or apparatus is controlled by suitable linked switch.	Yes/No Yes/No -----Nos. -----Nos. Yes/No
16.	Regulation-41	(i) Have the frames of every generator, stationary motor and so far as practicable portable motor and the metallic parts (not intended as conductors) of all other apparatus used for regulating or controlling electricity been earthed by two separate and distinct connections with earth ? (ii) Is the earth wire free from mechanical damage ? (iii) In the case of conduit, or lead covered wiring, has the conduit or lead-cover been efficiently earthed ? (iv) If the consumer has his own earth-electrode, state if it is properly executed and has been tested. If yes give value of earth resistance.	Yes/No Yes/No Yes/No ----- Ohms.
17.	Overhead Lines	(i) State if the consumer has any overhead lines. (ii) Does the overhead line near the premises of consumer meets the requirement of regulation 58, 60 and 61? If not, give details. (iii) Is guarding provided for overhead lines at road crossings? (iv) Any other remarks.	Yes/No Yes/No Yes/No
18.	Regulation 42	Whether earth leakage protective device (ELCB/RCCB) of appropriate capacity as defined in Regulation have been provided in each circuit?	Yes/No

Date :

Signature of the Inspecting Officer/Self-certifying supplier or owner

Name _____

Designation _____

File No. _____

Encl: Test reports

Copy forwarded To Chief Electrical Inspector / Electrical Inspector for

* Not applicable to isolated wall tubes or to brackets, electroliers, switches, ceiling fans and such other fittings (other than portable hand lamps and transportable apparatus) unless provided with earth terminal.

FORM II**(Installations of voltage level more than 250V up to and including 650V)**

Report No. _____

Date of Inspection by Electrical Inspector or self-certification by owner _____

Date of Last inspection or self certification _____

1. Consumer No. _____

2. Voltage and system of supply:

(i) Volts _____ (ii) No. of Phases _____ (iii) AC/DC _____

3. Name of the consumer or owner _____

4. Address of the consumer or owner _____

5. Location of the premises _____

6. Particulars of the installations

(a) Motors:

Make	No.	H.P.	Amps.	Voltage
------	-----	------	-------	---------

(i) _____

(ii) _____

(b) Other equipment (complete details to be furnished):

(i) _____

(ii) _____

Total connected load h.p./KVA _____

(c) Generators details i.e. Make, S. No, KVA rating and Voltage:

(i) _____

(ii) _____

General condition of the installation:

Sl. No.	Regulation Nos.	Requirements	Report
7.	Regulation-3	Is the register of designated persons properly made and kept up to date duly attested ?	Yes/No
8.	Regulation-12	(i) Is/Are there any visible sign(s) of overloading in respect of any apparatus wiring? (ii) Whether any unauthorised temporary installation exist? (iii) Are the electric supply lines and apparatus so installed, protected, worked and maintained as to prevent danger ? (iv) Any other general remarks.	Yes/No Yes/No Yes/No
9.	Regulation-13	Give report on condition of service lines, cables, wires, apparatus and such other fittings	Satisfactory/Not Satisfactory

		placed by the supplier or owner of the premises. If not satisfactory give details.	
10.	Regulation-14	Whether suitable cut-outs/MCBs provided by the supplier at the consumer's premises are within enclosed fire proof/resistant receptacle?	Yes/No
11.	Regulation-15	(i) Whether switches are provided on live conductors? (ii) Whether indication of a permanent nature is provided as per Regulation so as to distinguish neutral conductor from the live conductor as per IS color code? (iii) Whether a direct line is provided on the neutral in the case of single phase double pole iron clad switches/Isolators/MCBs instead of fuse ?	Yes/No Yes/No Yes/No
12.	Regulation-16	(i) Whether earthed terminal is provided by the supplier? (ii) General visible condition of the earthing arrangement.	Yes/No Satisfactory/Not Satisfactory
13.	Regulation-17	(i) Are bare conductors in building inaccessible? (ii) Whether readily accessible switches have been provided for rendering them dead ?	Yes/No Yes/No
14.	Regulation-18	Whether "Danger Notice" in Hindi and the local language of the district and of a design as per relevant Indian Standard is affixed permanently in conspicuous position?.	Yes/No
15.	Regulation-19	(i) Whether insulating floor or mats conforming to IS-15652:2006 have been provided? (ii) Whether identification of panel has been provided on the front and the rear of the panel?	Yes/No Yes/No
16.	Regulation-21	Whether flexible cables used for portable or transportable equipment covered under the Regulation, are heavily insulated and adequately protected from mechanical injury?.	Yes/No
17.	Regulation-22	State the condition of metallic coverings provided for various conductors.	Satisfactory/Not Satisfactory
18.	Regulation-24	Whether the circuits or apparatus intended for operating at different voltage(s) are distinguishable by means of indication(s) of permanent nature?.	Yes/No
19.	Regulation-26	Whether all circuits and apparatus are so arranged that there is no danger of any part(s) becoming accidentally charged to any voltage beyond the limits of voltage for which it/they is/are intended ?	Yes/No

20.	Regulation-27	<p>(i) In the case of generating stations, whether fire-buckets filled with clean dry sand have been conspicuously marked and kept in convenient situations in addition to fire-extinguishers as per IS 3034 suitable for dealing with minor electric fires ?</p> <p>(ii) Whether First Aid Boxes or cupboards conspicuously marked and properly equipped are provided and maintained?.</p> <p>(iii) Is adequate staff trained in First Aid Treatment and fire fighting?</p>	<p>Yes/No</p> <p>Yes/No</p> <p>Yes/No</p>
21.	Regulation-28	<p>(i) Whether instructions in English or Hindi and the local language of the district and where Hindi is the local language, in English and Hindi, for the resuscitation of persons suffering from electric shock have been affixed in a “conspicuous place” ?.</p> <p>(ii) Are the designated persons able to apply instructions for resuscitation of persons suffering from electric shock ?</p>	<p>Yes/No</p> <p>Yes/No</p>
22.	Regulation-34	Leakage on premises: State insulation resistance between conductors and earth in Mega Ohms.	----- M Ohms
23.	Regulation-35	<p>(i) Whether a suitable linked switch, or circuit breaker is placed near the point of commencement of supply so as to be readily accessible and capable of being easily operated to completely isolate the supply ?</p> <p>(ii) Whether every distinct circuit is protected against excess electricity by means of a suitable circuit breaker or cut-out ?</p> <p>(iii) Whether suitable linked switch or circuit breaker is provided near each motor or apparatus for controlling supply to the motor or apparatus?.</p> <p>(iv) Whether adequate precautions are taken to ensure that no live parts are so exposed as to cause danger?</p>	<p>Yes/No</p> <p>Yes/No</p> <p>Yes/No</p> <p>Yes/No</p>
24.	Regulation-37	<p>(i) Whether clear space of 100 cm is provided in front of the main switchboard?</p> <p>(ii) Whether the space behind the switchboard exceeds 75 cm in width or is less than 20 cm?</p> <p>(iii) In case the clear space behind the switchboard exceeds 75 cm. state whether a passage way from either end of the switchboard to a height of 1.80 metres is provided.</p>	<p>Yes/No</p> <p>Yes/No</p> <p>Yes/No</p>

25.	Regulation-41	<p>(i) Has the neutral point at the transformer and generator been earthed by two separate and distinct connections with earth?</p> <p>(ii) Have the frame of every generator, stationary motor and so far as practicable portable motor and the metallic parts (not intended as conductors) of all transformers and any other apparatus used for regulating or controlling electricity and all apparatus consuming electricity at voltage exceeding 250V but not exceeding 650V been earthed by two separate and distinct connections with earth ?</p> <p>(iii) Have the metal casings or metallic coverings containing or protecting any electric supply line or apparatus been properly earthed and so joined and connected across all junction boxes as to make good mechanical and electrical connection?</p> <p>(iv) Whether the consumer's earth-electrode is properly executed and has been tested. If yes, give value of earth resistance?</p> <p>(v) Is the earth wire free from any mechanical damage ?</p> <p>(vi) Whether record of earth resistance value maintained?</p>	<p>Yes/No</p> <p>Yes/No</p> <p>Yes/No</p> <p>Yes/No</p> <p>----- Ohms.</p> <p>Yes/No</p> <p>Yes/No</p>
26.	Regulation 42	Whether earth leakage protective device (ELCB/RCCB) of appropriate capacity as defined in Regulation have been provided in each circuit?	Yes/No
27.	Regulation-45	Have the protections and interlocks for the generating units been provided. If not, give details?	Yes/No
	Overhead Lines	<p>(i) State if the consumer has any overhead lines.</p> <p>(ii) Does the overhead line near the premises of consumer meets the requirement of regulations 58, 60 and 61? If not, give details.</p> <p>(iii) Is guarding provided for overhead lines at road crossings?</p> <p>(iv) Any other remarks.</p>	<p>Yes/No</p> <p>Yes/No</p> <p>Yes/No</p>

Date : _____ Signature of the Inspecting Officer/Self-certifying supplier or owner

Name _____

Designation _____

File No. _____

Encl: Test reports

Copy forwarded To Chief Electrical Inspector / Electrical Inspector for

* Not applicable to isolated wall tubes or to brackets, electroliers, switches, ceiling fans and such other fittings (other than portable hand lamps and transportable apparatus) unless provided with earth terminal.

FORM III**(Installations of voltage exceeding 650V)**

Report No. _____

Date of Inspection by Electrical Inspector or self-certification by owner _____

Date of Last inspection or self certification _____

1. Consumer No. _____
 2. Voltage and system of supply:
 - (i) Volts _____ (ii) No. of Phases _____ (iii) AC/DC _____
 3. Name of the consumer or owner _____
 4. Address of the consumer or owner _____
 5. Location of the premises _____
 6. Particulars of the installations
 - (a) Transformer: (complete detail to be enclosed)

Make	S. No.	K.V.A. rating	Voltage
------	--------	---------------	---------

 - (i) _____
 - (ii) _____
 - (b) Generators details i.e. Make, S. No, KVA rating and Voltage:
 - (i) _____
 - (ii) _____
 - (c) List of equipment (complete details of HT /LT switchgears to be furnished):
 - (i) _____
 - (ii) _____
 - (c) Total connected load KVA _____
- Complete list of connected load to be furnished:

Sl. No.	Regulation Nos	Requirements	Report
1.	Regulation-3	(i) Is the register of the designated persons properly made and kept up to date duly attested?	Yes/No
		(ii) Whether Electrical Safety Officer as required under the Regulation is designated?	Yes/No
2.	Regulation-12	(i) Is/Are there any visible sign(s) of overloading in respect of any apparatus?	Yes/No
		(ii) Whether any unauthorised temporary installation exist?	Yes/No
		(iii) Whether the motors and controlling equipment are being over hauled	Yes/No

		<p>periodically and record kept of the same in a register?</p> <p>(iv) Whether the transformer oil samples are being tested periodically and results recorded in a register? State value of dielectric strength of oil.</p> <p>(v) Whether suitable lightning arrestors have been provided near the transformers for protection against lightning?</p> <p>(vi) Whether earth resistance is being measured periodically in dry and wet season and results recorded in a register? Copy of record to be enclosed.</p> <p>(vii) Any other defect or condition which may be a source of danger. If Yes please explain?</p> <p>(viii) Whether operation and maintenance data has been clarified, categorized and computerized for prompt and easy retrieval?</p> <p>(ix) Whether predictive maintenance is being performed for installation of voltage exceeding 650V?</p> <p>(x) Whether residual life assessment and life extension programmes are being undertaken for installations or equipment of voltage exceeding 650V (applicable for installations or equipment more than 15 years old)?</p> <p>(xi) Whether all required type and routine tests at factory done for equipments. Deficiencies and Discrepancies in above test report and results, if any, shall be reported?</p> <p>(xii) Are there deficiencies in construction with reference to Indian Standard requirements. Please specify.</p>	<p>Yes/No</p> <p>---kV/mm</p> <p>Yes/No</p> <p>Yes/No</p> <p>Yes/No</p> <p>Yes/No</p> <p>Yes/No</p> <p>Yes/No</p> <p>Yes/No</p> <p>Yes/No</p>
3.	Regulation-13	Give report on condition of service lines, cables, wires, apparatus and such other fittings placed by the supplier or owner of the premises. If not satisfactory give details.	Satisfactory/Not Satisfactory
4.	Regulation-14	Whether suitable cut-outs/MCBs provided by the supplier at the consumer's premises are within enclosed fire proof/resistant receptacle?	Yes/No
5.	Regulation-15	<p>(i) Whether switches are provided on live conductors?.</p> <p>(ii) Whether indication of a permanent nature is provided as per Regulation so as to distinguish neutral conductor from the live conductor as per IS color code?</p>	<p>Yes/No</p> <p>Yes/No</p>

		(iii) Whether a direct line is provided on the neutral in the case of single phase double pole iron clad switches/Isolators/MCBs instead of fuse ?	Yes/No
6.	Regulation-16	(i) Whether earthed terminal is provided by the supplier? (ii) General visible condition of the earthing arrangement.	Yes/No Satisfactory/Not Satisfactory
7.	Regulation-17	(i) Are bare conductors in building inaccessible? (ii) Whether readily accessible switches have been provided for rendering them dead?	Yes/No Yes/No
8.	Regulation-18	Whether "Danger Notice" in Hindi and the local language of the district and of a design as per relevant Indian Standard is affixed permanently in conspicuous position?.	Yes/No
9.	Regulation-19	(i) Whether the practice of working on live lines and apparatus is adopted ? If so, have the safety measure been adopted as per Schedule-III ? (ii) Whether insulating floor or mats conforming to IS-15652:2006 have been provided? 14. (iii) Whether identification of panel has been provided on the front and the rear of the panel?	Yes/No Yes/No Yes/No
10.	Regulation-21	Whether flexible cables used for portable or transportable equipment covered under the Regulation, are heavily insulated and adequately protected from mechanical injury?.	Yes/No
11.	Regulation-22	State the condition of metallic coverings provided for various conductors.	Satisfactory/Not Satisfactory
12.	Regulation-24	Whether the circuits or apparatus intended for operating at different voltage(s) are distinguishable by means of indication(s) of permanent nature?.	Yes/No
13.	Regulation-26	Whether all circuits and apparatus are so arranged that there is no danger of any part(s) becoming accidentally charged to any voltage beyond the limits of voltage for which it/they is/are intended ?	Yes/No
14.	Regulation-27	(i) In the case of generating stations and enclosed sub stations, whether fire-buckets filled with clean dry sand have been conspicuously marked and kept in convenient situations in addition to fire-extinguishers as per IS 3034 suitable for	Yes/No

		dealing with minor electric fires ? (ii) Whether First Aid Boxes or cupboards conspicuously marked and properly equipped are provided and maintained?.	Yes/No
		(iii) Is adequate staff trained in First Aid Treatment and fire fighting?	Yes/No
15.	Regulation-28	(i) Whether instructions in English or Hindi and the local language of the district and where Hindi is the local language, in English and Hindi, for the resuscitation of persons suffering from electric shock have been affixed in a “conspicuous place” ?. (ii) Are the designated persons able to apply instructions for resuscitation of persons suffering from electric shock ?	Yes/No Yes/No
16.	Regulation-34	Leakage on premises: State insulation resistance between conductors and earth in Mega Ohms.	----- M Ohms
17.	Regulation-35	(i) Whether a suitable linked switch, or circuit breaker, or emergency tripping device is placed near the point of commencement of supply so as to be readily accessible and capable of being easily operated to completely isolate the supply? (ii) Whether suitable linked switch or a circuit breaker to carry and break the full load current on the secondary side of a transformer? (iii) Whether every distinct circuit is protected against excess electricity by means of a suitable circuit breaker or cut-out? (iv) Whether linked switch or circuit breaker or emergency tripping device is provided near the motor or other apparatus at voltage exceeding 650V but not exceeding 33kV for controlling supply to the motor or apparatus? (v) Whether adequate precautions are taken to ensure that no live parts are so exposed as to cause danger?	Yes/No Yes/No Yes/No Yes/No Yes/No
18.	Regulation-37	(i) Whether clear space of 100 cm is provided in front of the main switchboard? (ii) Whether the space behind the switchboard exceeds 75 cm in width or is less than 20 cm? (iii) In case the clear space behind the switchboard exceeds 75 cm. State whether a passage way from either end of the switchboard to a height of 1.80 meters is	Yes/No Yes/No Yes/No

		provided.	
19.	Regulation-44	<p>(i) Whether all conductors and apparatus including live parts thereof are inaccessible?</p> <p>(ii) Whether all windings of motors or other apparatus are suitably protected?</p> <p>(iii) State in case of transformers or reactors or switches or static condensers involving the use of more than 2,000 litres of oil in one chamber, if suitable oil soak pits are provided?</p> <p>(iv) Where 9,000 litres or more of oil is used in any one oil tank, has provision, been made for draining away or removal of oil which may leak or escape from such tank(s)?</p> <p>(v) Whether trenches inside sub-station containing cables are filled with non-inflammable material or completely covered with non- inflammable slabs?</p> <p>(vi) Are conductors and apparatus so arranged that they may be made dead in sections for carrying out work thereon?</p> <p>(vii) Whether separate cable trays are provided for control/Power/AC/DC cables?</p> <p>(viii) Whether suitable fire fighting system as per the Regulation has been provided?</p> <p>(ix) Whether the baffle walls of four hours fire rating between apparatus or consumer premises, in a substation or a switching station with apparatus having more than 2000 litres of oil are installed, has been provided as required under the Regulation?</p>	<p>Yes/No</p> <p>Yes/No</p> <p>Yes/No</p> <p>Yes/No</p> <p>Yes/No</p> <p>Yes/No</p> <p>Yes/No</p> <p>Yes/No</p> <p>Yes/No</p>
20.	Regulation-45	Whether protections and interlocks have been provided? If not, give details.	Yes/No
21.	Regulation-48	<p>(i) Have the frames of every generator, stationary motor, and so far as practicable portable motor and metallic parts not intended as conductors of all transformers and any other apparatus used for regulating or controlling electricity and all electricity consuming apparatus at voltage exceeding 650V but not exceeding 33kV been earthed by two separate and distinct connections with earth ?</p> <p>(ii) Is the earth wire free from any mechanical damage ?</p> <p>(iii) Has the neutral point at the transformer and generator been earthed by two separate and distinct connections with earth?</p>	<p>Yes/No</p> <p>Yes/No</p> <p>Yes/No</p>

		(iv) Have the metal casings or metallic coverings containing or protecting any electric supply line or apparatus been properly earthed and so joined and connected across all junction boxes as to make good mechanical and electrical connections throughout their whole length? (v) Whether earthing has been properly executed and has been tested. If yes, give value of earth resistance.	Yes/No Yes/No -----Ohms
22.	Regulation-49	Is the outdoor (except pole type) sub-station efficiently protected by fencing not less than 1.8 metres in height?	Yes/No
23	Regulation-50	(i) Where platform type construction is used for pole type sub-station, has sufficient space for a man to stand on the platform been provided? (ii) Has hand-rail been provided and connected with earth (if metallic and if sub-station has not been erected on wooden supports and wooden platform)?	Yes/No Yes/No
24.	Regulation-51	Has suitable provision been made for immediate and automatic or manual discharge of every static condenser on disconnection of supply ?	Yes/No
25	Overhead Lines	(i) What is the minimum size of the conductors of overhead lines used ? State the type of conductors. (ii) Whether clearances above ground of the lowest conductor of overhead lines are as per regulation 58? State clearance. (iii) On the basis of maximum sag, Whether vertical clearances where the line of voltage exceeding 650V passes above or adjacent to any building or part of a building are as per regulation 61? State clearance. (iv) On the basis of maximum deflection due to wind pressure, whether horizontal clearances between the nearest conductor and any part of such building are as per regulation 61? State clearance. (v) Where conductors forming parts of system at different voltages are erected on the same supports, whether adequate provision has been made as per regulation 62 to guard against danger to linemen and others	Size of Conductor --- Yes/No --- metres Yes/No --- metres Yes/No --- metres Yes/No

	<p>from the lower voltage system being charged above its normal working voltage by leakage from or contact with the higher voltage system ?</p> <p>(vi) Where overhead lines cross or are in proximity to each other whether they have been suitably protected to guard against possibility of their coming in contact with each other as per regulation 69?</p> <p>(vii) Has every guard wire been properly earthed as per regulation 70 at each point at which its electrical continuity is broken?</p> <p>(viii)(a) Whether metal supports of overhead lines and metallic fittings attached thereto are permanently earthed as per regulation 72?</p> <p>(b) Has each stay-wire (except in case where an insulator has been placed in it at a height not less than 3 meters from the ground) been earthed as per regulation 72?</p> <p>(ix)(a) Whether overhead line is suitably protected with a device for rendering the line electrically harmless in case it breaks as per regulation 73?</p> <p>(b) Whether anti-climbing devices have been provided at each support as per regulation 73?</p> <p>(x) (a) Has the owner of overhead lines adopted efficient means for diverting to earth any electrical surges due to lightning in every overhead line which is so exposed as to be liable to injury from lightning as per regulation 74?</p> <p>(b) Whether earth lead from the lightning arrestors is connected to a separate earth electrode as per regulation 74?</p> <p>(xi) Whether unused overhead lines are maintained in a safe mechanical condition as per regulation 75?</p> <p>(xii) Whether statutory clearances from Authorities i.e. Forest Department/Railways/ PTCC/Defence (AHQ)/Civil Aviation have been taken as per Indian standard. If yes, enclose copies of the same.</p> <p>(xii) Any other remarks.</p>	<p>Yes/No</p> <p>Yes/No</p> <p>Yes/No</p> <p>Yes/No</p> <p>Yes/No</p> <p>Yes/No</p> <p>Yes/No</p> <p>Yes/No</p> <p>Yes/No</p> <p>Yes/No</p>
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In addition to above, following electrical equipment wise test details to be given:

S.No.	Equipment	Test Conducted	Test Results	Remarks
1.	Linked Switch with fuses (s)	i) Mechanical operation ii) Rating of Fuse iii) Contact of blades	Smooth/Trouble some -----Amps Full/Partial	
2.	Isolator (Sl. No.--- Make: Capacity:-	i) Mechanical operation ii) Remote Operation iii) Local Operation iv) Measurement of contact resistance v) Interlocking with earth switch vi) Interlocking with Circuit Breaker vii) IR Values Open condition Closed condition	Ok/Not ok Ok/Not OK Ok/Not Ok ----- micro Ohms OK/Not OK Ok/Not OK Phase to Phase and Phase-Earth	
3.	Circuit Breaker (Circuit breaker location and no.)	1. Rating of Circuit Breaker a. Type b. Voltage c. Normal Current d. Rupturing Current 2. IR Values Open condition Closed Condition 3. Contact Resistance 4. Mechanical Operation 5. Remote operation 6. Local Operation 7. Interlocking with Isolator 8. Interlocking with earth switch Circuit breaker control circuits 9. Alarm and Trip for OTI/WTI/Buchholz/PRV/etc., 10. Earth Fault Relay 11. Over Current Relay 12. Under Voltage Relay 13. other safety Alarms 14. Whether all the provisions of Regulation 35 are satisfactory?		
4.	Transformer Transformer No., Location, (Transformer Sl. No. Make, Capacity, Voltage	1. Insulation Resistance Values i) HT to LT ii) HT to Earth iii) L T to Earth 2. Break down Voltage test Oil sample I (Top)		

	Ratio,)	<ul style="list-style-type: none"> Oil Sample II (Bottom) 3. Vector Group Test 4. Polarity Tests 5. Magnetising Balance 6. Tan Delta Test 7. Oil level in conservator tank 8. Oil level in breather cup 9. OTI/WTI settings 10. OTI/WTI alarm and trip operation 11. Operation of Buchholz relay 12. Operation of PRV 13. Oil leakage 14. Interlock of door switch of dry transformer 15. Clearances <ul style="list-style-type: none"> i) Side Clearance: ii) Between two Transformers 16. Body Earth Resistance 17. Neutral Earth Resistance 18. Earth Flat size Material used <ul style="list-style-type: none"> i)Body: ii)Neutral: 		
5	Generators: Generator No., Location, (Alternator and Engine Sl. No. Make, Capacity,)	<ul style="list-style-type: none"> 1. Type of Generator 2. Interlocking with other supply sources 3. Body earth resistance 4. Neutral earth resistance 5. Earth Flat size Material used <ul style="list-style-type: none"> i)Body: ii)Neutral: 6. Generator Protection details 		
6.	Cables	<ul style="list-style-type: none"> 1. Cable schedule showing the source, destination, size, length, type of cable, cable identification no., route, with IR values of phase to phase and phase to earth shall be enclosed. 2. Cable trays 3. Cable tray earthing 4. Cables bending radius 		
7.	LT Panels	<ul style="list-style-type: none"> 1. No. of panels 2. Location of panel 	Top Entry/Bottom Entry	

		<ol style="list-style-type: none"> 3. Rating of the panel 4. Size of the main Bus bars and the distribution Bus bars of the panel 5. Whether the Bus bar size of the panel suitable to rating of the panel 6. IP Protection of panel 7. Type of cable entry 8. No. of Incomers and Bus couplers in a Panel 9. Ratings of the Circuit Breakers 10. No. of MCCBs of each rating in the panel 11. No. of spare MCCBs of each rating 12. Panel Clearance from the wall 13. Clearance between two panels i.e. adjacent panels 14. Whether all the provisions of Regulation 37 followed 15. Size of the Earth strip used for earthing of the panel 		
8.	Motors	<ol style="list-style-type: none"> 1. List of Motors with their rating, protection, overload setting, size of earth conductor used. 		
8.	Earthing	<ol style="list-style-type: none"> 1. Metal and Size of Earth Strips 2. Type of earthings 3. Location and No. of earth electrode 4. Values of Earth resistance of each earth electrode 5. Earth mat resistance 		
9.	Over Head lines and DP structure	<ol style="list-style-type: none"> 1. Size of the Poles of DP structure 2. Clearance between the phases –phase and phase to earth. 3. Ground clearance of the bare conductors 4. Check of electrical clearance along the route of over head line, 5. Check of guarding and clearance at road crossings 6. Check the footings of the poles 7. Earthing arrangements 		

CHAPTER-12

PROTECTION OF ELECTRICAL SYSTEMS

12.1 Introduction

The electrical equipment and circuits in a substation must be protected in order to limit the damages due to abnormal currents and over voltages.

All equipment installed in a power electrical system have standardized ratings for short-time withstand current and short duration power frequency voltage. The role of the protections is to ensure that these withstand limits can never be exceeded, therefore clearing the faults as fast as possible.

In addition to this first requirement a system of protection must be selective. Selectivity means that any fault must be cleared by the device of current interruption (circuit breaker or fuses) being the nearest to the fault, even if the fault is detected by other protections associated with other interruption devices.

The objective of a protection scheme is to keep the power system stable by isolating only the components that are under fault, whilst leaving as much of the network as possible still in operation.

12.2 Components of Protection System

Protection systems normally comprise of five components.

- a. **Current and voltage transformers-** to step down the high voltages and currents of the electrical power system to convenient levels for the relays to deal with.
- b. **Protective relays-** to sense the fault and initiate a trip, or disconnection command.
- c. **Circuit breakers-** to open/close the system based on relay and auto re-closer commands.
- d. **Batteries:** to provide power in case of power disconnection in the system.
- e. **Communication channels-** to allow analysis of current and voltage at remote terminals of a line and to allow remote tripping of equipment.

12.3 Types of Protection

12.3.1 High-Voltage Transmission Protection

Protection on the transmission and distribution system serves two functions viz. protection of plant and protection of the public (including employees). At a basic level, protection disconnects equipment which experiences an overload or a short to earth. Some items in substations such as transformers might require additional protection based on temperature or gas pressure, among others.

12.3.2 Generator Sets Protection

In a power plant, the protective relays are intended to prevent damage to alternators or to the transformers in case of abnormal conditions of operation, due to internal failures, as well as insulating failures or regulation malfunctions. Such failures are unusual, so the protective relays have to operate very rarely. If a protective relay fails to detect a fault, the resulting damage to the alternator or to the transformer might require costly equipment repairs or replacement, as well as income loss from the inability to produce and sell energy.

12.3.3 Overload and Back-Up for Distance (Over-current Protection)

Overload protection requires a current transformer which simply measures the current in a circuit and compares it to the predetermined value. There are two types of overload protection: instantaneous over-current (IOC) and time over-current (TOC). Instantaneous over-current requires that the current exceeds a predetermined level for the circuit breaker to operate. Time over-current protection operates based on a current vs time curve. Based on this curve, if the measured current exceeds a given level for the preset amount of time, the circuit breaker or fuse will operate.

12.3.4 Earth Fault/Ground Fault Protection

Earth fault protection also requires current transformers and senses an imbalance in a three-phase circuit. Normally the three phase currents are in balance, i.e. roughly equal in magnitude. If one or two phases become connected to earth via a low impedance path, their magnitudes will increase dramatically, as will current imbalance. If this imbalance exceeds a pre-determined value, a circuit breaker should operate. Restricted earth fault protection is a type of earth fault protection which looks for earth fault between two sets of current transformers (hence restricted to that zone).

12.3.5 Distance (Impedance Relay)

Distance protection detects both voltage and current. A fault on a circuit will generally create a sag in the voltage level. If the ratio of voltage to current measured at the relay terminals, which equates to impedance, lands within a predetermined level the circuit breaker will operate. This is useful for reasonably long lines, lines longer than 10 miles, because their operating characteristics are based on the line characteristics. This means that when a fault appears on the line the impedance setting in the relay is compared to the apparent impedance of the line from the relay terminals to the fault. If the relay setting is determined to be below the apparent impedance it is determined that the fault is within the zone of protection. When the transmission line length is too short, less than 10 miles, distance protection becomes more difficult to coordinate. In these instances the best choice of protection is current differential protection.

12.3.6 Back-up Protection

The objective of protection is to remove only the affected portion of plant and nothing else. A circuit breaker or protection relay may fail to operate. In important systems, a failure of primary protection will usually result in the operation of back-up protection. Remote back-up protection will generally remove both the affected and unaffected items of plant to clear the fault. Local back-up protection will remove the affected items of the plant to clear the fault.

12.3.7 Low-Voltage Networks Protection

The low-voltage network generally relies upon fuses or low-voltage circuit breakers to remove both overload and earth faults.

12.3.8 Cyber Security

The bulk system which is a large interconnected electrical system including transmission and control system is experiencing new cyber security threats every day. ("Electric Grid Cyber security," 2019). Most of these attacks are aiming the control systems in the grids. These control systems are connected to the internet and makes it easier for hackers to attack them. These attacks can cause damage to equipment and limit the utility professional's ability to control the system.

12.4 Protection System in Electrical Equipment

12.4.1 Transformer Protection

The considerations for a transformer protection vary with the application and importance of the power transformer. However following table summarizes the basic protection systems of transformer.

S. No.	Fault Type	Protection used
1.	Primary winding Phase-Phase fault	Differential; Overcurrent
2.	Primary winding Phase-Earth fault	Differential; Overcurrent
3.	Secondary winding Phase-Phase fault	Differential
4.	Secondary winding Phase-Earth fault	Differential; Restricted Earth Fault (REF)
5.	Interturn Fault	Differential; Buchholz
6.	Core Fault	Differential; Buchholz
7.	Oil tank Fault	Differential; Buchholz; Tank Earth
8.	Overfluxing	Overflux Relay
9.	Overheating	Thermal

12.4.2 Feeder Protection

Protection of the feeder from the fault is necessary so that the power grid continues the supply of power. The feeder injects the electrical energy from the substation to the load end. So it is essential to protect the feeder from the various types of faults. The main requirements of the feeder protection are.

- i. During the short circuit, the circuit breaker nearest to the fault should open and all other circuit breakers remain in a closed position.
- ii. If the breaker nearest to the fault fails to open then, backup protection should be provided by the adjacent circuit breaker.
- iii. The relay operating time should be small to maintain the system stability without necessary tripping of a circuit.
- iv. **Time Graded Protection-** This is a scheme in which the time setting of relays is so consecutive that in the event of a fault, the smallest possible part of the system is isolated. The applications of time graded are explained below.
- v. **Protection of Radial Feeders-** The main characteristic of a radial system is that power flow only in one direction, i.e. from the generator or the supply end to the load end. It has the drawback that continuity of supply cannot be controlled at the load end in the occurrence of a fault. In a radial system when the number of feeders is connected in series as shown in the Fig.1. It is desired that the smallest possible part of the system should be off. This is conveniently achieved by employing time graded protection. The over current system should be adjusted in such a way that the longer the relay from the generating station the lesser the time of operation.

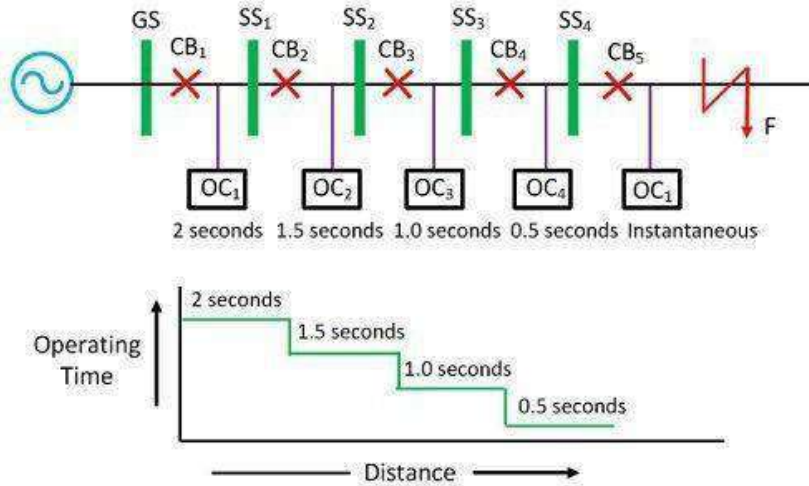


Fig. 12.1 – Time Graded Protection System for Radial Feeder

When the fault occurs on the SS4, the relay OC5 should operate first and not any other i.e. the time required to operate the relay OC4 must be less than the time required for relay OC3 and so on. This shows that the time setting required for these relays must be properly graded. The minimum interval of time which can be allowed for the two adjacent circuit breakers depends on its own clearance time, plus a small time for the safety margin.

With normal circuit breaker in use minimum discriminating time between adjacent breakers should be about 0.4 seconds. The time settings for relay OC1, OC2, OC3, OC4, and OC5 will be 0.2 seconds, 1.5 seconds, 1.5 seconds, 1.0 seconds, 0.5 seconds and instantaneous respectively. Along with the grading system, it is also essential that the time of operation for the severe fault should be less. This can be done by using time limiting fuse in parallel with the trip coils.

- i. Protection of Parallel Feeders-** The parallel connection of the supply is mainly used for the continuity of the supply and for sharing the load. When the fault occurs on the protective feeder, the protective device will select and isolate the defective feeder while the other instantly assumes the increased load.

One of the simplest methods for the protection of the relay is the time graded overload relay with inverse time characteristic at the sending end and instantaneous reverse power or directional relays at the receiving end as shown in the Fig.2 below.

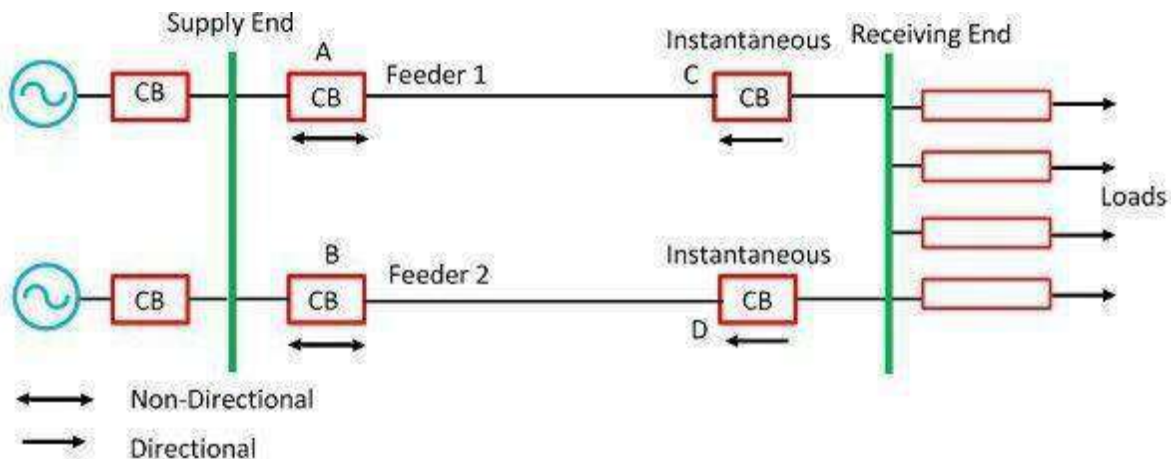


Fig. 12.2 – Protection of Parallel Feeders

When the heavy faults F occur on any one of the lines, and then the power is fed into fault from the sending end as well as from the receiving end of the line. The direction of power flow will be reversed through the relay on D, which will be open.

The excess current is then restricted to B until its overload relay operates and trips the circuit breaker, thus completely isolating the faulty feeder and supplying power through the healthy feeder. This method is only satisfactory when the fault is heavy and reverse the power at D. Hence differential protection is also added along with the overloaded protection at both the end of the line.

ii. Protection of Ring Main System- The ring main is a system of interconnection between a series of the power station by a different route. In the main ring system, the direction of power can be changed at will, particularly when the interconnection is used.

The elementary diagram of such a system is shown in the Fig.3 below where G is the generating station, and A, B, C, and D are the substations. At the generating station, the power flows only in one direction and hence no time lag overload relays is used. The time grade overload relay is placed at the end of the substation, and it will trip only when overload power flows away from the substation which they protect.

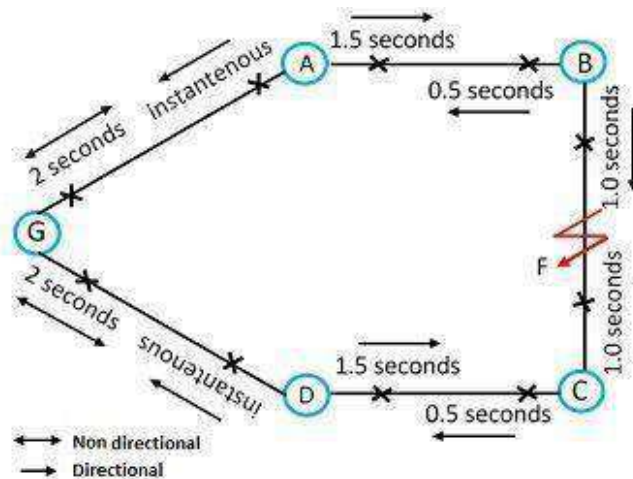


Fig. 12.3 – Protection of Ring System

Going round the ring in the direction GABCD, the relay on the farther side of each station are set with decreasing time lags. At generating station 2 seconds at station A, B, C and 1.5 seconds,

1.0 second, 0.5 second and instantaneous respectively. Similarly going round the ring in the opposite direction the relay on the outgoing sides would be set as follows.

If the fault occurs at point F, the power F is fed into the fault through two paths ABF and DCF. The relay to operate is that between substation B and fault point F and substation C and fault point F. Thus the fault on any section will cause the relay on that section to operate, and the healthy section will be operating uninterruptedly.

12.4.3 Protection of Pumps

Need for Pump Protection.

It is difficult to imagine a pumping system without providing for proper protection against various hazards.

Pumps employing 3-phase motors as prime movers are required to be protected from burning. The major causes of motor burn-outs are.

- a. Phase Failure (Single Phasing) or loss of one phase.
- b. Unbalanced supply.
- c. Dry running
- d. Overloading
- e. Overheating of windings.
- f. Under/Over Voltage.

Specialized protections like against moisture, earth leakage, bearing failure etc. may also be required for some pumps.

- a. **Phase Failure** causes burning of motors. Due to fuse failure, loose connections or loss of phase supply, one of the supply lines to the motor becomes dead. However, the motors continue to run on two phases, drawing heavy currents, and burnout.
- b. **Reverse Running** of pumps and certain machines due to wrong connections or reverse phase sequence endangers the motor and consequently the machine.
- c. **Unbalanced Supply** generates double frequency currents in the motor windings causing overheating. Unbalanced supply voltage produces heavy negative sequence currents. These are double frequency components of supply. They increase rotor resistance due to skin effect. Overheating of motor winding due to this, is unevenly distributed over the rotor. This leads to insulation breakdown.
- d. **Under Voltage** overloads the motors in continuous running and is particularly dangerous while starting. Motor draws more currents at reduced voltages, RPM, Torque and Power reduce due to under voltage.
- e. **Dry Running** is equally dangerous for submersible pumps. Motors of submersible pumps are designed for running under water. They use water as a heat-transfer medium. In case the water level goes down and the pump runs dry, the motor gets overheated and burns out. Due to such dry running the bearing temperature also increases, damaging the bearing and the surrounding portion of the pump.
- f. **Over Loading** is also one major cause of motor burning. It may occur due to phase failure condition, dry running condition or direct overloading condition of the pump. Overloading causes increase in currents, this in turn results in insulation failure.
- g. Any pump used for transfer of water should stop working if it is running empty. This may happen if the water level is lower than the inlet valve; the suction pipe is leaking and has picked up air; or the pump is started without priming (in case of pumps requiring priming) etc. In such conditions the pump should stop immediately even though continued running may not be hazardous to the pump.
- h. In majority cases, however, a bimetal (thermal) overload relay is relied upon for pump protection. When electronic phase failure relay is used for protection, it again generally is a voltage sensing relay. It is mostly preferred as it is suitable for motors of any HP rating and hence inventory or stocking is not a problem. However, these relays suffer from many disadvantages and limitations as compared to current sensing relays.

A. Protection by Thermal Overload Relay

Thermal overload relays with built-in phase failure protection offer protection only if the phase failure occurs at 100% loading of the motor. Moreover, the trip delay is over 10- 15 seconds. When the motor is partially loaded the trip time delay increases further and if the motor is loaded below 60% the overload relay will not trip on phase failure.



B. Overloading Protection

Due to the variable thermal-withstanding characteristics of different motors, overload protection for the motor must necessarily match its thermal – withstanding characteristics. In case of thermal overload, it is not possible to select a particular characteristic, since only one fixed characteristic is provided. Because of a single operating characteristic of thermal overload relay, it will fail to protect motors requiring precise and quicker overload protection (like Hermetically Sealed/Semi Sealed Compressor motors). It will also trip some motors unnecessarily much early, even though they can sustain even larger overloading conditions for longer times. By using an electronic overload relay, it is possible to match the motor's characteristics perfectly to ensure its optimum utilization.

C. Limitations of Voltage Sensing Phase Failure Relays

First, they offer protection against phase failure faults occurring from the incoming side up to sensing points only. Normally these devices are used along with the starter and hence sensing to these relays is normally taken from the outgoing terminals of the starter. From these points up to the motor terminals, a cable of variable length is used. If any fault develops along this cable length or at the motor terminals of the cable, the voltage sensing phase failure relay will not trip the starter and the motor will remain unprotected.

In case of phase failure faults, every motor generates back e.m.f. on phase failure condition. This happens even if the phase failure occurs during the running of the motor, the motor continues to run on the two remaining phases and acts as a generator rather than a motor and generates voltage which is fed back to the 3rd phase. Sometimes, this back e.m.f. is almost equivalent to the incoming supply voltage. Under such conditions, where very high e.m.f. is generated by the motors, the voltage sensing phase failure relay cannot offer any protection.

Similarly, when power factor correction capacitors are used, voltage sensing phase failure relay does not offer adequate protection. These capacitors are connected across the motor windings and are fully charged to the supply voltage. In case of phase failure, the capacitor has to discharge sufficiently to create unbalanced condition to ensure the operation of the phase failure relay, and under such conditions, delayed tripping of phase failure relays is observed.

Because of the above limitations, voltage sensing phase failure relays cannot be considered as perfect protection devices for the motor. As against this, current sensing phase failure relays have no such limitations, and they offer full proof protection during all the above conditions. Since all other switch gear items like cable, terminal strip contactor, overload relay, fuses etc. are selected according to the HP rating of the motor, it is very easy to select the proper current sensing phase failure relay.

D. Conclusions

A relay combining both current sensing and voltage sensing operating principle can satisfactorily cover the basic protection requirements, by doing away with limitations.

Microprocessor based protection relays may have such better protection level compared to solid state relays. This is because of facilities available for parameter settings as per site conditions. In addition, it may be programmable to take sensing from additional inputs like winding temperature, pressure, vibration, condition monitoring etc.

E. Under/Over Voltage Protection

Low Voltage compels electric motor to draw more current in order to deliver required power. This creates overloading condition. Moreover, power output, RPM and torque of the motor also drop considerable at low voltage (a change of 5% in supply voltage will cause about 10% change in rotor



torque, if V decreases, then T also decreases. Hence, for maintaining same torque, slip increases and speed falls). To a limited extent torque can be improved by improving power factor, by adding external resistance in rotor circuit. This could be effective during starting of AC induction motor, but is ineffective during running. Beyond the max. limit of torque, torque and speed continue to decrease as slip increases which eventually leads to zero speed i.e. “locked rotor condition”.

In case of high voltage, there is a field effect on the motor windings. Higher value of voltage will cause rupturing of insulation and leading to burnout. Dielectric strength of the insulating material reduces with temperature rise.

It is therefore essential that under/over voltage protection should have inverse time characteristics, so that there will be definite tripping at all varying voltage values. A protection relay with flat characteristics will not be able to protect motor perfectly.

F. Dry Running Protection

For protection against dry running a sensing prod is used. It is positioned inside the bore, slightly above the level of the pump. When the water levels on the bore drops lower than then the sensing prod, it is expected to trip the starter. However, this does not happen because of many problems like.

Corrosion of the prod after a certain period due to moist atmosphere leading to loss of sensitivity.

Incorrect dry-run signal due to formation of water film around the prod.

Incorrect continuity signal resulting from a humid and moist atmosphere around the prod, due to water yield from the top even if the water level is very low.

Failure of water level guard due to the absence of proper earthing on the control panel.

G. Difficulty in taking out the pump for servicing due to

- i. Loosening of the prod from the terminals or breaking of the cable.
- ii. Prod getting stuck in the lining.

Installation of a water level guard is not possible without removing the pump set completely. In short this prod fails to function as a water level guard in most installations. Hence, it is not advisable to depend upon a device which employs a prod for its dry running protection because of these limitations, normally the water level guard is by – passed immediately after commissioning of the pump and the pump is virtually denied dry running protection.

It is possible to offer protection against dry running by sensing the motor current which changes during dry running conditions or by sensing the motor current which changes during dry running conditions or by sensing the RPM of the motor and the water pressure which also change during dry running conditions. If suitable devices are used to sense the motor current or the motor RPM and water pressure, then it is possible to provide reliable protection against dry running. Sensing the water level in the bore-well is also possible with capacitance based water level guards or an ultrasonic level detector.

H. Winding Over Temperature

It is a common practice to sense the winding temperature by PTC type thermistors which are embedded in the windings during motor manufacturing or re-winding process. The output leads of PTCs are connected to an electronic switching device. The PTC sensors are available for different temperature ratings from 60 degree Centigrade to 180 degree Centigrade.

12.4.4 Motor Protection systemAC Motor Protection

There is a wide range of AC motors since they can be used in numerous applications. AC motors need to be protected but protection selection usually does not depend on the motor and load type. This selection is based on the fundamental AC motor operation processes. There are crucial differences between the protection of induction motors and synchronous motors. Motor operation characteristics have to be particularly considered when applying selected protection. This approach is more important for the motors than for any other power system element. For example, the starting and stalling currents/times have to be known and taken into account when using overload protection. Also the thermal withstand of the AC motor has to be precisely defined under balanced and unbalanced loading conditions. The conditions for which AC motor protection is needed can be separated into two main groups imposed external conditions and internal short circuits. Table 1 gives information of most likely issues that call for AC motor protection.

Table 1 – Typical Causes of Motor FaultsModern Relay Motor Protection Technology

External failures	Internal failures
Reverse phase sequence	Bearing faults
Under-voltages	Winding failures
Single phasing	Overloads
Unbalanced supplies	

12.4.4.1 Modern Relay Motor Protection Technology

Modern numerical motor relay protection technology must be sufficient to meet protection requirements of any one of the vast range of motor designs. Many motors designs do not tolerate overloads. A motor protection relay providing sufficient protection will have the following set of characteristics.

Induction and Synchronous Motors

- i. extended start relay protection
- ii. loss-of-load relay protection
- iii. number of starts limitation
- iv. stalling relay protection
- v. short circuit relay protection
- vi. thermal relay protection
- vii. earth fault relay protection
- viii. negative sequence current detection
- ix. winding RTD measurement/trip
- x. under-voltage relay protection
- xi. auxiliary supply supervision

12.4.4.2 Synchronous Motors in Particular

- i. loss of supply relay protection
- ii. out-of-step relay protection

Also, protection relays may provide options such as circuit breaker condition monitoring assessment that can be used for maintenance needs. Manufacturers may also provide protection relays that use smaller number of functions in situations when less sophisticated relay protection is warranted (e.g. low rating asynchronous motors). The following paragraphs comment on possible motor fault types.

12.4.4.3 Thermal (Overload) Relay Protection

The majority of winding faults are either indirectly or directly triggered by overloading (prolonged or cyclic). Also winding faults can be caused by operation on unbalanced supply voltage, or single



phasing. These effects cause excessive heating which deteriorates winding insulation and effectively creates electrical faults. Universally adopted rule is that insulation life is halved for each 10°C rise in temperature above the rated value. This rule is affected by the length of time spent at the higher temperature. As electric motors have a great heat storage capacity, it means that occasional short duration overloads may not adversely impact the motor. Nevertheless, prolonged overloads of only several percent may end in premature ageing and insulation fault. Next, the motor thermal withstand capacity is impacted by winding heating prior to a fault. Hence, it is crucial that the protection relay features consider extremes of zero and full-load pre-fault. These are known as the 'Cold' and 'Hot' conditions, respectively. Different motor designs, various usages, variety of different abnormal working conditions and resulting fault modes result in a complex thermal formula. Therefore, it is not possible to create universal mathematical model that is precise. Nevertheless, it is possible to make an approximate mathematical model. This model assumes that the motor is a homogeneous machine, producing and dissipating heat at a rate proportional to temperature rise. This rule known as the motor 'thermal replica' is used for overload relay protection.

12.4.4.4 Start/Stall Motor Protection

Once a motor starts, it takes a current greater than full load rating current. This lasts throughout the period that the motor needs to run-up to speed. Even though motor starting current decays as motor speeds up, in protection practice it is normal to assume that the motor current stays constant throughout the starting period. The starting current varies depending on the motor design and starting method. For direct-on-line (DOL) started motors, the nominal starting current can be 4- 8 times of full-load current. Nevertheless, when a star-delta starter is used, the line current will be only $1/\sqrt{3}$ of the DOL starting current. In the case motor stalls whilst running, or fails to start, due to great load, the motor will take a current equal to its locked rotor current. Hence, it is not possible to recognize stall condition and a healthy start solely on the basis of the taken current. Discrimination between the two conditions has to be made based on the duration of the taken current. For motors where the starting time is lower than the motor safe stall time, relay protection can be easily made. Nevertheless, in situations, where motors are used to power high inertia loads, the stall withstand time can be lower than the starting time. In these situations, extra methods have to be given to allow discrimination between the two conditions.

12.4.4.5 Prolonged Start Time/Locked Rotor Protection

A motor may fail to speed up for a number of different reasons.

- i. loss of a supply phase
- ii. excessive load torque
- iii. insufficient supply voltage
- iv. mechanical issues

A huge current will be taken from the supply, and create high temperatures within the motor. This situation gets even worse since the motor is not rotating, so it cannot be cooled down due to rotation. Winding faults can quickly happen— either to the stator or rotor windings. This depends on the motor thermal limitations (In this respect, motors are differentiated as stator or rotor limited). The protection method changes depending on whether the starting time is lower than or higher than the safe stall time. In both situations, starting may be detected by motor feeder switch closure (contactor or circuit breaker). Optionally it can be detected if current rises above a starting current threshold value—commonly 200% of motor nominal current. Sometimes, both conditions can be detected only if they happen within a narrow time aperture. Additional conditions may exist for certain motor types placed in hazardous areas. Relay protection has to take these into account. Occasionally, a permissive interlock for machine pressurization may be needed, and this can be conveniently accomplished by applying relay digital inputs and the built-in logic capabilities.

Case 1- Start Time Lower than Safe Stall Time

Protection is accomplished by application of a definite time overcurrent option. Current setting is greater than full load current but is lower than the motor starting current. Relay time setting should be a slightly longer than the start time, but lower than the allowed motor safe starting time.

Case 2- Start Time Greater or Equal to Safe Stall Time

In this situation, a definite time overcurrent option is not sufficient, since the needed delay time is greater than the motor maximum allowed starting time. Additional rotor movement detection, indicating a safe start, is needed. A speed-sensing switch typically gives this function. Successful start detection is used to choose the relay timer that is used for the safe run-up time of the motor. This time can be greater than the safe stall time due to decrease in current taken by the motor during the start. Also the rotor fans start to enhance machine cooling since motor accelerates. If a start is detected by the protection relay through monitoring current and/or start device closure, but the speed switch does not operate, the protection relay element uses the safe stall time setting to trip the motor before damage happens. An instantaneous overcurrent protection relay device gives protection. In many electrical systems, transient voltage loss (normally up to 2 seconds) does not lead to designated motor tripping. These motors are allowed to re-accelerate upon supply restoration. During re-acceleration, which may take several seconds, they take a current which is similar to the starting current. Hence, it is above the current threshold of the stall relay element.

The stall protection should function and defeat the object of the re-acceleration scheme. Therefore, motor protection relay will sense the presence of a voltage dip and recovery, and suppress stall protection for a defined time. Also, under-voltage protection device can be applied to sense the presence of the voltage dip and suppress stall protection for a defined time. Therefore, relay protection against stalled machines in case of an unsuccessful reacceleration is achieved. The time delay adjustment depends on the used re-acceleration arrangement and the features of particular motors.

12.4.4.6 Motor Short-Circuit Protection

Motor short-circuit relay protection is usually supplied to cater for significant stator winding failures and terminal flashovers. Failures between phases rarely happen due to great amount of insulation between phase windings. Since the stator windings are totally enclosed in earthed metal the failure would soon involve ground, which would then trip the instantaneous earth fault protection. A single definite time overcurrent relay protection device is all that is needed for this application, programmed to about 125% of motor starting current. The time delay is needed to prevent spurious tripping due to CT spill currents. Time delay is usually around 100ms. In the case motor is supplied from a fused contactor, co-ordination with the fuse is needed. This coordination typically involves application of a long time delay. Since relay protection objective is to provide quick fault clearance to minimize fault damage, the protection is worthless in these situations. Therefore, it is only put up on motors that are fed via circuit breakers. Differential (unit) relay protection may be provided on larger HV motors fed via circuit breakers to protect against line-line and line-ground faults. The differential protection can be set sensitive allowing early fault detection, so that motor damage can be minimized. The normal definite time overcurrent protection is not sufficiently sensitive. Also sensitive ground fault protection may not be installed. The end user may avoid the detailed computations that are needed to obtain capacitance current. This current is needed to set sensitive non-directional ground fault overcurrent protection. Also there may be no provision for a VT which would allow installation of directional sensitive ground fault protection. Nevertheless, non-directional ground fault overcurrent protection will usually be cheaper in situations where appropriate sensitivity can be provided.



12.4.4.7 Motor Ground Fault Protection

One of the most frequent motor failures is a stator winding fault. Regardless of the initial fault type (phase-phase, etc.) or the fault cause (cyclic overheating, etc.), surrounding metallic frame and casing will help that it quickly turns into a fault involving ground. Hence, provision of ground fault protection is very important. The type and sensitivity of used protection depends on the system grounding. However, it is common to provide instantaneous and time-delayed relay components to cater for major and slowly developing failures.

i. Solidly-Grounded System

Solidly-grounded arrangements are dominant in LV systems mainly due to personnel safety. Two ground fault protection types are frequently used—depending on the needed sensitivity. Conventional ground fault protection using the residual CT connection can be applied for systems where sensitivity higher than 20% of motor continuous rated current is acceptable. This arrangement is shown in Figure 5. A lower limit is imposed on the setting by possible load unbalance and/or system capacitive currents.

ii. Resistance-Grounded Electrical Systems

These are typically encountered on HV electrical systems, where the intention is to minimize damage caused by ground faults. This is done by limiting the ground-fault current that can flow. Resistance grounding can be achieved in two ways.

iii. Low Resistance Grounding

In this arrangement, the value of resistance is selected to limit the short circuit current to a few hundred amps—values of 200A-400A being common. With CT's line residual connection, the minimum achievable sensitivity is about 10% of CT rated primary current. This is due to the possibility of CT saturation during starting. For a core balance CT, the sensitivity that is feasible by using a simple non-directional ground fault relay protection element is limited to three times the steady-state feeder charging current. The setting should not be higher than about 30% of the minimum expected ground fault current. Apart from this, settings and time delay considerations are same as for solidly grounded systems.

iv. High Resistance Grounding

In particular HV electrical systems, high resistance grounding is applied to limit the ground fault current to several amps. In this situation, the electrical system capacitive charging current will stop applied sensitive ground fault protection, since the charging current amplitude will be comparable with the ground fault current. The solution is to apply a sensitive directional ground fault protection relay. A core balance CT is applied together with a VT measuring the system residual voltage, with a protection relay characteristic angle setting of $+45^\circ$. The VT has to be appropriate for the protection relay and hence the protection relay manufacturer should be consulted over appropriate types. Some protection relays need VT that is able to carry residual flux and this eliminates application of a 3-limb, 3-phase VT. Single phase capacitive charging current setting of 125% is possible using this approach. Applied time delay is not crucial but has to be sufficiently fast to quickly disconnect equipment in the case of a second ground fault that can happen right after the first. Minimal damage is caused by the first fault. However, the second effectively takes out the current limiting resistance from the fault path causing very high fault currents. Optional approach using residual voltage detection is also feasible.

v. Insulated Ground System

Ground fault detection causes problems on insulated ground systems since no ground fault current flows in the case of single ground fault. Nevertheless, detection is still important since over-voltages

appear on healthy phases and it is vital to locate and clear the fault before a fault happens. Two techniques are possible.

- i. Detection of the resulting unbalance in system charging currents
- ii. Residual overvoltage.

12.4.4.8 System Charging Current Unbalance

Sensitive ground fault protection using a core-balance CT is needed for this arrangement. The principle is the same as already explained, except that the voltage is phase shifted by $+90^\circ$ instead of -90° . Figure 8 presents the current distribution in an insulated system subjected to a C phase to ground fault while the Figure 9 presents relay vector diagram. The residual current sensed by the protection relay is the sum of the charging currents going through the healthy part of the system plus the healthy phase charging currents on the faulted feeder. A protection relay setting of 30% of this value can be used to give protection without the risk of a trip due to healthy system capacitive charging currents. Since there is no ground fault current, it is possible to set the protection relay at site after intentionally applying ground faults at different parts of the power system and measuring the resulting residual currents. If protection relay can be adjusted to a value between protected feeder charging current and the charging current for the rest of the system, the directional functionality is not needed.

12.4.4.9 Residual Voltage Technique

Ground to earth fault causes voltage rise between system neutral and the ground, and it can be detected by a protection relay measuring the residual system voltage. (Residual system voltage equals zero for a perfectly balanced, healthy system). Therefore CTs are not needed and this arrangement may be practical where provision of an extensive number of core-balance CTs is impossible or hard. This mainly happens due to physical constraints or limited budget. Selected VTs have to be suitable for the duty, therefore 3-limb; 3-phase VTs are not desirable. Protection relay typically has alarm and trip settings, each with adjustable time delays. Protection relay voltage setting can be computed using system grounding and impedances.

12.4.4.10 Petersen Coil Grounded Electrical System

HV power system grounding using a reactor equal to the system shunt capacitance is known as Petersen Coil (or resonant coil) grounding. If this grounding method is used, a single ground fault results in zero ground fault current (for perfect balance between the grounding inductance and power system shunt capacitance). Therefore, the system can operate under these conditions for a substantial time until the fault is located and fixed.

12.4.4.11 Negative Phase Sequence Relay Protection

Negative phase sequence current is generated from any unbalanced voltage condition. These situations include unbalanced loading, loss of a single line, or singleline faults. Single line faults are typically detected by ground-fault protection. Nevertheless, ground fault protection may not operate which depends on the fault location in a motor winding. The real value of the negative sequence current depends on the degree of unbalance in the supply voltage. It also depends on the ratio of the motor negative to the positive sequence impedance. The degree of unbalance depends on many components, but the negative sequence impedance is more easily determined.

12.4.4.12 Rotor Winding Faults

In the case of wound rotor electrical motors, certain degree of protection against faults in the rotor winding can be provided by an instantaneous stator current overcurrent relay element. As the starting



current is typically limited by resistance to a maximum of twice full load, the instantaneous element can safely be set to about three times full load. In that case a slight time delay of approximately 30 milliseconds should be used. It should be clear that faults happening in the rotor winding would not be discovered by any differential protection applied to the stator.

12.4.4.13 RTD Temperature Detection

RTDs are applied to assess temperatures of motor windings or shaft bearings. Temperature rise may refer to motor overloading, or the start of a fault in the affected part. A motor protection relay will hence have the capability of taking a number of RTD inputs and internal logic to start an alarm and/or trip when the temperature surpasses the appropriate set point. Sometimes, HV electric motors are supplied via a unit transformer, and in these situations, some of the electric motor protection relay RTD inputs may be assigned to the transformer winding temperature RTDs. In those cases they provide over transformer temperature protection without the use of a separate protection relay.

12.4.4.14 Bearing Failures

Two types of bearings have to be analyzed. the antifriction bearing (ball or roller), used typically on small motors (up to around 350kW), and the sleeve bearing, used mainly on large electric motors. The failure of ball or roller bearings typically happens very quickly, causing the electric motor to come to a standstill as parts of the damaged roller get entangled with the others. Therefore there is small chance that any protection relay functioning from the input current can discover bearing failures of this type before the bearing is totally destroyed. Hence, protection is limited to quickly disconnecting the stalled motor to avoid further damage. Failure of a sleeve bearing can be discovered by means of a rise in bearing temperature. The normal thermal overload protection relays cannot give adequate protection to the bearing itself but will function to protect the electric motor from excessive damage. Application of RTD temperature detection can give adequate protection since it would allow investigation into the cause of the bearing running hot prior to complete collapse.

12.4.4.15 Under Voltage Protection

Electric motors may stall when exposed to sustained under-voltage conditions. Transient under-voltages will typically allow a motor to recover when the voltage is fixed, unless the power supply is weak. Electric motors fed by contactors have inherent under-voltage protection, unless a latched contactor is applied. Where a particular under-voltage trip is needed, a definite time under-voltage element is applied. If two elements are given, alarm and trip settings can be applied. An interlock with the motor starter is needed to block relay function when the starting element is open, Otherwise a start will never be allowed. The voltage and time delay settings depend on the particular system. They must allow for all voltage dips likely to happen on the system during transient faults, motor starts, etc. to avoid spurious trips. Since motor start can lead to voltage depression to 80% of nominal, the voltage setting is likely to be below this figure. Re-acceleration is typically possible for voltage dips lasting between 0.5-2 seconds. However, this depends on electrical system, motor and drive characteristics, and hence the time delay will be set bearing these factors in mind.

12.4.4.16 Loss-of-Load Protection

Loss-of-load protection has a number of possible features. It can be applied to protect a pump against becoming unprimed, or to stop a motor in case of a failure in a mechanical transmission (e.g. conveyor belt). Also it can be applied with synchronous motors to protect against loss-of-supply conditions. Implementation of the function is by a low forward power relay element, interlocked with the motor starting element to prevent operation when the motor is tripped and therefore preventing a motor start. When starting against a very low load (e.g. a compressor), the protection function may also

need to be suppressed for the duration of the start, to prevent mal-operation. The protection setting will be affected by the function to be performed by the protection relay. A time delay may be needed after pickup of the protection element to prevent operation during system transients. This is particularly important for synchronous motor loss-of supply protection.

12.4.4.17 Extra Protection for Synchronous Motors

The differences in construction and operational features of synchronous motors mean that extra protection is needed for these motor types. This extra protection is described in the following sections.

12.4.4.18 Out-of-Step Protection

A synchronous electric motor may slow down and lose synchronism (fall out-of-step) if a mechanical overload exceeding the peak motor torque happens. Other conditions that may cause this situation are a fall in the applied voltage to stator or field windings. Such a fall may not need to be extended. Voltage dip of a few seconds could be sufficient. An out of step condition causes the electric motor to take excessive current and create a pulsating torque. Even if the cause is promptly eliminated, the electric motor will likely not recover synchronism and will finally stall. Therefore, it must be disconnected from the supply. The current drawn during an out-of-step condition is at a very low power factor. Therefore a protection relay element that reacts to low power factor can be applied to give protection. The element must be suppressed during start, when a similar low power factor condition happens. This can conveniently be accomplished by use of a definite time delay, set to a value slightly higher of the motor start time. The power factor setting will change depending on the motor rated power factor. Commonly, it would be 0.1 less than the motor rated power factor i.e. for a motor rated at 0.85 power factor, the setting would be 0.75.

12.4.4.19 Protection against Sudden Supply Restoration

If the supply to a synchronous motor is cut off, it is vital that the electric motor breaker is tripped as quickly as possible. This is even more important in the case there is any chance of the supply being automatically fixed. This is essential in order to prevent the supply being restored out of phase with the motor generated voltage. Two methods are typically used to discover this condition, in order to cover different motor operating modes.

12.4.4.20 Under Frequency Protection

The under frequency protection relay element will function in the case of the supply failing when the motor is on load, which causes the motor to quickly slow down. Generally, two elements are given, for alarm and trip indications. The under-frequency setting value has to consider the power system features. In some power systems, prolonged periods of operation at frequencies substantially below normal happen and they should not result in a motor trip. The minimum safe operating frequency of the motor under load conditions must hence be determined, along with minimum system frequency.

12.4.4.21 Low Forward Power Protection

This protection can be used in conjunction with a time delay to discover a loss-of supply condition when the electric motor may share a bus-bar with other loads. The motor may try to supply the other loads with power from the stored kinetic energy of rotation. A low-forward-power protection relay can discover this condition. A time delay will be needed to prevent service during system transients leading to momentary reverse power flow in the motor.



12.4.5 Domestic Wiring Protection

A typical domestic wiring should be capable of fulfilling all performance and safety regulations and therefore must be planned and approved before its implementation.

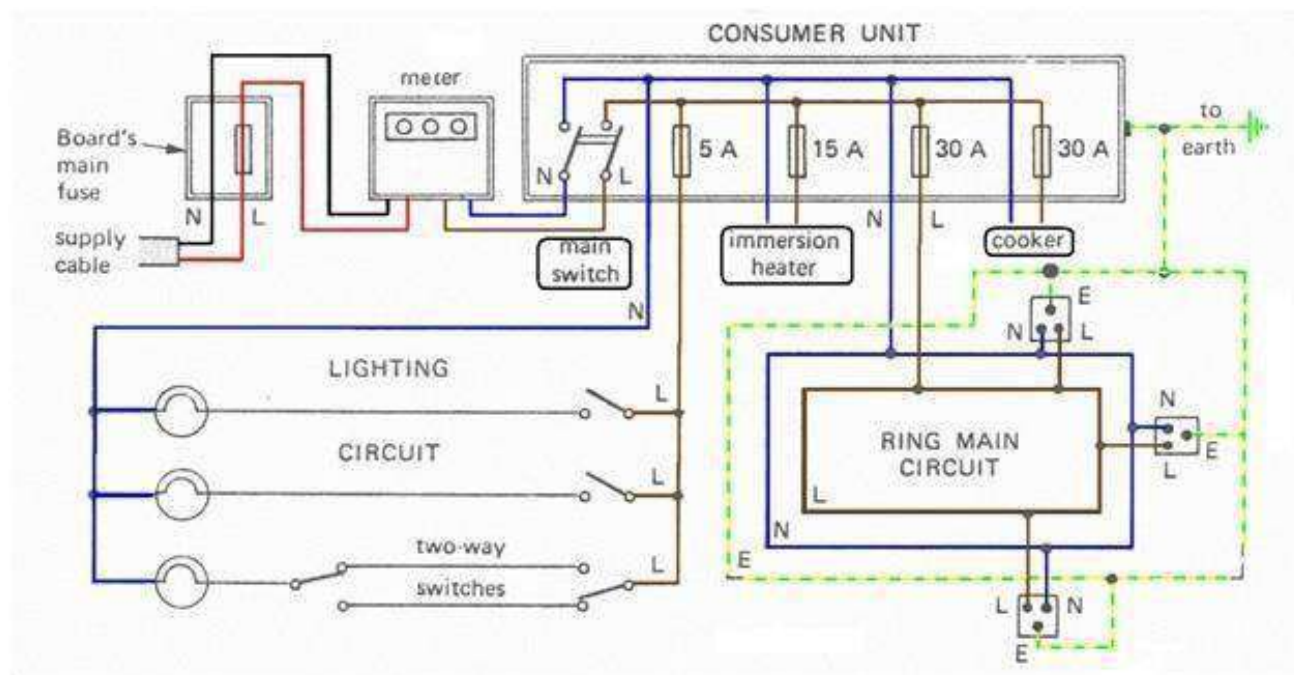


Fig 12.4 – Wiring Scheme of a Household

Following components are necessary for an efficient electrical wiring system

- Live and neutral connections from energy meter to the main consumer unit. A split consumer unit is also installed for more redundancy and user friendly operations.
- Proper circuit breakers are part and parcel of a successful electrical supply system. Ring type circuits are installed for feeding the main sockets of consumer units.
- Lighting circuits are considered an important part of wiring system and they are radial in nature (most of the time). Miniature circuit breakers of proper rating (usually 6 amperes) are also installed for the protection purpose.
- Incomer to consumer unit grounding connections.
- Heavy duty electrical wiring backed by dedicated breakers (radial) for high power equipment like HVAC, cookers, heavy duty geysers etc.
- Two way switches as desired.
- Outdoor connections (outside the premises) are also used for lighting purposes. Rating of the breaker governing these circuits should be tightly close to the maximum load to avoid power theft (in case).
- Very high power equipment like storage heating equipment should be powered directly by the consumer unit.

12.4.5.1 Consumer Unit/Fuse Box

A consumer unit comprises of an isolator, dedicated miniature circuit breakers (separate for every major circuit), grounding terminals and well defined circuit paths.

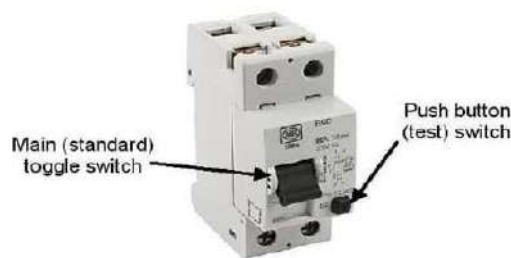
12.4.5.2 Grounding Connections

Proper grounding connection is a vital part of every electrical installation. Basic purpose of earthing is to ensure that fault current flows through the system immediately after the fault has occurred resultantly tripping the main circuit. This prevents the floating voltage condition and thus fatal/non-fatal accidents.

A functional earthing system is a must have for every domestic/industrial wiring system. In case the power company does not provide it, it should be arranged locally for the greater good.

12.4.5.3 Electric Shock Prevention/Minimization

Recent wiring regulations emphasize on RCBOs or RCDs (residual current devices) in an electrical wiring circuit.



Residual Current Device

These devices are crucial for electric shock prevention but relying on them for personnel safety is highly not recommended. Especially sockets and vulnerable switches must be protected by residual current devices. Separate RCBOs or RCDs are recommended for every ring or radial circuit.

12.4.5.4 Sockets

Recommended number of sockets is crucial for residents' satisfaction and safety. Number and location of sockets in a wiring system should be precisely taken care of. Less and widely spread sockets encourage the use of circuit extensions which pose a safety risk.

12.4.5.5 Fuses/MCBs

Fuses and MCBs serve the same purpose i.e. disconnection of fault from the circuit. Fuses are recommended for lighting circuits as they are less sensitive to false alarms and bulb failure or other extremely transient faults do not cause trouble or unnecessary nuisance. Some MCBs are lesser sensitive and they can be used for lighting purpose.

Fuses and miniature circuit breakers are backbone of domestic electrical protection. Failure to design and implement an effective fuse/breaker sequence always results in catastrophic scenarios.

12.4.5.6 Voltage Fluctuation Protection

Voltage provided by a power company is prone to fluctuate no matter how well designed a system is. There are documented incidents where domestic electric wiring was exposed to high voltages. This is a very undesirable consequence and should be countered with the installation of voltage sensors.

Voltage fluctuation control system identifies voltage abnormalities and trips the circuit. Over voltage exposure can cause the weakening or failure of cables' insulation. Voltages below the rated values can also damage the equipment and can render the protection devices useless. A well designed voltage controller is always recommended for domestic electric wiring.

CHAPTER-13

ELECTRICAL FIRE SAFETY

13.1 Introduction

Electrical fires are one of the causes of fires and can lead to serious damage to life and property. Precautions should be taken during construction of a building and during its usage to prevent electrical fire.

13.2 Major Causes

Short Circuit – Because of touching of two conductors. Can result in very high currents, overheating, arcing, smoke, fire & further short-circuiting. Protection includes insulation of conductors, fuses and circuit breakers & substantial enclosures.

A. Loose Connections – It generates heat as the current flows. This can result in insulation failure & arcing etc. Protective measures include workmanship standards, inspection, training & infrared inspection of systems.

B. Overload – Can lead to insulation failure, shorting, arcing & fire. Prevention by designing with consideration of worst-case of loads, thermal environment, nearby conductors and insulation type.

Arcing – Localized extreme heating of conductors resulting in plasma (arc) and incandescent metal particles (sparks). Prevented by keeping conductors apart with insulation or spacing.

C. Early Signs –

- i. Flickering or dimming lights.
- ii. Switches or outlets that is hot to touch and or emit an acrid odor.
- iii. Discolored cords, outlets and switch plates.
- iv. Repeatedly blown fuses and tripped circuit breakers.

13.3 Class of Fire

Material on Fire	Indian standard	UK/ Europe	US	Australian
Solid combustible materials of organic nature	Class A	Class A	Class A	Class A
Flammable liquids	Class B	Class B	Class B	Class B
Flammable gases under pressure	Class C	Class C	Class B	Class C
Combustible metals	Class D	Class D	Class D	Class D
Cooking media (Kitchen Fire)	Class F	Class F	Class K	Class F
Energised electrical conductors/ equipment	No class	No class	Class C	Class E

Many wrong and misleading information on “Classification of Fires and Fire Extinguishers” are available online which are not as per Indian Standards as details given in table above. This leads to confusion over correct selection of fire extinguishers based on material on fire (fuel), since all available fire extinguishers in India are being manufactured as per Indian Standards. If wrong type of fire extinguisher is used for extinguishing the fire, it might make matters worse.



13.3.1 Fire Triangle

The fire requires three elements to ignite: heat, fuel, and an oxidizing agent (usually oxygen).

By eliminating any one of the elements, fire can be extinguished.

CLASSIFICATION OF FIRE ACCORDING TO TYPE OF FUEL

Ref: para 3.1 of IS 15683: 2018 & para 9 of IS 2190:2010

Fires are classified according to the type of fuel that is burning, which is as under:

Class of Fire	Symbol	Definition
Class A		Fires involving solid combustible materials of organic nature such as wood, paper, rubber, plastics, etc. where the cooling effect of water is essential to extinguish the fire.
Class B		Fires involving flammable liquids or liquefiable solids or the like where a blanketing effect is essential to extinguish the fire.
Class C		Fires involving flammable gases under pressure including liquefied gases, where it is necessary to inhibit the burning gas at fast rate with an inert gas, powder or vaporizing liquid for extinguishment.
Class D		Fires involving combustible metals such as magnesium, aluminium, zinc, sodium, potassium etc., when the burning metals are reactive to water containing agents and in certain cases carbon dioxide, halogenated hydrocarbons and ordinary dry powders. These fires require special media and techniques to extinguish.
Class F		Fires involving cooking media (vegetable or animal oils and fats) in cooking appliances and may be called kitchen fire.
No class		Where fire involves energized electrical equipment.

13.3.2 ELECTRICAL FIRES

Ref: para 9 of IS 2190 : 2010 and para 10.2.3 of IS 15683: 2018

In Indian Standards, Electrical fires (fires involving energised electrical conductors/ equipment) are not given specific class, as they can fall into any of the classifications as per the **material on fire (fuel)**. Electricity may initiate fire but it is not the electricity that is burning but surrounding material that has been set alight. For example, if a computer will burn due to a short circuit, then the computer is on fire and not electricity. In de-energised condition, this is then class A fire.

Therefore, it is important to decide selection and use of extinguisher on live electrical installations. The extinguisher that have passed **electrical conductivity test** should only be used on fires involving energised electrical conductors/equipment and fire extinguishers shall have this symbol marked on it.



13.3.3 Dealing with Electrical Fires

Fire extinguishers with **Class C** ratings shall be required **where energized electrical equipment** can be encountered. This requirement includes situations where fire either directly involves or surrounds electrical equipment. Since the fire itself is a Class A or Class B hazard, the fire extinguishers shall be sized and located on the basis of the anticipated Class A or Class B hazard. (Ref: para 5.4.3 of IS 2190 : 2010)

Where energized electrical equipment is involved in a fire, **non-conductivity of the extinguishing media** is of utmost importance, and only extinguishers **expelling dry powder, carbon dioxide (without metal horn) or clean agent** should be used. Once the electrical equipment is de-energized, extinguishers suitable for the class of the fire risk involved can be used safely. (Ref: para 10.2 of IS 2190 : 2010).

Where **cleanliness and contamination of sensitive electrical equipment** are of importance or where the sensitivity of the control instruments or electronic equipment and systems are likely to be affected, only **Carbon Di-oxide or Clean Agent** type extinguishers should be used. (Ref: para 10.3 of IS 2190 : 2010).

TYPES OF FIRE EXTINGUISHERS (PORTABLE)

Ref: para 4 of IS 15683 : 2018

Portable fire extinguishers are not expected to deal with large fires but, these are very valuable if used promptly and efficiently in the early stages of fire. Extinguishers are labelled with either letter-shaped or pictorial symbols that indicate what types of fires the extinguisher is designed to fight.

Fire Extinguishers may be classified by the type of extinguishing medium which they contain. At present, the main types of extinguishers are:

13.3.4 Water or APW (Air-Pressurized Water) based Fire Extinguishers

- Extinguishing Media - Water and Water Mist
- Suitable for - CLASS A (Wood, paper, cloth etc.) fires
- APWs extinguish fire by taking away the **“heat”** element of the Fire Triangle.
- Water extinguishers can be very dangerous in the wrong type of situation. Only fight the fire if you're certain as it contains ordinary combustible materials only.



13.3.5 Foam based Fire Extinguishers

- Extinguishing Media - foam (mixed with water)
- Suitable for - class A and class B (flammable liquids)
- They spray a type of foam (mixed with water) that expands when it hits the air and blankets the fire.
- This blanket prevents the vapours from rising off the liquid to feed the fire, thus starving it of **fuel**. Also, because the foam is mixed with water, it has a **cooling** effect as well.



13.3.6 Dry Chemical Powder (DCP) Based Fire Extinguishers

- Extinguishing Media - Dry Chemical Powder
- Suitable for - suitable for a combination of Class A, B, C fires
- The greatest portion of this powder is composed of **Mono Ammonium Phosphate (MAP)** and the extinguishers are pressurized with nitrogen.
- Dry chemical extinguishers put out fire by coating the fuel with a thin layer of dust. This separates the **fuel** from the oxygen in the air.

- i. The powder also works to interrupt the chemical reaction of fire. These extinguishers are very effective at putting out fire.
- ii. DCP fire extinguishers are available in variety of types and are suitable for a combination of Class A, B, C fires.
- iii. It is extremely important to identify which types of dry chemical extinguishers are available at the site.
- iv. DCP (Dry Chemical Powder) extinguishers have an **advantage over CO₂** extinguishers since that leave a non-flammable substance on the extinguished material, **reducing the likelihood of re-ignition**.
- v. **Note:** Dry powder extinguishers, when used in confined areas may reduce visibility for a few minute, which may temporarily jeopardize escape, rescue or other emergency action. (Ref: 10.5 of IS 2190:2010)



13.3.7 Carbon Dioxide (CO₂) Based Fire Extinguishers

- i. *Extinguishing Media* - Carbon Dioxide (CO₂), a non-flammable gas
- ii. *Suitable for* - suitable for Class B and C fires
- iii. Carbon dioxide is a non-flammable gas that takes away the oxygen element of the fire triangle. Without oxygen, there is no fire.
- iv. CO₂ is very cold as it comes out of the extinguisher, so it cools the fuel as well.
- v. The pressure in this extinguisher is so great that it is not uncommon for bits of dry ice to shoot out the nozzle/horn.
- vi. A CO₂ may be ineffective in extinguishing a Class A fire because it may not be able to displace enough oxygen to successfully put the fire out, causing it to re-ignite.
- vii. CO₂ extinguishers have an advantage over DCP since they don't leave a harmful residue, therefore it is a good choice for an electrical fire on sensitive electrical equipment, control instruments or electronic equipment where cleanliness and contamination of are of importance.



13.3.8 Clean Agents Based Fire Extinguishers

Ref: para 3.13 of IS 15683 : 2018

- i. Clean agents are electrically non-conductive which are in gaseous or vaporizing liquid form that do not leave a residue upon evaporation and are not toxic to level of concentration at which it extinguishes the fire.
- ii. Clean agents are halon substitutes such as HFC, HCFC, HBFC, their blends and fluoro- ketone, etc.
- iii. Name of clean agent shall be marked on the label of the extinguishers.



13.3.9 Wet Chemical extinguisher

- i. Wet chemical fire extinguisher is specially designed for **CLASS F FIRES**, those involving cooking media such as animal and vegetable fats or oils.
- ii. These extinguishers contain a solution composed of **Potassium** that effectively launches a two-pronged assault on fires:
 - i. First, the liquid mist, it sprays acts to **cool** the fire.
 - ii. Second, due to the chemical reaction of the solution with the cooking medium, a thick soap-like substance forms, sealing the surface of the liquid to prevent re-ignition.



13.3.10 Special Fire Extinguishers

Fire Suppression Balls

Ref: Rly. Bd. L. No. 2001/Elect (G)/113/4/Safety dated 07.01.2021

- i. These are “**Self activating Fire Extinguishing balls**” and they contain MAP (Mono Ammonium Phosphate) in range of 90 to 95%.
- ii. These fire extinguishing balls are a good low cost source to control spread of fire.
- iii. Whenever these balls come in contact with fire, they burst automatically means even if the place of probable fire is unmanned, after start of fire, these balls will burst without any manual intervention.
- iv. These fire balls may be used in electrical sub-stations, workshops, in coal or metal mines, oil mines etc.



Automatic Cylinder-less Fire Detection & Suppression Tube System

- i. This system consists of a heat sensitive tube made of special plastic which is closed by a stainless steel fitting on each end.
- ii. The tube has both storage and detection function which means that the extinguishing agent is stored directly in the tube and no additional storage device such as cylinder is needed.
- iii. The system is suitable for protection of small enclosures with greater risk of fire such as electrical panels, server racks, telecommunication cabinets etc.
- iv. It operates automatically without any power supply by detecting higher temperatures. When the temperature in the protected enclosure rises to a critical threshold (between 95°C-120°C), the heat sensitive tube melts/ruptures down at the point where the affecting temperature is the highest.
- v. Melting of the tube creates a hole releasing the entire extinguishing agent stored in the tube directly onto the source of the fire.



13.3.11 Marking and Colour

Ref: para 10.1 of IS 15683: 2018

The recommended colour for extinguisher bodies is **RED**. A small band of distinguishing colour of approx. 5 percent/prominent of surface area shall be painted for different type of extinguishers as given below:

Extinguishers	Band Colour
Water based/ Water mist extinguishers	Red
Foam based extinguishers	Yellow
Powder based extinguisher	Blue
Carbon dioxide based extinguishers	Black
Clean agent extinguishers	Green

13.3.12 Suitability of Different Types of Fire Extinguishers

Ref: Table 3 of IS 2190:2010

S.N.	Type of Extinguisher	Class of Fire			
		A	B	C	D
1.	Water type (gas cartridge or stored pressure)	YES	NO	NO	NO
2.	Mechanical foam type (gas cartridge or stored pressure)	YES	YES	NO	NO
3.	Dry powder type (gas cartridge or stored pressure)	YES	YES	YES	NO
4.	Dry powder type for metal fires	NO	NO	NO	YES
5.	Carbon dioxide type	NO	YES	YES	NO
6.	Clean agent gas type	YES	YES	YES	NO

13.3.13 Summary of Fire Classes & Types of Fire Extinguishers

Fire Class	Material on Fire i.e. Fuel (Ref: para 3.1 of IS 15683: 2018 & para 9 of IS 2190:2010)	Suitable type of Fire Extinguisher (Ref para 10.1 of IS 2190:2010)
Class A	Ordinary combustible solids such as wood, paper, rubber, plastics, furniture, curtains etc.	water, foam, ABC dry chemical powder and halo carbons extinguishers
Class B	Flammable liquids or liquefiable solids such as petrol, diesel oil, acetone, wax etc.	Foam, dry chemical powder, clean Agents and carbon dioxide (CO ₂) extinguishers
Class C	Flammable gases under pressure including liquefied gases such as LPG, natural gas, propane, methane etc.	Dry chemical powder, clean agents, and carbon dioxide (CO ₂) extinguishers
Class D	Combustible metals such as magnesium, aluminium, zinc, sodium, potassium, etc.	Extinguishers with special dry powder suitable for metal fires
Class F (Kitchen Fire)	Cooking media such vegetable or animal oils and fats etc.	Wet chemical fire extinguisher
Energized Electrical equipment	Energised electrical conductors / equipment involved in fire	non-conducting extinguishing media such as dry chemical powder, carbon dioxide (without metal horn) or clean agent.

13.3.14 Points To Be Inspected For Fire Extinguishers

Ref: Para 11 of IS 2190:2010

Periodic inspection of fire extinguishers shall include a check of at least the following items:



a. Location in designated place.



b. No obstruction to access or visibility.



c. Operating instructions on nameplate legible and facing outward.

d. Safety seals and tamper indicators not broken or missing.

e. Fullness determined by weighing or lifting.

f. Examination for obvious physical damage, corrosion, leakage, or clogged nozzle.



g. Pressure gauge reading or indicator in the operable range or position.

h. Condition of tyres, wheels, carriage, hose, and nozzle checked (for wheeled units).

Maintenance, servicing, and recharging shall be performed by **trained persons** and Record of the date of inspection, recharging, etc. should be maintained in the register.

13.3.15 Selection of Location

Ref: para 6 of IS 2190: 2010

- i. When selecting locations for fire extinguishers, due consideration should be given to the nature of risk to be covered. Ex. Class of Fire risk involved.
- ii. The extinguishers should be placed in visible positions and shall be readily accessible for immediate use in all parts of occupancy.
- iii. Generally, fire extinguishers should be placed as near as possible to exits or stair lands without hindering the escape routes.
- iv. Extinguishers should be sited in such a way that the user may not have to travel more than 15 m from the site of the fire to reach the extinguishers.

13.3.16 How to Use a Fire Extinguisher (Pass)

The use of a portable fire extinguisher, can be remembered easily as the **PASS** method. Using a fire extinguisher requires just 4 easy steps, each represented by a letter in the word **PASS**:

Pull	Pull the safety pin on the extinguisher.		Hold the extinguisher with the nozzle pointing away from you and release the locking mechanism. This will allow you to discharge the extinguisher.
Aim	Aim the hose of the extinguisher at the base of the fire.		If you aim at the flames (which is frequently the temptation), the extinguishing agent will fly right through and do no good. You need to hit the fuel.
Squeeze	Squeeze the top handle/ trigger/ lever to discharge the extinguishing material/ media.		This depresses a button that releases the pressurized extinguishing agent in the extinguisher. Remember to squeeze it slowly and evenly, so the extinguisher is as effective as possible.
Sweep	Sweep the nozzle from side to side (slowly) until the fire is completely out.		Start using the extinguisher from a safe distance away, then move forward. Once the fire is out, keep an eye on the area in case it re-ignites.

13.4 Guide Lines of National Building Code

The NBC 2016 has enumerated detailed guidelines of fire safety issues related to electrical installations. The details of these guidelines are as under.

In general, it is desirable that the wiring and cabling are with flame retardant property. Medium and low voltage wiring running in shafts and within false ceiling shall run in metal conduit. Any 230 V wiring for lighting or other services, above false ceiling, shall have 660 V grade insulation. The electric distribution cables/wiring shall be laid in a separate shaft. The shaft shall be sealed at every floor with fire stop materials having the same fire resistance as that of the floor. High, medium and low voltage wiring running in shaft and in false ceiling shall run in separate shaft/conduits. Water mains, gas pipes, telephone lines, intercom lines or any other service line shall not be laid in the duct for electrical cables; use of bus ducts/solid rising mains instead of cables is preferred. All metallic items like steel structural members, etc., shall be bonded properly to the earthing system.

A. Electrical Services

Electrical Services shall conform to the following.

- 13.4.1 The electric distribution cables/wiring shall be laid in a separate duct shall be sealed at every floor with non-combustible material having the same fire resistance as that of the duct. Low and medium voltage wiring running in shaft and in false ceiling shall run in separate conduits.

- 13.4.2 Water mains, telephone wires, inter-com lines, gas pipes or any other service lines shall not be laid in ducts for electric cables.
- 13.4.3 Separate conduits for water pumps, lifts, staircases and corridor lighting and blowers for pressuring system shall be directly from the main switch panel and these circuits shall be laid in separate conduit pipes, so that fire in one circuit will not affect the others. Master switches controlling essential service circuits shall be clearly labeled.
- 13.4.4 The inspection panel doors and any other opening in the shaft shall be provided with airtight fire doors having fire resistance of not less than 1 hour.
- 13.4.5 Medium and low voltage wiring running in shafts and within false ceiling shall run in metal conduits. Any 230 voltage wiring for lighting or other services, above false ceiling should have 660V grade insulation. The false ceiling including all fixtures used for its suspension shall be of non-combustible material.
- 13.4.6 An independent and well-ventilated service room shall be provided on the ground floor with direct access from outside or from the corridor for the purpose of termination of electrical supply from the licensee's service and alternative supply cables. The doors provided for the service room shall have fire resistance of not less than 1 hour.
- 13.4.7 MCB and ELCB shall be provided for electrical circuit.

B. Substation/Transformers

- a. Areas in substation shall not be used as storage/dump areas or for other utility purposes other than those required for the functioning of the substation.
- b. The substation area should be adequately ventilated.
- c. An independent, ventilated or air conditioned MV panel room shall be provided on the ground level or first basement. This room shall be provided with access from outside (or through exit passageway accessible from outside).
- d. The MV panel room shall be provided with fire resistant walls and doors of fire resistance of not less than 120 min.
- e. If the licensee agrees to provide meters on upper floors, the licensee's cables shall be segregated from consumer's cables by providing a partition in the shaft.
- f. Meter rooms on upper floors shall not open into staircase enclosures and should be ventilated directly to open air outside or in electrical room of 120 min fire resistant walls.
- g. Electrical MV main distribution panel and lift panels shall be provided with CO₂/inert gas flooding system for all panel compartments with a cylinder located beside the panel.

C. Oil filled substation

- a. A substation or a switch-station with oil-filled equipment shall be limited to be installed in utility building or in outdoor location. Such substation/utility building shall be at least 7 m away from the adjoining building(s).
- b. Substation equipment (exceeding oil capacity of 2000 litre) in utility building shall have fire rated baffle walls of 240 min rating constructed between such equipment, raised to at least 600 mm above the height of the equipment (including height of oil conservators) and exceeding 300 mm on each side of the equipment.
- c. All transformers where capacity exceeds 10 MVA shall be protected by high velocity water spray systems or nitrogen injection system.



D. Dry type substation

- a. Transformers located inside a building shall be of dry type and all substation/switch room walls, ceiling, floor, opening including doors shall have a fire resistance rating of 120 min.
- b. Access to the substation shall be provided from the nearest fire exit/exit staircase for the purpose of electrical isolation.

E. Miscellaneous safety guide lines for electric sub-station

- i. The major fire risks and detection difficulties within sub-stations arise as a result of the following.
 1. Electrical arcing and the buildup of static electrical charge within equipment.
 2. Overheating of electrical control equipment, switchgear and cabling.
 3. Once initiated a fire may rapidly spread due to the presence of large amount of combustible materials in the form of hydrocarbons contained in cabling and insulation.
 4. The environment within uninterrupted power supply areas (i.e. battery room) may become explosive from the buildup of high concentration of hydrogen gas.
 5. Substations are usually unmanned, thus early intervention by staff may not be possible in the event of a fire.
 6. High air movement caused by air-conditioning dilutes and disperses the smoke.
 7. Underground cable trenches linking the main areas of the sub-station are considered hostile movements. High level of background pollution present in these areas will affect the reliable operation of conventional detectors as well as being a source of false alarms.
- ii. Precautions
 1. Clear independent approach to the sub-station from outside the building shall be made available round the clock.
 2. The approaches/corridors to the sub-station area shall be kept clear for movement of men and material at all times.
 3. The sub-station space is required to be provided with proper internal lighting arrangements.
 4. In addition to natural ventilation, proper ventilation to the sub-station area is to be provided by grill shutters and exhaust fans at suitable places so as to discharge all smoke from the sub-station without delay in case of fire so that sub-station operations can be carried out expeditiously.
 5. Cable trenches of 0.6 m. X 0.6 m. dummy floor of 0.6m. depth shall be provided to facilitate laying of cable inside the building for connecting to the equipment.
 6. Steel shutters of 8' X 8' with suitable grills shall be provided for transformers and sub-station room.
 7. Sub-station space should be clear from any water, sewer, air conditioning, and gas pipe or telephone services. No other service should pass through the substation space or the cable trenches.
 8. RCC pipes at suitable places as required will be provided for the cable entries to the substation space and making suitable arrangement for non-ingress of water through these pipes.
 9. Provision shall be kept for the sumps to accommodate complete volume of transformer oil, which can spillover in the event of explosion of the transformer in the basement of the building. Sufficient arrangement should exist to avoid fire in the sub-station building from spread of the oil from the sumps.
 10. Arrangement should be made for the provision of fire retardant cables to avoid chances of spread of fire in the sub-station building.
 11. Sufficient pumping arrangement should exist for pumping the water out, in case of fire to ensure minimum loss to the switchgear and transformer.



12. No combustible material should be stacked inside the substation premises or in the vicinity to avoid chances of fire.
13. It should be made mandatory that the promoters of the multistoried building should get substation premises inspected once a year to get their license revalidated for the provision of electric supply from Electricity Board so that suitable action can be taken against the Owner/ Builder in case of non- implementation of Bye-Laws
14. The sub-station must not be located below the first basement and above the ground floor.
15. The substation space should be totally segregated from the other areas of the basement by fire resisting wall. The ramp should have a slope of 1:10 with entry from ground level. The entire substation space, including the entrance at ground floor, be handed over to the licensee of electricity free of cost and rent.
16. The sub-station area shall have a clear height of 12 feet (3.65 m.) below beams. Further, the substation area will have level above the rest of basement level by 2 feet.
17. It is to be ensured that the substation area is free of seepage / leakage of water.
18. The licensee of electricity will have the power to disconnect the supply of the building in case of violation of any of the above points.
19. Electric substation enclosure must be completely segregated with 4-hours fire rating wall from remaining part of basement.
20. The Sub-station should be located on periphery /sub-basement and (not above ground floor).
21. Additional exit shall be provided if travel distance from farthest corner to ramp is more than 15 m.
22. Perfect independent vent system 30 air changes per hour linked with detection as well as automatic high velocity water spray system shall be provided.
23. All the transformers shall be protected with high velocity water spray system / Nitrogen Injection System Carbon Dioxide total flooding system in case of oil filled transformer. In addition to this, manual control of auto high velocity spray system for individual transformers shall be located outside the building at ground floor.
24. Suitable arrangement for pump house, water storage tanks with main electrical pump and a diesel-operated pump shall be made if no such arrangement is provided in the building. In case the water pumping facilities are existing in the building for sprinkler system, the same should however be utilized for high velocity water spray system. Alternatively, automatic CO2 total flooding system shall be provided with manual controls outside the electric sub- station.
25. System shall have facility to give an audio alarm in the basement as well as at the control room.
26. Fire control room shall be manned round the clock.
27. The electric substation shall have electric supply from alternate source for operation of vent System lighting arrangements.
28. Cable trenches shall be filled with sand
29. Partition walls shall be provided between two transformers as per the rules.
30. Electric control panels shall be segregated.
31. Exits from basement electric substation shall have self-closing fire smoke check doors of 2-hours fire rating near entry to ramp.
32. All openings to lower basement or to ground floor shall be sealed properly.
33. Yearly inspection shall be carried out by electrical load sanctioning Authority.
34. D.C. supply (UPS and Battery) is important and vulnerable part of any installation. They are generally derived from stationary Batteries which give off flammable and toxic gases. Batteries



should be in a separate room with an acid –resistant floor. The room must be properly ventilated but sunlight must not be allowed to shine directly on to the cell.

F. Standby supply

- a. Diesel generator set(s) shall not be installed at any floor other than ground/first basement. If the same are installed indoors, proper ventilation and exhaust shall be planned.
- b. The DG set room shall be separated by a 120 min fire resistance rated walls and doors.
- c. The oil tank for the DG sets (if not in the base of the DG) shall be provided with a dyked enclosure having a volumetric capacity of at least 10 percent more than the volume of the oil tank.
- d. The enclosure shall be filled with sand for a height of 300 mm.

For detailed information regarding fire safety requirements for hazardous petroleum products, reference may be made to The Petroleum Act, 1934 and the Rules framed thereunder.

G. Lightning protection of buildings

Routing of down conductors (insulated or uninsulated) of lightning protection through electrical or other service shafts are not allowed as it can create fire and explosion during lightning.

H. Air Conditioning, Ventilation and Smoke Control

1. Air conditioning and ventilating systems shall be so installed and maintained as to minimise the danger of spread of fire, smoke or fumes from one floor to other or from outside to any occupied building or structure. Many high-rise buildings integrate smoke management systems into their conventional HVAC systems. In such installation, it requires special design considerations, including safe and adequate controls, acceptable and documented testing and regular maintenance systems. Wherever batteries are provided, the same shall be segregated by 120 min fire rated construction. Ventilation to the room shall be provided as per manufacturer's instructions.
2. Air handling unit
 - i. From fire safety point of view, separate air handling units (AHU) for each floor shall be provided to avoid the hazards arising from spread of fire and smoke through the air conditioning ducts. The air ducts shall be separate from each AHU to its floor and in no way shall interconnect with the duct of any other floor. Within a floor, it would be desirable to have separate air handling unit provided for each compartment. Air handling unit shall be provided with effective means for preventing circulation of smoke through the system in the case of a fire in air filters or from other sources drawn into the system, and shall have smoke sensitive devices for actuation in accordance with the accepted standard and control.
 - ii. Shafts or ducts, if penetrating multiple floors, shall be of masonry construction with fire damper in connecting ductwork or shall have fire rated ductwork with fire dampers at floor crossing. Alternatively, the duct and equipment may be installed in room having walls, doors and fire damper in duct exiting/entering the room of 120 min fire resistance rating. Such shafts and ducts shall have all passive fire control meeting 120 min fire resistance rating requirement to meet the objective of isolation of the floor from spread of fire to upper and lower floors through shaft/duct work.
 - iii. *NOTE-Zoned and compartmented HVAC systems are encouraged with an approach to avoid common exhaust shafts and fresh air intake shafts, which will limit the requirement of such passive measure and fire rated ductwork and dampers.*

- iv. The air filters of the air-handling units shall be made of non-combustible materials.
 - v. The air handling unit room shall not be used for storage of any combustible materials.
3. Duct work
- i. Air ducts serving main floor areas, corridors, etc., shall not pass through the exits/exit passageway/ exit enclosure. Exits and lift lobbies, etc., shall not be used as return air passage.
 - ii. As far as possible, metallic ducts shall be used even for the return air instead of space above the false ceiling.
 - iii. Wherever the ducts pass through firewalls or floors, the opening around the ducts shall be sealed with materials having fire resistance rating of the compartment. Such duct shall also be provided with fire dampers at all fire walls and floors unless such ducts are required to perform for fire safety operation; and in such case fire damper may be avoided at fire wall and floor while integrity of the duct shall be maintained with 120 min fire resistance rating to allow the emergency operations for fire safety requirements.
 - iv. The ducting within compartment would require minimum fire resistance rating of 30 min. Such ducting material in substantial gauge shall be in accordance with good practice. If such duct crosses adjacent compartment/floor and not having fire dampers in such compartment/floor, it would require fire resistance ductwork rating of 120 min. The requirements of support of the duct shall meet its functional time requirement as above.
 - v. The materials used for insulating the duct system (inside or outside) shall be of non-combustible type. Any such insulating material shall not be wrapped or secured by any material of combustible nature.
 - vi. Inspection panels shall be provided in the ductwork to facilitate the cleaning accumulated dust in ducts and to obtain access for maintenance of fire dampers.
4. Fire or fire/smoke dampers
- i. These dampers shall be evaluated to be located in supply air ducts, fresh air and return air ducts/passages at the following point.
 - a. At the fire separation wall,
 - b. Where ducts/passages enter the vertical shaft,
 - c. Where the ducts pass through floors, and
 - d. At the inlet of supply air duct and the return air duct of each compartment on every floor.
 - ii. Damper shall be of motorized type/fusible link. Damper shall be so installed to provide complete integrity of the compartment with all passive fire protection sealing. Damper should be accessible to maintain, test and replace, if so required. Damper shall be integrated with Fire Alarm Panel and shall be sequenced to operate as per requirement and have interlocking arrangement for fire safety of the building. Manual operation facilities for damper operation shall also be provided.

I. Lift & Lift Enclosure

General requirements shall be as follows

- a. Walls of lift enclosures shall have a fire rating of two hours. Lift shafts shall have a vent at the top of area not less than 0.2 sq. m.
- b. Lift motor room shall be located preferably on top of the shaft and separated from the shaft by the floor of the room.
- c. Landing door in lift enclosures shall have a fire resistance of not less than one hour.



- d. The number of lifts in one lift bank shall not exceed four. A wall of two hours fire ratings shall separate individual shafts in a bank.
- e. Lift car door shall have a fire resistance rating of 1 hour.
- f. For buildings 15.0 m. and above in height, collapsible gates shall not be permitted for lifts and solid doors with fire resistance of at least one hour shall be provided.
- g. If the lift shaft and lobby is in the core of the building, a positive pressure between 25 and 30 pa shall be maintained in the lobby and a possible pressure of 50 pa shall be maintained in the lift shaft. The mechanism for the pressurization shall act automatically with the fire alarm/sprinkler system and it shall be possible to operate this mechanically also.
- h. Exit from the lift lobby, if located in the core of the building, shall be through a self-closing fire smoke check door of one-hour fire resistance.
- i. Lift shall not normally communicate with the basement. If however, lifts are in communication, the lift lobby of the basement shall be pressurized as in (g) with self-closing door as in (h).
- j. Grounding switches at ground floor level shall be provided to enable the fire service to ground the lifts.
- k. Telephone/talk back communication facilities may be provided in lift cars for communication system and lifts shall be connected to the fire control room of the building.
- l. Suitable arrangements such as providing slope in the floor of the lift lobby shall be made to prevent water used during firefighting, etc. at any landing from entering the lift shafts.
- m. A sign shall be posted and maintained on every floor at or near the lift indicating that in case of fire, occupants shall use the stairs unless instructed otherwise. The sign shall also contain a plan for each floor showing the location of the stairways. Floor marking shall be done at each floor on the wall in front of the lift-landing door.
- n. Alternate power supply shall be provided in all the lifts.

J. Emergency Power for Fire and Life Safety Systems

Emergency power supplying distribution system for critical requirement for functioning of fire and life safety system and equipment shall be planned for efficient and reliable power and control supply to the following systems and equipment where provided

- i. Fire pumps.
- ii. Pressurization and smoke venting; including its ancillary systems such as dampers and actuators.
- iii. Fireman's lifts (including all lifts).
- iv. Exit signage lighting.
- v. Emergency lighting.
- vi. Fire alarm system.
- vii. Public address (PA) system (relating to emergency voice evacuation and annunciation).
- viii. Magnetic door hold open devices.
- ix. Lighting in fire command centre and security room.

Power supply to these systems and equipment shall be from normal and emergency (standby generator) power sources with changeover facility. If power supply, is from HV source and HV generation, the transformer should be planned in standby capacity to ensure continuity of power to such systems. Wherever, transformers are installed at higher levels in buildings and backup DG sets are of higher voltage rating, then dual redundant cables shall be taken to all transformers. The generator shall be capable of taking starting current of all the fire and life safety systems and equipment as above. Where



parallel HV/LV supply from a separate substation fed from different grid is provided with appropriate transformer for emergency, the provision of generator may be waived in consultation with the Authority.

The power supply to the panel/distribution board of these fire and life safety systems shall be through fireproof enclosures or circuit integrity cables or through alternate route in the adjoining fire compartment to ensure supply of power is reliable to these systems and equipment. It shall be ensured that the cabling from the adjoining fire compartment is protected within the compartment of vulnerability. The location of the panel/distribution board feeding the fire and life safety system shall be in fire safe zone ensuring supply of power to these systems.

Circuits of such emergency system shall be protected at origin by an automatic circuit breaker with its no-volt coil removed. Master switches controlling essential service circuits shall be clearly labelled.

Cables for fire alarm and PA system shall be laid in metal conduits or armoured to provide physical segregation from the power cables.

K. Fire Detection and Alarm

- a. Fire detection and alarm systems in buildings shall be so planned and programmed so as to enable operations of various systems and equipment to facilitate requirements leading to life safety, compartmentation and fire protection. These systems and equipment may include electromechanical systems such as air handling units; pressurization systems; smoke management systems; creation of compartmentation through the release of fire barrier, hold-up fire doors, etc; and monitoring of fire water storage tanks and pumps, pressures in hydrant and sprinkler system, etc. These planning and requirements shall be based on building occupancy and other requirements on case-to-case basis.
- b. Voice evacuation systems shall employ Hindi, English and vernacular language using pre-recorded messages and integrate with fire alarm panels for alerting the zone of fire and surrounding zones/floors as required for annunciation.
- c. Appropriate visual warning arrangement through visual strobes/beacons may be considered in appropriate situations particularly in public buildings, at required locations to ensure visual as well as alarm for persons with hearing impairment.
- d. For assembly buildings, institutional buildings and all buildings above 30 m in height where fire alarm system is provided, detectors shall also be provided inside the electrical shafts, and lift machine rooms, etc., besides occupancy areas.
- e. Fire alarm panels shall be connected in peer-to-peer network or with redundant cables, run in different shafts. Each panel shall be able to work in standalone mode and master slave architecture may be used where required.
- f. The fire detection system shall be in accordance with accepted standards. Guidelines for selection of various types of fire detectors for different occupancies and their installation and maintenance shall be in accordance with good practice.
- g. In buildings where automatic fire alarm system is provided, the following shall be monitored from fire alarm panel.
 1. Water level in all tanks.
 2. Hydrant and sprinkler pressures of respective zones as provided.
 3. Pump ON/OFF status.
 4. All isolation valves, wherever provided with supervisory switch (non-padlock valves).
 5. Other requirements to meet electro-mechanical services interface.



L. Smoking restrictions

- a. Smoking shall be prohibited throughout the basement and in all areas where there is a profusion of combustible materials.
- b. In all places where smoking is permitted astray, half filled with water must be placed on each suitable location for safe disposal of spent smoking materials.

M. Fire drills and fire orders

- a. Staff must be trained in fire-fighting. There should be regular drills to ascertain the competency of staff and proper working of the firefighting system.

N. Miscellaneous fire prevention

- b. Storage of flammable substances such as diesel oil, gasoline, motor oils etc. must not be allowed anywhere within the buildings.
- c. Where heaters are used during winter.

O. Firefighting pump house

The requirements shall be as given below.

- a. It is preferable to install the pump house at ground level. Pump house shall be situated so as to be directly accessible from the surrounding ground level.
- b. Pump house shall be installed not lower than the second basement. When installed in the (or through enclosed passageway with 120 min fire rating) from the ground, shall be provided. Access to the pump room shall not require negotiating through other occupancies within the basement.
- c. Pump house shall be separated by firewalls all around and doors shall be protected by fire doors (120 min rating).
- d. Pump house shall be well ventilated and due care shall be taken to avoid water stagnation.
- e. No other utility equipment shall be installed inside fire pump room.
- f. Insertions like flexible couplings, bellows, etc., in the suction and delivery piping shall be suitably planned and installed.
- g. Installation of negative suction arrangement and submersible pumps shall not be allowed.
- h. Pump house shall be sufficiently large to accommodate all pumps, and their accessories like PRVs, installation control valve, valves, diesel tank and electrical panel.
- i. Battery of diesel engine operated fire pump shall have separate charger from emergency power supply circuit.
- j. Exhaust pipe of diesel engine shall be insulated as per best engineering practice and taken to a safe location at ground level, considering the back pressure.
- k. Fire pumps shall be provided with soft starter or variable frequency drive starter.

P. Escape Lighting and Exit Signage

Exit access, exits and exit discharge shall be properly identified, with adequate lighting maintained in the elements of the egress systems so that all occupants shall be able to leave the facility safely.

1. Lighting

- a. The exit, exit access and exit discharge systems shall be illuminated continuously. The floors of the means of egress shall be illuminated at all points, including angles and intersections, in corridors and passageways, stairwells, landings of stairwells and exit.

- b. Emergency lighting shall be powered from a source independent of that supplying the normal lighting.
- c. Escape lighting shall be capable of,
 - i. indicating clearly and unambiguously the escape routes;
 - 2. providing adequate illumination along such routes to allow safe movement of persons towards and through the exits; and
 - 3. ensuring that fire alarm call points and firefighting equipment provided along the escape routes can be readily located.
- d. The horizontal luminance at floor level on the centerline of an escape route shall not be less than 10 lumen/m². In addition, for escape routes up to 2 m wide, 50 percent of the route width shall be lit to a minimum of 5 lumen/m². In auditoriums, theatres, concert halls and such other places of assembly, the illumination of floor exit/access may be reduced during period of performances to values not less than 2 lux.
- e. Required illumination shall be arranged such that the failure of any single lighting unit, such as the burning out of one luminaire, will not leave any area in darkness and does not impede the functioning of the system further.
- f. The emergency lighting shall be provided to be put on within 5 seconds of the failure of the normal lighting supply. In addition, emergency lighting shall be able to maintain the required illumination level for a period of not less than 90 min in the event of failure of the normal lighting even for smaller premises.
- g. Battery pack emergency lighting, because of its limited duration and reliability, shall not be allowed to be used in lieu of a diesel engine driven emergency power supply.
- h. Escape lighting luminaires should be sited to cover the following location.
 - 1. Near each intersection of corridors,
 - 2. At exits and at each exit door,
 - 3. Near each change of direction in the escape route,
 - 4. Near each staircase so that each flight of stairs receives direct light,
 - 5. Near any other change of floor level,
 - 6. Outside each final exit and close to it,
 - 7. Near each fire alarm call point,
 - 8. Near firefighting equipment, and
 - 9. To illuminate exit and safety signs as required by the enforcing authority.

NOTE - For the purpose of this Clause near is normally considered to be within 2 m measured horizontally.

- i. The luminaires shall be mounted as low as possible, but at least 2 m above the floor level.
- j. Signs are required at all exits, emergency exits and escape routes, which should comply with the graphic requirements of the relevant Indian Standards.

1.1 Exit passageway (at ground) and staircase lighting shall also be connected to alternative supply. The alternative source of supply may be provided by battery continuously trickle charged from the electric mains.

1.2 Suitable arrangements shall be made by installing double throw switches to ensure that the lighting installed in the staircase and the corridor does not get connected to two sources of supply simultaneously. Double throw switch shall be installed in the service room for terminating the stand-by supply. The emergency lighting system shall be well maintained by periodical inspections and tests so as to ensure their perfect serviceability at all times.



1.3 Exit signage

- a. Where exit access is provided through corridors/paths, the occupants shall be able to easily identify the way to exits.
- b. Exit signs shall be provided such that no point in an exit access is more than 30 m from a visible exit directional sign.
- c. An exit sign indicating the direction to an exit shall be provided at all changes in direction.
- d. Exits shall be clearly visible, the route to reach the exits shall be clearly marked, and signs posted to guide the occupants of the floor concerned.
- e. Signs shall be illuminated and wired to an independent electrical circuit on an alternative source of supply.
- f. The sizes and colours of the exit signs shall be in accordance with good practice.
- g. The colour of the exit signs shall be green.
NOTE - This provision shall not apply to A-2 and A-4 occupancies less than 15 m in height.
- h. The exit sign with arrow indicating the way to the escape route shall be provided at a suitable height from the floor level on the wall and shall be illuminated by electric light connected to corridor circuits.
- i. All exit way marking signs should be so installed that no mechanical damage shall occur to them due to moving of furniture or other heavy equipment.
- j. Further, all landings of floor shall have floor indicating boards prominently indicating the number of the floor.
- k. Photo luminescent markings shall be pasted at internal hydrant boxes

Q. Staircase and Corridor Lights

The staircase and corridor lighting shall be on separate circuits and shall be independently connected so that it could be operated by one switch installation on the ground floor easily accessible to firefighting staff at any time irrespective of the position of the individual control of the light points, if any. It should be of miniature circuit breaker type of switch so as to avoid replacement of fuse in case of crisis.

- a. Staircase and corridor lighting shall also be connected to alternate source of power supply.
- b. Suitable arrangement shall be made by installing double throw switches to ensure that the lighting installed in the staircase and the corridor is not connected to two sources of supply simultaneously. Double throw switch shall be installed in the service room for terminating the stand by supply.

Emergency lights shall be provided in the staircase and corridor.

R. Mode of Fire Protection

1. Sand/ Water buckets
2. Dry/ Wet Hydrant risers
3. Heat/ Smoke Detectors
4. Automatic/ Manual Fire Alarm
5. Sprinklers
6. Lightning Conductors
7. Fire Dampers in AC Ducts
8. Fire Doors with fusible link
9. Pressurization Plant
10. Public Address System
11. Fire Escapes/ External Stairs



14.1 Introduction

Central Electricity Authority has been constituted under Section -70 of the Electricity Act, 2003 to exercise such functions and perform such duties as are assigned to it under this Act. Amongst various function and duties assigned to CEA, it has been given the responsibility to frame Regulation and Measures relating to Safety and Electric Supply under Section 53 and 177 of Electricity Act, 2003. In line with that, CEA Regulation on Measures relating to Safety and Electric Supply 2010 was notified on 24th September, 2010.

Subsequently IE Regulations, 1956 got repealed with the notification of these Regulations in terms of Section 185 (2) (c) of EA, 2003. Details of regulations and amendments upto 2019 are as following.

1. Central Electricity Authority (Measures relating to Safety and Electricity Supply) Regulations, 2010
2. Central Electricity Authority (Measures relating to Safety and Electric Supply) (Amendment) Regulations 2015
3. Central Electricity Authority (Measures relating to Safety and Electric Supply) (Amendment) Regulations, 2018
4. Central Electricity Authority (Measures relating to Safety and Electric Supply) (Amendment) Regulations, 2019

14.2 Chapters on Safety and Electricity Supply Regulations

The regulations are divided in following chapters.

- i. Chapter - I Definitions
- ii. Chapter - II Personnel Competencies, Safety measures and Record keeping (Regulation # 3-11)
- iii. Chapter - III General safety requirements (Regulation # 12-32)
- iv. Chapter - IV General conditions relating to supply and use of electricity (Regulation # 33-39)
- v. Chapter - V Safety Provisions for Electrical Installations and apparatus of voltage not exceeding 650 Volts (Regulation # 40-42)
- vi. Chapter - VI Safety Provisions for Electrical Installations and apparatus of voltage exceeding 650 Volts (Regulation # 43-54)
- vii. Chapter - VII Safety requirements for overhead lines, underground cables and generating stations (Regulation # 55-77)
- viii. Chapter - VIII Safety requirements for Electric Traction (Regulation # 78-92)
- ix. Chapter - IX Safety requirements for mines and oil fields (Regulation # 93-115)
- x. Chapter - X Miscellaneous (Regulation # 116 Deviations in Regulations)
- xi. Chapter - XI Safety Provisions for Electric Vehicle Charging Stations (Regulation # 117-123) (Added in 2019 Amendment)

14.3 Important Regulations

Following are important regulations which are to be followed.

Regulation 3- Designating person(s) to operate and carry out the work on electrical lines and apparatus-

A supplier or a consumer, or the owner, agent or manager of mine, or the agent of any company operating in an oil field or the owner of a drilled well in an oil field or a contractor who has entered into a contract with a supplier or a consumer to carry out duties incidental to the generation, transformation, transmission, conversion, distribution or use of electricity shall designate persons for the purpose to operate and carry out the work on electrical lines and apparatus.

The supplier or consumer, or the owner, agent or manager of a mine, or the agent of any company operating in an oil-field or the owner of a drilled well in an oil field or a contractor referred to on sub-regulation (1) shall maintain a register wherein the names of the designated persons and the purpose for which they are engaged, shall be entered

No person shall be designated under sub-regulation (1) unless, -

He possesses a certificate of competency or electrical work permit, issued by the Appropriate Government.

His name is entered in the register referred to in sub regulation (2) Regulation 4- Inspection of designated officers and other safety measures-

The register maintained under sub-regulation (2) of regulation 3 shall be produced before the Electrical Inspector when required by him.

If on inspection, the Electrical Inspector finds that the designated person does not fulfill the required qualification, he shall recommend the removal of the name of such persons from the register.

Regulation 5- Electrical Safety Officer-

All suppliers of electricity including generating companies, transmission companies and distribution companies shall designate an Electrical Safety Officer for ensuring observance of safety measures specified under these regulations in their organisation, for construction, operation and maintenance of power stations, sub-stations, transmission and distribution lines.

The Electrical Safety Officer shall possess a degree in Electrical Engineering with at least five years' experience in operation and maintenance of electrical installation or a diploma in Electrical Engineering with at least ten years experience in operation and maintenance of electrical installations. The Electrical Safety Officer designated under, sub-regulation (1), shall carry out periodic tests as per the relevant standards and inspection of such installations for ensuring observance of safety measures specified under these regulations at intervals not exceeding one year, and keep a record thereof in Form I or Form II or Form III, as the case may be, of Schedule IV and test reports, and also keep a register of recommended safety requirements duly acknowledged by the owner with date and compliances thereafter; and such records shall be made available to the Electrical Inspector, as and when required.

For every electrical installation including factory registered under the Factories Act, 1948 (63 of 1948) and mines and oil field as defined in the Mines Act, 1952 (35 of 1952), where more than 250 kW of electrical load is connected, the owner of the installation or the management of the factory or mines, as the case may be, shall designate Electrical Safety Officer having qualification and experience specified in sub-regulation (2), for ensuring the observance of the safety provisions laid under the Act and the regulations made thereunder, who shall carry out recommended periodic tests as per the relevant standards, and inspect such installation at intervals not exceeding one year, and keep a record

thereof in Form I or Form II or Form III, as the case may be, of Schedule IV to these regulations; test reports and a register of recommendations in regard with safety duly acknowledged by owner; compliances made thereafter; and such records shall be made available to the Electrical Inspector, as and when required.

Regulation 5A- Chartered Electrical Safety Engineer-

The Appropriate Government shall authorise Chartered Electrical Safety Engineer from amongst persons having the qualification and experience as specified by the Authority under sub-regulation (3) to assist the owner or supplier or consumer of electrical installations for the purpose of self- certification under regulation 30 and regulation 43.

The Appropriate Government shall upload the name of the Chartered Electrical Safety Engineer, as soon as any person is authorised as Chartered Electrical Safety Engineer, on the web portal of the Government or Department dealing with matters of inspection of electrical installations for the information of the owner or supplier or consumer.

The Central Electricity Authority shall, within a period of six months, frame and publish the guidelines including the eligibility conditions for the purpose of authorising the Chartered Electrical Safety Engineer.

Regulation 7- Safety measures for operation and maintenance of transmission, distribution systems-

Engineers or supervisors engaged in operation and maintenance of transmission and distribution systems shall hold diploma in electrical, mechanical, electronics and instrumentation engineering from a recognized institute or university.

The Technicians to assist engineers or supervisors shall possess a certificate in appropriate trade, preferably with a two years course from a Industrial Training institute recognized by the Central Government or State Government.

Engineers, supervisors and Technicians engaged for operation and maintenance of transmission and distribution systems electric plants should have successfully undergone the type of training as specified in Schedule-II.

Provided that the existing employees shall have to undergo the training mentioned in sub-regulation (3) within three years from the date of coming into force of these regulations

Owner of every transmission or distribution system shall arrange for training of their personal engaged in the operation and maintenance of transmission and distribution system in his own institute or any other institute recognized by the Central Government or State Government.

Regulation 16- Earthed terminal on consumer's premises-

The supplier shall provide and maintain on the consumer's premises for the consumer's use, a suitable earthed terminal in an accessible position at or near the point of commencement of supply. Provided that in the case of installation of voltage exceeding 250V the consumer shall, in addition to the aforementioned earthing arrangement, provide his own earthing system with an independent electrode. Provided further that the supplier may not provide any earthed terminal in the case of installations already connected to his system on or before the date to be specified by the State Government in this behalf if he is satisfied that the consumer's earthing arrangement is efficient.

The-consumer shall take all reasonable precautions to prevent mechanical damage to the earthed terminal and its lead belonging to the supplier.



The supplier may, recover from the consumer the cost of installation on the basis of schedule of charges published by him in advance and where such schedule of charges is not published, the procedure laid down, in regulation 63 shall apply.

Explanation- For the purposes of sub-regulation (1), the expression “point of commencement of supply of electricity” shall mean the point at the incoming terminal of the switchgear installed by the consumer.

Regulation 17- Accessibility of bare conductors- Where bare conductors are used in a building, the owner of such conductors shall

Ensure that they are inaccessible;

Provide in readily accessible position switches for rendering them dead whenever necessary; and Take such other safety measures as are specified in the relevant Indian Standards.

Regulation 18- Danger Notice Boards- The owner of every installation of voltage exceeding 250V shall affix permanently in a conspicuous position a danger notice in Hindi or English and the local language of the District, with a sign of skull and bones of a design as per IS -2551 or latest on-

Every motor, generator, transformer and other electrical plant and equipment together with apparatus used for controlling or regulating the same;

All supports of overhead lines of voltage exceeding 650V which can be easily climbed upon without the aid of ladder or special appliances;

Luminous tube sign requiring supply, X-ray and similar high frequency installations of voltage exceeding 550V but not exceeding 33kV.

Provided that where it is not possible to affix such notices on any generator, motor, transformer or other apparatus, they shall be affixed as near as possible thereto, or the word ‘danger’ and the voltage of the apparatus concerned shall be permanently painted on it-

Provided further that where the generator, motor, transformer or other apparatus is within an enclosure one notice affixed to the said enclosure shall be sufficient for the purposes of this regulation.

Explanation- For the purpose of Clause (b) rails, tubular poles, wooden supports, reinforced cement concrete poles without steps, I-sections and channels, shall be deemed as supports which cannot be easily climbed upon.

Regulation 19- Handling of electric supply lines and apparatus-

Before any conductor or apparatus is handled, adequate precautions shall be taken, by earthing or othersuitable means, to discharge electrically such conductor or apparatus, and any adjacent conductor or apparatus if there is danger there from, and to prevent any conductor or apparatus from being accidentally or inadvertently electrically charged when persons are working thereon.

Every person who is working on an electric supply line or apparatus or both shall be provided with tools and devices such as gloves, rubber shoes, safety belts, ladders, earthing devices, safety chain, helmets, line testers, hand lines and the like for protecting him from mechanical and electrical injury and such tools and devices shall always be maintained in sound and efficient working condition.

No person shall work on any live electric supply line or apparatus and no person shall assist such person on such work, unless he is designated in that behalf and takes the safety precautions given in Schedule-III.

Every telecommunication line on supports carrying a line of voltage exceeding 650V but not exceeding 33kV shall, for the purpose of working thereon, be deemed to be a line of voltage exceeding 650V.

All non-current carrying metal parts of switchgear and control panels shall be properly earthed and insulating floors or mat conforming to IS-15652: 2006 or the latest, of appropriate voltage level shall be provided in front of the panels for the safety of operating personnel.

All panels shall be painted with the description of its identification at front and at the rear.

Regulation 20- Supply to vehicles and cranes-

Every person owning a vehicle, traveling crane, or the like to which electricity is supplied from an external source shall ensure that it is efficiently controlled by a suitable switch enabling all voltage to be cut off in one operation and, where such vehicle, traveling crane or the like runs on metal rails, the owner shall ensure that the rails are electrically continuous and earthed.

Regulation 21- Cables for portable or transportable apparatus -

Flexible cables shall not be used for portable or transportable motors, generators, transformers, rectifiers, electric drills, electric sprayers, welding sets or any other portable or transportable apparatus unless they are heavily insulated and adequately protected from mechanical injury.

Where the protection is by means of metallic covering, the covering shall be in metallic connection with the frame of any such apparatus and earthed.

The cables shall be three core type and four core type for portable and transportable apparatus working on single phase and three phase supply respectively and the wire meant to be used for ground connection shall be easily identifiable.

Regulation 25- Distinction of the installations having more than one feed-

The owner of every installation including sub-station, double pole structure, four pole structure or any other structure having more than one feed, shall ensure by means of indication of permanent nature, that the installation is readily distinguishable from other installations.

Regulation 26- Accidental charging-

The owners of all circuits and apparatus shall so arrange them that there shall be no danger of any part thereof becoming accidentally charged to any voltage beyond the limits of voltage for which they are intended.

Where alternating current and direct current circuits are installed on the same box or support, they shall be so arranged and protected that they shall not come into contact with each other when live.

Regulation 27- Provisions applicable to protective equipment-

Fire buckets filled with clean dry sand, covered and protected from water ready for immediate use for extinguishing fires in addition to fire extinguishers suitable for dealing with fires, shall be conspicuously marked and kept in all generating stations, enclosed substations and switching-stations in convenient location.

The fire extinguishers shall be tested for satisfactory operation as per relevant Indian Standard at least once a year and record of such tests shall be maintained. The refilling and expiry date should be mentioned on the extinguishers.

First-aid boxes or cupboards conspicuously marked and equipped with such contents as the State Government may specify, shall be provided and maintained in every generating station, enclosed sub-station, enclosed switching station and in vehicles used for maintenance of lines so as to be readily accessible during all working hours and all such boxes and cupboards shall, except, in the case of



unattended sub-stations and switching stations, be kept in charge of responsible persons' who are trained in first-aid treatment and one of such persons shall be available during working hours. The medicines available in the boxes shall be checked for their date of expiry at least once in a year & replaced as and when required

Two or more gas masks shall be provided conspicuously and installed and maintained at accessible places in every generating station with capacity of 5 MW and above and enclosed sub-station, with transformation capacity of 5 MVA and above for use in the event of fire or smoke.

Provided that where more than one generator with capacity of 5 MW and above is installed in a power station, each-generator shall be provided with at least two separate gas masks in an accessible and conspicuous place-

Provided further that adequate number of gas masks shall be provided by the owner at every generating station and enclosed sub-station with capacity less than 5 MW and 5 MVA respectively.

Water supply connection should be available at sub-station.

Regulation 28- Display of Instructions for Resuscitation of Persons Suffering from Electric Shock.

Instructions, in English or Hindi and the local language of the District and where Hindi is the local language, in English and Hindi for the resuscitation of persons suffering from electric shock, shall be affixed; by the owner in a conspicuous place in every generating station, enclosed sub-station, enclosed switching station, mines and in every factory as defined in Clause (m) of section 2 of the Factory Act, 1948 (63 of 1948) in which electricity is used and in such other premises where electricity is used as the. Electrical Inspector may, by notice in writing served on the owner, direct.

The owner of every generating station, enclosed sub-station, enclosed switching station and every factory or other premises to which these regulations apply shall ensure that all designated persons employed by him are acquainted with and are competent to apply the instructions referred to in sub-regulation (1).

In every manned generating station, sub-station or switching station of voltage exceeding 650 V, an artificial respirator shall be provided and kept in good working condition.

Regulation 29- Precautions to be adopted by consumers, owners, occupiers, electrical contractors, electrical workmen and suppliers-

No electrical installation work, including additions, alterations, repairs and adjustments to existing installations, except such replacement of lamps; fans, fuses, switches, domestic appliances of voltage not exceeding 250V and fittings as in no way alters its capacity or character, shall be carried out upon the premises of or on behalf of any consumer, supplier, owner or occupier for the purpose of supply to such consumer, supplier, owner or occupier except by an electrical contractor licensed in this behalf by the State Government and under the direct supervision of a person holding a certificate of competency and by a person holding a permit issued or recognised by the State Government. Provided that in the case of works executed for or on behalf of the Central Government and in the case of installations in mines, oil fields and railways, the Central Government and in other cases the State Government, may, by notification in the Official Gazette, exempt on such conditions as it may impose, any such work described therein either generally or in the case of any specified class of consumers, suppliers, owners or occupiers.

No electrical installation work which has been carried out in contravention of subregulation 1. shall either be energized or connected to the works of any supplier.

Regulation 30- Periodical inspection and testing of Installations-

Where an installation is already connected to the supply system of the supplier or trader, every such installation shall be periodically inspected and tested at intervals not exceeding five years either by the Electrical Inspector or by the supplier as may be directed by the State Government in this behalf or in the case of installations belonging to, or under the control of the Central Government, and in the case of installation in mines, oilfields and railways, by the Central Government.

The periodical inspection and testing of installation of voltage equal to or below the notified voltage belonging to the owner or supplier or consumer, as the case may be, shall be carried out by the owner or supplier or consumer and shall be self-certified for ensuring observance of safety measures specified under these regulations and the owner or supplier or consumer, as the case may be, shall submit the report of self-certification to the Electrical Inspector in the format as specified by the Authority.

Provided that the electrical installation so self-certified shall be considered as duly inspected and tested only after the report of self-certification is duly received by the office of Electrical Inspector.

Provided further that the owner or supplier or consumer has the option to get his installation inspected and tested by the Electrical Inspector of the Appropriate Government.

(2A) Notwithstanding anything contained in sub-regulation (2), every electrical installation covered under section 54 of the Act including every electrical installation of mines, oil fields and railways shall be periodically inspected and tested by the Electrical Inspector of the Appropriate Government.

(2B) The Electrical Inspector shall, on receipt of the report of self-certification of electrical installation referred in sub-regulation (2), verify the report submitted by the owner or supplier or consumer, as the case may be, and record variation, if any, in accordance with these regulations.

(2C) The Electrical Inspector in case of variations, which require rectification, direct the owner or supplier or consumer, as the case may be, to rectify the same within a period of fifteen days and the owner or supplier or consumer, as the case may be, shall send a report of compliance to the Electrical Inspector.

(2D) The Electrical Inspector, in case not satisfied with the compliance report submitted under sub-regulation (2C), shall inspect the electrical installation within a period of one year from the date of submission of self-certification report and intimate the owner or supplier or consumer of the installation the defects, if any, for rectification within fifteen days.

(2E) If the owner or supplier or consumer, as the case may be, fails to comply with the directions as given under sub-regulation (2D), such installation shall be liable to be disconnected under the directions of the Electrical Inspector after serving the owner or supplier or consumer, as the case may be, of such installation with a notice for a period not less than forty-eight hours.

The periodical inspection and testing of installation of voltage above the notified voltage belonging to the owner or supplier or consumer shall be carried out by the Electrical Inspector.

Provided that the supplier or owner or consumer has the option to get his installation inspected and tested by the Electrical Inspector of the Appropriate Government.

Provided further that every electrical installations of mines, oil fields and railways shall be periodically inspected and tested by the Electrical Inspector of the Appropriate Government.

Where the supplier is directed by the Central Government or the State Government, as the case may be, to inspect and test the installation, such supplier shall report on the condition of the installation to the consumer concerned in the Forms I, II and III as specified in Schedule-IV and shall submit a copy of such report to the Electrical Inspector.



Note. Forms I, II and III as specified in Schedule-IV have been included in Chapter on Testing and EIG

The Electrical Inspector may, on receipt of such report, accept the report submitted by the supplier or record variations as the circumstances of each case may require and may recommend that the defects may be rectified as per report.

In the event of the failure of the owner of any installation to rectify the defects in his installation pointed out by the Electrical Inspector in his report and within the time indicated therein, such installation shall be liable to be disconnected under the directions of the Electrical Inspector after serving the owner of such installation with a notice for a period not less than forty eight hours.

Provided that the installation shall not be disconnected in case an appeal is made under sub section (2) of section 162 of the Act and the appellate authority has stayed the orders of disconnection.

It shall be the responsibility of the owner of all installations to maintain and operate the installations in a condition free from danger and as recommended by the manufacturer or by the relevant codes of practice of the Bureau of Indian Standards.

Regulation 31- Testing of consumer's installation -

Upon receipt of an application for a new or additional supply of electricity and before connecting the supply or reconnecting the same after a period of six months, the supplier shall either test the installation himself or, accept the test results submitted by the consumer when the same has been duly signed by the licensed Elected Contractor.

The supplier shall maintain a record of test results obtained at each supply point to a consumer, in a Schedule-V.

If as a result of such inspection and test, the supplier is satisfied that the installation is likely to be dangerous, he shall serve, on the applicant a notice in writing requiring him to make such modifications as are necessary to render the installation safe and may refuse to connect or reconnect the supply until the required modifications have been completed.

Regulation 33-Precautions against leakage before connection-

The supplier shall not connect with his works the installation or apparatus on the premises of any applicant for supply unless he is reasonably satisfied that the connection will not at the time of making the connection cause a leakage from that installation or apparatus of a magnitude detrimental to safety which shall be checked by measuring the installation resistance as under,-

all equipments shall have the insulation resistance (IR) value as stipulated in the relevant Indian Standards;

on application of 500 V DC between each live conductor and earth for a period of one minute the insulation resistance of installation and equipment of voltage not exceeding 650 V shall be at least 1 MEGAOHM or as specified in the relevant Indian Standard;

on application of 2.5 kV-DC between each live conductor and earth for a period of one minute, the insulation resistance, of installation and equipment of voltage exceeding 650 V but not exceeding 33 kV shall be at least 5 MEGA OHM or as specified in the relevant Indian Standard.

If the supplier declines to make a connection under the provisions of sub- regulation (1) he shall convey to the applicant, the reasons in writing for so declining.

Regulation 34- Leakage on consumer's premises-

If the Electrical Inspector or the supplier has reasons to believe that there is leakage in the system of a

consumer which is likely to affect injuriously the use of electricity by the supplier or by other persons, or which is likely to cause danger, he may give the consumer notice in writing that he desires to inspect and test the consumer's installation.

If on such notice being given the consumer does not give all reasonable facilities for inspection and testing of his installation, or when an insulation resistance of the consumer's installation is so low as to prevent safe use of electricity, the supplier may, and if directed so to do by the Electrical Inspector shall discontinue the supply of electricity to the installation but only after giving to the consumer forty eight hours' notice in writing of disconnection of supply and shall not recommence the supply until he or the Electrical Inspector is satisfied that the cause of the leakage has been removed.

Regulation 35- **Supply and use of Electricity-**

The electricity shall not be supplied, transformed, converted, inverted or used or continued to be supplied, transformed, converted, inverted or used unless the conditions contained in sub-regulations (2) to (8) are complied with.

The following controls of requisite capacity to carry and break the current shall be placed as near as possible after the point of commencement of supply so as to be readily accessible and capable of being easily operated to completely isolate the supply to the installation, such equipment being in addition to any equipment installed for controlling individual circuits or apparatus, namely-

- A linked switch with fuse or a circuit breaker by consumers of voltage which does not exceed 650V;
- A linked switch with fuse or a circuit breaker by a consumer of voltage exceeding 650V but not exceeding 33 kV having aggregate installed transformer or apparatus capacity up to 1000 kVA to be supplied at voltage up to 11 kV and 2500 kVA at higher voltages (above 11 kV and not exceeding 33 kV);
- A circuit breaker by consumers at voltage exceeding 650 V but not exceeding 33 kV having an aggregate installed transformer and apparatus capacity above 1000kVA and supplied at voltage up to 11 kV and above 2500 KVA at higher voltages (above 11 kV and not exceeding 33 kV);
- A circuit breaker by a consumer of voltage exceeding 33 kV.

Provided that where the point of commencement of supply and the consumer apparatus are near each other, one linked switch with fuse or circuit breaker

In case of every transformer the following shall be provided, namely-

On primary side for transformers a linked switch with fuse or circuit breaker of adequate capacity.

Provided that the linked switch on the primary side of the transformer may be of such capacity as to carry the- full load current and to break only the magnetising current of the transformer. Provided further that for all transformers.

Having a capacity of 5000kVA and above installed before the year 2000; and

Having a capacity 1000kVA and above installed in or after the year 2000, a circuit breaker shall be provided.

Provided also that the linked switch on the primary side of the transformer shall not be required for the unit auxiliary transformer and generator transformer;

In respect of all transformers installed in or after the year 2000, on the secondary side of all transformers a circuit breaker of adequate rating shall be installed.

Provided that for suppliers transformers of capacity below 1000 KVA, a linked switch with fuse or circuit breaker of adequate rating shall be installed on secondary side.



Except in the case of composite control gear designed as a unit each distinct circuit is to be protected against excess energy by means of suitable cut-out or a circuit breaker of adequate breaking capacity suitably located and so constructed as to prevent danger from overheating, arcing or scattering of hot metal when it comes into operation and to permit for ready renewal of the fusible metal of the cut-out without danger.

The supply of electricity to each motor or a group of motors or other apparatus meant for operating one particular machine shall be controlled by a suitable linked switch or a circuit breaker or an emergency tripping device with manual reset of requisite capacity placed in such a position as to be adjacent to the motor or a group of motors or other apparatus readily accessible to and easily operated by the person in-charge and so connected in the circuit that by its means all supply of electricity can be cut off from the motor or group of motors or apparatus from any regulating switch, resistance of other device associated therewith.

All insulating materials shall be chosen with special regard to the circumstances of their proposed use and their mechanical strength shall be sufficient for their purpose and so far as is practicable of such a character or so protected as to maintain adequately their insulating property under all working conditions in respect of temperature and moisture; and

Adequate precautions shall be taken to ensure that no live parts are so exposed as to cause danger. Every consumer shall use all reasonable means to ensure that where electricity is supplied by a supplier no person, other than the supplier shall interfere with service lines and apparatus placed by the supplier on the premises of the consumer.

Regulation 36- Provisions for supply and use of electricity in multi-storied building more than 15 meters in height-

The connected load and voltage of supply above which inspection is to be carried out by an Electrical Inspector for a multi-storied building of more than fifteen meters height shall be notified by the Appropriate Government.

Before making an application for commencement of supply or recommencement of supply after an installation has been disconnected for a period of six months or more, the owner or occupier of a multi-storied building shall give not less than thirty days' notice in writing to the Electrical Inspector specify therein the particulars of installation and the supply of electricity shall not be commenced or recommenced within-this period, without the approval in writing of the Electrical Inspector.

The supplier or owner of the installation shall provide at the point of commencement of supply; a suitable isolating device with cut-out or breaker to operate on all phases except neutral in the 3-phase, 4-wire circuit and fixed in a conspicuous position at not more than 1.70 meters above the ground so as to completely isolate the supply to the building in case of emergency.

The owner or occupier of a multi-storied building shall ensure that electrical installations and works inside the building are carried out and maintained in such a manner as to prevent danger due to shock, and fire hazards, and the installation is carried out in accordance with the relevant codes of practice.

No other service pipes and cables shall be taken along the ducts provided for laying power cables and all ducts provided for power cables and other services shall be provided with fire barrier at each floor crossing.

Regulation 37- Conditions applicable to installations of voltage exceeding 250 Volts-

The following conditions shall, be complied with where electricity of voltage above 250 V is supplied, converted, transformed or used; namely-

All conductors, other than those of overhead lines, shall be completely enclosed in mechanically strong metal casing or metallic covering which is electrically and mechanically continuous and adequately protected against mechanical damage unless the said conductors are accessible only to a designated person or are installed and protected so as to prevent danger.

Provided that non-metallic conduits conforming to the relevant Indian Standard Specifications may be used for installations of voltage not exceeding 650 V.

All metal works, enclosing, supporting or associated with the installation, other than that designed to serve as a conductor shall be connected with an earthing system as per standards laid down in the Indian Standards in this regard and the provisions of regulation 41.

Every switchboard shall comply with the following,-

A clear space of not less than one meter in width shall be provided in front of the switchboard;

If there are any attachments or bare connections at the back of the switchboard, the space, if any, behind the switchboard shall be either less than twenty centimeters or more than seventy five centimeters in width, measured from the farthest protruding part of any attachment or conductor;

If the space behind the switchboard exceeds seventy five centimeters in width, there shall be a passage way from either end of the switchboard, clear to a height of 1.8 meters.

In case of installations provided in premises where inflammable materials including gases and chemicals are produced, handled or stored, the electrical installations, equipment and apparatus shall comply with the requirements of flame proof, dust tight, totally enclosed or any other suitable type of electrical fittings depending upon the hazardous zones as per the relevant Indian Standard Specifications.

Where an application has been made to a supplier for supply of electricity to any installation, he shall not commence the supply or where the supply has been discontinued for a period of six months and above, recommence the supply unless the consumer has complied with, in all respects the conditions of supply set out in these regulations.

Where a supplier proposes to supply or use electricity at or to recommence supply of voltage exceeding 250 V but not exceeding 650 V after it has been discontinued for a period of six months, he shall, before connecting or reconnecting the supply, give notice in writing of such intention to the Electrical Inspector.

If at any time after connecting the supply, the supplier is satisfied that any provision of these regulations are not being observed he shall give notice of the same in writing to the consumer and the

Electrical Inspector, specifying how the provisions have not been observed and to rectify such defects in a reasonable time and if the consumer fails to rectify such defects pointed out, he may discontinue the supply after giving the consumer a reasonable opportunity of being heard and recording reasons in writing and the supply shall be discontinued only on written orders of an officer duly notified by the supplier in this behalf and shall be restored with all possible speed after such defects are rectified by the consumer to the satisfaction of the supplier

Regulation 38- Appeal to Electrical Inspector in regard to defects -

If any applicant for a supply or a consumer is dissatisfied with the action of the supplier in declining to commence, to continue or to recommence the supply of electricity to his premises on the grounds that the installation is defective or is likely to be dangerous, he may appeal to the Electrical Inspector to test the installation and the supplier shall not, if the Electrical Inspector intimates that the installation is free from the defect or danger complained of, refuse supply to the consumer on the grounds aforesaid, and shall, within twenty four hours after the receipt of such, intimation from the Electrical Inspector, commence, continue or recommence the supply of electricity.



Any test for which application has been made under sub regulation (1) shall be carried out within seven days after the receipt of such application.

Regulation 39- **Precautions against failure of supply and notice of failures-**

The layout of the electric supply lines of the supplier for the supply of electricity throughout his area of supply shall under normal working conditions be sectionalised and so arranged, and provided with switchgear or circuit breakers, so located, as to restrict within reasonable limits the extent of the portion of the system affected by any failure of supply.

The supplier shall take all reasonable precautions to avoid any accidental interruptions of supply, and also to avoid danger to the public or to any employee or designated person when engaged on any operation during and in connection with the installation, extension, replacement, repair and maintenance of any works.

The supplier shall send to the Electrical Inspector a notice of failure of supply of such kind as the Electrical Inspector may from time to time require to be notified to him, and such notice shall be sent by the earliest mode of communication after the failure occurs or after the failure becomes known to the supplier and shall be in the Form given in Schedule-VI.

For the purpose of testing or for any other purpose connected with the efficient working of the suppliers installations, the supply of electricity may be discontinued by the supplier for such period as may be necessary, subject to not less than twenty four hours notice being given by the supplier to all consumers likely to be affected by such discontinuance.

Provided that no such notice shall be given in cases of emergency.

Regulation 40- **Test for resistance of insulation-**

Where any electric supply line for use at voltages not exceeding 650 V has been disconnected from a system for the purpose of addition, alteration or repair, such electric supply line shall not be reconnected to the system until the supplier or the owner has applied the test prescribed under regulation 33.

The provision under sub-regulation (1) shall not apply to overhead lines except overhead insulated cables, unless the Electrical Inspector otherwise directs in any particular case.

Regulation 41- **Connection with earth-**

The following conditions shall apply to the connection with earth of systems at voltage normally exceeding 125 V but not exceeding 650 V, namely-

Neutral conductor of a 3-phase, 4-wire system and the middle conductor of a 2-phase, 3-wire system shall be earthed by not less than two separate and distinct connections with a minimum of two different earth electrodes or such large number as may be necessary to bring the earth resistance to a satisfactory value both at the generating station and at the sub-station.

The earth electrodes so provided, shall be inter-connected to reduce earth resistance.

Neutral conductor shall also be earthed at one or more points along the distribution system or service line in addition to any connection with earth which may be at the consumer's premises.

In the case of a system comprising electric supply lines having concentric cables, the external conductor of such cables, shall be earthed by two separate and distinct connections with earth.

The connection with earth may include a link by means of which the connection may be temporarily interrupted for the purpose of testing or for locating fault.

In a direct current three wire system, the middle conductor shall be earthed at the generating station only and the current from the middle conductor to earth shall be continuously recorded by means of a recording ammeter, and if at any time the current exceeds one- thousandth part of the maximum supply current, immediate steps shall be taken to improve the insulation of the system.

Where the middle conductor is earthed by means of a circuit breaker with a resistance connected in parallel, the resistance shall not exceed ten ohms and on the opening of the circuit breaker, immediate steps shall be taken to improve the insulation of the system, and the circuit breaker shall be re-closed as soon as possible.

The resistance shall be used only as a protection for the ammeter in case of earths on the system and until such earths are removed and immediate steps shall be taken to locate and remove the earth.

In the case of an alternating current system, there shall not be inserted in the, connection with earth any impedance, other than that required solely for the operation of switchgear or instruments, cut-out or circuit breaker, and the result of any test made to ascertain whether the current, if any, passing through the connection with earth is normal, shall be duly recorded by the supplier.

No person shall make connection with earth by the aid of, nor shall he keep it in contact with, any water mains not belonging to him except with the consent of the owner thereof and of the Electrical Inspector.

Alternating current systems which are connected with earth as aforesaid shall be electrically interconnected.

Provided that each connection with earth is bonded to the metal sheathing and metallic armouring, if any, of the electric supply lines concerned.

The frame of every generator, stationary motor, portable motor, and the metallic parts, not intended as conductors, of all transformers and any other apparatus used for regulating or controlling electricity, and all electricity consuming apparatus, of voltage exceeding 250 V but not exceeding 650 V shall be earthed by the owner by two separate and distinct connections with earth.

Neutral point of every generator and transformer shall be earthed by connecting it to the earthing system by not less than two separate and distinct connections.

All metal casing or metallic coverings containing or protecting any electric supply line or apparatus shall be connected with earth and shall be so joined and connected across all junction boxes and other openings as to make good mechanical and electrical connection throughout their whole length.

Provided that conditions mentioned in this regulation shall not apply, where the supply voltage does not exceed 250 V and the apparatus consists of wall tubes or brackets, electroliers, switches, ceiling fans or other fittings, other than portable hand lamps and portable and transportable apparatus, unless provided with earth terminal and to class-II apparatus and appliances.

Provided further that where the supply voltage is not exceeding 250 V and where the installations are either new or renovated, all plug sockets shall be of the three pin type, and the third pin shall be permanently and efficiently earthed.

All earthing systems shall-

Consist of equipotential bonding conductors capable of carrying the prospective earth fault current and a group of pipes, rods and plate electrodes for dissipating the current to the general mass of earth without exceeding the allowable temperature limits as per relevant Indian Standards in order to maintain all non-current carrying metal works reasonably at earth potential and to avoid dangerous contact potentials being developed on such metal works;



Limit earth resistance sufficiently low to permit adequate fault current for the operation of protective devices in time and to reduce neutral shifting;

Be mechanically strong, withstand corrosion and retain electrical continuity during the life of the installation and all earthing systems shall be tested to ensure efficient earthing, before the electric supply lines or apparatus are energised.

All earthing systems belonging to the supplier shall in addition, be tested for resistance on dry day during the dry season not less than once every two years.

A record of every earth test made and the result thereof shall be kept by the supplier for a period of not less than two years after the day of testing and shall be available to the Electrical Inspector when required.

Explanation- The expression “Class-II apparatus and appliance” shall have the same meaning as is assigned to it in the relevant Indian Standards.

Regulation 42- Earth leakage protective device-

The supply of electricity to every electrical installation other than voltage not exceeding 250 V, below 2 kW and those installations of voltage not exceeding 250V, which do not attract provisions of section 54 of the Act, shall be controlled by an earth leakage protective device whose maximum earth leakage threshold for tripping should not exceed 30 milliamps for domestic connections and 100 milliamps for all other installations, so as to disconnect the supply instantly on the occurrence of earth fault or leakage of current.

Provided that such earth leakage protective device shall not be required for overhead supply lines having protective devices which are effectively bonded to the neutral of supply transformers and conforming to Regulation 73.

Regulation 43- Approval by Electrical Inspector and self-certification

Every electrical installation of notified voltage and below shall be inspected, tested and self-certified by the owner or supplier or consumer, as the case may be, of the installation before commencement of supply or recommencement after shutdown for six months and above for ensuring observance of safety measures specified under these regulations and such owner or supplier or consumer, as the case may be, shall submit the report of self-certification to the Electrical Inspector in the formats as framed and issued by the Authority.

Provided that the electrical installation so self-certified shall be considered fit for the commencement of supply or recommencement after shutdown for six months only after the report of self-certification is duly received by the office of Electrical Inspector.

Provided further that the owner or supplier or consumer, as the case may be, has the option to get his installation inspected and tested by the Electrical Inspector of the Appropriate Government.

Notwithstanding anything contained in Clause (a), every electrical installation covered under section 54 of the Act including every electrical installation of mines, oil fields and railways shall be inspected and tested by the Electrical Inspector of the Appropriate Government as specified in sub-regulation (3) The voltage above which inspection and testing of electrical installations including installations of supplier or consumer shall be carried out by the Electrical Inspector shall be notified by the Appropriate Government.

Every electrical installation of voltage above the notified voltage and all the apparatus of the generating stations and above the capacity specified under regulation 32, shall be inspected and tested

by the Electrical Inspector before commencement of supply or recommencement after shutdown for six months and above for ensuring observance of safety measures specified under these regulations.

The Electrical Inspector shall, on receipt of the report of self-certification of electrical installation referred in sub-regulation (1), verify the report submitted by the owner or supplier or consumer, as the case may be, and record variation, if any, in accordance with these regulations;

The Electrical Inspector in case of variations which require rectification, direct the owner or supplier or consumer to rectify the same within a period of fifteen days from the date of recording of the variations and the owner or supplier or consumer, as the case may be, shall send a report of compliance to the Electrical Inspector;

If the Electrical Inspector, is not satisfied with the compliance report submitted under Clause (b), shall inspect the electrical installation within a period of ninety days from the date of submission of self-certification report and intimate the owner or supplier or consumer of the installation the defects, if any, for rectification within fifteen days;

If the owner or supplier or consumer, as the case may be, fails to comply the directions as given under Clause (c), such installation shall be liable to be disconnected under the directions of the Electrical Inspector after serving the owner or supplier or consumer, as the case may be, of such installation with a notice for a period not less than forty-eight hours

Before making an application to the Electrical Inspector for permission to commence or recommence supply in installations above the notified voltage after an installation has been disconnected for six months, the supplier shall ensure that electric supply lines or apparatus of more than notified voltage belonging to him are placed in position, properly joined, and duly completed and examined, and the supply of electricity shall not be commenced by the supplier for installations of voltage needing inspection under these regulations unless the provisions of regulations 12 to 29, regulations 33 to 35, regulations 44 to 51 and regulations 55 to 77 have been complied with and the approval in writing of the Electrical Inspector has been obtained by him.

Provided that the supplier may energise the aforesaid electric supply lines or apparatus for the purpose of tests specified in regulation 46 and after successful testing, the owner may energise the section of a line to prevent theft of conductors or towers, subject to compliance of all the provisions of these regulations.

The owner of any installations of voltage above the notified voltage shall, before making application to the Electrical Inspector for approval of his installation or additions thereto, test every circuit or additions thereto, other than an overhead line, and satisfy himself that they withstand the application of the testing voltage set out in sub-regulation (1) of regulation 46 and shall duly record the results of such tests and forward them to the Electrical Inspector.

Provided that an Electrical Inspector may direct such owner to carry out such tests as he deems necessary or accept the certified tests of the manufacturer in respect of any particular apparatus in place of the tests required by this regulation.

The owner of any installation who makes any addition or alteration to his installation shall not connect to the supply his apparatus or electric supply lines, comprising the said alterations or additions, unless and until such alteration or addition has been approved in writing by the Electrical Inspector or self-certified by the owner of the installation, as the case may be.

Regulation 45- Inter-locks and protection for use of electricity at voltage exceeding 650 Volts-

The owner shall ensure the following, namely-



Isolators and the controlling circuit breakers shall be interlocked so that the isolators cannot be operated unless the corresponding breaker is in open position;

Isolators and the corresponding earthing switches shall be inter-locked so that no earthing switch can be closed unless and until the corresponding isolator is in open position;

Where two or more supplies are not intended to be operated in parallel, the respective circuit breakers or linked switches controlling the supplies shall be inter-locked to prevent possibility of any inadvertent paralleling or feedback;

When two or more transformers are operated in parallel, the system shall be so arranged as to trip the secondary breaker of a transformer in case the primary breaker of that transformer trips;

All gates or doors which give access to live parts of an installation shall be inter-locked in such a way that these cannot be opened unless the live parts are made dead and proper discharging and earthing of these parts should be ensured before any person comes in close proximity of such parts;

Where two or more generators operate-t in parallel and neutral switching is adopted, inter-lock shall be provided to ensure that generator breaker cannot be closed unless one of the neutrals is connected to the earthing system.

The following protection shall be provided in all systems and circuits to automatically disconnect the supply under abnormal conditions, namely-

Over current protection to disconnect the supply automatically if the rated current of the equipment, cable or supply line is exceeded for a time which the equipment, cable or supply line is not designed to withstand;

Earth fault or earth leakage protection to disconnect the supply automatically if the earth fault current exceeds the limit of current for keeping the contact potential within the reasonable values;

Gas pressure type and winding and oil temperature protection to give alarm and tripping shall be provided on all transformers of ratings 1000 kVA and above;

Transformers of capacity 10 MVA and above shall be protected against incipient faults by differential protection;

All generators with rating of 100 kVA and above shall be protected against earth fault or leakage;

All generators of rating 1000 kVA and above shall be protected against faults within the generator winding using restricted earth fault protection or differential protection or by both;

High speed bus bar differential protection along with local breaker back up protection shall be commissioned and shall always be available at all 132 kV and above voltage sub-stations and switching stations and generating stations connected with the grid.

Provided that in respect of existing 132 kV sub-stations and switching stations having more than one incoming feeders, the high speed bus bar differential protection along with local breaker back up protection, shall be commissioned and shall always be available;

Every generating station and sub-station connected to the grid at 220 kV and above shall be provided with disturbance recording and event logging facilities and all such equipment shall be provided with time synchronization facility for global common time reference but wherever numerical relays with provision of recording fault data are installed, disturbance recorder and event logger may not be installed;

Distance protection and carrier communication protection shall be provided for all lines connecting to 400/220 kV substation.

Regulation 46- Testing, Operation and Maintenance-

Before approval is accorded by the Electrical Inspector under regulation 43 the manufacturer's test certificates shall, if required, be produced for all the routine tests as required under the relevant Indian Standards.

No new apparatus, cable or supply line of voltage exceeding 650 Volts shall be commissioned unless such apparatus, cable or supply line are subjected to site tests as per relevant code of practice of the Bureau of Indian Standards.

No apparatus, cable or supply line of voltage exceeding 650 V which has been kept disconnected, for a period of six months or more, from the system for alterations or repair, shall be connected to the system until such apparatus, cable or supply line are subjected to the relevant tests as per code of practice of Bureau of Indian Standards.

Notwithstanding the provisions of this regulation, the Electrical Inspector may require certain tests to be carried out before or after charging the installations.

All apparatus, cables and supply lines shall be maintained in healthy conditions and tests shall be carried out periodically as per the relevant code of practice of the Bureau of Indian Standards.

Records of all tests, tripping, maintenance works and repairs of all equipment's cables and supply lines shall be duly kept in such a way that these records can be compared with earlier ones.

It shall be the responsibility of the owner of all installations of voltage exceeding 650 V to maintain and operate the installations in a condition free from danger and as recommended by the manufacturer or by the relevant codes of practice of the Bureau of Indian Standards.

Failures of transformers and reactors of 20 MVA or MVAR and higher capacity shall be reported by the consumer and the suppliers of electricity, within forty eight hours of the occurrence of the failure, to the Central Electricity Authority and the reasons for failure and measures to be taken to avoid recurrence of failure shall be sent to the Central Electricity Authority within one month of the occurrence in the format given in Schedule-IX.

Regulation 48- Connection with earth for apparatus exceeding 650V -

All non-current carrying metal parts associated with an installation of voltage exceeding 650 V shall be effectively earthed to a grounding system or mat which shall,-

Limit the touch and step potential to tolerable values;

Limit the ground potential rise to tolerable values so as to prevent danger due to transfer of potential through ground, earth wires, cable sheath, fences, pipelines, etc.;

Maintain the resistance of the earth connection to such a value as to make operation of the protective device effective;

In the case of star connected system with earthed neutrals or delta connected system with earthed artificial neutral point,-

The neutral point of every generator and transformer shall be earthed by connecting it to the earthing system not by less than two separate and distinct connections:

Provided, that the neutral point of a generator may be connected to the, earthing system through an impedance to limit the fault current to the earth.

Provided further that in the case of multi-machine systems neutral switching may be resorted to, for limiting the injurious effect of harmonic current circulation in the system;



The generator or transformer neutral shall be earthed through a suitable impedance where an appreciable harmonic current flowing in the neutral connection causes interference, with communication circuits;

In case of the delta connected system the neutral point shall be obtained by the insertion of a grounding transformer and current limiting resistance or impedance wherever considered necessary at the commencement of such a system.

In case of generating stations, sub-stations and industrial installations of voltage exceeding 33 kV, the system neutral earthing and protective frame earthing may be, if system design so warrants integrated into common earthing grid provided the resistance to earth of combined mat does not cause the step and touch potential to exceed its permissible values.

Single phase systems of voltage exceeding 650 V shall be effectively earthed.

In the case of a system comprising electric supply lines having concentric cables, the external conductor shall be connected with earth.

Where a supplier proposes to connect with earth an existing system for use at voltage exceeding 650 V which has not hitherto been so connected with earth, he shall give not less than fourteen days' notice in writing together with particulars of the proposed connection with earth to the telegraph-authority established under the Indian Telegraph Act, 1885 (13 of 1885).

Where the earthing lead and earth connection are used only in connection with earthing guards erected under overhead lines of voltage exceeding 650 V where they cross a telecommunication line or a railway line, and where such lines are equipped with earth leakage, the earth resistance shall not exceed twenty five ohms and the project authorities shall obtain No Objection Certificate (NOC) from Railway Authorities and Power and Telecommunication Co-ordination Committee before energisation of the facilities.

Every earthing system belonging to either the supplier or the consumer shall be tested for its resistance to earth on a dry day during dry season not less than once a year and records of such tests shall be maintained and produced, if so required, before the Electrical Inspector.

Regulation 49- General conditions as to transformation and control of electricity-

Where electricity of voltage exceeding 650 V is transformed, converted, regulated or otherwise controlled in sub-stations or switching stations including outdoor substations and outdoor switching stations to be transformed or in street boxes constructed underground, the following provisions shall be observed, namely-

Substations and switching stations shall preferably be erected above ground, but where necessarily constructed; underground due provisions for ventilation and drainage shall be made and any space housing switchgear shall not be used for storage of any materials especially inflammable and combustible materials or refuse;

Outdoor sub-stations except pole type sub-stations and outdoor switching stations shall, unless the apparatus is completely enclosed in a metal covering connected with earth, the said apparatus also being connected with the system by armoured cables, be efficiently protected by fencing not less than 1.8 meters in height or other means so as to prevent access to the electric supply lines and apparatus therein by an undesignated person and the fencing of such area shall be earthed efficiently; Underground street boxes, other than sub-stations, which contain transformers shall not contain switches or other apparatus, and switches, cut-outs or other apparatus required for controlling or other purposes shall be fixed in separate receptacle above ground wherever practicable.

Where electricity is transformed, suitable connection shall be made by connecting with earth a point of the

system at the lower voltage and also to guard against danger by reason of the said system becoming accidentally charged above its normal voltage by leakage from a contact with the system at the higher voltage.

Regulation 55- **Material and strength-**

All conductors of overhead lines other than those specified in regulation 68 shall have a breaking strength of not less than 350 kg.

Where the voltage does not exceed 250 V and the span is of less than fifteen meters and is drawn through the owner's or consumer's premises, a conductor having an actual breaking strength of not less than 150 kg may be used.

Regulation 56- **Joints-**

No conductor of an overhead line shall have more than one joint in a span and joints between conductors of overhead lines shall be mechanically and electrically secure under the conditions of operation.

The ultimate strength and the electrical conductivity of the joint shall be as per relevant Indian Standards.

Regulation 58- **Clearance above ground of the lowest conductor of overhead lines-**

No conductor of an overhead line, including service lines, erected across a street shall at any part thereof be at a height of less than-

- i. for lines of voltage not exceeding 650 Volts -5.8 meters
- ii. for lines of voltage exceeding 650 Volts but not exceeding 33 kV- 6.1 meters

No conductor of an overhead line, including service lines, erected along any street shall at any part thereof be at a height less than-

- i. for lines of voltage not exceeding 650Volts - 5.5 meters
- ii. for lines of voltage exceeding 650 Volts but not exceeding 33 kV- 5.8 meters

No conductor of an overhead line including service lines, erected elsewhere than along or across any street shall be at a height less than –

- i. for lines of voltage up to and including 11,000 Volts, if bare- 4.6 meters for lines of voltage up to and including 11,000 Volts, if insulated- 4.0 meters
- ii. for lines of voltage exceeding 11,000 Volts but not exceeding 33 kV-5.2 meters
- iii. For lines of voltage exceeding 33 kV the clearance above ground shall not be less than 5.2 meters plus

0.3 metre for every 33,000 Volts or part thereof by which the voltage of the line exceeds 33,000 Volts. Provided that the minimum clearance along or across any street shall not be less than 6.1 meters.

For High Voltage Direct Current (HVDC) lines, the clearance above ground shall not be less than:-

Sl. No.	DC Voltage (kV)	Ground Clearance (mtrs.)
1	100 kV	6.1
2	200 kV	7.3
3	300 kV	8.5
4	400 kV	9.4
5	500 kV	10.6
6	600 kV	11.8
7	800kV	13.9

Ground clearances shall be as specified in schedule-X.

Regulation 60- Clearance from buildings of lines of voltage and service lines not exceeding 650 Volts-

An overhead line shall not cross over an existing building as far as possible and no building shall be constructed under an existing overhead line.

Where an overhead line of voltage not exceeding 650 V passes above or adjacent to or terminates on any building, the following minimum clearances from any accessible point, on the basis of maximum sag, shall be observed, namely-

For any flat roof, open balcony, varandah roof and lean-to-roof-

- i. when the line passes above the building a vertical clearance of 2.5 meters from the highest point, and when the line passes adjacent to the building a horizontal clearance of 1.2 meters from the nearest point, and

For pitched roof-

- i. when the line passes above the building a vertical clearance of 2.5 meters immediately under the line, and
- ii. When the line passes adjacent to the building a horizontal clearance of 1.2 meters.
- iii. Any conductor so situated as to have a clearance less than that specified above shall be adequately insulated and shall be attached at suitable intervals to a bare earthed bearer wire having a breaking strength of not less than 350 kg.

The horizontal clearance shall be measured when the line is at a maximum deflection from the vertical due to wind pressure.

Vertical and horizontal clearances shall be as specified in schedule-X.

Explanation: - For the purpose of this regulation, the expression “building” shall be deemed to include any structure, whether permanent or temporary.

Regulation 61- Clearances from buildings of lines of voltage exceeding 650 V-

An overhead line shall not cross over an existing building as far as possible and no building shall be constructed under an existing overhead line.

Where an overhead line of voltage, exceeding 650 V passes above or adjacent to any building or part of a building it shall have on the basis of maximum sag a vertical clearance above the highest part of the building immediately under such line, of not less than-

for lines of voltages exceeding 650 Volts up to and including 33,000 Volts - 3.7 meters

for lines of voltages exceeding 33 kV-3.7 meters plus 0.30 metre for every additional 33,000 Volts or part thereof.

The horizontal clearance between the nearest conductor and any part of such building shall, on the basis of maximum deflection due to wind pressure, be not less than-

- i. for lines of voltages exceeding 650 V up to and including 11,000 Volts- 1.2 meters
- ii. for lines of voltages exceeding 11,000 V and up to and including 33,000 V- 2.0 meters
- iii. for lines of voltages exceeding 33 kV-2.0 meters plus 0.30 metre for every additional 33kV or part thereof

For High Voltage Direct Current (HVDC) systems, vertical clearance and horizontal clearance, on the basis of maximum deflection due to wind pressure, from buildings shall be maintained as below:

Sl. No.	DC Voltage (kV)	Vertical Clearance (mtrs.)	Horizontal Clearance (mtrs.)
1	100 kV	4.6	2.9
2	200 kV	5.8	4.1
3	300 kV	7.0	5.3
4	400 kV	7.9	6.2
5	500 kV	9.1	7.4
6	600 kV	10.3	8.6
7	800 kV	12.4	10.7

Vertical and horizontal clearances shall be as specified in schedule-X.

Explanation: - For the purpose of this regulation the expression “building” shall be deemed to include any structure, whether permanent or temporary.

Regulation 64- Transporting and storing of material near overhead lines.-

No rods, pipes or similar materials shall be taken below, or in the vicinity of, any bare overhead conductors or lines if these contravene the provisions of regulations 60 and 61 unless such materials” are transported under the direct supervision of a person designated in this behalf by the owner of such overhead conductors or lines. No rods, pipes or other similar materials shall be brought within the flash over distance of bare live conductors or lines.

No material or earth work or Agricultural produce shall be dumped or stored, no trees grown below or in the vicinity of, bare overhead conductors, or lines to contravene the provision of regulations 60 and 61.

No flammable material shall be stored under the electric supply line.

No fire shall be allowed above underground cables.

Firing of any material below electric lines shall be prohibited.

Regulation 69- Lines crossing or approaching each other and lines crossing street and road-

Where an overhead line crosses or is in proximity to any telecommunication line, the owner of either the overhead line or the telecommunication line, whoever lays his line later, shall arrange to provide for protective devices or .guarding arrangement and shall observe the following provisions, namely-

When it is intended to erect a telecommunication line or an overhead line which will cross or be in proximity to an overhead line or a telecommunication line, as the case may be, the person proposing to erect such line shall give one month’s notice of his’ intention so to do along with the relevant details of protection and drawings to the owner of the existing line;

Guarding shall be provided where lines of voltage not exceeding 33 kV cross a road or street;

Where an overhead line crosses or is in proximity to another overhead line, guarding arrangements shall be provided so to guard against the possibility of their coming into contact with each other;

Where an overhead line crosses another overhead line, clearances shall be as under-

(Minimum clearances in meters between lines crossing each other)

S. No	Nominal System Voltage	11-66 kV	110-132 kV	220 kV	400 kV	800kV
1	Low and Medium	2.44	3.05	4.58	5.49	7.94
2	11-66 kV	2.44	3.05	4.58	5.49	7.94

S. No	Nominal System Voltage	11-66 kV	110-132 kV	220 kV	400 kV	800kV
3	110-132 kV	3.05	3.05	4.58	5.49	7.94
4	220 kV	4.58	4.58	4.58	5.49	7.94
5	400 kV	5.49	5.49	5.49	5.49	7.94
6	800kV	7.94	7.94	7.94	7.94	7.94

Provided that no guarding are required when line of voltage exceeding 33 kV crosses over another line of 250 V and above voltage or a road or a tram subject to the condition that adequate clearances are provided between the lowest conductor of the line of voltage exceeding 33 kV and the top most conductor of the overhead line crossing underneath the line of voltage exceeding 33 kV and the clearances as stipulated in regulation 58 from the topmost surface of the road maintained;

Where an overhead direct current (DC) line crosses another overhead line, clearances shall be as under.

(Minimum clearances in meters between AC and DC lines crossing each other)

S No	System Voltage AC/DC	100kV DC	200kV DC	300kV DC	400kV DC	500kV DC	600kV DC
1	Low and Medium AC	3.05	4.71	5.32	6.04	6.79	7.54
2	11-66 kV AC	3.05	4.71	5.32	6.04	6.79	7.54
3	110-132 kV AC	3.05	4.71	5.32	6.04	6.79	7.54
4	220 kV AC	4.58	4.71	5.32	6.04	6.79	7.54
5	200 kV DC	4.71	4.71	5.32	6.04	6.79	7.54
6	300 kV AC	5.32	5.32	5.32	6.04	6.79	7.54
7	400 kV AC	5.49	5.49	5.49	6.04	6.79	7.54
8	400 kV DC	6.04	6.04	6.04	6.04	6.79	7.54
9	500 kV DC	6.79	6.79	6.79	6.79	6.79	7.54
10	600 kV DC	7.54	7.54	7.54	7.54	7.54	7.54
11	800 kV DC	7.94	7.94	7.94	7.94	7.94	7.94

A person erecting or proposing to erect a line which may cross or be in proximity with an existing line, shall provide arrangements on his own line or require the owner of the other overhead line to provide guarding arrangements as referred to in Clause (iii) and (iv);

In all cases referred to in this regulation the expenses of providing the guarding arrangements or protective devices shall be borne by the person whose line was last erected;

Where two lines cross, the crossing shall be made as nearly at right angles as the nature of the case admits and as near the support of the line as practicable, and the support of the lower line shall not be erected below the upper line;

The guarding arrangements shall ordinarily be carried out by the owner of the supports on which it is made and he shall be responsible for its efficient maintenance.

Regulation 70- Guarding-

Where guarding is required under these regulations the following shall be observed, namely:-

Every guard-wire shall be connected with earth at each point at which its electrical continuity is broken;

Every guard-wire shall have an actual breaking strength of not less than 635 kg and if made of iron or steel, shall be galvanised;

Every guard-wire or cross-connected systems of guard-wires shall have sufficient current-carrying



capacity to ensure them rendering dead, without risk of fusing of the guard-wire or wires, till the contact of any live wire has been removed.

In the case of a line crossing over a trolley wire the guarding shall be subjected to the following conditions, namely:-

Where there is only one trolley-wire, two guard wires shall be erected as in Diagram-A;

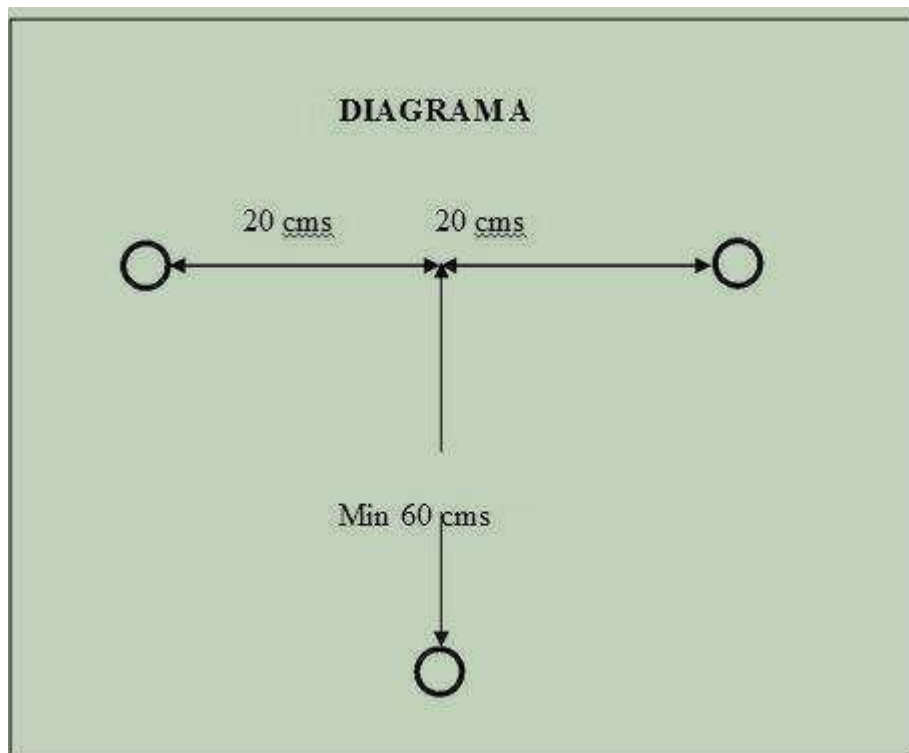
Where there are two trolley -wires and the distance between them does not exceed 40cms, two guard-wires shall be erected as in Diagram-B;

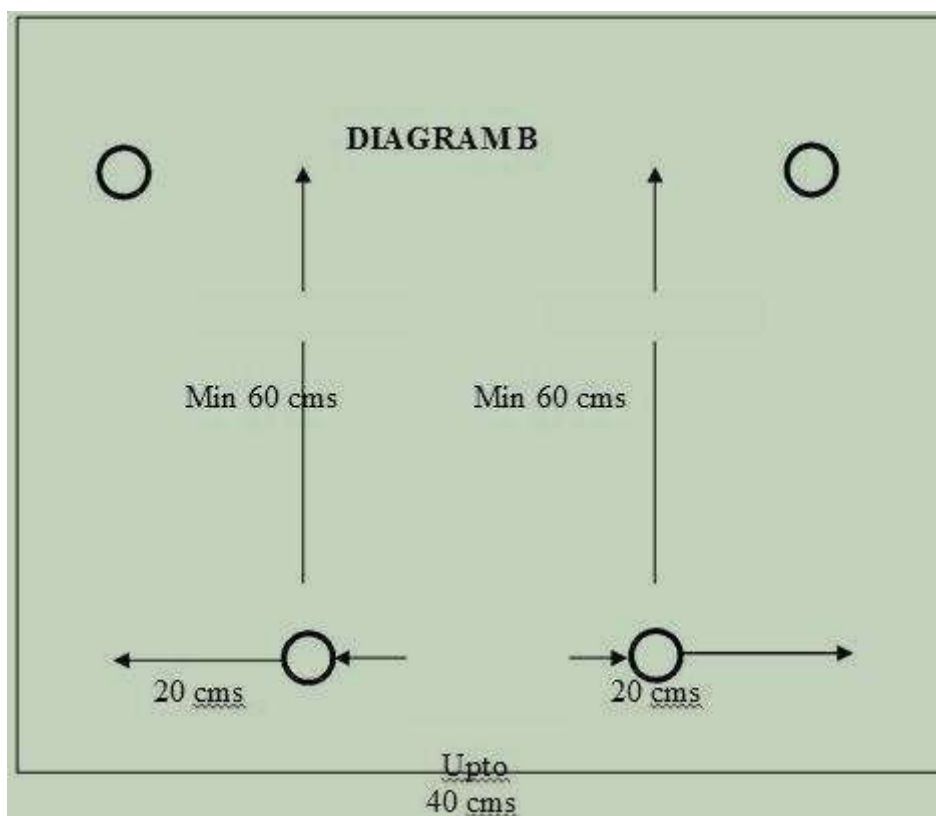
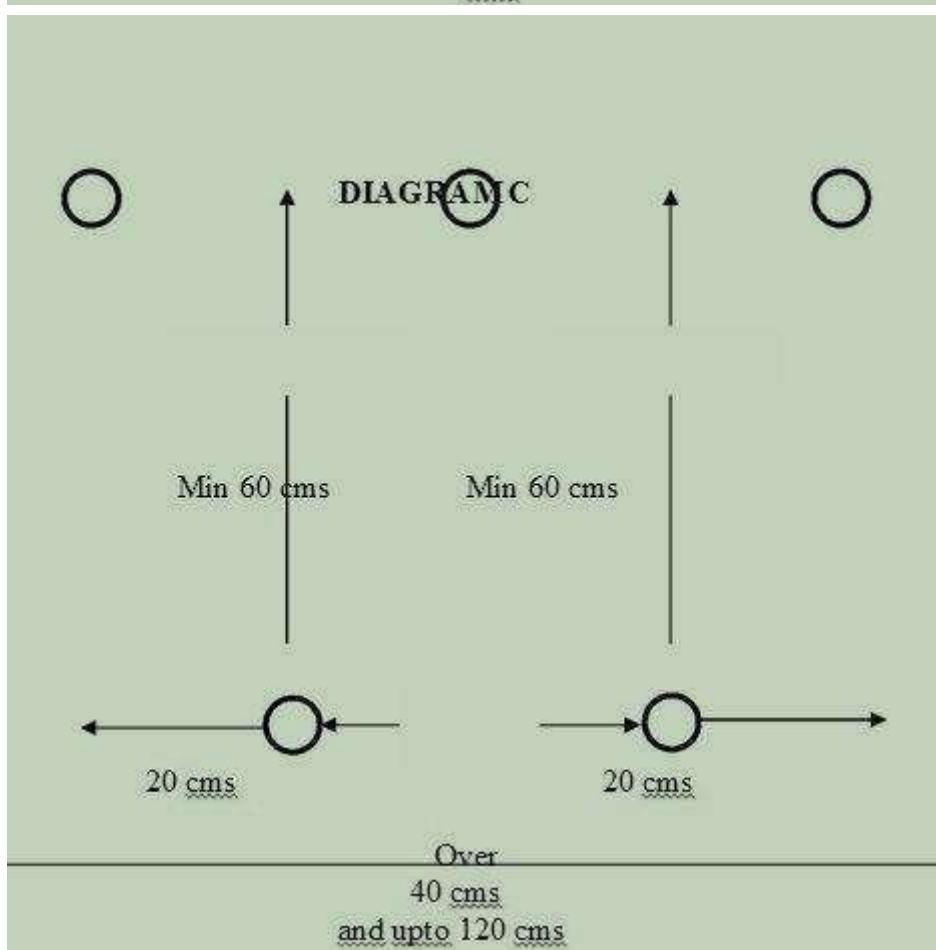
Where there are two trolley wires and the distance between them exceeds 40cms but does not exceed 1.2 meters, three guard-wires shall be erected as in Diagram-C;

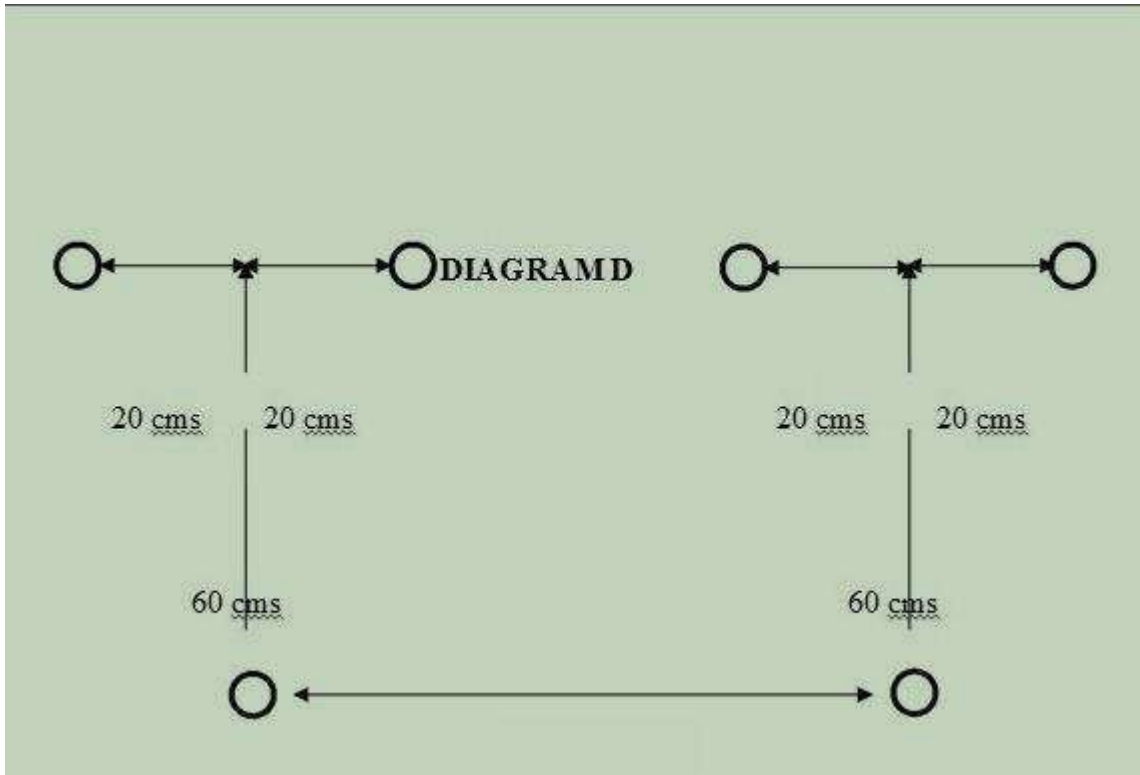
Where there are two trolley-wires and the distance between them exceeds 1.2 meters, each trolley-wire shall be separately guarded as in DIAGRAM-D;

The rise of trolley boom shall be so limited that when the trolley leaves the trolley-wire, it shall not foul the guard-wires; and

Where a telegraph-line, is liable to fall or be blown down upon an arm, stay- wire or span-wire and so slide-down upon a trolley-wire, guard hooks shall be provided to prevent such sliding.







Regulation 71- Service lines from overhead lines–

No service-line of tapping shall be taken off an overhead line except at a point of support:

Provided that the number of tapping per conductor shall not be more than four in case of connections at voltage not exceeding 650 V.

Regulation 72- Earthing-

All metal supports and all reinforced and pre-stressed cement concrete supports of overhead lines and metallic fittings attached thereto, shall be either permanently and efficiently earthed by providing a continuous earth wire and securely fastening to each pole and connecting with earth ordinarily at three points in every km. with the spacing between the points being as nearly equidistant as possible or each support and the metallic fitting attached thereto shall be efficiently earthed.

Metallic bearer wire used for supporting -insulated wire of overhead service lines of voltage not exceeding 650 V shall be efficiently earthed or insulated.

Each stay-wire shall be similarly earthed unless insulator has been placed in it at a height not less than 3.0 meters from the ground.

Regulation 73- Safety and protective devices-

Every overhead line Which is not being suspended from a dead bearer wire, not being covered with insulating material and not being a trolley-wire, is erected over any part of a street or other public place or in any factory or mine or on any consumer's premises shall be protected with earth guarding for rendering the line electrically harmless in case it breaks.

An Electrical Inspector may, by notice in writing, require the owner of any such overhead line, wherever it may be erected, to protect it in the manner specified in sub- regulation (1).

The owner of every overhead line of voltage exceeding 650 V shall make adequate arrangements as per relevant Indian Standards to prevent undesigned persons from ascending any of the supports of such

overhead lines which can be easily climbed upon without the help of a ladder or special appliances.

Explanation- For the purpose of this regulation, rails, reinforced cement concrete poles and pre-stressed cement concrete poles without steps, tubular poles, wooden supports without steps, I- sections and channels' shall be deemed as supports which cannot be easily climbed upon.

Regulation 74- **Protection against lightning-**

The owner of every overhead line, sub-station or generating station which is exposed to lightning shall adopt efficient means for diverting to earth any electrical surges due to lightning which may result into injuries.

The earthing lead for any lightning arrestor shall not pass through any iron or steel pipe, but shall be taken as directly as possible from the lightning arrestor "without touching any metal part to a separate-vertical ground electrode or junction of the earth mat already provided for the sub- station of voltage exceeding 650 V subject to the avoidance of bends wherever practicable.

Regulation 75- **Unused overhead lines–**

Where an overhead line ceases to be used as an electric supply line.

The owner shall maintain it in a safe mechanical condition in accordance with regulation 57 or remove it.

The Electrical Inspector shall, by a notice in writing served on the owner, require him to maintain it in a safe mechanical condition or to remove it within thirty days of the receipt of the notice.

Regulation 76- **Laying of cables–**

No underground telecommunication cable shall be laid without a minimum separation distance of 0.6 meters to the underground power cable of voltage exceeding 33 kV.

No underground power cable of voltage exceeding 33 kV shall be laid without a minimum underground depth of 1.2 meters.

Regulation 77- **Protection against electromagnetic interference –**

The owner of every overhead power line of voltage level 11 kV or higher shall submit proposal for obtaining Power Telecommunication Co-ordination Committee clearance to ensure safety of the personnel and telecom equipment.

***Note 1:** Regulations 78 through 92 pertaining to Safety requirements for Electric Traction have not been included as the extant rules/regulations are already covered in detail in Indian Railways Manual of AC Traction Maintenance and Operation.*

***Note 2:** Regulations 93 through 115 pertaining to Safety requirements for mines and oil fields have not been covered as they are not applicable to Indian Railways.*

Regulation 116- **Deviations-**

The Central Government or the State Government, as the case may. be, by order in writing, allow deviations in respect of matters referred in these regulations except regulation 30.

Regulation 117- **General safety requirement for electric vehicle charging stations –**

All electric vehicle charging stations shall be designed, installed, tested, certified, inspected and connected in accordance with the provisions of this chapter.

All electric vehicle charging stations shall be provided with protection against the overload of input supply and output supply fittings.

All electric vehicle charging points shall be installed so that any socket-outlet of supply is at least 800 millimeter above the finished ground level.

A cord extension set or second supply lead shall not be used in addition to the supply lead for the connection of the electric vehicle to the electric vehicle charging point and it shall be so constructed so that it cannot be used as a cord extension set.

An adaptor shall not be used to connect a vehicle connector to a vehicle inlet.

The electric vehicle parking place shall be such that the connection on the vehicle when parked for charging shall be within five meter from the electric vehicle charging point.

Portable socket-outlets are not permitted to be used for electric vehicle charging.

Suitable lightning protection system shall be provided for the electric vehicles charging stations as per Indian Standards Code IS/ IEC 62305.

The electric vehicle charging station shall be equipped with a protective device against the uncontrolled reverse power flow from vehicle.

One second after having disconnected the electric vehicle from the supply (mains), the voltage between accessible conductive parts or any accessible conductive part and earth shall be less than or equal to 42.4 V peak (30 V rms) , or 60 V D.C., and the stored energy available shall be less than 20 J (as per IEC 60950) and if the voltage is greater than 42.4 V peak (30 V rms) or 60 V D.C., or the energy is 20J or more, a warning label shall be attached in an appropriate position on the charging stations.

A vehicle connector used for Direct Current (D.C.) charging shall be locked on a vehicle inlet if the voltage is higher than 60 V D.C. and the vehicle connector shall not be unlocked (if the locking mechanism is engaged) when hazardous voltage is detected through charging process including after the end of charging and in case of charging system malfunction, a means for safe disconnection shall be provided.

The Direct Current (D.C.) electric vehicle charging point shall disconnect supply of electricity to prevent overvoltage at the battery, if output voltage exceeds maximum voltage limit sent by the vehicle.

The electric vehicle charging points shall not energize the charging cable when the vehicle connector is unlocked and the voltage at which the vehicle connector unlocks shall be lower than 60V.

Regulation 118- **Earth protection system for charging stations –**

All residual current device for the protection of supplies for electric vehicle shall, Have a residual operating current of not greater than 30 mA;

Interrupt all live conductors, including the neutral; and

Have a performance at least equal to Type A and be in conformity with IS 732-2018.

All residual current devices used for the protection of supplies to electric vehicle shall be permanently marked to identify their function and the location of the charging station or socket outlet they protect.

Each electric vehicle charging points shall be supplied individually by a dedicated final sub-circuit protected by an overcurrent protective device complying with IEC 60947-2, IEC 60947-6-2 or the IEC 60269 series and the overcurrent protective device shall be part of a switchboard. Co-ordination of various protective devices shall be required.

Where required for service reasons, discrimination (selectivity) shall be maintained between the



residual current device protecting a connecting point and a residual current device installed upstream. All electric vehicle charging stations shall be supplied from a sub-circuit protected by a voltage independent residual current device and also providing personal protection that is compatible with a charging supply for an electric vehicle.

All electric vehicle charging stations shall be provided with an earth continuity monitoring system that disconnects the supply in the event that the earthing connection to the vehicle becomes ineffective.

Earthing of all electric vehicle charging stations shall be as per IS 732.

The cable may be fitted with an earth-connected metal shielding and the cable insulation shall be wear resistant and maintain flexibility over the full temperature range.

A protective earth conductor shall be provided to establish an equipotential connection between the earth terminal of the supply and the conductive parts of the vehicle which shall be of sufficient rating to satisfy the requirements of IEC 60364-5-54.

Regulation 119- Requirement to prevent fire for electric vehicle charging stations-

Firefighting system for charging stations shall be provided in accordance with the provisions of these regulations.

Enclosure of charging stations shall be made of fire retardant material with self-extinguishing property and free from Halogen.

Fire detection, alarm and control system shall be provided as per relevant Indian Standards.

Power supply cables used in charging station or charging points shall conform to IEC 62893-1 and its relevant parts.

Regulation 120- Testing of charging stations-

All apparatus of charging stations shall have the insulation resistance value as stipulated in the relevant IEC 61851-1.

The owner of the charging station shall ensure that the tests as specified in the manufacturer's instructions for the residual current device and the charging station have been carried out.

Regulation 121- Inspection and periodic assessment of charging stations–

Every charging station shall be tested and inspected by the owner or the Electrical Inspector or Chartered Electrical Safety Engineer before energisation of charging stations.

The owner of the charging station shall ensure that test and inspection of charging station is being carried out every year in the initial period of first three years after the energisation of charging station and in every four years thereafter.

The owner of the charging station shall establish and implement a safety assessment programme for regular periodic assessment of the electrical safety of charging station.

Regulation 122- Maintenance of records –

The owner of the charging station shall keep records in regard to design, construction and labelling to be compatible with a supply of standard voltage at a nominal frequency of 50 Hertz of the charging station.

The owner of the charging station shall keep records of the relevant test certificate as indicated in these regulations and as per IEC 61851.

The owner of the charging station shall keep records of the results of every inspection, testing and periodic assessment and details of any issues observed during the assessment and any actions required

to be taken in relation to those issues.

The owner of the charging station shall retain a copy of all records, as specified in sub regulation (1), and (3) of above, either in hard form or in electronic form, for at least seven years and shall provide a copy of the records to the officials during the inspection.

Regulation 123- International Standard for charging stations–

The safety provisions of all Alternating Current charging stations shall be in accordance with IEC 61851-1, IEC 61851-21 and IEC 61851-22.

The safety provisions of all Direct Current charging stations shall be in accordance with IEC 61851-1, IEC 61851-21, IEC 61851-23 and IEC 61851-24.

Where the connection point is installed outdoors, or in a damp location, the equipment shall have a degree of protection of at least IPX4 (Ingress Protection Code) in accordance with IEC 60529.”

***Note:** All regulations listed in this chapter are updated up to amendments issued till July 2022.*

CHAPTER-15

SAFETY PROCEDURES

15.1 General

It is essential that safety should be preached and practiced at all times by all concerned in installation, operation and maintenance of electric lines and apparatus. Safety instructions must be regarded as normal routine duty and not as involving extra and laborious operations. General instructions regarding safety procedures and practices to be followed in all major electrical installations like such as generating stations, sub-stations, industrial establishments, transmission and distribution lines, will be discussed which are derived from IS 5216, 1982. For precautions to be observed while installing, operating or maintaining any particular electrical equipment, reference shall also be made to the relevant Codes of Practice.

15.2 Statutory Regulations

- i. It is the duty of all persons who may be concerned with the installation, operation and maintenance of electric lines and apparatus to make themselves thoroughly conversant with the regulations and safety rules governing the work they may have to undertake on these lines and apparatus.
- ii. Generation, transmission, distribution and utilization of electrical energy in our country is governed by Electricity Supply 2003, and the regulations made under Central Electricity Authority (Measures relating to Safety and Electricity Supply) Regulations, 2010 and its amendments issued in 2015, 2018 and 2019.
- iii. The electricity supply undertakings are required to comply with other statutory acts besides those given in 16.2.2, and these shall be taken into account.
- iv. In addition to the statutory regulations mentioned in 16.2.2 and 16.2.3, electric supply undertakings usually lay down safety instructions in the form of safety rules or standing orders for the guidance of the staff employed in connection with the execution of work on or near the electric lines and apparatus and for their operation and-maintenance which should be strictly complied with at all times.
- v. It shall be the responsibility of the person-in-charge to interpret and explain correctly the rules and regulations to all staff concerned and to ensure that the staff thoroughly understands the same.
- vi. For the purpose of this standard, a competent person is one who had been certified so by the State Government, for the specific category of electrical work, as laid down in Regulation 29 of Measures relating to Safety and Electricity Supply) Regulations, 2010

15.3 Permit to Work System

- i. All work on major electrical installations shall be carried out under permit-to-work system which is now well established, unless standing instructions are issued by the competent authority to follow other procedures. In extenuating circumstances, such as for the purpose of saving life or time in the event of an emergency, it may become necessary to start the work without being able to obtain the necessary permit-to-work; in such cases, the action taken shall be reported to the person-in-charge as soon as possible. The permit-to-work certificate from the person-in-charge of operation to the



person- in-charge of the men selected to carry out any particular work ensures that the portion of the installation where the work is to be carried out is rendered -dead and safe for working. All work shall be carried out under the personal supervision of a competent person. If more than one department is working on the same apparatus, a permit-to-work should be issued to the person-in-charge of each department.

- ii. No work shall be commenced on live mains unless it is specifically intended to be so done by specially trained staff. In such cases all possible precautions shall be taken to ensure the safety of the staff engaged for such work, and also of others who may be directly or indirectly connected with the work. Such work shall only be carried out with proper equipment provided for the purpose and, after taking necessary precautions, by specially trained and experienced persons who are aware of the danger that exists when working on or near live mains or apparatus.
- iii. On completion of the work for which the permit-to-work is issued, the person-in-charge of the maintenance staff should return the permit duly discharged to the issuing authority.
- iv. In all cases, the issue and return of permits shall be recorded in a special register provided for that purpose.
- v. The permits shall be issued not only to the staff of the supply undertakings, but also to the staff of other departments, contractors, engineers, etc., who might be required to work adjacent to live electrical mains or apparatus.
- vi. A model form of permit-to-work certificate is given in Annexure 16.A.
- vii. Permit books should be treated as important records. All sheets in the permit books and the books themselves should be serially numbered. No page should be detached or used for any other except bona fide work. If any sheet is inadvertently detached, a dated and initialed statement shall then and there be recorded in the book by the person responsible for it.
- viii. Permit books shall be kept only by the person-in-charge of operation who shall maintain a record of the receipts and issues made by him.
- ix. It is important that the special instructions given in Annexure 16.B are strictly complied with at all times by the person-in-charge and his staff working on any job with a permit-to-work.

15.4 Register of Messages

- i. All messages and instructions relating to the operation of switches and other important communication concerning the work shall be recorded in the register of messages, preferably by an independent person not directly connected with the work.
- ii. The issue (or return) of permit shall be entered in the log book or log sheet either in red ink or should be underlined. When change of shift occurs during the pendency of a permit, the outgoing permit issuing officer shall inform his relief by entering in the logbook or log sheet, before handing over, the existence of all permits. The incoming permit issuing officer shall also sign the log book or log sheet in taking over and indicate that he has noted the pendency of the permits.
- iii. All the permit issuing officers and persons-in-charge concerned with the permit shall adopt similar logging procedure.

15.5 Instructions for Working on Low and Medium Voltage Mains and Apparatus

- i. **Work on Dead Low and Medium Voltage Mains and Apparatus** - Unless a person is authorised to work on live low and medium voltage mains and apparatus, all mains and apparatus to be worked upon shall be isolated from all sources of supply before starting the work, proved dead, earthed and

short-circuited. For earthing and short-circuiting, only recognized methods should be used which have been elaborated in Annexure 16.E. Measures shall be taken against the inadvertent energizing of the mains and apparatus.

- ii. **Work on Live Low and Medium Voltage Mains and Apparatus** - Only competent, experienced and authorized persons shall work on live mains and apparatus, and such persons should take all safety measures as may be required under Measures relating to Safety and Electricity Supply Regulations, 2010.
 - a. Warning boards shall be attached on or adjacent to the live apparatus and at the-limits of the zone in which work may be carried out.
 - b. Immediately before starting work, rubber gauntlets, if used, shall be thoroughly examined to see whether they are in sound condition. Under no circumstances shall a person work with unsound gauntlets, mats, stools, platforms or other accessories and safety devices.
 - c. It shall be ensured that no other live parts come within safe distance of a person working on low and medium voltage mains so that he does not come in accidental contact with it unless he is properly protected.
- iii. **Testing of Mains and Apparatus with Low Voltage** - No person shall apply test voltage to any mains unless he has received a permit-to-work and has warned all persons working on the mains of the proposed application of test voltage. If any part which will thus become alive is exposed, the person-in-charge of the test shall take due precautions to ensure that the exposed live portion does not constitute danger to any person. It should also be ensured before the application of test voltage that no other permit-to-work has been issued for working on these mains.
- iv. **Connecting Dead Mains to Live Mains** - When dead mains are connected to live mains, all connections to the live parts shall be made last, and in all cases the phase sequence should be checked to ensure that only like phases are connected together. Before inserting fuses or links in a feeder or distribution pillar controlling the cable on which a fault has been cleared, each phase shall first be connected through a test switch fuse.

15.6 Instructions for Working on High Voltage Mains and Apparatus

- 15.6.1 **General** -All high voltage mains and apparatus shall be regarded as alive and a source of danger and treated accordingly unless it is positively known to be dead and earthed.
 - 15.6.1.1 No person shall work on test or earth high voltage mains or apparatus unless covered by a permit-to-work and after proving the mains dead except for the purpose of connecting the testing apparatus, etc., which is specially designed for connecting to the live parts.
 - 15.6.1.2 The operations of proving dead, earthing and short-circuiting of any mains shall be carried out only by an authorized person under the instructions of the person-in-charge of maintenance.
 - 15.6.1.3 While working on high voltage mains, the following precautions shall be taken:
 - 15.6.1.3.1 No person, after receiving a permit-to-work, shall work on, or in any way interfere with any high voltage mains or conduits or trough containing a high voltage mains except under the personal instructions and supervision, on the site of work, of a competent person;
 - 15.6.1.3.2 When any high voltage mains is to be earthed, the procedure prescribed in 16.6.4.6 shall be scrupulously followed; and



15.6.1.3.3 The earths and short-circuits specified -on the permit-to-work shall not be removed or interfered with except by authority from the person-in-charge of the work.

15.6.2 **Minimum Working Distance** - No person shall work within the minimum working distance (asspecified in the relevant standard) from the exposed live high voltage mains and apparatus. The minimum working distance depend upon the actual voltage. It does not apply to operations carried out on mains and apparatus which are so constructed as to permit safe operation within these distances.

15.6.3 **Isolation of High Voltage Mains** - Isolation of high voltage mains shall be effected by the following methods:

- a. The electrical circuits shall be broken only by authorized persons by disconnecting switches, isolating links, unbolting connections or switches which are racked out. Where possible, the isolation should be visibly checked; and
- b. Where the means of isolation are provided with a device to prevent their reclosure by unauthorized persons, such a device shall be used. The isolation shall be maintained until necessary by suitable interlocking arrangements to prevent inadvertent energizing of the circuit.

15.6.4 **Devices for Proving High Voltage Mains and Apparatus Dead**

15.6.4.1 High voltage neon lamp contact indicator rods are often used for proving exposed high voltage mains and apparatus dead. Each rod is fitted with an indicating neon tube or other means whichglows when the contact end of the rod comes in contact with exposed live high voltage parts. Each rod is clearly marked for the maximum voltage on which it may be safely used and shall not, under any circumstances, be used on higher voltages.

15.6.4.2 High voltage contact indicator and phasing rods are provided for phasing and proving exposedhigh voltage mains and apparatus dead. A set consists of two rods connected in series by a length of insulated cables. Both rods are fitted with contact tips and indicating tubes. When the contact tip of onerod is applied to exposed live high voltage parts and that of the other to earth or other exposed live high voltage parts provided there is sufficient voltage difference between the two, the indicating tubes should glow. Each set of rods is normally marked for the maximum voltage on which it may be used and shall not, under any circumstances, be used on higher voltages.

15.6.4.3 **Use of High Voltage Contact Indicator and Phasing Rods** - While using the high voltage contact indicator and phasing rods for proving the high voltage mains or apparatus dead, following precautions should be taken:

- a. Ensure that the rod is clean and dry;
- b. Check the rod by applying it to known live parts of the correct voltage, the indicating tube shall glow;
- c. Apply the rod to each phase required to be proved dead, the indicating tube shall not glow. Be very careful to be in a position to see the glow, if any, appearing in the indicating tube; and
- d. Again check the rod by applying it to live parts as in (b) above, again the indicating tubes shall glow.

NOTE 1 - All the above operations shall be carried out at the same place and at the same time if no live high voltage parts are available on the site; rods up to 11 kV may be tested by applying them to the top of the spark plug in a running motor car engine. If the rod is in order,



the indicating tube will glow each time the plug sparks. Therefore, the glow will be Intermittent, but the indicating tube should glow on this test or the rod is useless as a means of proving the mains or apparatus dead.

NOTE 2 - The rod should be tested both before and after the use.

15.6.4.4 Testing and Marking of Devices for Proving High Voltage Mains and Apparatus Dead -It shall be ensured that all devices for proving high voltage mains and apparatus dead are marked clearly with the maximum voltage for which they are intended and should be tested periodically as recommended in 16.6.4.3.

15.6.4.5 Identification of Cables to be Worked Upon - A high voltage cable shall be identified as that having been proved dead prior to cutting or carrying out any operation which may involve work on or movement of the cable. A non-contact indicating rod, induction testing set or spiking device maybe used for proving the cable dead.

15.6.4.6 Earthing and Short-Circuiting High Voltage Mains

- a. High voltage mains shall not be worked upon unless they are discharged to -earth after making them dead and are earthed and short-circuited with earthing and short-circuiting equipment adequate to carry possible short-circuit currents and which are specially meant for the purpose. All earthing switches wherever installed should be locked up.
- b. If a high voltage cable is required to be cut, a steel wedge shall be carefully driven through it at-the point where it is to be cut or preferably by means of a spiking gun of approved design.
- c. After testing the high voltage cable with dc voltage, the cable shall be discharged through a 2 mega ohms resistance and not directly, owing to dielectric absorption which is particularly prominent in the dc voltage testing of high voltage cables. The cable shall be discharged for asufficiently long period to prevent re-building up of voltage.
- d. The earthing device when used shall be first connected to an effective earth. The other end of the device shall then be connected to the conductors to be earthed.
- e. Except for the purpose of testing, phasing, etc, the earthing and short-circuiting device shall remain connected for the duration of the work.

15.6.4.7 Removing the Earth Connections - On completion of work, removal of the earthing and short-circuiting devices shall be carried out in the reverse order to that adopted for placing them (see 16.6.4.6), that is, the end of the earthing device attached to the conductors of the earthed mains or apparatus shall be removed first and the other end connected to earth shall be removed last. The conductor shall not be touched after the earthing device has been removed from it.

15.6.4.8 Safety Precautions for Earthing - The precautions mentioned in a) to e) should be adopted to the extent applicable and possible.

- a. Examine earthing devices periodically and always prior to their use.
- b. Use only earthing switches or any other special apparatus where provided for earthing.
- c. Verify that the circuit is dead by means of discharging rod or potential indicator of approved type. The indicator itself should first be tested on a live circuit before and after the verification.
- d. Earthing should be done in such a manner that the persons doing the job are protected by earth connections on both sides of their working zone.
- e. All the three phases should be effectively earthed and short-circuited even though work may be proceeding on one phase only.



- 15.6.4.9 **Working on Mains Where Visible Isolation Cannot be Carried Out** -Where the electrical circuit cannot be broken visibly as set out in 16.6.3, the circuit may be broken by two circuit opening devices, one on each side of the work zone, where duplicate feed is available and by one circuit opening device where duplicate feed is not available provided the following conditions are fulfilled:
- a. The position of the contacts of the circuit opening device(s) - ‘ open ’ or ‘ closed ’ - is clearly indicated by the position of the operating handle or by signal lights or by other means.
 - b. The circuit opening device(s) can be locked mechanically in the open position.
 - c. The mains and apparatus to be worked on are adequately earthed and short-circuited between the circuit opening device and the position of the work.
 - d. In cases where duplicate feed is available, both the circuit opening devices are in series between the mains and apparatus to be worked, on and any source of supply.
 - e. In cases where duplicate feed is not available, the circuit opening device is between the mains to be worked on and any source of supply.

NOTE - The circuit opening devices mentioned in 16.6.4.9 shall be locked in the open position before the work on the mains and apparatus is commenced. The locking devices shall be removed only by a competent person and not until the work has been completed, any short-circuiting and earthing removed and the permit-to-work form duly returned and cancelled.

- 15.6.4.10 **Work on High Voltage Mains with Two or More Sections** -When the mains to be worked upon are to be divided into two or more sections, the provisions of 16.6.3, 16.6.4.6 and 16.6.4.9 shall be observed with regard to each section.

- 15.6.5 In addition to the general safety instructions provided above, further specific guidelines from the safety point of view applicable for installation and maintenance work on individual electrical equipment are given in individual Codes of Practice. These shall be taken note of as appropriate.

15.7 Workmen’s Safety Devices and Appliances

15.7.1 General

- 15.7.1.1 Rubber gauntlets, gloves, mats, boots and galoshes, insulated platforms and stools, safety belts, hand lamps, tower wagons and other special insulated devices shall be used, as required, for working on electrical equipment and apparatus as precaution against accidental electric shock.
- 15.7.1.2 Tools insulated with brittle material or otherwise liable to have its insulation damaged when in use shall be used carefully. If the insulation has been damaged, these tools shall not be used.
- 15.7.1.3 The person-in-charge of the work should ensure proper maintenance and use of the safety equipment.
- 15.7.1.4 *Durability of Rubber Devices* - As rubber perishes rapidly in tropical climate, great care shall be exercised in seeing that only sound rubber gauntlets, gloves, mats, boots, galoshes and other safety devices depending upon rubber insulation are issued to employees for working on live apparatus.

15.7.2 Care of Rubber Gauntlets, Gloves, Etc

- 15.7.2.1 No person should put his rubber gauntlets or gloves into his coat or trouser pocket along

with other tools. Gauntlets carried in this way are liable to get damaged and consequently become a source of danger to the wearer.

- 15.7.2.2 After the rubber gauntlets and gloves have been in use, they should be carefully cleaned at once and stored in a suitable chalk in a suitable container. No tool or other material shall be stored in this container.

15.7.3 Testing Rubber Gauntlets or Gloves

- 15.7.3.1 Before a person puts on his rubber gauntlets or gloves to start work on a new job, he should check each one for cuts, cracks and weak spots by rolling it up tightly, beginning at the gauntlets end, and notice if any air escapes. This is usually called as 'air test'. Gauntlets or gloves which show visible cuts, cracks or weak spots or air leakage in this test shall not be used and shall be returned and a new pair obtained. The visual lamp test may also be adopted to determine the condition of gauntlets and gloves (IS: 4770-1968).
- 15.7.3.2 Every pair of rubber gauntlets and gloves shall be carefully examined on each occasion before and after the work by the person-in-charge of the work to ensure safety to the workmen. They should be tested for leakage current at frequent intervals in accordance with IS: 4770-1968.
- 15.7.3.3 The right hand gauntlet wears out more quickly than the left hand one and in such cases the whole pair should be condemned. Under no circumstances a left hand gauntlet should be allowed to be used on the right hand as it is cumbersome and the workman is likely to discard it and meet with accident.

15.7.4 Inspection of Safety Equipment

- 15.7.4.1 Rubber gauntlets, gloves, boots and galoshes shall be inspected periodically.
- 15.7.4.2 All safety equipment should be inspected by frequent surprise checks by competent persons at intervals of not more than six months.
- 15.7.4.3 Any safety device found defective on inspection shall be repaired immediately; if it is not possible to effect repairs satisfactorily, the defective ones shall be discarded at once.

15.8 Safety Practices

- 15.8.1 In all electrical work, it is very necessary that certain elementary safety practices are observed. It has been found that quite a large number of accidents occur due to the neglect of these practices. The details of such practices are given in Annexure 16.C.

15.8.2 Fires and Fire Extinguishers

- 15.8.2.1 In the event of fire on electrical mains or apparatus, the effected parts shall immediately be isolated completely from its source of supply of electrical energy.
- 15.8.2.2 Fire extinguishers, which are not insulated, should never be employed in fighting fires near exposed live conductors. Only such fire extinguishers should be used on electrical mains and apparatus which are marked as suitable for the purpose. When using fire hose, it should be ensured that the jet of water does not come into contact with live conductors (IS: 1646-1961).
- 15.8.2.3 It is dangerous to throw a stream of water, a wet blanket or a stream from ordinary soda-acid type extinguishers on live mains or apparatus. When found necessary to use them, have all the neighboring mains or apparatus made dead. Carbon dioxide, carbon



tetrachloride and other specialty of extinguishers, sand nor dry blanket may be used on live conductors and static apparatus.

15.8.3 Lighting - Inadequate lighting of working areas is by itself a source of danger, particularly when work is undertaken at night. Never, therefore, allow any work in the dark in badly illuminated or ill-ventilated places. A schedule for values of safe and adequate illumination is given in IS:3646

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15.9 Training of Employees

15.9.1 General-For maximum effectiveness, a sound safety procedure would include, in addition to the instructions on the hazards of electricity, thorough training of all employees who work on electrical installations and equipments. The employees should be trained in first aid, firefighting, use of warning signs, guards and other protective devices and safe operational procedures.

15.9.2 Training Programme- The training programme should consist of not merely generalizations and indefinite recommendations, but should be specifically based upon demonstrations and training in the correct operation and maintenance of lines and apparatus.

15.9.3 Supervision

15.9.3.1 Supervising officers should maintain a close supervision over all operation and maintenance works and defective or careless handling of equipment should not be permitted.

15.9.3.2 Under no circumstances should deviation from safe practices be tolerated, as this could result in unnecessary hazards and danger to workmen or apparatus.

15.10 Electrical Room Related Safety Measures

15.10.1 The Electrical Installations for Medium, High and Extra high voltage shall have a danger notice both in English or Hindi and local language of the district with a sign of skulls and bones.

15.10.2 Minimum PPE requirement, Hazards & precautions to be taken, Unauthorized Access Prohibited Signage, Schematic layout of the Electrical Area with emergency Equipment location etc. are to be displayed at the entrance of Electrical Room.

15.10.3 Electrical Shock Chart with instructions in English or Hindi and the local language of the district and where Hindi is the local language, in English and Hindi for the restoration of persons suffering from electric shock have to be affixed in a conspicuous place.

15.10.4 Single Line Diagram to be displayed inside Electrical rooms.

15.10.5 The Emergency Action Plan with Emergency contact numbers, Employees' name who are trained on CPR & first aid to be displayed in Electrical rooms.

15.10.6 First aid boxes, stretchers, Oxypack, Gas Mask etc to be made available in Electrical rooms or near vicinity.

15.10.7 The Electrical Installations for high and extra high voltage shall have a running tap of drinking water and Emergency Safety shower with drinking water connection and proper drainage facility. In case of electric burns, the burnt portion should be cooled down using drinking water. In every manned high and extra high voltage sub section, an artificial respirator to be provided.

- 15.10.8 Good housekeeping to be maintained within the electrical room. The floor of Electrical Substation should be kept free from slip/ trip/ fall hazard like open cable riser, moving checker plate or floor board etc.
- 15.10.9 Along with the main exit door, Emergency Exit door is to be provided and should be in accessible safe condition in the 415V and above electrical rooms.

15.11 Electrical Accidents

- 15.11.1 Most accidents are generally due to carelessness and result in fall, fire or electric shock to personnel. Extreme care is therefore recommended while working on, or in close proximity to live mains or apparatus. However, in cases of untoward accidents, the safety instructions are to be strictly adhered to with speed and precision by personnel.

15.11.2 First Aid, Fire Fighting and Resuscitation

- i. All technical staff should be familiar with first aid and artificial respiration techniques. They should be encouraged to obtain the Certificate of Proficiency issued by the St. John's Ambulance Association.
- ii. All technical staff should be made familiar with fire fighting techniques and the equipment used in it.
- iii. The person-in-charge should also conduct drills in artificial respiration, rendering first aid and fire fighting.
- iv. First Aid Box - A box containing first aid equipment shall be kept handy for use when required. A periodical check shall be made of its contents. Any deficiencies shall be immediately made up.
- v. Stretchers - Stretchers should be kept at all important electrical installations.

15.11.3 Rescue & First Aid Measures for Electrical shock

- i. The victim usually gets stuck to the source of the electricity, and it is important that the victim should be first separated from the electrical source.
- ii. The main power supply switch to be adequately turned off.
- iii. In certain circumstances, it may be quicker to simply pull the victim away from the electrical source.
- iv. The victim should not be touched with bare hands, or the electric current will pass through the rescuer as well. Some dry, nonconductive material such as a wood, insulated rod etc. to be used to separate the victim from the live current whatever is handy.
- v. Once the victim has been separated, it is to be checked to see if he is breathing.
- vi. If breathing has stopped or seems slow, CPR (Cardio-Pulmonary Resuscitation) to be administered immediately by a trained person.
- vii. The victim should be moved as little as possible because the person may have suffered injuries to spine and neck.
- viii. If the victim has an electric burn, the clothing from the burned area to be removed gently (unless it's stuck to the skin) and the burned area to be rinsed in cool, running drinking water.
- ix. Emergency medical attention to be called as soon as possible



15.11.4 Reporting of Accidents

- i. All accidents to persons; whether minor or major, fatal or nonfatal, including slight injuries (when the injured person is capable of performing his duties), shall be immediately reported in according with the rules in force. First aid shall be rendered, where necessary. The injured person shall be sent to the doctor for medical examination or the doctor sent for to attend on the patient.
- ii. The provisions of Section 161 of the Electricity Act, 2003 and Intimation of Accidents (Form and Time of Service of Notice) Rules, 2004 shall be complied with for the purpose of intimation of accidents.
- iii. If any accident occurs in connection with the generation, transmission, supply or use of electricity in or in connection with, any part of the electric lines or other works of any person and the accident results in or is likely to have resulted in loss of human or animal life or in any injury to a human being or an animal, such person or any authorized person of the generating company or licensee, not below the rank of a Junior Engineer or equivalent shall send to the Inspector a telegraphic report within 24 hours of the knowledge of the occurrence of the fatal accident and a report in writing in Form A (Annexure 16.D) within 48 hours of the knowledge of occurrence of fatal and all other accidents. Where possible a telephonic message should also be given to the Inspector immediately, if the accident comes to the knowledge of the authorized officer of the generating company/licensee or other person concerned.
- iv. For the intimation of the accident, telephone numbers, fax numbers and addresses of Chief Electrical Inspector or Electrical Inspectors, District Magistrate, police station, Fire Brigade and nearest hospital shall be displayed at the conspicuous place in the generating station, sub-station, enclosed substation/switching station and maintained in the Office of the in-charge/owner of the Medium Voltage (MV)/High Voltage (HV)/Extra High Voltage (EHV) installations.

Model Form of Permit-To-Work

Name of the Organization.....

Department (issuing the permit)

Permit No. Time Date

1. I, certify that the following apparatus has been made dead, is isolated from all live conductors and has been connected to earth and the work mentioned in para (3) can now be carried out in accordance with the safety rules and regulations:

2. For the purpose of making the above apparatus dead, the following switches/isolators/links/fuses have been opened and the section so isolated has been earthed at each isolation point and danger notice plates tied thereon:

Switches.....

Isolators.....

Links.....

Fuses.....

3. Work to be carried out (testing work, if any, to be specifically mentioned).....
.....

4. I have also recorded the above operations in the Log Sheet/Log Book including the instructions for the person who may relieve me.

5. This permit is now being issued to (name of the person to whom the permit is being issued) for carrying out the work mentioned in para (3).

(Signature of the permit issuing authority) (Designation).....

Department (receiving the permit).....

Permit No. Time Date

I, confirm that

I have been issued this permit by (name of the permit issuing officer) and have been placed in direct and continuous charge of the work mentioned in para and accept the responsibility of carrying out the said work taking all necessary safety precautions to avoid danger and no attempt will be made either by me or by men working under my control to carry



out any other work on any apparatus other than that detailed in paras (1) and (3) on the reverse.

(Signature of the person receiving the permit and
responsible for carrying out the above work)

(Designation).....

I have transferred this permit to.....
who will now be responsible for carrying out all the works mentioned in para (3) on the reverse.

(Signature of the person transferring the permit)(Designation).....

(Signature of the person receiving the permit)(Designation).....

Time

Date.....

I confirm that the work specified in para (3) on reverse has been completed and all workmen withdrawn and warned that it is no longer safe to work on the apparatus mentioned in para (1) on the reverse. I also confirm that all temporary earths and other connections made by me and by men under my control have been removed except that any precautionary steps taken by the permit issuing officer before the issue of this permit have not been interfered with by me or by men under my control. I hereby return the permit for cancellation leaving the dead apparatus ready for putting into service.

Time

Date.....

The work mentioned in para (3) on the reverse has been carried out; all earths made for the purpose have been removed and danger notice plates put aside. The following switches/isolators/links/fuses have been closed and apparatus put back into service. Entry has been made in the Log Sheet/Log Book:

Switches.....

Isolators.....

Links.....

Fuses.....

(Signature of the permit cancelling authority)(Designation).....

Special Instructions for the Safety of Persons Working on a job with a Permit-To-Work

1. The following special instructions primarily to provide safe working conditions shall be rigidly complied with by all persons and at all times when working on a job with a permit-to-work. Any one disregarding these instructions or behaving in a manner likely to cause danger, either to himself or to anyone else, should be properly punished.
2. No person shall carry out or attempt any work on-live mains or apparatus except with a permit-to-work and under the direct supervision of a competent person.
3. The person-in-charge shall explain the nature and duration of work to be carried out to the permit issuing authority, and obtain from him a permit-to-work before commencing any work.
4. The permit issuing authority shall not issue a permit unless: the switches have been withdrawn and are completely isolated on both sides, links and fuses opened, mains and apparatus discharged and ~earthed, and all adjacent live parts adequately protected. Where possible, the switches shall be locked and keys handed over to the person-in-charge, who will not return them until completion of the work. Switches and fuses of all control panels shall also be rendered inoperative, danger notice plates are attached in conspicuous place on the mains and apparatus, and at all other control points, under the permit-to-work; and an entry is made in the Log book or Log Sheet to the effect that the mains and apparatus under permit have been made dead. On no account shall they again be made alive until the return by the person-in-charge of the permit-to-work and the keys.
5. The person-in-charge before allowing any workman to commence work on the mains and apparatus shall take the following precautions:

Explain the nature of work, and the precautions taken by the permit issuing authority to ensure the safety of the workmen and also the precautions to be taken by them during the progress of the work;

Satisfy himself that the switches controlling the mains and apparatus have been isolated, discharged, properly earthed where possible and tested with a discharge rod and that danger notice plates have been placed at conspicuous places; and

Warn the workmen and public of the danger that exists in the vicinity of the area covered by the permit.

6. Where work is to be carried out on live low or medium voltage mains or apparatus, the following additional instructions shall be complied with:

No work shall be carried out by any person unless he is adequately protected from the risk of electric shock by the use of rubber gloves or other approved equipment specially provided for the purpose.



When a person is working on live mains or apparatus, he shall always be accompanied by a second person who shall preferably be capable of rendering first aid and artificial respirations.

When a man ascends a pole where the line is alive, he shall make use of a safety belt and rubber gloves; such work shall be carried out under the direction of an experienced person who is competent to supervise the specific work and who shall remain present in the immediate vicinity for the whole time the work is in progress.

The person-in-charge shall examine the safety equipment before use by the workmen to ensure that it is in sound condition, and also that it is being properly used.

7. On completion of the work, remove all earthing devices so that the mains and apparatus are fit in all respects for charging; withdraw all workmen and warn them that it is no longer safe to touch or approach the mains and apparatus, and thereafter return the keys and the permit duly discharged to the permit cancelling authority for cancellation.

8. All accidents shall be immediately attended to and reported to the proper authorities. In the event of a serious accident involving danger to life, the person-in-charge shall immediately get a doctor on site or remove the victim to the nearest hospital with the minimum delay. In the event of the victim being certified dead by a doctor, the body should NOT be removed without the permission of the police.

9. The instructions shall be read out and explained to the workmen in the language they understand, and copies shall be pasted on the various notice boards. Ignorance of the instructions shall not be accepted as an excuse for non-compliance with them.

General Safety Practices in Electrical Work

1. Exercise Care

Place yourself in a safe and secure position to avoid slipping, stumbling or moving backward against live conductors or apparatus. Do not rely for protection upon the care assumed to be exercised by others.

In the event of near approach of a lightning storm, all outdoor work on electrical system should cease. Make a habit of being cautious. Be on the lookout for danger notice plates, danger flags, warning boards and signals, etc. Warn others when they seem to be in danger near live conductors or apparatus.

2. Personal Apparel

Use of overalls, dungarees, jumpers and coats having metal buttons, metal straps and similar metal fittings should be avoided. Bone buttons may be used. Buttons should be sewed in place with thread. Loose clothing should not be worn.

While working on live conductors, do not roll up sleeves as dry cloth gives some protection against shocks.

Do not wear shoes with nailed soles. Shoes should have sewn soles, or preferably rubber soles.

Do not wear suspenders and arm bands with metal buckles or other metal parts. These might come in close proximity to live parts and cause serious, if not fatal, injury.

Metal key chains, or metal keepers for key rings or watch chains should not be worn on the outside of clothing. There is always a possibility that they may come in contact with live conductors -or live apparatus.

While welding wear goggles, safety glasses or any other eye protection as instructed by, the person-in-charge depending upon the type of work handled.

3. Treat Everything As Live

Treat all electrical conductors and apparatus always as live and consequently dangerous to human life, unless it is positively known to be dead and properly earthed and take precautions accordingly.

4. Think Before You Act

Think carefully before you act. Make sure you are right. Watch out for the other man and make sure he is right.

Never speak to any person working upon live mains or apparatus, unless the person doing the work is aware of your presence.

5. Dangerous Voltages

All voltages are dangerous. It shall be borne in mind that even low voltage shock may be fatal.

Every person-in-charge of work on any mains or apparatus shall ensure himself that the same is free from dangerous leakage or induction and has been effectively earthed locally before permitting men to work upon it.

6. Dangerous Areas

When working in areas which contain or may contain live mains and apparatus, fix danger notice plates, barriers, rails or other guarding arrangement for the working area. Do not store materials within high voltage enclosures or low voltage areas.

7. Warning Boards

Warning boards shall be placed by the person-in-charge on all switchgear before men are permitted to work and should only be removed by the person who has placed them. It is desirable that the person issuing the permit shall place one warning board on the switch energizing the mains for each permit issued so that he can be sure that all the permits-to-work are returned when he has to charge the mains.

8. Visitors and Unauthorized Persons

Visitors and unauthorized persons shall not be allowed to proceed in the vicinity of live mains and apparatus, unless accompanied by an authorized person whose responsibility it shall be to ensure that his instructions regarding safety are strictly complied with.

9. Working in Damp Situations

Extra precautions should be taken when working in abnormally damp areas.

10. Use of Tong or Clip-On Ammeters

These shall not be used on high voltage conductors, unless the conductors are lead-sheathed. On low voltage conductors, all persons, not accustomed to the handling of tong or clip-on ammeter, shall be warned of the necessary precautions to be observed before being allowed to use it.

11. Warning the public

When, either accidentally or otherwise, live mains and apparatus constitute a danger to persons in a public place, a person shall be detailed to stand by and personally warn the public until the danger has been removed.

12. Portable Electrical Apparatus

All portable electrical apparatus shall be regularly examined, tested and maintained to ensure that the apparatus and leads are in good order.

Ensure that all portable appliances are provided with 3-pin plug and socket connections and that the metal work of the apparatus is effectively earthed.

All loose wiring, such as flexible cables for portable lamps, tools and trailing cables and other portable and transportable apparatus, shall be tested regularly at frequent intervals to ensure safety.

Form A

(Form for reporting electrical accidents)

Date and time of accident.Place of accident.

(Village/Town, Tehsil/Thana, District and State).

System and voltage of supply (Whether Extra High Voltage (EHV)/High Voltage (HV)/Low Voltage (LV) Line, sub-station/generation station/consumer's installations/service lines/other installations).

Designation of the Officer-in-charge of the generating company/licensee in whose jurisdiction the accident occurred.

Name of owner/user of energy in whose premises the accident occurred.Details of victim(s):

Human

Sr. No.	Name	Father'sName	Sex ofvictim	Full Postal address	Approximate age	Fatal/ Non-fatal
1	2	3	4	5	6	7

Animal

Sr. No.	Description of animal(s)	Number(s)	Name(s) of owner(s)	Address(es)of owner(s)	Fatal/ Non-fatal
1	2	3	4	5	7

In case the victim(s) is/are employee(s) of supplier:-

- designation of such person(s);
- brief description of the job undertaken, if any;
- whether such person/persons was/were allowed to work on the job.

In case the victim(s) is/are employee(s) of a licensed contractor, -

- did the victim(s) possess any electric workmen's permit(s), supervisor's certificate of competency?
If yes, give number and date of issue and the name of issuing authority;
name and designation of the person who assigned the duties of the victim(s).

In case of accident in the system of the generating company/licensee, was the permit to work (PTW) taken?



- a. Describe fully the nature and extent of injuries, eg. fatal/disablement (permanent or temporary) of any portion of the body or burns or other injuries.

In case of fatal accident, was the post mortem performed?

Detailed causes leading to the accident.

(To be given in a separate sheet annexed to this form).

Action taken regarding first aid, medical attendance etc. immediately after the occurrence of the accident (give details).

Whether the District Magistrate and Police Station concerned have been informed of the accident (if so, give details).

Steps taken to preserve the evidence in connection with the accident to extent possible.

Name and designation(s) of the person(s) assisting, supervising the person(s) killed or injured.

What safety equipments were given to or used by the person(s) who met with this accident (e.g. rubber gloves, rubber mats, safety belts and ladders etc.)?

Whether isolating switches and other sectionalizing devices were employed to deaden the sections for working on the same? Whether working section was earthed at the site of work?

Whether the work on the live lines was undertaken by authorised person(s)? If so, the name and the designation of such person(s) may be given.

Whether artificial resuscitation treatment was given to the person(s) who met with the electric accident? If yes, how long was it continued before its abandonment?

Names and designations of persons present at, and witnessed, the accident. Any other information/ remarks.

Signature

Place:

Time:

Date:

Name

Designation

Address of the person reporting

Guidelines on Electrical Safety in Low Voltage Installations

GUIDELINES ON ELECTRICAL SAFETY IN LOW VOLTAGE INSTALLATIONS

This guideline covers earthing , equipotential bonding, selection of appropriate protective device and testing to ensure Electrical safety in Low Voltage Installation.

1. Earthing:

The process of transferring the immediate discharge of the electrical energy directly to the earth by the help of the low resistance wire is known as the electrical earthing.

An earthing system or grounding system connects specific parts of an electric power system with the ground, typically the Earth's conductive surface, for safety and functional purposes. The choice of earthing system can affect the safety of the installation.

1.1 Purpose of Earthing:

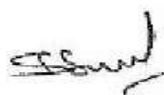
- 1.1.1 Earthing of an electrical installation is provided for the purpose of safety. The earth connection improves service continuity, avoids damage to equipment and danger to human life.
- 1.1.2 Earthing also reduces the risk of a person in the vicinity of earthed facilities being exposed to the danger of critical electric shock.
- 1.1.3 Earthing in a substation is done to provide as nearly as possible a surface at a uniform potential and as nearly as zero or absolute earth potential. The purpose of this is to ensure that all parts (metal parts/exposed conductive parts) of apparatus/equipment other than live parts shall be at uniform/earth potential. This will also ensure that user/operator will always remain at earth potential at all times.
- 1.1.4 Earthing also provides a low earth fault loop impedance to facilitate automatic disconnection of supply in the event of a fault to exposed conductive parts of equipment/apparatus.
- 1.1.5 Earthing also provides stable platform for operation of sensitive electronic equipment i.e. to maintain the voltage at any part of an electrical system at a known value so as to prevent over current or excessive voltage on the appliances or equipment.
- 1.1.6 Earthing will also help to limit the rise in potential (touch voltage) of non-current carrying metal parts with respect to earth under earth-fault conditions to a value which is not harmful for the safety of persons/animals in contact/proximity to such metal parts.
- 1.1.7 Earthing also provides safe path to dissipate lightning current to earth.
- 1.1.8 It should stabilize circuit potentials with respect to ground and limit the overall potential rise.

1.2 Equipment Earthing:

Earthing of non-current carrying metal work and conductor which is essential to the safety of human life, animals and property is known as Equipment Earthing or Protective Earthing.

(Ref:- IS 3043 : 2018 Forward para 6)

"Equipment earthing or protective earthing of low voltage installation as per IS 732:2019 is provided to limit the potential with respect to the general mass of earth of non-current




carrying metal works associated with equipment, apparatus and appliance connected to the system”.

(Ref:- IS 3043 : 2018 1.1 (a))

The basic objectives of equipment earthing are:

- a) “To ensure freedom from dangerous electric shock/voltages exposure to persons in the area”.
- b) “To provide adequate earth fault current carrying capability, both in magnitude and duration, permitted by the protective system without creating a fire or explosive hazard to building/equipment”.

When there is unintentional contact between an energized electric conductor (live conductor) and the metal frame (body) or enclosure/structure, the frame or structure tends to become energized to the same voltage level as exists on the energized conductor.

In such cases, to avoid the dangerous voltage on exposed metal frame (body) the equipment earthing conductor provides a low impedance path from the metal frame to the zero potential earth junction (MET).

Impedance/Resistance of Protective conductor from point of installation (Equipment) to MET should be sufficiently low enough to avoid creation of dangerous voltage on equipment.

Class I appliances are usually made of metal, have three cables, it has a metal Earth pin (Earth wire of the equipment which comes to the earth pin of 3 pin plug top). Appliances under Class I have two levels of protection, the basic insulation and the earth connection. Accessible/exposed metal parts of Class-I equipment/appliances that may become live in the event of an insulation failure, shall be permanently and reliably connected to an earthing terminal within the appliance or to the earthing contact of the appliance inlet. Ex. Iron, refrigerators, microwaves, etc.

A Class II (double insulated) electrical appliance is one which has been designed in such a way that it does not require a safety connection to electrical earth. Class II equipment, may not have provision for connection of exposed metal work of the equipment to a protective/earth conductor. Ex Mobile chargers, Hand Dryers, TV, etc.

1.3 System Earthing:

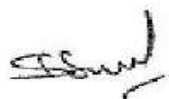
(Ref:- IS 3043 : 2018 para 11.0)

Earthing associated with current-carrying conductor which is normally essential to the security of the system is known as System Earthing.

System earthing of low voltage installation is carried out to limit the potential of current carrying conductor forming part of the electrical system with respect to general mass of earth. Earthing of system is designed primarily to preserve the security of the system by ensuring that the potential on each conductor is restricted to such a value as is consistent with the level of insulation applied.

Earthing of system is designed primarily to preserve the security of the system by ensuring that the potential on each conductor is restricted to such a value as is consistent with the level of insulation applied. From the point of view of safety, it is equally important that earthing should ensure efficient and fast operation of protective gear in the case of earth faults. Most high voltage public supply systems are earthed. Approval has been given in recent years to unearthed overhead line systems in certain countries, but these have only been small 11 kV systems derived from 33 kV mains, where the capacity earth current is less than 4 A and circumstances are such that the system will not be appreciably extended.

The limitation of earthing to one point on each system is designed to prevent the passage of current through the earth under normal conditions, and thus to avoid the accompanying



risks of electrolysis and interference with communication circuits. With a suitable designed system, properly operated and maintained, earthing at several points may be permitted. This method of earthing becomes economically essential in systems at 200 kV and upwards.

The system earth-resistance should be such that, when any fault occurs against which earthing is designed to give protection, the protective gear will operate to make the faulty main or plant harmless. In most cases, such operation involves isolation of the faulty main or plant, for example, by circuit-breakers or fuses.

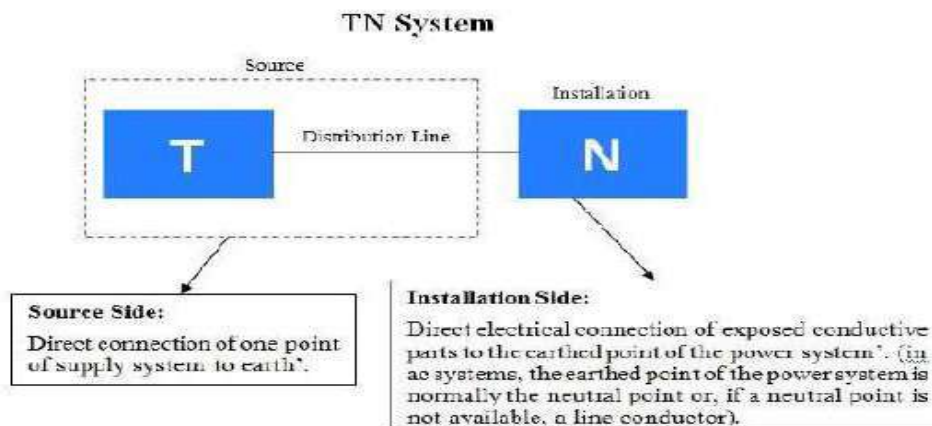
In the case of underground systems, there is no difficulty whatever but, for example, in the case of overhead-line systems protected by fuses or circuit breakers fitted with overcurrent protection only, there may be difficulty in arranging that the value of the system earth-resistance is such that a conductor falling and making good contact with the ground results in operation of the protection. A low system-earth resistance is required even in the cases where an arc suppression coil is installed, as its operation may be frustrated by too high an earth-electrode resistance.

Earthing may not give protection against faults that are not essentially earth faults. For example, if a phase conductor on an overhead spur line breaks, and the part remote from the supply falls to the ground, it is unlikely that any protective gear relying on earthing, other than current balance protection at the substation, will operate since the earth-fault current circuit includes the impedance of the load that would be high relative to the rest of the circuit.

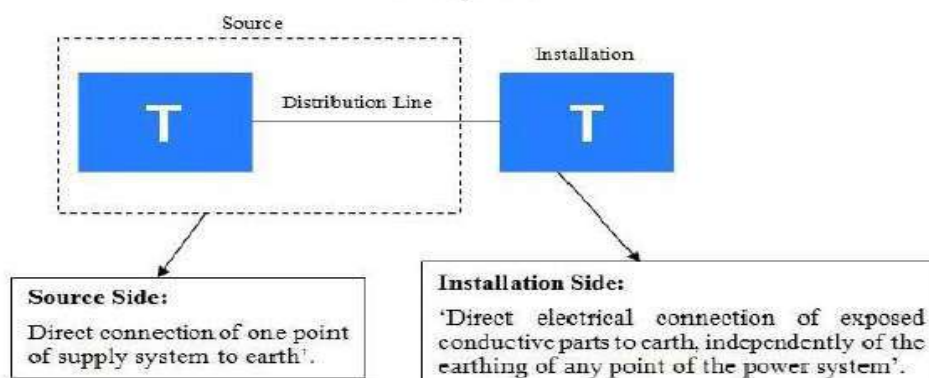
For the purposes of this Code of practice, it is convenient to consider a system as comprising a source of energy and an installation; the former including the supply cables to the latter.

1.3.1 Types of System Earthing:

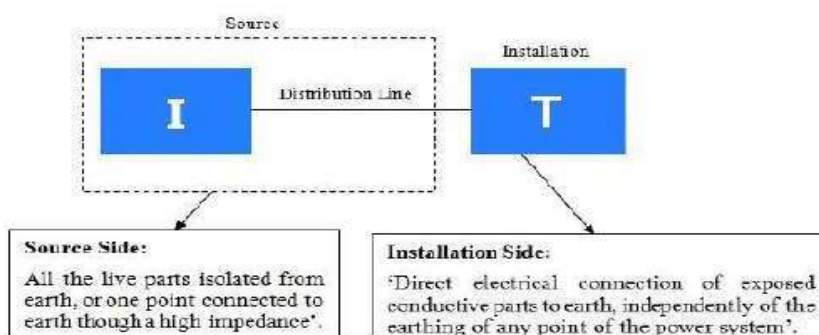
Any system comprises mainly two portions, first the source of energy (transformer/DG) and second is installation. The source includes supply cables/conductor connecting to the installation. The supply system is generally denoted by two letters as shown below:



TT System



IT System



Description of Letters:

The first letter refers to the relationship of the power system (source) to the earth	
T	Direct connection of one point
I	All the live parts isolated from earth, or one point connected to earth through a high impedance
Second letter refers to the relationship of the exposed-conductive-parts of the installation to earth	
T	Direct electrical connection of exposed conductive parts to earth, independently of the earthing of any point of the power system.
N	Direct electrical connection of exposed conductive parts to the earthed point of the power system.
Subsequent letters if any	
S	Separate neutral and protective earth functions provide by separate conductors i.e. PE and N conductor.
C	Combined neutral and protective earth functions provided by same conductor i.e. PEN/CNE conductor

1.3.1.1 TN System:

TN system has one or more points of the source of energy (preferably Neutral point of Transformer or DG) directly earthed at source end. The exposed and extraneous conductive parts of the consumer installation are connected by means of protective conductors to the earthed point(s) of the source. In this way, there is a metallic return path for earth fault

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currents to flow from the installation to the earthed point(s) of the source. TN systems are further sub-divided into TN-S, TN-C and TN-C-S systems.

1.3.1.1 (a) TN-S System:

In the system where separate conductors each for neutral and protective functions are provided throughout the system is called as TN-S system.

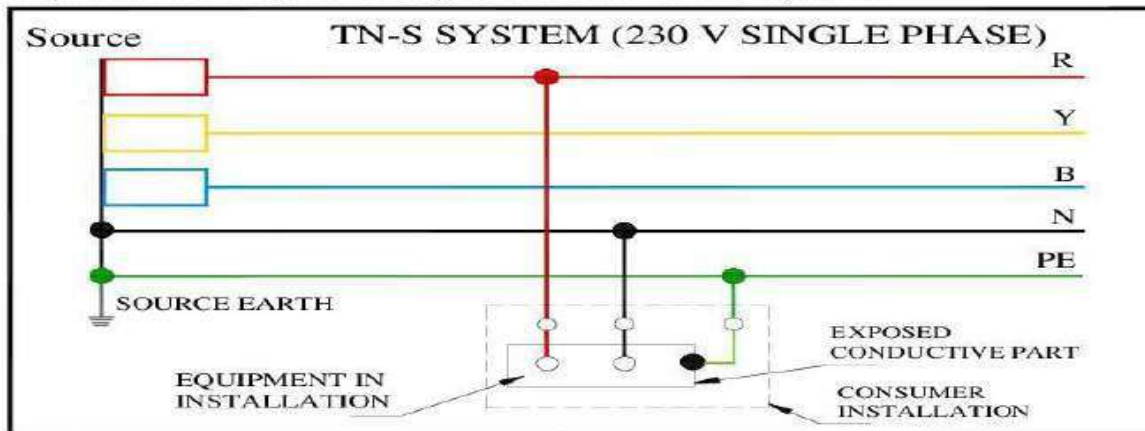


Figure : TN-S System for 230V Single Phase

- The protective conductor (PE) is the metallic covering (armour or sheath of the cable supplying the installation) or a separate conductor.
- All exposed conductive parts of an installation are connected to this protective conductor via main earthing terminal of the installation.

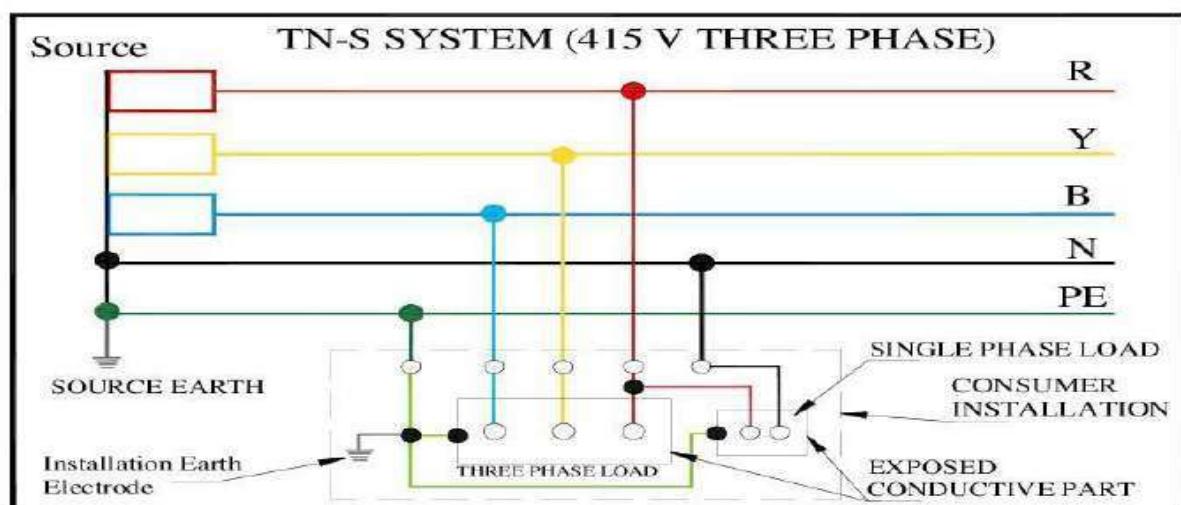


Figure : TN-S System for 415 V three-phase domestic commercial supply having Three Phase Loads

- All exposed conductive parts of the installation are connected to protective conductor via the main earthing terminal of the installation.
- For Three Phase consumers, it is necessary to install an independent earth electrode within the consumer's premises and same to be connected as shown in the figure given below (Ref: Fig. 13 of IS 3043-2018).

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- TN-S system requires 5 conductors (three lines, one neutral and one protective conductor), due to this, cost of installation is high as compared to other systems.

1.3.1.1 (b) TN-C System:

In TN-C system, neutral and protective functions are combined in a single conductor throughout the system.

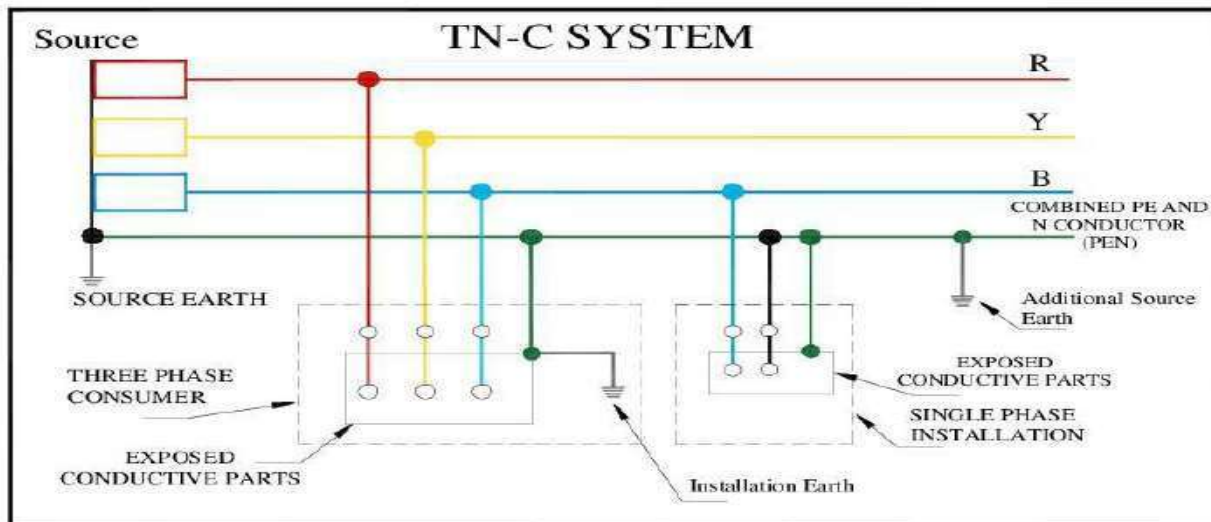


Figure : TN-C System

- All exposed conductive parts are connected to the PEN conductor.
- For three phase consumer, local earth electrode has to be provided in addition.
- TN-C systems are not suitable for modern installations with electronic equipment.

1.3.1.1 (c) TN-C-S System:

In TN-C-S system, neutral and protective functions are combined in a single conductor (PEN conductor) only in part of the system. Usually, the neutral and protective functions are combined in a single conductor up-to consumer's premises and separate at installation. All exposed conductive parts of an installation are connected through protective conductors. All the protective conductors/connections run separately inside consumer's premises and connected to main earthing terminal (MET) and then to the PEN conductor.

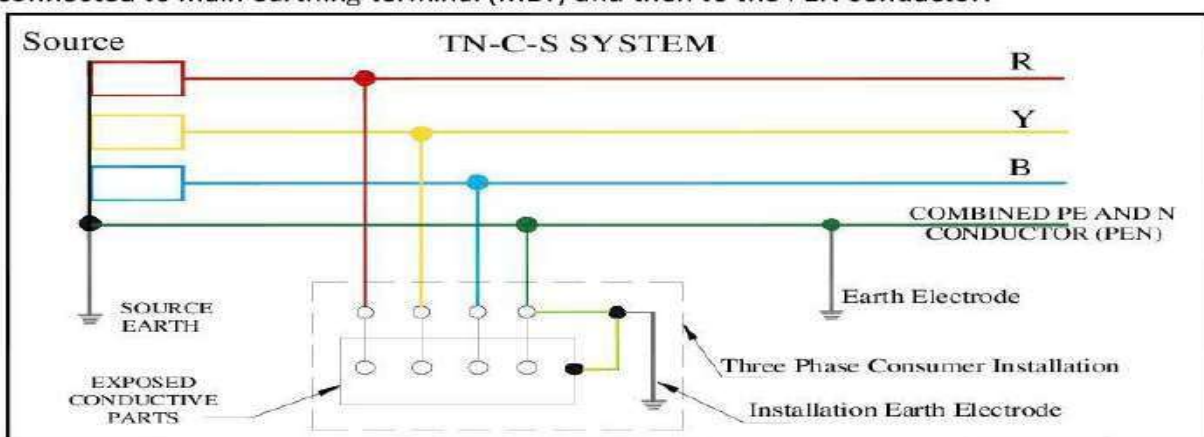


Figure : TN-C-S System

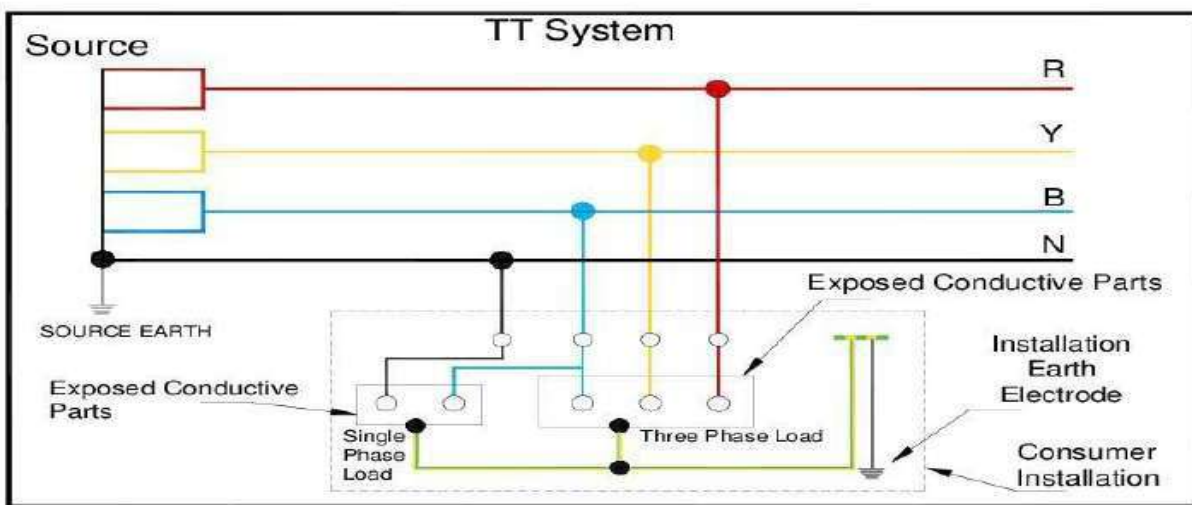
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- In this system the supply is TN-C and arrangement in the installation is TN-S.
- This system requires only four conductors in public distribution (i.e. up-to incoming supply at consumer's premises). This saves the cost of 5th conductor in public distribution.
- The supply system PEN conductor is earthed at several points. Therefore, this type of distribution is known also as Protective Multiple Earthing (PME) and the PEN conductor is also referred to as the Combined Neutral and Earth (CNE) conductor.
- As per statutory provisions for earthing mentioned in Cl. No. 4 of IS 3043-2018. The TN-C-S is the most common system adopted by Electrical supply undertakings. TN-C-S system is also called as Protective Multiple Earthed (PME) system.

1.3.1.2 TT System:

TT system has one or more points of the source of energy directly earthed and the exposed and extraneous conductive parts of the installation are connected to a local earth electrode. Source and installation earth electrodes are electrically independent.



- All exposed conductive parts of an installation are connected to an independent earth electrode.
- Single phase TT system is not present in India.

1.3.1.3 IT System:

IT system has the source either unearthed or earthed through a **high impedance** and the exposed conductive parts of the installation are connected to electrically independent earth electrodes.

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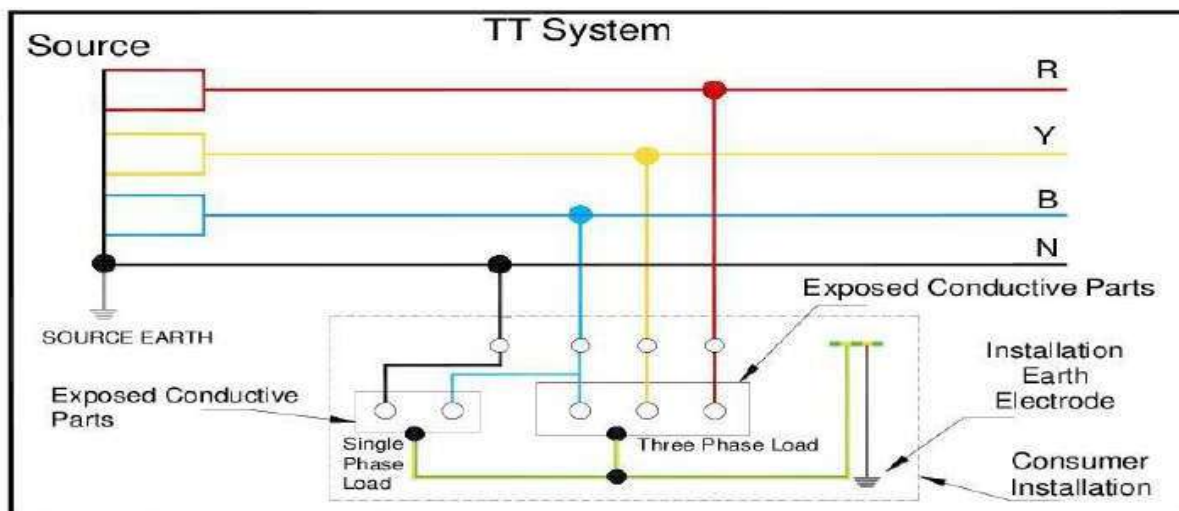


Figure : IT System

- All exposed conductive parts of an installation are connected to an earth electrode.
- The source is either connected to earth through deliberately introduced earthing impedance or is isolated from earth.

2. Earthing and Protective conductors:

2.1 Earthing Conductor: - A protective conductor connecting the main earthing terminal (or the equipotential bonding conductor of an installation when there is no earth bus) to an earth electrode or to other means of earthing. (Ref: IS 3043 : 2018, para 3.13)

Avoidance of Thermal Distress - The earthing conductor also functions to carry the full earth fault current without excessively raising the temperature of the earthing conductor or causing the expulsion of arcs and sparks that could initiate a fire or explosion.

Preservation of System Performance - The earthing conductor must return the earth fault current back to the source without introducing additional resistance/impedance to such an extent that would affect the operation of OCPD (Over current protective device).

2.2 Protective conductor - A conductor used as a measure of protection against electric shock and intended for connecting any of the following parts:

- a) Exposed conductive parts
- b) Extraneous conductive parts
- c) Main earthing terminal.
- d) Earthed point of the source or an artificial neutral.

The protective conductor designated as 'PE' shall have bi-colour combination, **green and yellow** (green/yellow), for identification as protective conductor and for no other purpose.

- Parts not required to be earthed are Overhead line insulator brackets and metal parts connected to them if such parts are not within arm's reach.

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3 Equipotential Bonding:

“Electrical connection putting various exposed conductive parts and extraneous conductive parts at a substantially equal potential is termed as equipotential bonding”. (ref: IS:3043-2018 para no. 3.15)

Equipotential is derived from Equal potential between two points. In a system, connections of all non-current carrying (exposed conductive parts) parts of a current using equipment like metal body of equipment, etc. and connections of all non-electrical metallic items embedded in building structure (extraneous conductive parts) for example Reinforced steel in concrete, Metallic pipe lines, etc. to main earthing terminal in order to bring all at same potential (Equipotential) in event of an earth fault is called Equipotential bonding.

3.1 Protective Equipotential Bonding:

Equipotential bonding done for the purpose of safety is termed as “Protective Equipotential bonding”. In this protection is achieved by automatic disconnection of supply.

3.2 Supplementary Equipotential Bonding:

Supplementary Equipotential Bonding is also called as Local Equipotential Bonding. This is done to achieve high degree of safety against electric shock, Supplementary equipotential bonding is considered as an addition to fault protection. This will also reduce the voltages occurring in the event of an earth fault still further.

During design of an electrical system if the fault loop impedance which is required for automatic disconnection of supply is not achieved through equipotential bonding, then it is necessary to provide supplementary equipotential bonding.

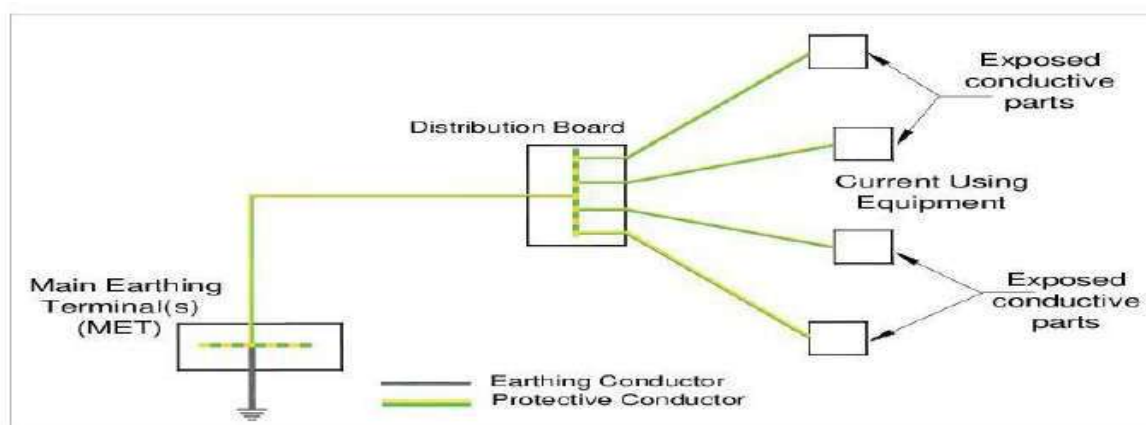
3.3 Main Earthing Terminal (MET):

The function of MET is to provide a reference point for the installation, it consists of a terminal or bar provided for the connection of earthing conductor for functional earthing.

MET is connected to earth, but it remains rarely at zero potential because of the potential difference caused by leakage and other current flowing to earth.

3.4 Typical Schematic of Earthing and Protective Conductor:

A typical schematic of earthing and protective conductors is shown in given below figure. In the installation, all protective conductors of exposed conductive parts are connected to main earthing terminal at distribution boards. Further the METs of all distribution boards are connected to main MET. All extraneous conductive parts, incoming metallic service pipes, are also connected to main MET. Further this main MET is connected to earth electrodes by Earth conductor or PEN conductor as per design of the supply system.



3.5 Extraneous Conductive Parts:

The extraneous conductive parts that are required to be bonded to the main earthing terminal of the installation (or to the earth electrode of the installation) include:

- Gas pipes,
- Other service pipes and ducting,
- Risers and pipes of fire protection equipment,
- Exposed metallic parts of the building structure, and
- Lightening conductors.

3.6 Exposed Conductive Parts to be earthed:

(Ref: IS 3043 : 2018 para 23.2.4)

Exposed conductive parts that are required to be connected by means of protective conductors to the main earthing terminal of the installation are as follows:

- All metal structure associated with wiring system (other than current-carrying parts) including cable metal sheaths and armour, conduit, ducting, trunking, boxes and catenary wires.
- The exposed metal structure of all Class I equipment fixed and portable current-using equipment. All fixed wiring accessories should incorporate an earthing terminal that is connected to the main earthing terminal by means of the protective conductors of the circuits concerned.
- The exposed metal structure of transformers used in the installation other than those that are an integral part of equipment.
- Exposed conductive parts of small dimensions that cannot be gripped or contacted by a major surface of the human body (that is, a human body surface not exceeding 50 mm x 50 mm) need not be earthed if the connection of those parts to a protective conductor cannot readily be made and reliably maintained. Typical examples of such parts are: screws and nameplate, cable clips and lamp caps. Other exposed conductive

4. Protection in LV Installation:

The fundamental rule of protection against electric shock is "Hazardous live parts must not be accessible and accessible conductive parts must not be hazardous live"(IS 732:2019 para 4.2).

Electric Shock:

4.1 Range of Tolerable Current:

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Effects of an electric current passing through the vital parts of a human body depend on the duration, magnitude, and frequency. The most dangerous consequence of such an exposure is a heart condition known as ventricular fibrillation, resulting in immediate arrest of blood circulation.

A circuit connected to the earthing arrangement (protective equipotential bonding) will protect us from an electrical shock if the supply is disconnected within the recommended time. Connection to earth electrode (plate/pipe/rod) will not protect us from electric shocks. The only way to prevent or stop an electric shock is to turn off the circuit before it creates a shock.

4.2 Effect of Frequency:

Humans are very vulnerable to the effects of electric current at frequencies of 50 Hz. Currents of approximately 100 mA can be lethal. Research indicates that the human body can tolerate a slightly higher 25 Hz current and approximately five times higher direct current.

4.3 Effect of Magnitude and Duration of Current Passing through Body:

S. No	Current Range	Repercussion on Body
1	1 mA	Threshold of perception; that is, the current magnitude at which a person is just able to detect a slight tingling sensation in his hands or fingertips.
2	1 mA to 6 mA	Let-go currents, though unpleasant to sustain, generally do not impair the ability of a person holding an energized object to control his muscles and release it.
3	9 mA to 25 mA	This currents range may be painful and can make it difficult or impossible to release energized objects grasped by the hand.
4	25mA to 60mA	This currents range could lead to muscular contractions which can make breathing difficult. These effects are not permanent and disappear when the current is interrupted, unless the contraction is very severe and breathing is stopped for minutes rather than seconds.
5	60mA to 100 mA	This currents range may cause ventricular fibrillation, stoppage of the heart, or inhibition of respiration might occur and cause injury or death.

If shock currents can be kept below this value by a carefully designed earthing system by reducing the shock voltage (shock voltage can be reduced by protective equipotential bonding) and duration, injury or death may be avoided. The magnitude and duration of the current conducted through a human body at 50 Hz should be less than the value that can cause ventricular fibrillation of the heart.

4.4 Touch Voltage:

(Ref:- IS 3043 : 2018 para 3.36)

Voltage between conductive parts when touched simultaneously that is the potential difference between an earthed conductor part of equipment, (that is exposed conductive part) which can be touched and which is not a live part but which may become live under fault condition and a point on a conductive part (that is extraneous conductive part) liable to

transmit a potential including earth potential and not forming part of the electrical installation or a point on earth's surface separated by a distance equal to the maximum normal reach (hand to hand or hand to foot) approximately one metre.

4.5 Disconnecting Times for Different Touch Voltages:

Limits of touch voltage are based on studies on the effects of current on human body (Ref IS/ IEC 60479 : 2005). The values disconnection time limits (t) for different touch voltages for two most common conditions (dry and wet conditions) for safety of human beings. If the system has to protect the human, it should trip within the stipulated time limits. During the designing of system, the selection of protective devices can be done based on the tripping time w.r.t the prospective fault current. This fault current can be calculated with the help of System voltage and Fault loop impedance.

(Ref- IS 3043 : 2018, Table 13) Prospective Touch Voltage U_c	Condition 1 Dry or moist locations, dry skin and significant floor resistance			Condition 2 Wet locations, wet skin and low floor resistance		
	Z_1	I	t	Z_2	I	t
(V)	(Ω)	(mA)	(s)	(Ω)	(mA)	(s)
(1)	(2)	(3)	(4)	(5)	(6)	(7)
25	--	--	--	075	23	5
50	1725	29	5	925	54	0.47
75	1625	46	0.60	825	91	0.30
90	1600	56	0.45	780	115	0.25
110	1535	72	0.36	730	151	0.18
150	1475	102	0.27	660	227	0.10
220	1375	160	0.17	575	383	0.035
280	1370	204	0.12	570	491	0.020
350	1365	256	0.08	565	620	--
500	1360	368	0.04	560	893	--

Z_1 - Total Impedance of human body in Dry condition (IS 60479:2005 part 1)
 Z_2 - Total Impedance of human body in wet condition (IS 60479:2005 part 1)
 I – Current that will flow through the human body
 t- Disconnecting time limit which will not result in harmful physiological effects on Human body.

4.6 Types of Voltage System:

Low Voltage	The voltage which does not normally exceed 250 V
Medium Voltage	The voltage which normally exceeds 250 V but does not exceed 650 V
High Voltage	The voltage which normally exceeds 650 V (but less than 33 kV)
Extra High Voltage	The voltage exceeding 33 kV under normal conditions.

(Ref: Para 3.3.37 to 3.3.40 of Part 1 – Section 2 of NEC 2011 & IS:12360 forward para 0.5)

Standard Values of Voltages in LV Installations:

For medium and low voltage of distribution system, the recommended standard values of nominal voltages are 240 V single-phase and 415 V three-phase with a tolerance of ± 6 percent (IS 12360:1988 R2010).

4.7 Step Voltage:

(Ref:- IS 3043 : 2018 para 3.37)

The potential difference between two points on the earth's surface, separated by distance of one pace, that will be assumed to be 1 m in the direction of maximum potential gradient.

5. LV Protection System:

(Ref: Para 4 of IS 732:2019)

System that is essential to safeguard persons, property and electrical equipment against ill effects of electricity is called Electrical Protection system. The LV protection required for different faults are protection against Electric shock, thermal effects, over current, fault currents, etc.

5.1 Reasons for Electrical Faults:

There is a number of reasons for the occurrence of a fault in the Electrical system. Some of the possible reasons of faults are as below:

- 5.1.1 Overload:** Operating conditions in an electrically undamaged circuit, which causes an over current. It is mainly caused when one tries to use a equipment beyond its rated capacity, or there is a fault within equipment.
- 5.1.2 Short-circuit:** The intentional or accidental connection of two points of a circuit through a negligible impedance. Examples Insulation Failures, Shorting of the Phase to Phase or Phase and Neutral Wires
- 5.1.3 Earth Fault:** Accidental connection/contact of a live conductor to earth (exposed conductive parts/earth conductor) with negligible impedance is called an earth faults. Ex- Short circuit between Phase and Earth Conductor.
- 5.1.4 Earth Leakage:** Electric current that finds its way to earth via an unintended path due to poor/bad insulation then it is called Earth Leakage current.

5.2 Short circuit Loop Impedance:

The short circuit loop impedance (phase to neutral or phase to phase) comprises the following, starting at the point of short

1. The Neutral conductor up to main distribution board;
2. The PEN conductor (For TN-C-S) and Neutral conductor for TN-S/ TT system
3. The path through the earthed neutral point of the transformer;
4. The transformer winding; and
5. The line conductor from the transformer to the point of short.

5.3 Earth Fault Loop Impedance:

(Ref: Para 3.64 of IS 732:2019)

Impedance/resistance encountered by earth fault current under earth fault condition is called "earth fault loop impedance". This is the most important parameter to be known/measured to decide the effectiveness of the protection system.

The earth fault loop comprises the following, starting at the point of earth fault

- 5.3.1** The circuit protective conductor (earth conductor)
- 5.3.2** The consumer's earthing terminal and earthing conductor.

- 5.3.3 In TN systems, the metallic return path; i.e. PEN/ PE conductor and for TT systems, the earth return path through soil.
- 5.3.4 The path through the earth neutral point of the transformer.
- 5.3.5 The transformer winding.
- 5.3.6 The line conductor from the transformer to the point of fault.

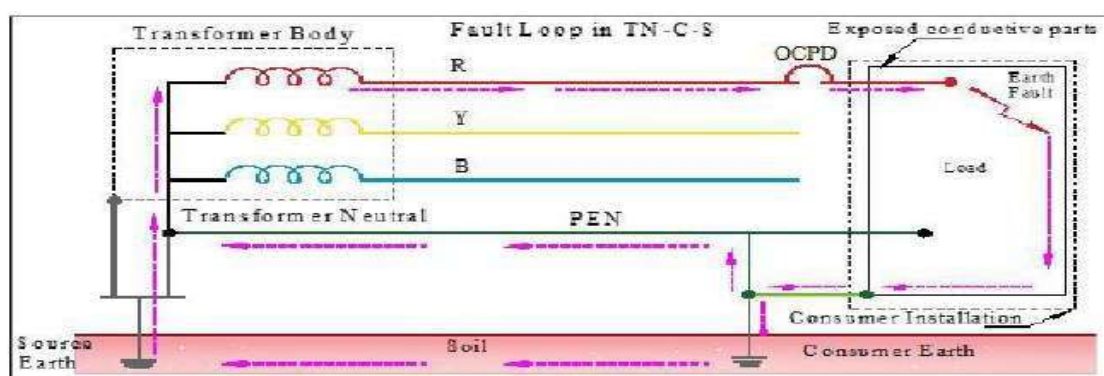
Whenever fault occurs the current will flow through this fault loop and protection system will be designed accordingly with prospective fault current. This fault current can be calculated with the help of System voltage and Fault loop impedance.

5.4 Earth Fault Loop Paths in Different Earthing System:

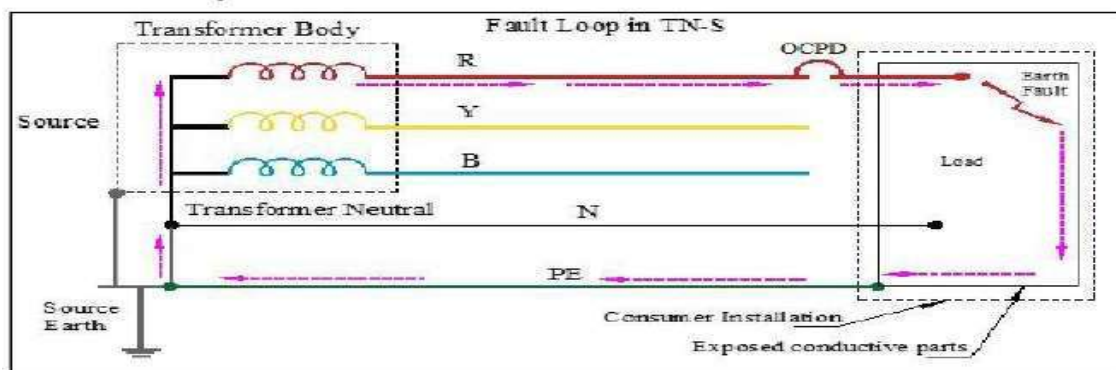
Different Earthing systems have different earth fault path as shown below.

5.4.1 T N System

5.4.1.1 T N-C-S system (Most common system used by Electrical Utilities)



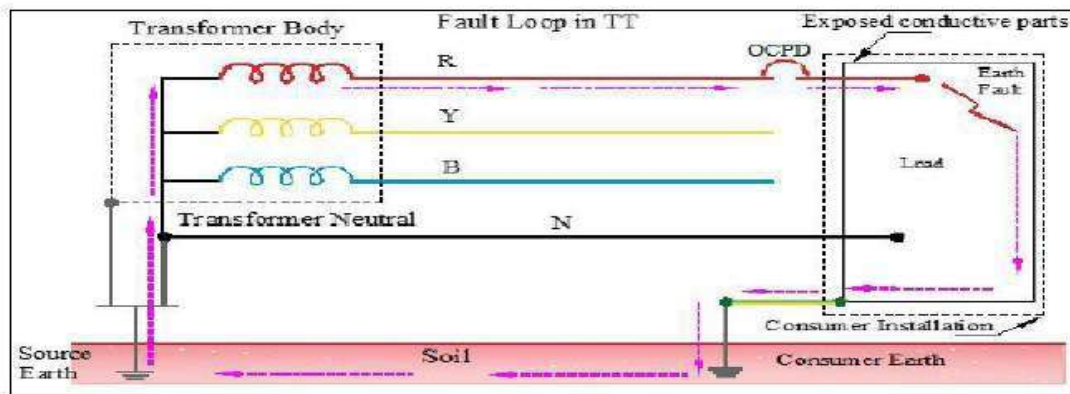
5.4.1.2 T N-S System:



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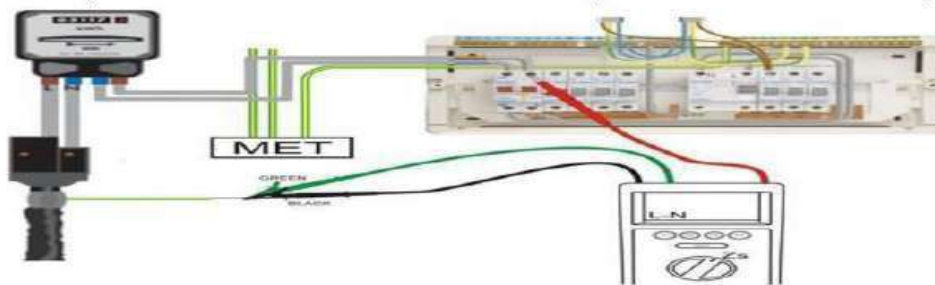
5.4.2 T T System:



5.5 Measurement of Fault Loop Impedance:

Measurement of fault loop impedance using fault loop impedance tester (practically used):

Fault Loop impedance testers are used to measure earth fault loop impedance between Phase to earth and short circuit loop impedance (phase to neutral). This equipment also gives prospective earth fault current/ short circuit current to decide suitable protective device for the system.



The above method is practically used in field, although loop impedance can also be measured by voltage drop method.

6. Protective Devices for LV Installation:

Generally, there are three types of protective devices in an LV installation : Overcurrent Protection Devices, Residual Current Devices and Other Protective Devices. Under these categories, following devices are seen commonly in LV system:

Over current protective devices- MCB, MCCB & ACB.

Residual current devices - RCCB & CBCT.

Other protective Devices-RCBO& AFDD

6.1 Over Current Protective Devices:

6.1.1 Miniature Circuit Breaker (MCB):

MCB are widely used in electrical distribution system for switching ON/OFF Electrical supply and for protection against over current and short circuit currents.

Working Principal of MCB:

There are essentially two different mechanisms inside the MCB that provides overload/Short Circuit protection:

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i. **Bimetallic Strip for overload:**

Whenever continuous over current flows through MCB, the bimetallic strip is heated and deflects by bending. This deflection of bi-metallic strip releases a mechanical latch. As this mechanical latch is attached with the operating mechanism, it causes to open the miniature circuit breaker contacts, and the MCB turns off thereby stopping the current to flow in the circuit

ii. **Magnetic Trip Coil for short circuit:** This mechanism comes in force in case of a short circuit event. A short circuit event is associated with the large fault current energizes the solenoid and the magnetic field of the solenoid attracts the plunger which in turn strikes the trip lever and hence the immediate release of the latch mechanism.

The arc is produced during the separation of the contacts at overload as well as short circuit conditions. This arc is moved into the arc-cute stack under the influence of a magnetic field. So, the arc broken down into partial arcs in arc chutes and they no longer exist due to the voltage drop of the arcs.

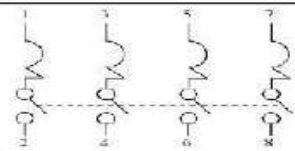
6.1.1.1 Classification of MCB: MCBs are mainly classified on the following basis:-**6.1.1.1.1 On the basis of rated current/ Rated short-circuit capacity:**

S.N	Rated	Types
1.	Rated current	1A,2A,3A,4A,6A,8A,10A,16A,20A,25A,32A,40A,50A,63A,80A,100A,125A
2.	Rated short-circuit capacity (I_{cn})	1.5KA,3KA,4.5KA,6KA & 10KA

(ref.: para 5.3.2,5.3.4 of IS 60898)

6.1.1.1.2 On the basis of number of poles:

S.N	Number of Poles	Short Name	Description	Wiring Diagram
1.	Single Pole	SP	Switching & protection (overload & Short circuit) is affected in only one phase	
2.	Single Pole and Neutral	SPN	Protection (overload & Short circuit) is affected in phases. Neutral is part of the MCB as a separate pole but without any protective given in the neutral pole	
3.	Double Pole	DP	Switching & protection (overload & Short circuit) is affected in phases and the neutral	
4.	Triple Pole	TP	Switching & protection (overload & Short circuit) is affected in only three phases and the neutral is not part.	
5.	Triple Pole and Neutral	TPN	Protection (overload & Short circuit) is affected in only three phases. Neutral is part of the MCB as a separate pole but without any protective given in the neutral pole	

6.	Four Pole	FP	Switching & protection (overload & Short circuit) is affected in three phases and the neutral.	
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6.1.1.1.3 On the basis of tripping current v/s time characteristics:

Type of MCB	Operating current	Operating Time	Intended Load
Type B	3 to 5 times the full load current	0.04 To 13 Sec	Resistive circuits eg. Lighting etc.
Type C	5 to 10 times the full load current	0.04 To 5 Sec	Medium inductive loads eg. Inductive motors, Fluorescent lightings etc.
Type D	10 to 20 times the full load current	0.04 To 3 Sec	Highly inductive and capacitive loads eg. Motors, Transformers etc.
Type K	8 To 12 times the full load current	<0.1 Sec	Inductive and motor loads with high inrush currents.
Type Z	2 To 3 times the full load current	<0.1 Se	Protection of highly sensitive devices such as semiconductor devices.

(ref.: para 5.3.2,5.3.4 of IS 60898)

6.1.1.2 Selection of right MCB:

There are two important criteria for selection of suitably rated MCB for giving protection to an electrical circuit/equipment against overload & short circuit within permissible time.

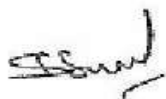
1. Selection of Current rating of MCB: - Primary job of the MCB is to protect the wiring and installation from over current and short circuits as well as provide shock protection by automatic disconnection of supply within permissible time. The disconnection of MCB will depend upon earth fault/short circuit loop impedance. Earth fault loop impedance will further depend upon type of system earthing (TN or TT). On the basis of measured earth fault/short circuit loop impedance, the prospective earth fault/short circuit current which is required for immediate tripping (i.e. ≤ 0.1 sec) of MCB can be calculated. On the basis of calculated earth fault/short circuit current, the MCB of particular current rating should be selected.

2. Type of Load : - Selection between Type B,C & D MCBs:

The role of a circuit breaker is to trip quickly enough to avoid equipment or wiring failure, but not so fast as to give false, or nuisance trips.

It is important that equipment having high inrush currents should not cause the circuit breaker to trip unnecessarily, and yet the device should trip in the event of a short-circuit current that could damage the circuit cables.

We need different types of MCBs in order to balance the right amount of overcurrent protection against optimal machine operation. Choosing a circuit breaker that trips too soon can result in nuisance tripping. Choosing a circuit breaker that trips too late can result in catastrophic damage to machine and cables.




Type B devices are generally suitable for domestic applications. They may also be used in light commercial applications where switching surges are low or non-existent.

Type C devices are the normal choice for commercial and industrial applications where fluorescent lighting, motors etc. are in use.

The Type D devices have more limited applications, normally in industrial use where high inrush currents may be expected. Examples include large battery charging systems, winding motors, transformers, X-ray machines and some types of discharge lighting.

6.1.1.3 Effect of Temperature & Grouping on rating of MCB:

Appropriate MCB selection requires consideration of operating conditions that can affect their electrical characteristics. The following factors need to be considered.

6.1.1.4 Temperature de-rating:

The rated value of the current of the B & C type MCB refers to a reference ambient temperature of 30°C. MCB can be used at temperatures ranging from -30°C to 60°C/70°C. The range of temperature is specified by the manufacturer.

Installation/ operation at higher ambient temperature requires progressively less rated current of MCB. The de-rating factor due to change in ambient temperature are different for each manufacturer, which may be considered before installation.

6.1.1.5 Grouping Factor:

When a number of MCB or combined RCD/MCB's are mounted side by side in a small enclosure, the temperature rise inside the enclosure may cause a reduction in the rated current. The reduction can be calculated by multiplying the rated current by a 'grouping factor'. The grouping factor is depend on manufacture

6.1.2 Molded case circuit breakers (MCCB):

MCCB stands for Molded Case Circuit Breaker. It is another type of electrical protection device which is used when load current exceeds the limit of MCB (MCBs are rated up to 125 Ampere while MCCBs are rated up to 1600 Amp).

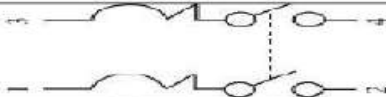
MCCBs have all of the operating parts contained within a case that is fabricated of a non-conducting material which is usually a thermoset plastic and which is "molded."

The MCCB provides protection against overload, short circuit faults and is also used for switching the circuits. It can be used for higher current rating and fault level even in domestic applications. The wide current ratings and high breaking capacity in MCCB find their use in industrial applications. MCCB can be used for protection of capacitor bank, generator protection and main electric feeder distribution. It offers adequate protection whenever an application requires discrimination, adjustable overload setting or earth fault protection.

MCCBs could be thermal magnetic type or microprocessor type.

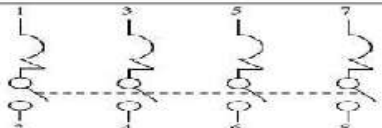
6.1.2.1 Classification of MCCB:

6.1.2.1.1 On the basis of Number of Poles:

S.N.	Number of Pole	Short Name	Description	Wiring Diagram
1.	Two Pole	2P	Switching & protection (overload & Short circuit) is affected in phases and the neutral.	
2.	Triple Pole	3P	Switching & protection (overload & Short circuit) is affected in only three phases and the neutral is not part	

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3.	Four Pole	4P	Switching & protection (overload & Short circuit) is affected in three phases and the neutral	
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6.1.2.2 On the basis of tripping current v/s time characteristics:

Same criteria as applicable for MCB

6.1.2.3 Air Circuit Breaker (ACB):

Air Circuit Breaker (ACB) is an electrical protection device used for short circuit and overcurrent protection mainly at Main distribution board. It is used for higher current carrying capacity. The main aim of circuit breaker is to prevent reestablishment of arcing after current zero where the contact gap will withstand the system recovery voltage. It does it same work, but in a different manner. During interruption of arc, it creates an arc voltage instead of supply voltage. Arc voltage is defined as the minimum voltage required for maintaining arc. The circuit breaker increases the voltage in three different ways:

- 1 Arc voltage can be increased by cooling arc plasma. As soon as the temperature of arc plasma motion of particle in arc plasma is reduced, more voltage gradient will be required to maintain the arc.
- 2 By splitting the arc into a number of series will increases the arc voltage.
- 3 Arc voltage can be increased by lengthening the arc path. As soon length of arc path is increased the resistance path will increase more arc voltage is applied across the arc path hence arc voltage is increased.

ACBs could be thermal magnetic type or microprocessor type.

Classification of ACB:

6.1.2.3.1 On the basis of number of poles:

1. Triple Pole 3P
2. Four Pole 4P

6.1.2.4 On the basis of rated current:

S.N.	1	2	3	4	5	6	7	8	9	10	11
Rating	400 A	630 A	800 A	1000 A	1250 A	1600 A	2500 A	3200 A	4000 A	5000 A	6300 A

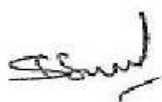
6.1.3 Residual Current Devices:

Residual Current Device (RCD) (IS 732:2019 para 3.157) — A mechanical switching device or association of devices intended to cause the opening of the contacts when the residual current attains a given value under specified conditions. RCD is a life-saving device which is designed to prevent you from getting a fatal electric shock if you touch something live, such as a bare wire. It can also provide some protection against electrical fires.

Working Principle: RCCB (Residual Current Circuit Breaker) works on 'Kirchhoff's Current Law' which states that 'The amount of current entering the circuit must be equal to the amount of current leaving the circuit' i.e. the sum of the total (incoming + outgoing) current should be zero. If these do not sum to zero, there is a leakage of current to somewhere else (to earth/ground or to another circuit), and the device will open its contacts.

6.1.4 Residual Current Circuit Breaker (RCCB):

RCCB is the most common RCD used in electrical system. Inside RCCB there is a CBCT (Core Balance Current Transformer) which senses the magnitude of current entering the circuit & leaving the circuit. Whenever a current leakage is sensed, the relay associated with CBCT gets energized and trips the RCCB. This is to mention that RCCB is not designed to perform the functions of protection against overload and/or short-circuit.

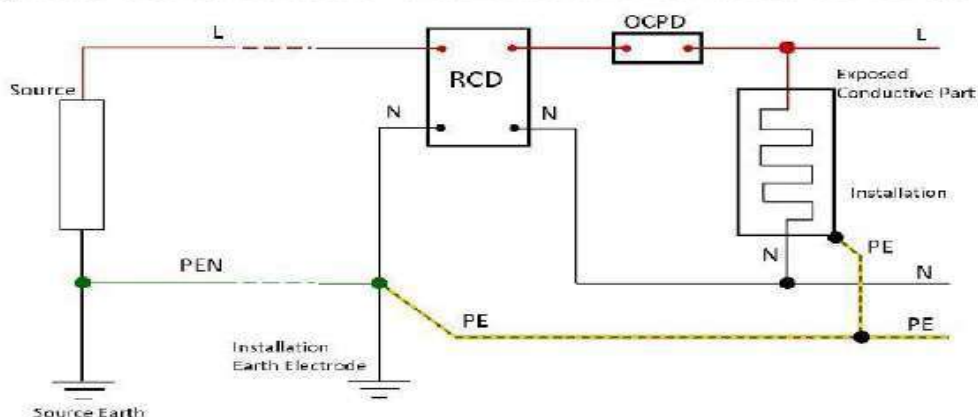



6.1.4.1 Connection of RCD in different Earthing system:

Electrical supply systems are further classified as TN system, TT system based on system earthing.

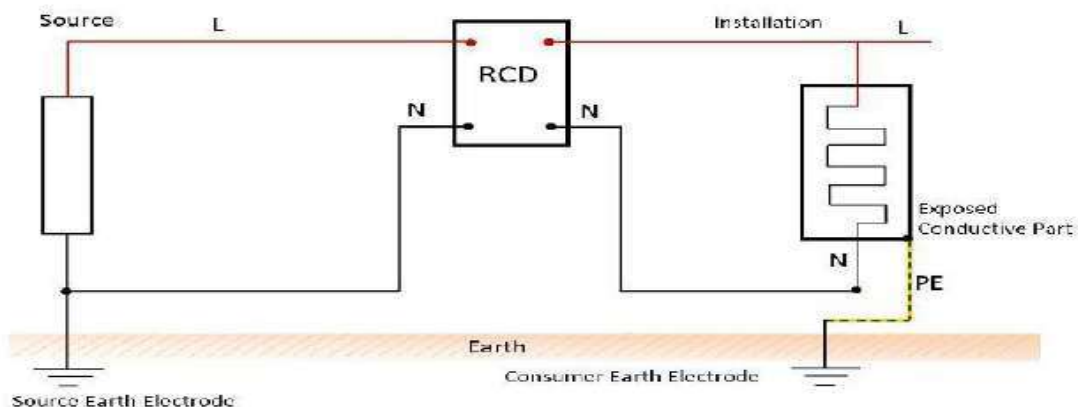
6.1.4.1.1 TN System:

In TN systems, the most commonly used system is TN-C-S system. The OCPD & RCD may be used as protective devices for fault protection in TN system. Where an RCD is used in a TN-C-S system, a PEN conductor shall not be used on the load side. The connection of the protective conductor to the PEN conductor shall be made on the source side of the RCD.



6.1.4.1.2 TT System:

In TT systems RCD may be used for fault protection in addition to OCPD. Following protective devices may be used for fault protection,



RCD is used as a mandatory protection against earth fault & leakages in TT system since Earth Fault loop impedance is very high and fault current is not sufficient to enable Circuit breaker tripping

Points to be noted while selecting and installing RCD

- RCD to be provided at the incoming supply of every sub-distribution board having one or more outgoing circuits with fixed installation and socket-outlets. Ex. Domestic and similar applications
- Mobile equipment ex Portable gen-set, and hand-held equipment.

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- c. In addition to giving protection against indirect contact or direct contact RCDs may also give fire risk protection, As per IEC 60364-4-422.3.9 & IS 732:2019 (para 4.3.2.3.9) 300 milliamps RCD is recommended to prevent fire due to leakage current in the building.
- d. An RCD should be chosen having the lowest suitable operating current. The minimum operating current will be above any standing leakage that may be unavoidable on the system.

6.1.5 Other Protective Devices:

6.1.5.1 Residual Current Breaker with Over Current (RCBO):

It a combination of MCB and RCCB. RCBO is designed to provide protection against both residual current and overcurrent/ short circuit current. It can be used independently of any other overcurrent protective device within its rated short-circuit capacity.

6.1.5.2 Arc Fault Detection Device (AFDD):

An Arc Fault device detects series (arcing within one of the conductors), parallel (line to line, line to neutral and line to earth) or ground arc fault on an early stage, before a fire can occur and disconnect the final circuit with the associated circuit breaker, ground leakage device or break.

An AFDD utilizes electronic technology to analyze the signature (waveform) of an arc to differentiate between normal arcing and arcing faults. It constantly monitor and analyze patterns in electrical current and voltage waveforms. They monitor for the random, non-predictable yet persistent patterns of waveforms that denote a potentially dangerous arc upon detection of an arcing fault, the AFDD disconnects the final circuit from the supply. It shall be installed at the origin of the final circuits to be protected. AFDD are available in the current ratings of 6A, 8A, 10A, 13A, 16A, 20A, 25A, 32A, 40A, 50A & 63 A.

7. Inspection of LV Installation:

Initial Inspection shall precede testing and shall be done prior to energizing the installation. The purpose of inspection is to ensure following aspects:

- i. Checking of Wiring & Earthing system.
- ii. Checking of Protection system.
- iii. To ensure that the electrical equipment fixed in the installation are correctly selected and erected according to IS 732:2019 and as per the manufacturer's installation guidelines duly ensuring safety requirements.
- iv. To ensure that the electrical equipment fixed in installation are not in visibly damaged condition which may impair safety.

7.1 Points to be check during Inspection:

(Ref: Para 6.2.2.3 of IS 732:2019)

Inspection shall include at least the checking of the following, where relevant:

- i. Provisions for protection against electric shock.
- ii. Provisions for protection to limit propagation of fire and protection against thermal effects like provision of fire barriers and other precautions.
- iii. Selection of conductors according to current-carrying capacity and voltage drop.
- iv. Selection and setting of protective and monitoring devices.
- v. Presence and correct location of suitable isolating and switching devices.
- vi. Selection of equipment and protective measures appropriate to external influences.
- vii. Connection of single-pole switching devices in the line conductors.
- viii. Selection of equipment and protective measures appropriate to external influences.
- ix. Correct identification of line, neutral and protective conductors (earth wires).
- x. Identification of circuits, overcurrent protective devices, switches, terminals, etc. and presence of circuit diagrams, warning notices or other similar information.
- xi. Adequacy of termination and connection of cables and conductors.

- xii. Presence and adequacy of protective conductors (earth wires), including main and supplementary equipotential bonding conductors.
- xiii. Accessibility of equipment for convenience of operation, identification and maintenance.
- xiv. Presence of diagrams, warning notices or other similar information.

8 Testing of LV Installation:

(Ref:- Para 6.2.3 of IS 732:2019)

The following tests shall be carried out where relevant and should preferably be made in the following sequence:

- a) Continuity of conductors.
- b) Insulation resistance of the electrical installation.
- c) Protection by SELV, PELV or by electrical separation.
- d) Floor and wall resistance/impedance.
- e) Automatic disconnection of supply.
- f) Additional protection.
- g) Polarity test.
- h) Test of the order of the phases.
- i) Functional and operational tests.
- j) Voltage drop test.

a) Continuity of conductors:

An electrical continuity test shall be made on protective conductors, including main and supplementary equipotential bonding conductors, and in the case of ring final circuits, live conductors.

NOTE — A ring final circuit is a final circuit arranged in a form of a ring connected to a single point of supply.

b) Insulation resistance of the electrical installation:

The insulation resistance shall be measured between live conductors and the protective conductor connected to the earthing arrangement. For the purposes of this test, live conductors may be connected together.

The insulation resistance, measured with the test voltage is satisfactory if each circuit, with the appliances disconnected, has an insulation resistance not less than the appropriate value given in table given below.

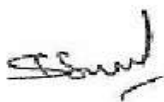
Table given below shall be applied for a verification of the insulation resistance between non-earthed protective conductors and earth.

Where surge protective devices (SPDs) or other equipment are likely to influence the verification test, or be damaged, such equipment shall be disconnected before carrying out the insulation resistance test.

Where it is not reasonably practicable to disconnect such equipment (for example, in case of fixed socket- outlets incorporating an SPD), the test voltage for the particular circuit may be reduced to 250 V d.c., but the insulation resistance must have a value of at least 1 MΩ.

NOTES:

1. For measurement purposes, the neutral conductor is disconnected from the protective conductor.
2. In TN-C systems, measurement is made between the live conductors and the PEN conductor.



3. In locations exposed to fire hazard, a measurement of the insulation resistance between the live conductors should be applied. In practice, it may be necessary to carry out this measurement during erection of the installation before the connection of the equipment.
4. Insulation resistance values are usually much higher than those of Table as Annexure A. When such values show evident differences, further investigation is needed to identify the reasons.

Nominal Circuit Voltage V	Test Voltage d.c. V	Insulation Resistance MΩ
SELV and PELV	250	≥ 0.5
Up to and including 500 V, including FELV	500	≥ 1.0
Above 500 V	1 000	≥ 1.0

c) Protection by SELV, PELV or by electrical separation:

In each part of an LV installation, one or more following protective measures are applied, taking into account of the requirement of the system:-

- a) Automatic disconnection of supply through various protective devices- This most commonly used protective measure . This has already been describes in detail in this guideline.
- b) Barring the contact with the live parts / insulation .
- c) Provision of Extra Low Voltage (SELV and PELV) –

Extra-low voltage (ELV) is an electricity supply voltage which carries a low risk of dangerous electrical shock. limitation of voltage in the SELV or PELV system is the upper limit of Voltage Band I, 50 V a.c. or 120 V d.c. [see IS 12360 (Part 2)]. Extra-low voltage is used where the risks are great: swimming pools, wandering-lead hand lamps, and other portable appliances for outdoor use, amusement parks, etc.

SELV stands for Separated or safety Extra Low-Voltage and PELV stands for Protective Extra Low-Voltage.

- SELV system is an electrical system in which the voltage cannot exceed ELV under normal conditions, and under single-fault conditions, including earth faults in other circuits. Supplying power at extra-low voltage from the secondary windings of isolating transformers especially designed according to standard. The secondary voltage never exceeds 50 V rms. No live conductor at SELV must be connected to earth. SELV is used in situations where the operation of electrical equipment presents a serious hazard (swimming pools, amusement parks, etc.)
- PELV system is an electrical system in which the voltage cannot exceed ELV under normal conditions, and under single-fault conditions, except earth faults in other circuits. This system is for general use where low voltage is required, or preferred for safety reasons, other than in the high-risk locations noted above. The conception is similar to that of the SELV system, but the secondary circuit may earthed at one point.
- FELV- where, for functional reasons, a voltage of 50 V or less is used, but not all the requirements relating to SELV or PELV are fulfilled. Such conditions may, for example, be encountered when the circuit contains equipment (such as transformers, relays, remote-control switches, contactors) insufficiently insulated with respect to circuits at higher voltages.

d) Insulation resistance/impedance of floors and walls:

(Ref.: para 6.2.3.5 of IS732:2019)

At least three measurements shall be made in the same location, one of these measurements being approximately 1 m from any accessible extraneous- conductive-part in the location. The other two measurements shall be made at greater distances.

The measurement of resistance/impedance of insulating floors and walls is carried out with the system voltage to earth at nominal frequency.

The above series of measurements shall be repeated for each relevant surface of the location.

e) Protection by automatic disconnection of the supply:

(Ref: Para 6.2.3.6 of IS732:2019)

i) General:

The verification of the effectiveness of the measures for protection against indirect contact by automatic disconnection of supply is effected as follows:

➤ **For TN systems:**

- Measurement of the fault loop impedance (NOTE — When RCDs with $I_n < 500$ mA are used as disconnecting devices, measurement of the fault loop impedance is normally not necessary).

Alternatively, where the calculation of the fault loop impedance or of the resistance of the protective conductors are available, and where the arrangement of the installation permits the verification of the length and cross-sectional area of the conductors, the verification of the electrical continuity of the protective conductors is sufficient.

- Verification of the characteristics and/or the effectiveness of the associated protective device. This verification shall be made for:

- Overcurrent protective devices, by visual inspection (that is, short time or instantaneous tripping setting for circuit-breakers, current rating and type for fuses).
- RCDs, by visual inspection and test:

The effectiveness of automatic disconnection of supply by RCDs shall be verified using suitable test equipment. It is recommended that the disconnecting times required to be verified in case of (i) Re-used RCDs, (ii) additions or alterations to an existing installation where existing RCDs are also to be used as disconnecting devices for such additions or alterations.

(Note — Where the effectiveness of the protective measure has been confirmed at a point located downstream of an RCD, the protection of the installation downstream from this point may be proved by confirmation of the continuity of the protective conductors).

➤ **For TT systems:**

- Measurement of the resistance of the earth electrode for exposed-conductive-parts of the installation.

(NOTE — Where the measurement of earth resistance is not possible, it may be possible to replace it by the measure of the fault loop impedance.)

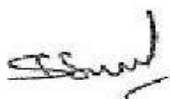
- Verification of the characteristics and/or effectiveness of the associated protective device. This verification shall be made as done for TN System

➤ **For IT systems:**

Exposed conductive parts shall be earthed individually, in groups, or collectively.

The following condition shall be fulfilled:

- in a.c. systems $R_A \times I_d < 120$ V



— in d.c. systems $RA \times I_d < 120 \text{ V}$ where

RA = the sum of the resistance of the earth electrode and protective conductor for the exposed conductive parts; and

I_d = the fault current in A of the first fault of negligible impedance between a line conductor and an exposed conductive part. The value of I_d takes account of leakage currents and the total earthing impedance of the electrical installation.

Compliance with the rules of above shall be verified by calculation or measurement of the current I_d in case of a first fault at the line conductor or at the neutral.

NOTE — The measurement is made only if the calculation is not possible, because all the parameters are not known. Precautions are to be taken while making the measurement in order to avoid the danger due to a double fault.

Where conditions that are similar to conditions of TT systems occur, in the event of a second fault in another circuit, verification is made as for TT systems.

Where conditions that are similar to conditions of TN systems occur, in the event of a second fault in another circuit, verification is made as for TN systems.

ii) Measurement of the resistance of the earth electrode:

(Ref.: 6.2.3.6.2 of IS 732:2019)

The resistance offered by the earth electrode to the flow of current into the ground is known as the earth resistance or resistance to earth. The tests done are measurement of earth resistance of each electrode and measurement of resistance of entire earthing system when all electrodes are connected to the grid. These tests shall preferably be done during the summer months.

One of the methods for measuring earth resistance is using auxiliary earth electrodes. An alternating current of a steady value is passed between the earth electrode, T, and an auxiliary earth electrode, T1, placed at a distance such that the resistance areas of the two electrodes do not overlap. A second auxiliary earth electrode, T2, is then inserted half-way between T and T1, and the voltage drop between T and T2 is measured. The resistance of the earth electrode is then the voltage between T and T2, divided by the current flowing between T and T1, provided that there is no overlap of the resistance areas. At the time of test, the test electrode shall be separated from earthing system. The auxiliary electrodes usually consist of 12.5 mm dia MS steel rod driven up to 1 m into the ground. In the case of rod, pipe and plate, the auxiliary earth electrode T1 shall be placed at least 30 m away from it and the auxiliary potential electrode midway between them. To check that the resistance of the earth electrode is a true value, two further readings are taken with the second auxiliary electrode T2 moved 6 m from and 6 m nearer to T, respectively. If the three results are substantially in agreement, the mean of the three readings is taken as the resistance of the earth electrode T. If there is no such agreement, the tests are repeated with the distance between T and T1 increased.

Where the location of the installation (for example, in towns) is such that it is not possible in practice to provide the two auxiliary earth electrodes, measurement of the fault loop impedance.

f) Additional protection:

The verification of the effectiveness of the measures applied for additional protection is fulfilled by visual inspection and test.

- i. Where RCDs are required for additional protection, the effectiveness of automatic disconnection of supply by RCDs shall be verified.
- ii. Where the rules forbid the installation of single-pole switching devices in the neutral conductor, a test shall be made to verify that all such devices are connected in the line conductor(s) only.

g) Test of the order of the phases (Phase sequence):

In case of multiphase circuits, it shall be verified that the phase sequence is maintained.

This will require confirmation that the phase rotation at three-phase distribution boards and the like is the same as that at the origin of the installation.

The main types of instrument suitable for carrying out such checks that are readily available are:

- rotating disc type
- indicator lamp type

Instruments containing both of the above forms of indication are also available.

Both types consist of an instrument body housing, the indicator and three insulated and fused leads which are identified either by colour or as L1, L2 and L3 typically at least one of the leads is fitted with an insulated 'crocodile' type clip to enable a single user to carry out the check.

In either case, the leads are connected in the correct sequence to the live conductors within the first piece of switchgear within the consumer's installation or as close to that point as is practically possible, and the phase sequence at that point is observed and noted.

In the case of a rotating disc type instrument, the disc will be rotating either clockwise or anticlockwise.

With the indicator lamp type either the L1/L2/L3 (formerly K/Y/B) lamp or the L1/L3/L2 (formerly R/B/Y) lamp will be illuminated.

The phase sequence is then checked at the other three-phase distribution boards, panels, etc. within the installation, and final connections corrected as necessary to maintain the correct sequence throughout the installation.

h) Functional and operational tests:

All assemblies, such as switchgear and controlgear assemblies, drives, controls and interlocks, shall be subjected to a test of their function to verify that they are properly mounted, adjusted and installed in accordance with the relevant requirements.

i) Verification of voltage drop test:

(Ref.: Annexure Y of IS 732: 2019)

In the absence of any other consideration, the voltage drop between the origin of the consumer's installation and the equipment should not be greater than that shown in the table below:

Type of Installation Lighting	Lighting % of the nominal voltage of the installation	Other Uses % of the nominal voltage of the installation
A – Low voltage installations supplied directly from a public low voltage distribution system	3	5
B – Low voltage installation supplied from private LV supply	6	8

It should be remembered that voltage drop may exceed the specified in situations such as motor starting periods end where equipment has a nigh inrush current where such events remain

within the limits specified in the relevant product standard or reasonable recommendation by a manufacturer.

9 Earth Electrodes:

“A conductor or group of conductors in intimate contact with and providing an electrical connection to earth”. (Ref: IS3043 : 2018 para3.7)

9.1 Effect of Shape on Electrode Resistance:

(Ref: IS 3043 : 2018 para 14.1)

The greater part of the fall in potential occurs in the soil within a few feet of the electrode surface, since it is here that the current density is highest. To obtain a low overall resistance of the earth the current density should be as low as possible in the medium adjacent to the electrode and it should be so designed as to cause the current density to decrease rapidly with distance from the electrode.

To achieve the above requirement the dimensions (i.e. Length, width and thickness) of earth electrode is made large in **one direction** compared with other 2 directions (), thus a **pipe, rod or strip has a much lower resistance than a plate of equal surface area**. However, resistance is not inversely proportional to the surface area of the electrode.

9.2 Multiple Earth Electrodes:

In this system more than one electrode is driven into the ground and connected in parallel to lower the resistance. Each earth electrode has its own sphere of influence and for additional electrodes to be effective the spacing of additional rods needs to be at least equal to the depth of the driven rod. Without proper spacing of earth electrodes, the spheres of influence will intersect and the lowering of the resistance will be minimal and of little value.

9.3 Common Types of Earth Electrodes:

9.3.1 Plate electrode:

According to CI 14.2.1 of IS 3043 – 2018 the approximate resistance to earth of a plate can be calculated from:

$$R = \frac{\rho}{4} \sqrt{\frac{\pi}{A}} \Omega$$

where

ρ = resistivity of the soil in $\Omega\text{-m}$ (assumed uniform), and

A = area of both sides of the plate (in m^2).

Plate electrodes shall be of the size at least 60 cm × 60 cm. Plates are generally of cast iron not less than 12 mm thick and preferably ribbed. The earth connection should be joined to the plate at not less than two separate points. Plate electrodes, when made of GI or steel, shall be not less than 6.3 mm in thickness. Plate electrodes of Cu shall be not less than 3.15 mm in thickness. Plate electrodes shall be buried such that its top edge is at a depth not less than 1.5 m from the surface of the ground.

The use of coke breeze as an infill is not recommended as it may result in rapid corrosion not only of the electrode itself but also of cable sheaths, etc. to which it may be bonded.

9.3.2 Pipes or Rods electrode

According to CI 14.2.2 of IS 3043 – 2018, the resistance of a pipe or rod electrode is given by:

$$R = \frac{100\rho}{2\pi l} \log_e \frac{2l}{d} \Omega$$

Where,

ρ = resistivity of the soil, in Ω -m (assumed uniform).

l = length of rod or pipe, in cm,

d = diameter of rod or pipe, in cm,

The earth resistance diminishes rapidly with the first few feet of driving, but less so at depths greater than 2 to 3 m in soil of uniform resistivity. If required to achieve less resistance a number of rods or pipes may be connected in parallel than to increase the length of earth electrode.

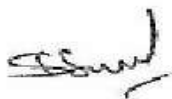
9.3.2.1 Erection of pipe Earth electrode:

Construction of pipe electrode along with earth pit shall be as per figure shown below (Fig 25 of IS 3043:2018) all dimensions are in millimetre. The earth fill shall be of homogenous layers of common earth soil (In Earlier version of IS 3043:1987 with amendments the earth fill was a homogenous layer of coke/charcoal, salt). Where soil resistivity is high, earth resistivity enhancement material may be used. Bentonite or similar earth enhancing material may be advantageous in rocky terrain. Bentonite packing will increase the contact efficiency with the general mass of ground.

Copper clad mild steel rods can be used in place of normal mild steel rods where the soil is corrosive.

Mutual separation between multiple earth electrodes of Length (L) should be between L to 2L. In case of mutual separation is not possible between L to 2L, a substantial gain is affected even at 2 m separation.

In case of rocky area where it is difficult to drive the electrode up to required depth or high resistivity soil occur at relatively small depths, considerable advantage may result from driving rods at an angle of about 30° to the horizontal, thus increasing the installed length of electrode for a given depth.



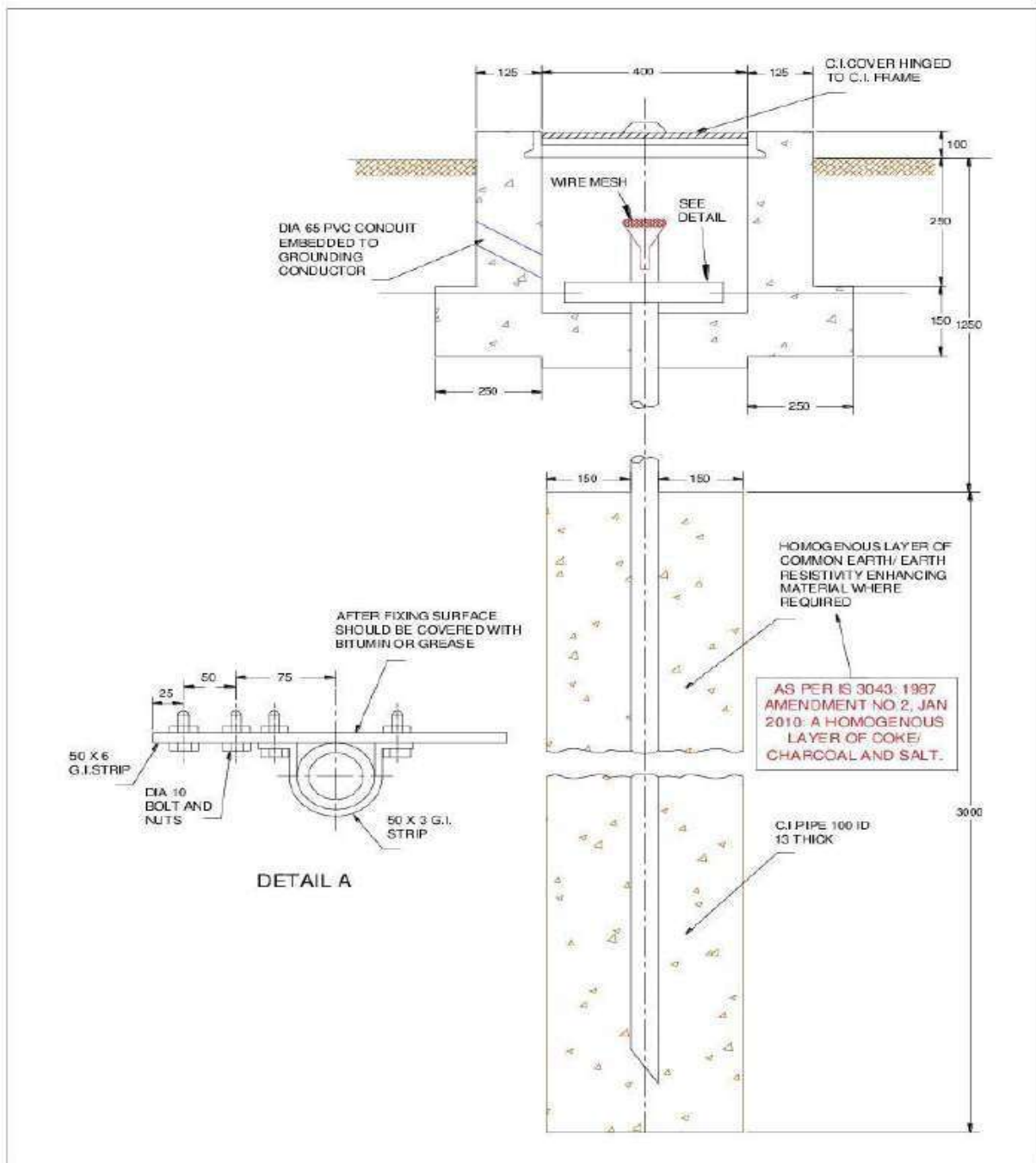



Figure: Typical arrangement of pipe electrode (Ref fig 25 of IS 3043:2018)

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9.3.3 Strip or Conductor Electrodes:

According to Cl 14.2.3 of IS 3043 – 2018 the resistance of a strip or conductor electrode is given by:

$$R = \frac{100\rho}{2\pi l} \log_e \frac{4l}{d} \Omega$$

where,

ρ = resistivity of the soil, in Ω -m (assumed uniform),

l = length of the Strip in cm, and

d = width (strip) or twice the diameter (conductors) in cm.

Strip or conductor electrode has special advantages where low resistivity soil is at shallow depth and high resistivity soil below surface layers of low resistivity soil. In such cases Plate/pipe/rod electrode will not give satisfactory results. As seen from the graph below, the earth resistance of electrode reduces substantially up to certain length, further increase in length of electrode will not have any significant reduction in earth resistance.

To reduce resistance further strip or conductor electrode may be connected in parallel or they may radiate from a point. In case of parallel connections of two strips at a separation of 2.4 m, the total resistance (R_t) will be less than 65% of the individual resistance (R) (i.e. $R_t < 0.65R$).

The care should be taken of these electrodes so as to avoid damages during civil or agriculture work/ in positioning operations.

9.4 Other Means of Earthing:

9.4.1 Cable Sheaths:

Where an extensive underground cable system is available, the sheath and armour form a most effective earth-electrode. In the majority of cases, the resistance to earth of such a system is less than 1 Ω . Cable sheaths are more commonly used to provide a metallic path to the fault current returning to the neutral.

9.4.2 Structural Steelwork as Earth Electrodes:

The resistance to earth of steel frames or reinforced concrete buildings will vary considerably according to the type of soil and its moisture content, and the design of the stanchion bases. For this reason, it is essential to measure the resistance to earth of any structural steelwork that it is employing and at frequent intervals thereafter. These are called as foundation earth electrodes, which is a recommended practice in modern electro-technical standards.

9.4.3 Reinforcement of Piles:

At power stations and large substations, it is often possible to secure an effective earth-electrode by making use of the reinforcement in concrete piles. The earth strap should be bonded to a minimum of four piles and all the piles between the bonds should be bonded together. Each set of four piles should be connected to the main earthing-strap of the substation.

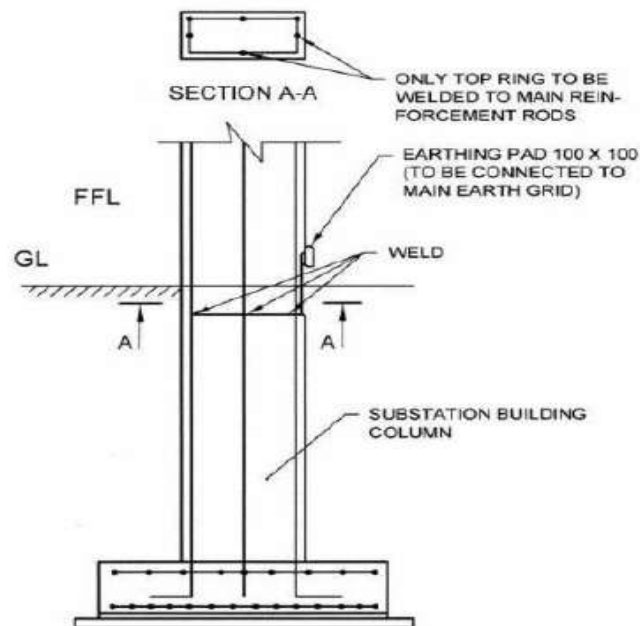


Figure: Earthing of Foundation Reinforcement

- Top ring should be half the size of main vertical reinforcement rod and to be welded to main reinforcement rods.
- Earthing Pads should be welded to reinforcement rods and shall be connected to main earth grid.
- Inserts other than earthing pads may or may not be welded to reinforcement.

9.4.4 Water Pipes:

All Metallic pipe systems of services like water service, flammable liquids or gases, heating systems, etc. **shall not be used as earth electrodes for protective purposes**. For existing installations in which a water pipe is used as a sole earth electrode; an independent means of earthing should be provided at the first practicable opportunity.

9.5 Connections to Earth Electrodes:

The materials used for making connections have to be compatible with the earth rod and the copper earthing conductor so that galvanic corrosion is minimized. In all cases, the connections have to be mechanically strong.

For large earthing installations, such as at major substations, it is common to make provision for the testing of earth electrodes. This is achieved by connecting a group of rod driven electrodes to the main earth grid through a bolted link adjacent to the electrodes in a sunken concrete box. Simpler disconnecting arrangements (or none at all) may be acceptable for small earthing installations.

The connection of an earthing conductor to an earth electrode shall be soundly made and electrically satisfactory. Where a clamp is used, it shall not damage the electrode or the earthing conductor.

A consumer's electrical installation of voltage 250 V but not exceeding 650 V supplied from TN (TN-S, TN-C-S, TN-C) distributor network should have a main earthing terminal (MET) that is connected to the protective conductor of the source and via this to earth electrode installed in the electricity distributor supply system.

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9.6 Artificial treatment of soil:

(Ref – IS 3043:2018 para 13.8)

In areas of high soil resistivity, and where it is difficult to achieve low resistance to earth even after providing multiple earth electrodes, for such types of locations artificial treatment of soil by adding earth enhancing material can be done.

Such installation requires constant monitoring and replacement of the additives as migration and leaching of applied chemicals over a period of time reduces the efficiency of the system. Chemical treatment of soil also has environmental effects and should not be considered as a long term solution in order to meet a specified level of resistance.

To reduce the soil resistivity of the soil immediately surrounding the earth electrode, alternative earth enhancing material which are easily dissolvable in the moisture (contained in the soil), and are highly conductive may be used. These alternative substances are common salt (sodium chloride = NaCl), calcium chloride (CaCl₂), sodium carbonate (Na₂CO₃), copper sulphate (CuSO₄), salt and soft coke, and salt and charcoal in suitable proportions. These agents form a conducting electrolyte throughout a wide region surrounding the earth electrode. In using artificial treatment, the possible corrosive effect of the earth enhancing material salt on the driven rods and connections should be considered.

9.6.1 Procedure for Artificial treatment:

In general when artificial treatment of earth electrode pit is done, it is done by dissolving salt in water and further pouring this solution inside the hollow earth electrode pipe considering that the solution will disperse around the electrode through the perforated earth electrode but this is not the correct practice.

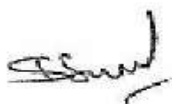
As per IS 3043:2018 para 13.8.1 approximately 90 percent of the resistance between a driven rod and earth lies within a radius of about 2 m from the rod. This should be kept in mind when applying the agents for artificial treatment of soil. The correct and simplest application is by excavating a shallow basin around the top of the rod, 1 m in diameter and about 30 cm deep, and applying the artificial agent in this basin. The basin should subsequently be filled several times with water, which should be allowed each time to soak into the ground, thus carrying the artificial treatment, in electrolyte form, to considerable depths and allowing the artificial agent to become diffused throughout the greater part of the effective cylinder of earth surrounding the driven rod.

10 Periodic Verification:

10.1 Periodic verification of every electrical installation shall be carried out, the records and recommendations of previous periodic verifications shall be taken into account.

10.2 Periodic inspection comprising a detailed examination of the installation shall be carried out supplemented by appropriate tests, including verification, to show that the requirements for disconnecting times as set out in for RCDs are complied by measurements for:

- a) Safety of persons and livestock against the effects of electric shock and burn.
- b) Protection against damage to property by fire.
- c) Confirmation that the installation is not damaged or deteriorated so as to impair safety.



d) The identification of installation defects and departures from the requirements of this standard that may give rise to danger.

10.3 The frequency of periodic verification of an installation shall be determined having regard to the type of installation and equipment, its use and operation, the frequency and quality of maintenance and the external influences to which it is subjected.

NOTES

1. The maximum interval between periodic verifications may be recommended for guidance in the Regulatory Measures Relating to Electrical Safety and Supply under the Electricity Act, 2003.

2. The periodic report should recommend to the person carrying out the periodic verification the interval to the next periodic verification.

3. The interval may be, for instance some years (for example, 4 years), with the exception of the following cases where a higher risk may exist and shorter periods may be required:

a) Working places or locations where risks of electric shock, fire or explosion exist due to degradation.

b) Working places or locations where both high and low voltage installations exist.

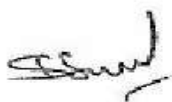
c) Communal facilities.

d) Construction sites.

e) Safety installations (for example emergency luminaires).

For residential dwellings, occupied by the owner himself, longer periods (for example, 10 years) between initial inspections and first periodical inspection may be appropriate. The periodical interval however, may be shorter (for example, 5 years) after a life period of 20 years from initial erection. It is the primary responsibility of the owner to carry out verification (inspection and testing) of the electrical installation in residential dwelling at the time of renting to a tenant or at the time when the tenant is changed and report of inspection and testing of the electrical installation in the building premises should be attached with the rent agreement document. When occupancy of a dwelling has changed (for example, from residential to office etc), a verification of the electrical installation is strongly recommended.

The results and recommendations of the previous reports, where available, shall be taken into account.

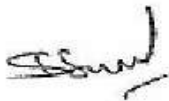



ABBREVIATIONS

Abbreviation	Full Form
LV	Low Voltage
IS	Indian Standard
MET	Main Earthing Terminal
T	Terre (French word for earth)
N	Neutral
PE	Protective Conductor
PEN	Protective and Neutral conductor combined
PME	Protective Multiple Earthing
CNE	Combined Neutral and Earth
OCPD	Over current protective device
MCB	Miniature Circuit Breaker
MCCB	Molded case circuit breakers
ACB	Air Circuit Breaker
SP	Single Pole
SPN	Single Pole and Neutral
DP	Double Pole
TP	Triple Pole
TPN	Triple Pole and Neutral
FP	Four Pole
PME	Protective Multiple Earthed
2P	Two Pole
3P	Triple Pole
4P	Four Pole
RCCB	Residual Current Circuit Breaker
RCBO	Residual Current Breaker with Over Current
AFDD	Arc Fault Detection Device
SELV	Separated or safety Extra Low-Voltage
PELV	Protective Extra Low-Voltage
FELV	Functional Extra Low Voltage
CBCT	Core Balance Current Transformer

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CHAPTER-16

SCADA IN GENERAL SERVICES

16.1 Introduction

SCADA is an acronym for Supervisory Control and Data Acquisition. SCADA systems are used to monitor and control a plant or equipment in industries. These systems encompass the transfer of data between a SCADA central host computer and a number of Remote Terminal Units (RTUs). A SCADA system gathers information (such as where the fault in transmission line has occurred), transfers the information back to a central site, then alerts the home station that a fault has occurred, carrying out necessary analysis and control, such as determining if the fault is critical, and displaying the information in a logical and organized fashion. SCADA systems have made use of the infrastructure of the corporate Local Area Network (LAN)/Wide Area Network (WAN), Wireless technologies for monitoring purposes.

Power distribution SCADA system is a computer-based production process control and scheduling automation system. It uses the data acquisition module to monitor and control the operation of field devices so as to achieve data acquisition, device control, measurement, parameter adjustment, and various signal alarms. The power distribution SCADA system has many advantages, such as information integrity, efficiency, correct grasp of system running status, speeding up decision-making, and can help quickly diagnose the failure state of the system. It has become an indispensable tool for power dispatching.

The SCADA system can monitor and control equipment operated on the site so as to achieve functions, such as data acquisition, measurement, parameter adjustment, and various signal alarms. The power distribution monitoring system uses two monitoring hosts (one main host, and one standby host) to call and monitor the load status, load distribution curve, important alarm, accident statistics, working status, and other electricity monitoring data of various substations.

16.2 System Components

Specific terminology is associated with the components of SCADA systems. These SCADA elements are categorized as Hardware based and Software based and are defined as follows.

16.2.1 Hardware System Components Operator

Human operator who monitors the SCADA system and performs supervisory control functions for the remote plant operations.

16.2.1.1 Human Machine Interface (HMI)

These are the computer terminals consisting of standard HMI (Human Machine Interface) software and are networked with a central host computer. These workstations are operator terminals that request and send the information to host client computer in order to monitor and control the remote field parameters. It presents data to the operator and provides for control inputs in a variety of formats, including graphics, schematics, windows, pull down menus, touch-screens, and so on.



16.2.1.2 Master Terminal Unit (MTU)

It is also termed as Central Monitoring Station (CMS) which is equivalent to a master unit in a master/ slave architecture. The MTU presents data to the operator through the HMI, gathers data from the distant site, and transmits control signals to the remote site. The transmission rate of data between the MTU and the remote site is relatively low and the control method is usually open loop because of possible time delays or data flow interruptions.

16.2.1.3 Communications Means

Communication method between the MTU and remote controllers. Communication can be through the Internet, wireless or wired networks, or the switched public telephone network and fiber optic or satellite communication system. The fiber Optic System is currently preferable to the other media because of the following factors.

- i. Simplified Installation
- ii. Immunity from EM interface
- iii. Reliability and high Bandwidth
- iv. Availability of Direct Metallic Contacts for devices in the same region
- v. Two way communication unlike that provided by radio.
- vi. Break in a fiber cable will not cause a loss of data

16.2.1.4 Remote Terminal Unit (RTU)

The remote station is installed at the remote plant with equipment being monitored and controlled by the central host computer. This can be a RTU or PLC. Field instrumentation, connected to the plant or equipment being monitored and controlled, is interfaced to the remote station to allow process manipulation at a remote site. It is also used to gather data from the equipment and transfer it to the central SCADA system.

An RTU is a microprocessor controlled device used to interface the various power system components and their operation to the MTU/CMS. It gathers local information and transmits it to the MTU and also accepts commands and logging requests sent to it by the MTU. Hence the MTU can control and monitor the distribution networks by interfacing with the various RTUs. It has a capability to exchange the information with intelligent electronic devices (IEDs) such as IED meter and IED relays.

16.2.1.5 Field Instrumentation

Field instrumentation generally comprises sensors, transmitters and actuators that are directly interfaced to the plant or equipment and generate the analog and digital signals that will be monitored by the remote station. Signals are also conditioned to make sure they are compatible with the inputs/ outputs of the Remote Terminal Unit (RTU) or a Programmable Logic Controller (PLC) at the remote Station. It also refers to the devices that are connected to the equipment or machines being controlled and monitored by the SCADA system. These are sensors for monitoring certain parameters and actuators for controlling certain modules of the system

16.2.2 Software System Components

Apart from the hardware components, Software components comprising a SCADA system are the following.

16.2.2.1 Data Acquisition and Processing

This is done by Master Distribution Automation Software. This serves as a data collector from the

devices to our SCADA system and presents it as a processed data to the user. Data acquisition can be done in multiple scan rates and uses different protocols. The data can be fetched as a whole or as a group and also report by exception. Data processing means conversion of fetched data into engineering conversions, zero suppression, reasonability check, and calculation subsystem. So, user can use this processed data for future purposes.

16.2.2.2 Control

This is done by Engineering Analysis Software. Users are allocated to groups, which have defined read/write access privileges to the process parameters in the system and often also to specific product functionality. The allocated users can have the access to the devices, which are to be controlled. Control can be single or group, open or closed loop control. The execution of control can be executed at selective places, can be immediately executed, can be executed at required time etc.

16.2.2.3 Human Machine Interface (Software component)

The products support multiple screens, which can contain combinations of synoptic diagrams and text. Standard windows editing facilities are provided. zooming, re-sizing, scrolling etc. On-line configuration and customization of the HMI is possible for users with the appropriate privileges. Links can be created between display pages to navigate from one view to another.

16.2.2.4 Logging and Archiving

The terms logging and archiving are often used to describe the same facility. However, logging can be thought of as medium-term storage of data on disk, whereas archiving is long-term storage of data either on disk or on another permanent storage medium. The logging of user actions is in general performed together with either a user ID or station ID.

16.2.2.5 Automated Mapping and Facilities Management (AM/FM)

SCADA systems can be made use to have GUI system. GUI system can be used to have maps, graphical representation of the required area. Using SCADA these maps can be layered, zoomed, scrolled and planned.

16.2.2.6 Application Programs

The various application programs that can be implemented using SCADA systems are clearly explained here. The following are the applications that can be used for remote monitoring, control, safety, efficient utilization of resources etc.

- i. Fault location, isolation and Service Restoration.

This function determines alternate paths for restoring service to the affected load points due to a fault on a section of the feeder considering current loading conditions. Most of the rural feeders do not have an alternate supply for service restoration. In urban areas, many alternate paths are available to a feeder; therefore, this function will be more effective. To implement this function, load switches or sectionalizers are needed at selected feeder locations. Earlier, sectionalizers were air-break switches without any remote-control features. All such switches should be replaced with remotely controllable switches.

- ii. Maintaining good voltage profile.

This function controls the capacitor banks and voltage regulators to provide a good voltage profile in the distribution feeders. An appropriate schedule for switching on/off of capacitor banks and raise/lower voltage regulator taps was based on the feeders' reactive load curves in order to get good voltage profiles and reduce energy losses.



iii. Load Balancing.

This function distributes the system total load among the available transformers and the feeders in proportion to their capacities. As explained above, there was a need to replace the existing switches with remotely controllable switches in order to reconfigure the network for load balancing.

iv. Load Control. Load Management Function is divided into three categories

- During summer there is usually a generation shortage. Therefore, loads need to be shed for long durations. A restriction and control schedule is worked out based on which of the loads at different substations are shed on a rotation basis.

- Emergency Based Load Shedding.

During emergencies, the utility needs to shed some load to keep up the balance between generation and demand. Instructions are sent to respective substations to shed load. Based on the amount of relief requested, the operator would select some loads and shed them. This function will help to identify loads to be shed considering their priority, time when they were last shed and the duration of the last interruption to ensure that only the required amount of load shedding is done.

v. Remote metering.

The function of remote metering is to read data from the meters and to provide information to the operator of the consumption patterns of the high-value HV customers. Its main feature is to provide a multiple tariff to the customers to encourage them to shift their loads from peak times to off-peak times. This function also provides meter tampering detection.

vi. Fuse of call operations.

This consumer-aid application function responds to complaints from consumers. It has the following features. Accepts interruption/restoration data from the operator, identifies the interruption source whenever possible and gives information on the outage effects to the operator, displays status of energized/de-energized status of the consumer. This function will improve the response time to the consumer complaints.

vii. Energy accounting.

This function helps in arriving at the system's load patterns, which helps in planning expansion. It also helps in detecting abnormal energy consumption patterns of the consumers and identifying high-loss areas. Processing the data obtained by the remote metering function and the data obtained from the substation does this.

16.3 Interfacing between SCADA and Substation Control

Distribution system is concerned with hardware components such as generator, transformers, transmission lines and circuit breakers etc. SCADA system has participated with software packages and main target is for supervisory control and data acquisition. For this reasons, distribution system components must connect to the various sensing devices (such as CTs, PTs) for collecting data from the power lines.

There are interfaces to substation intelligent electronic devices (IEDs) to acquire data, determine the operation status of each IED and interface to the energy management system (EMS) to receive data from the substation integration and automation system at different periodicities. The system must interface with all of the IEDs in the substation. This includes polling the IEDs for readings and event notifications. The data from all the IEDs must be sent to the utility enterprise to populate the data warehouse or be sent to an appropriate location for storage of the substation data. The system must know the status of all connected IEDs at all times.

Basic information describing the operation state of the power network is passed to the SCADA

system. This information is collected automatically by the equipment in various substation and devices and can be categorized as status indication, measured values and energy values. The status of switching devices and alarm signals are represented by status indications and these indications are already closings connected to digital input boards of the RTUs. Measured values reflect different time varying quantities, such as voltage, current, temperature and tap changer positions, which are collected from the power system. They fall into two basic types, analog and digital. All analog signals are transformed via an A/D converter to binary format because treated as momentary-value that they have to be normalized before storing in the SCADA database. The SCADA system is configured around the following standard functions such as data acquisition, monitoring and event supervising, control, data storage archiving and analysis, and then reporting.

16.4 Automation of Electrical Distribution System

Modern SCADA systems replace the manual labour to perform electrical distribution tasks and manual processes in distribution systems with automated equipments. SCADA maximizes the efficiency of power distribution system by providing the features like real-time view into the operations, data trending and logging, maintaining desired voltages, currents and power factors, generating alarms, etc.

SCADA performs automatic monitoring, protecting and controlling of various equipments in distribution systems with the use of Intelligent Electronic Devices (or RTUs). It restores the power service during fault condition and also maintains the desired operating conditions.

SCADA improves the reliability of supply by reducing duration of outages and also gives the cost-effective operation of distribution system. Therefore, distribution SCADA supervises the entire electrical distribution system. The major functions of SCADA can be categorized into following types.

- Substation Control
- Feeder Control
- End User Load Control

16.4.1 Substation Control using SCADA

In substation automation system, SCADA performs the operations like bus voltage control, bus load balancing, circulating current control, overload control, transformer fault protection, bus fault protection, etc. SCADA system continuously monitors the status of various equipments in substation and accordingly sends control signals to the remote control equipments. Also, it collects the historical data of the substation and generates the alarms in the event of electrical accidents or faults.

Various input/output (I/O) modules connected to the substation equipment gathers the field parameters data, including status of switches, circuit breakers, transformers, capacitors and batteries, voltage and current magnitudes, etc. RTUs collect I/O data and transfers to remote master unit via network interface modules. The central control or master unit receives and logs the information, displays on HMI and generate the control actions based on received data. This central controller also responsible for generating trend analysis centralized alarming, and reporting.

The data historian, workstations, master terminal unit and communications servers are connected by LAN at the control center. A Wide Area Network (WAN) connection with standard protocol communication is used to transfer the information between field sites and central controller.

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Thus, by implementing SCADA for substation control eventually improves the reliability of the network and minimizes the downtime with high speed transfer of measurements and control commands.

16.4.2 Feeder Control using SCADA

This automation includes feeder voltage or VAR control and feeder automatic switching. Feeder voltage control performs voltage regulation and capacitor placement operations while feeder switching deals with remote switching of various feeders, detection of faults, identifying fault location, isolating operation and restoration of service.

In this system, SCADA architecture continuously checks the faults and their location by using wireless fault detector units deployed at various feeding stations. In addition, it facilitates the remote circuit switching and historical data collection of feeder parameters and their status. The figure below illustrates feeder automation using SCADA.

In the above typical SCADA network, different feeders (underground as well as overhead networks) are automated with modular and integrated devices in order to decrease the number and duration of outages. Underground and overhead fault detection devices provide accurate information about transient and permanent faults so that at the remote side preventive and corrective measures can be performed in order to reduce the fault repeatability.

Ring main units and Remote Control Units (RTUs) of underground and overhead network responsible for maintenance and operational duties such as remote load switching, capacitor bank insertion and voltage regulation. The entire network is connected with a communication medium in order to facilitate remote energy management at the central monitoring station.

16.4.3 End User Load Control Automation by SCADA

This type of automation at user end side implements functions like remote load control, automatic meter reading and billing generation, etc. It provides the energy consumption by the large consumers and appropriate pricing on demand or time slots wise. Also detects energy meter tampering and theft and accordingly disconnects the remote service. Once the problem is resolved, it reconnects the service.

A centralized meter data-management system using SCADA is an easy and cost-effective solution for automating the energy meter data for billing purpose. In this, smart meters with a communication unit extract the energy consumption information and made it available to a central control room as well as local data storage unit. At the central control room, AMR control unit automatically retrieves, stores and converts all meter data

Modems or communication devices at each meter provide secure two way communication between central control and monitoring room and remote sites.

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List of important Indian Standards (IS) for Electrical General Services applications. Whenever these standards are referred their latest versions may also be seen

Sr. No.	Standard No.	Title
1.	IS 16444 : 2015	AC Static Direct Connected Watt-hour Smart Meter Class-1 and 2-Specification
2.	IS 16444 : PART 1 : 2015	AC Static Direct Connected Watt-hour Smart Meter Class 1 and 2 - Specification
3.	IS 16444 : PART 2 : 2017	AC Static Transformer Operated Watt-hour and VAR-Hour Smart Meters, Class 0.2S, 0.5S and 1.0S : Part 2- Specification Transformer Operated Smart Meters
4.	IS 13779 : 1999 (REAFFIRMED 2014)	AC static watt-hour meters (Class 1 and 2)
5.	IS 15884 : 2010 (REAFFIRMED 2016)	AC Direct Connected Static Prepayment Meters for Active Energy (Class 1 and 2)
6.	IS 14697 : 1999 (REAFFIRMED 2019)	AC Static Transformer Operated Watt-hour and VAR-Hour Meters, Class 0.2 S and 0.5 S - Specification
7.	IS 15959 : PART 1 : 2011 (REAFFIRMED 2016)	Data Exchange for Electricity Meter Reading, Tariff and Load Control-Companion Specification : Part 1 Static Energy Meter
8.	IS 15959 : PART 2 : 2016	Data Exchange for Electricity Meter Reading, Tariff and Load Control - Companion Specification : Part 2 Smart Meter
9.	IS 15959 : PART 3 : 2017	Data Exchange for Electricity Meter Reading, Tariff and Load Control-Companion Specification : Part 3 Smart Meter (Transformer Operated kWh and kVARh, Class 0.2 S, 0.5 S and 1.0 S)
10.	IS 14665 : PART 1 : 2000 (REAFFIRMED 2015)	Electric Traction Lifts : Part 1 : Guidelines for Outline Dimensions of Passenger, Goods, Service and Hospital Lifts
11.	IS 14665 : PART 2 : SEC 1 AND 2 : 2000 (REAFFIRMED 2015)	Electric Traction Lifts : Part 2 : Code of Practice for Installation, Operation and Maintenance - Section 1 : Passenger and Goods Lifts - Section 2 : Service Lifts
12.	IS 14665 : PART 3 : SEC 1 AND 2 : 2000 (REAFFIRMED 2015)	Electric Traction Lifts : Part 3 : Safety Rules - Section 1 : Passenger and Goods Lifts - Section 2 : Service Lifts
13.	IS 14665 : PART 4 : SEC 1 TO 9 : 2001 (REAFFIRMED 2016)	Electric Traction Lifts : Part 4 : Components - Section 1 : Lifts Buffers - Section 2 : Lift Guide Rails and Guide Shoes - Section 3 : Lift Carframe
14.	IS 14665 : PART 5 : 1999 (REAFFIRMED 2019)	Electric Traction Lifts - Specification : Part 5 : Inspection Manual
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16.	IS 12026 : PART 1 : 1986 (REAFFIRMED 2016)	Guide for the determination of the aromatic hydrocarbon content of new insulating oils: Part 1 Asorption chromatographic method
17.	IS 12026 : PART 2 : 1986 (REAFFIRMED 2016)	Guide for the determination of the aromatic hydrocarbon content of new insulating oils: Part 2 Infra red spectrophotometric method
18.	IS 2026 : PART 1 : 2011 (REAFFIRMED 2016)	Power transformers: Part 1 General
19.	IS 2026 : PART 10 : 2009 (REAFFIRMED 2019)	Power Transformers : Part 10 Determination of sound levents



Sr. No.	Standard No.	Title
20.	IS 2026 : PART 10 : SEC 1 : 2018	Power Transformers : Part 10 Determination of Sound Levels - Section 1 Application guide
21.	IS 2026 : PART 12 : 2018	Power Transformers : Part 12 Loading Guide for Dry- type Power Transformers
22.	IS 2026 : PART 14 : 2018	Power Transformers : Part 14 Liquid-Immersed Power Transformers Using High-Temperature Insulation Materials
23.	IS 2026 : PART 15 : 2018	Power Transformers : Part 15 Gas-filled Power Transformers
24.	IS 2026 : PART 16 : 2018	Power Transformers : Part 16 Transformers for Wind Turbine Applications
25.	IS 2026 : PART 18 : 2018	Power Transformers : Part 18 Measurement of Frequency Response
26.	IS 2026 : PART 19 : 2018	Power Transformers : Part 19 Rules for the Determination of Uncertainties in the Measurement of the Losses on Power Transformers and Reactors
27.	IS 2026 : PART 2 : 2010 (REAFFIRMED 2015)	Power transformers : Part 2 Temperature rise
28.	IS 2026 : PART 21 : 2018	Power Transformers : Part 21 Standard Requirements, Terminology and Test Code for Step-Voltage Regulators
29.	IS 2026 : PART 3 : 2018	Power Transformers : Part 3 Insulation Levels, Dielectric Tests and External Clearances in Air
30.	IS 2026 : PART 4 : 1977 (REAFFIRMED 2016)	Power transformers: Part 4 Terminal marking,tappings and connectionis
31.	IS 2026 : PART 5 : 2011 (REAFFIRMED 2016)	Power Transformers : Part 5 Ability to Withstand Short Circuit
32.	IS 2026 : PART 6 : 2017	Power Transformers : Part 6 Reactors
33.	IS 2026 : PART 7 : 2009 (REAFFIRMED 2019)	Power Transformers : Part 7 Loading Guide for Oil-Immersed Power Transformers
34.	IS 2026 : PART 8 : 2009 (REAFFIRMED 2019)	Power Transformers : Part 8 : Application Guide
35.	IS 4648 : 1968 (REAFFIRMED 2017)	Guide for Electrical Layout in Residential Buildings
36.	IS 8884 : 1978 (REAFFIRMED 2017)	Code of practice for the installation of electric bells and call system
37.	IS 5578 : 1984 (REAFFIRMED 2016)	Guide for marking of insulated conductors
38.	IS 3043 : 2018	Code of Practice for Earthing
39.	IS 9000 : PART 1 : 1988 (REAFFIRMED 2016)	Basic environmental testing procedures for electronic and electrical items: Part 1 General
40.	IS 9000 : PART 10 : 1979 (REAFFIRMED 2018)	Basic environmental testing procedures for electronic and electrical items: Part 10 Mould growth test (Redesignation of IS:7805-1975)
41.	IS 9000 : PART 11 : 1983 (REAFFIRMED 2016)	Basic environmental testing procedures for electronic and electrical items: Part 11 Salt mist test
42.	IS 9000 : PART 12 : 1981 (REAFFIRMED 2016)	Basic environmental testing procedures for electronic and electrical items: Part 12 Dust test
43.	IS 9000 : PART 13 : 1981 (REAFFIRMED 2016)	Basic environmental testing procedures for electronic and electrical items: Part 13 Low air pressure test
44.	IS 9000 : PART 14 : SEC 1 TO 3 : 1988 (REAFFIRMED 2018)	Basic environmental testing procedures for electronic and electrical items: Part 14
45.	IS 9000 : PART 15 : SEC 1 TO 9 : 1982 (REAFFIRMED 2016)	Basic Environmental Testing Procedures for Electronic and Electrical Items: Part XV : Sealing Test

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46.	IS 9000 : PART 16 : 1983 (REAFFIRMED 2016)	Basic environmental testing procedures for electronic and electrical items 16. Driving rain test
47.	IS 9000 : PART 17 : 1985 (REAFFIRMED 2016)	Basic environmental testing procedures for electronic and electrical items: Part 17 Radiation test
48.	IS 9000 : PART 18 : SEC 1 TO 3 : 1981 (REAFFIRMED 2018)	Basic Environmental Testing Procedures for Electronic and Electrical Items: Part XVIII : Solderability Test
49.	IS 9000 : PART 19 : SEC 1 TO 5 : 1986 (REAFFIRMED 2016)	Basic environmental testing procedures for electronic and electrical items: Part 19 Test U: Robustness of terminations and integral mounting devices
50.	IS 9000 : PART 2 : SEC 1 TO 4 : 1977 (REAFFIRMED 2016)	Basic environmental testing procedures for electronic and electrical items: Part 2 Cold test
51.	IS 9000 : PART 20 : 1979 (REAFFIRMED 2016)	Basic environmental testing procedures for electronic and electrical items: Part 20 Resistance to cleaning solvents and permanence of markings
52.	IS 9000 : PART 21 : 1985 (REAFFIRMED 2016)	Basic environmental testing procedures for electronic & electrical items: Part 21 Acoustics noise test
53.	IS 9000 : PART 22 : 1983 (REAFFIRMED 2016)	Basic environmental testing procedures for electronic and electrical items: Part 22 Fine mist test
54.	IS 9000 : PART 23 : 1984 (REAFFIRMED 2016)	Basic environmental testing procedures for electronic and electrical items: Part 23 Drip proof test
55.	IS 9000 : PART 25 : 1980 (REAFFIRMED 2018)	Basic environmental testing procedures for electronic and electrical items: Part 25 Hydrogen sulphide test for contacts and connections
56.	IS 9000 : PART 26 : 1980 (REAFFIRMED 2018)	Basic environmental testing procedures for electronic & electrical items: Part 26 Sulphur dioxide test for contacts and connections
57.	IS 9000 : PART 27 : 1986 (REAFFIRMED 2016)	Basic environmental testing procedures for electronic and electrical items: Part 27 Ultrasonic cleaning test
58.	IS 9000 : PART 3 : SEC 1 TO 5 : 1977 (REAFFIRMED 2016)	Basic environmental testing procedures for electronic and electrical items: Part 3 Dry heat test
59.	IS 9000 : PART 31 : 1978 (REAFFIRMED 2016)	Basic environmental testing procedures for electronic and electrical items: Part 31 Combined cold/low air pressure tests
60.	IS 9000 : PART 32 : 2006 (REAFFIRMED 2016)	Basic Environmental Testing Procedures for Electronic and Electrical Items : Part 32 Information for Specification Writers - Test Summaries
61.	IS 9000 : PART 4 : 2008 (REAFFIRMED 2018)	Basic Environmental Testing Procedures for Electronic and Electrical items : Part 4 : Damp Heat (Steady State)
62.	IS 9000 : PART 5 : SEC 1 AND 2 : 1981 (REAFFIRMED 2016)	Basic environmental testing procedures for electronic and electrical items: Part 5 Damp heat (cyclic) test
63.	IS 9000 : PART 6 : 1978 (REAFFIRMED 2016)	Basic environmental testing procedures for electronic and electrical items: Part 6 Composite temperature/humidity cyclic test
64.	IS 9000 : PART 7 : SEC 1 : 2018	Basic Environmental Testing Procedures for Electronic and Electrical Items : Part 7 Impact Test - Section 1 Shock (Test Ea)
65.	IS 9000 : PART 7 : SEC 1 TO 5 : 1979 (REAFFIRMED 2016)	Basic environmental testing procedures for electronic and electrical items: Part 7 Impact test, Sec 1 Shock
66.	IS 9000 : PART 7 : SEC 3 : 2019	Environmental Testing : Part 7 Tests - Section 3 Test Ec: Rough handling shocks, primarily for equipment-types specimens



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67.	IS 9000 : PART 7 : SEC 6 : 1988 (REAFFIRMED 2018)	Basic environmental testing procedures for electronic and electrical items: Part 7 Impact test, Section 6 Test Ee: Bounce
68.	IS 9000 : PART 7 : SEC 7 : 2006 (REAFFIRMED 2016)	Basic Environmental Testing Procedures for Electronic and Electrical Items: Part 7 Impact Test Section 7 Test Eh : Hammer Tests
69.	IS 9000 : PART 8 : 1981 (REAFFIRMED 2018)	Basic environmental testing procedures for electronic and electrical items: Part 8 Vibration (sinusoidal) test
70.	IS 9000 : PART 9 : 1984 (REAFFIRMED 2018)	Basic environmental testing procedures for electronic and electrical items: Part 9 Acceleration (steady state)
71.	IS/ISO 9000 : 2015	Quality Management Systems - Fundamentals and Vocabulary
72.	IS/ISO/IEC 90003 : 2014	Software Engineering-Guidelines for the Application of ISO 9001 : 2008 to Computer Software
73.	IS/QC 390000 : 1994 (REAFFIRMED 2018)	Fixed Film Resistor Networks for Use in Electronic Equipment - Generic Specification
74.	IS 12834 : 2013 (REAFFIRMED 2018)	Solar photovoltaic energy systems-Terms, Definitions and Symbols
75.		
76.	IS 8270 : PART 1 : 1976 (REAFFIRMED 2019)	Guide for preparation of diagrams, charts and tables for electrotechnology: Part 1 Definitions and classification
77.	IS 1885 : PART 16 : SEC 3 : 1967 (REAFFIRMED 2017)	Electrotechnical Vocabulary : Part XVI : Lighting - Section 3 : Lamps and Auxiliary Apparatus
78.	IS 1885 : PART 17 : 1979 (REAFFIRMED 2017)	Electrotechnical Vocabulary : Part XVII : Switchgear and Controlgear
79.	IS 1885 : PART 32 : 2019	Electrotechnical Vocabulary : Part 32 Electric Cables
80.	IS 1885 : PART 78 : 1993 (REAFFIRMED 2019)	Electrotechnical Vocabulary: Part 78 Generation, transmission and distribution of electricity - General
81.	IS 12032 : PART 6 : 1987 (REAFFIRMED 2019)	Graphical symbols for diagrams in the field of electrotechnology: Part 6 Production and conversion of electrical energy
82.	IS 12032 : PART 7 : 1987 (REAFFIRMED 2019)	Graphical symbols for diagrams in the field of electrotechnology: Part 7 Switchgear, controlgear and protective devices
83.	IS 16246 : 2015	Elastomer Insulated Cables with Limited Circuit Integrity when Affected by Fire - Specification
84.	IS/IEC 62271 : PART 202 : 2014	High-Voltage Switchgear and Controlgear : Part 202 High-Voltage/Low-Voltage Prefabricated Substation
85.	IS/IEC 60947 : PART 1 : 2007 (REAFFIRMED 2017)	Low-voltage switchgear and controlgear : Part 1 General rules
86.	IS/IEC 60947 : PART 2 : 2016	Low-Voltage Switchgear and Controlgear : Part 2 Circuit-Breakers
87.	IS/IEC 60947 : PART 3 : 2012 (REAFFIRMED 2018) IS/IEC 60947 : PART 4 :	Low-Voltage Switchgear and Controlgear : Part 3 Switches, Disconnectors, Switch- Disconnectors and Fuse-Combination Units Low-Voltage Switchgear and Controlgear : Part 4
88.	SEC 1 : 2012 (REAFFIRMED 2018)	Contactors and Motor-Starters - Section 1 Electromechanical contactors and motor-starters
89.	IS/IEC 60947 : PART 4 : SEC 2 : 2011 (REAFFIRMED 2018)	Low-Voltage Switchgear and Controlgear : Part 4 Contractors and Motor-Starters - Section 2 AC Semiconductor Motor Controllers and Starters
90.	IS/IEC 60947 : PART 4 : SEC 3 : 2014	Low-Voltage Switchgear and Controlgear : Part 4 Contactors and Motor-Starters - Section 3 AC semiconductor motor controllers and contractors for non-motor loads
91.	IS/IEC 60947 : PART 5 : SEC 1 : 2009 (REAFFIRMED 2018)	Low-Voltage Switchgear and Controlgear : Part 5 Control Circuit Devices and Switching Elements - Section 1 Electromechanical control circuit devices

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92.	IS/IEC 60947 : PART 5 : SEC 2 : 2007 (REAFFIRMED 2017)	Low-Voltage Switchgear and Control Gear : Part 5 Control Circuit Devices and Switching Elements - Section 2 Proximity Switches
93.	IS/IEC 60947 : PART 5 : SEC 5 : 2016	Low-Voltage Switchgear and Controlgear : Part 5 Control Circuit Devices and Switching Elements - Section 5 Electrical emergency stop devices with mechanical latching function
94.	IS/IEC 60529 : 2001 (REAFFIRMED 2019)	Degrees of protection provided by enclosures (IP CODE)
95.	IS 7752 : PART 1 : 1975 (REAFFIRMED 2016)	Guide for improvement of power factor in consumer installation: Part 1 Low and medium supply voltages
96.	IS 5216 : PART 1 : 1982 (REAFFIRMED 2015)	Recommendations on Safety Procedures and Practices in Electrical Work : Part I : General
97.	IS 5216 : PART 2 : 1982 (REAFFIRMED 2015)	Recommendation on Safety Procedures and Practices in Electrical Work : Part II : Life Saving Techniques
98.	IS 10028 : PART 1 : 1985 (REAFFIRMED 2016)	Code of Practice for Selection, Installation and Maintenance of Transformers : Part 1 : Selection
99.	IS 10028 : PART 2 : 1981 (REAFFIRMED 2016)	Code of practice for selection, installation and maintenance of transformers : Part 2 Installation (superseding IS:1886)
100.	IS 10028 : PART 3 : 1981 (REAFFIRMED 2018)	Code of practice for selection, installation and maintenance of transformers: Part 3 Maintenance (superseding IS:1886)
101.	IS 10118 : PART 1 : 2018	Code of Practice for Selection, Installation and Maintenance of Switchgear and Controlgear : Part 1 General
102.	IS 10118 : PART 2 : 1982 (REAFFIRMED 2016)	Code of practice for selection, installation and maintenance of Switchgear and controlgear : Part 2 Selection
103.	IS 10118 : PART 3 : 1982 (REAFFIRMED 2016)	Code of practice for selection, installation and maintenance of switchgear and controlgear : Part 3 Installation
104.	IS 10118 : PART 4 : 1982 (REAFFIRMED 2016)	Code of practice for selection, installation and maintenance of switchgear and controlgear : Part 4 Maintenance
105.	IS 732 : 2019	Code of Practice for Electrical Wiring Installations
106.	IS/IEC 62271 : PART 1 : 2007 (REAFFIRMED 2018)	High-Voltage Switchgear and Controlgear : Part 1 Common Specifications
107.	IS/IEC 62271 : PART 100 : 2008 (REAFFIRMED 2017)	High - Voltage Switchgear and Controlgear : Part 100 Alternating - Current Circuit - Breakers
108.	IS/IEC 62271 : PART 102 : 2003 (REAFFIRMED 2018)	High-Voltage Switchgear and Controlgear : Part 102 : Alternating Current Disconnectors and Earthing Switches
109.	IS/IEC 62271 : PART 103 : 2011 (REAFFIRMED 2015)	High-Voltage Switchgear and Controlgear : Part 103 Switches for Rated Voltages Above 1 kV Up to and Including 52 kV
110.	IS/IEC 62271 : PART 104 : 2009 (REAFFIRMED 2015)	High-Voltage Switchgear and Controlgear : Part 104 Alternating Current Switches for Rated Voltages of 52 kV and Above
111.	IS/IEC 62271 : PART 105 : 2012	High-Voltage Switchgear and Controlgear : Part 105 Alternating Current Switch-Fuse Combinations for Rated Voltages Above 1 kV Up to and Including 52 kV
112.	IS/IEC 62271 : PART 106 : 2011	High-Voltage Switchgear and Controlgear : Part 106 Alternating Current Contactors, Contactor-Based Controllers and Motor-Starters
113.	IS/IEC 62271 : PART 109 : 2008 (REAFFIRMED 2017)	High - Voltage Switchgear and Controlgear : Part 109 Alternating - Current Series Capacitor by - Pass Switches
114.	IS/IEC 62271 : PART 111 : 2012 (REAFFIRMED 2016)	High-Voltage Switchgear and Controlgear : Part 111 Automatic Circuit Reclosers and Fault Interrupters for Alternating Current Systems Up to 38 kV
115.	IS/IEC 62271 : PART 200 : 2011 (REAFFIRMED 2018)	High-Voltage Switchgear and Controlgear : Part 200 AC Metal- Enclosed Switchgear and Controlgear for Rated Voltages Above 1 kV Up to and Including 52 kV



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116.	IS/IEC 62271 : PART 201 : 2014	High-Voltage Switchgear and Controlgear : Part 201 AC Solid-Insulation Enclosed Switchgear and Controlgear for Rated Voltages Above 1 kV up to and Including 52 kV
117.	IS/IEC 62271 : PART 202 : 2014	High-Voltage Switchgear and Controlgear : Part 202 High- Voltage/Low-Voltage Prefabricated Substation
118.	IS/IEC 62271 : PART 203 : 2011 (REAFFIRMED 2018)	High-Voltage Switchgear and Controlgear : Part 203 Gas-Insulated Metal-Enclosed Switchgear for Rated Voltages Above 52 kV
119.	IS/IEC 62271 : PART 207 :2012	High-Voltage Switchgear and Controlgear : Part 207 Seismic Qualification for Gas-Insulated Switchgear Assemblies for Rated Voltages Above 52 kV
120.	IS/IEC 62271 : PART 300 : 2006	High-Voltage Switchgear and Controlgear : Part 300 Seismic Qualification of Alternating Current Circuit-Breakers
121.	IS/IEC/TR 62271 : PART 301 : 2009	High-Voltage Switchgear and Controlgear : Part 301 Dimensional Standardisation of High-Voltage Terminals
122.	IS 1255 : 1983 (REAFFIRMED 2016)	Code of practice for installation and maintenance of power cables upto and including 33 kV rating
123.	IS 8084 : 1976 (REAFFIRMED 2017)	Interconnecting busbars for AC voltage above 1 kV upto and including 36 kV
124.	IS 1180 : PART 1 : 2014 (REAFFIRMED 2019)	Outdoor Type Oil Immersed Distribution Transformers Upto and Including 2 500 kVA, 33kV - Specification : Part 1 Mineral Oil Immersed (Fourth Revision)
125.	IS 2026 : PART 1 : 2011 (REAFFIRMED 2016)	Power transformers: Part 1 General
126.	IS 2026 : PART 10 : 2009 (REAFFIRMED 2019)	Power Transformers : Part 10 Determination of sound levels
127.	IS 2026 : PART 10 : SEC 1 : 2018	Power Transformers : Part 10 Determination of Sound Levels - Section 1 Application guide
128.	IS 2026 : PART 12 : 2018	Power Transformers : Part 12 Loading Guide for Dry-type Power Transformers
129.	IS 2026 : PART 14 : 2018	Power Transformers : Part 14 Liquid-Immersed Power Transformers Using High-Temperature Insulation Materials
130.	IS 2026 : PART 15 : 2018	Power Transformers : Part 15 Gas-filled Power Transformers
131.	IS 2026 : PART 16 : 2018	Power Transformers : Part 16 Transformers for Wind Turbine Applications
132.	IS 2026 : PART 18 : 2018	Power Transformers : Part 18 Measurement of Frequency Response
133.	IS 2026 : PART 19 : 2018	Power Transformers : Part 19 Rules for the Determination of Uncertainties in the Measurement of the Losses on Power Transformers and Reactors
134.	IS 2026 : PART 2 : 2010 (REAFFIRMED 2015)	Power transformers : Part 2 Temperature-rise
135.	IS 2026 : PART 21 : 2018	Power Transformers : Part 21 Standard Requirements, Terminology and Test Code for Step-Voltage Regulators
136.	IS 2026 : PART 3 : 2018	Power Transformers : Part 3 Insulation Levels, Dielectric Tests and External Clearances in Air
137.	IS 2026 : PART 4 : 1977 (REAFFIRMED 2016)	Power transformers: Part 4 Terminal marking, tappings and connections
138.	IS 2026 : PART 5 : 2011 (REAFFIRMED 2016)	Power Transformers : Part 5 Ability to Withstand Short Circuit
139.	IS 2026 : PART 6 : 2017	Power Transformers : Part 6 Reactors
140.	IS 2026 : PART 7 : 2009 (REAFFIRMED 2019)	Power Transformers : Part 7 Loading Guide for Oil- Immersed Power Transformers
141.	IS 2026 : PART 8 : 2009 (REAFFIRMED 2019)	Power Transformers : Part 8 : Application Guide

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142.	IS 11171 : 1985 (REAFFIRMED 2016)	Specification for Dry-Type Power Transformers
143.	IS 8623 : PART 1 : 1993 (REAFFIRMED 2018)	Low-Voltage Switchgear and Control gear Assemblies : Part 1 : Requirements for Type-Tested and Partially Type-Tested Assemblies
144.	IS 8623 : PART 2 : 1993 (REAFFIRMED 2018)	Specification for Low-voltage Switchgear and Control gear Assemblies : Part 2 : Particular Requirements for Busbar Trunking Systems (Busway)
145.	IS 8623 : PART 3 : 1993 (REAFFIRMED 2018)	Specification for Low-Voltage Switchgear and Control gear Assemblies : Part 3 : Particular Requirements for Equipment Where Unskilled Persons have Access for Their Use
146.	IS/IEC 60947 : PART 1 : 2007 (REAFFIRMED 2017)	Low-voltage switchgear and control gear : Part 1 General rules
147.	IS/IEC 60947 : PART 2 : 2016	Low-Voltage Switchgear and Control gear : Part 2 Circuit- Breakers
148.	IS/IEC 60947 : PART 3 : 2012 (REAFFIRMED 2018)	Low-Voltage Switchgear and Control gear : Part 3 Switches, Disconnectors, Switch- Disconnectors and Fuse-Combination Units
149.	IS/IEC 60947 : PART 4 : SEC 1 : 2012 (REAFFIRMED 2018)	Low-Voltage Switchgear and Control gear : Part 4 Contactors and Motor-Starters - Section 1 Electromechanical contactors and motor-starters
150.	IS/IEC 60947 : PART 4 : SEC 2 : 2011 (REAFFIRMED 2018)	Low-Voltage Switchgear and Control gear : Part 4 Contractors and Motor-Starters - Section 2 AC Semiconductor Motor Controllers and Starters
151.	IS/IEC 60947 : PART 4 : SEC 3 : 2014	Low-Voltage Switchgear and Control gear : Part 4 Contactors and Motor-Starters - Section 3 AC semiconductor motor controllers and contractors for non- motor loads
152.	IS/IEC 60947 : PART 5 : SEC 1 : 2009 (REAFFIRMED 2018)	Low-Voltage Switchgear and Control gear : Part 5 Control Circuit Devices and Switching Elements - Section 1 Electromechanical control circuit devices
153.	IS/IEC 60947 : PART 5 : SEC 2 : 2007 (REAFFIRMED 2017)	Low-Voltage Switchgear and Control Gear : Part 5 Control Circuit Devices and Switching Elements - Section 2 Proximity Switches
154.	IS/IEC 60947 : PART 5 : SEC 5 : 2016	Low-Voltage Switchgear and Control gear : Part 5 Control Circuit Devices and Switching Elements - Section 5 Electrical emergency stop devices with mechanical latching function
155.	IS/IEC 61439 : PART 0 : 2010	Low-Voltage Switchgear and Control gear Assemblies : Part 0 Guidance to Specifying Assemblies
156.	IS/IEC 61439 : PART 1 : 2011	Low-Voltage Switchgear and Control gear Assemblies : Part 1 General Rules
157.	IS/IEC 61439 : PART 2 : 2011 (REAFFIRMED 2018)	Low-voltage Switchgear and Control gear Assemblies : Part 2 Power Switchgear and Control gear Assemblies
158.	IS/IEC 61439 : PART 3 : 2012	Low-Voltage Switchgear and Control gear Assemblies : Part 3 Distribution Boards Intended to be Operated by Ordinary Persons (DBO)
159.	IS/IEC 61439 : PART 4 : 2012	Low-Voltage Switchgear and Control gear Assemblies : Part 4 Particular Requirements for Assemblies for Construction Sites (ACS)
160.	IS/IEC 61439 : PART 5 : 2014	Low-Voltage Switchgear and Control gear Assemblies : Part 5 Assemblies for Power Distribution in Public Networks
161.	IS/IEC 61439 : PART 6 : 2012	Low-Voltage Switchgear and Control gear Assemblies : Part 6 Busbar Trunking Systems (Busways) Low-Voltage Switchgear and Control gear Assemblies :



Sr. No.	Standard No.	Title
162.	IS/IEC/TS 61439 : PART 7 : 2014	Part 7 Assemblies for Specific Applications such as Marinas, Camping Sites, Market Squares, Electric Vehicles Charging Stations
163.	IS 11353 : 1985 (REAFFIRMED 2017)	Guide for Uniform System of Marking and Identification of Conductors and Apparatus Terminals
164.	IS 8623 : PART 1 : 1993 (REAFFIRMED 2018)	Low-Voltage Switchgear and Controlgear Assemblies : Part 1 : Requirements for Type-Tested and Partially Type-Tested Assemblies
165.	IS 8623 : PART 2 : 1993 (REAFFIRMED 2018)	Specification for Low-voltage Switchgear and Controlgear Assemblies : Part 2 : Particular Requirements for Busbar Trunking Systems (Busway)
166.	IS 8623 : PART 3 : 1993 (REAFFIRMED 2018)	Specification for Low-Voltage Switchgear and Controlgear Assemblies : Part 3 : Particular Requirements for Equipment Where Unskilled Persons have Access for Their Use
167.	IS 13010 : 2002 (REAFFIRMED 2017)	AC Watt-hour Meters, Class 0.5, 1 and 2 - Specification
168.	IS 14372 : 1996 (REAFFIRMED 2019)	Volt-Ampere hour meters for full power factor range [superseding IS:722(Part 7/Sections 1, 2 and 3)-1987]
169.	IS 14415 : 1997 (REAFFIRMED 2017)	Volt-Ampere hour meters for restricted power factor range - specification ((superseding IS:722 (Part 5):1980)
170.	IS 16444 : 2015	AC Static Direct Connected Watt-hour Smart Meter Class 1 and 2-Specification
171.	IS 16444 : PART 1 : 2015	AC Static Direct Connected Watt-hour Smart Meter Class 1 and 2 - Specification
172.	IS 16444 : PART 2 : 2017	AC Static Transformer Operated Watt-hour and VAR- Hour Smart Meters, Class 0.2S, 0.5S and 1.0S : Part 2 Specification Transformer Operated Smart Meters
173.	IS 15707 : 2006 (REAFFIRMED 2016)	Testing, Evaluation, Installation and Maintenance of AC Electricity Meters - Code of Practice
174.	IS/IEC 60079 : PART 1 : 2014	Explosive Atmospheres : Part 1 Equipment Protection by Flame proof Enclosures
175.	IS 5578 : 1984 (REAFFIRMED 2016)	Guide for marking of insulated conductors
176.	IS 11353 : 1985 (REAFFIRMED 2017)	Guide for Uniform System of Marking and Identification of Conductors and Apparatus Terminals
177.	IS/IEC 60309 : PART 1 : 2002 (REAFFIRMED 2017)	Plugs, Socket-Outlets and Couplers for Industrial Purposes : Part 1 : General Requirements
178.	IS/IEC 60309 : PART 2 : 2002 (REAFFIRMED 2017)	Plugs, Socket-Outlets and Couplers for Industrial Purposes : Part 2 : Dimensional Interchangeability Requirements for Pin and Contact-Tube Accessories
179.	IS 2206 : PART 1 : 1984 (REAFFIRMED 2005)	Flameproof electric lighting fittings: Part 1 Well-glass and bulkhead types
180.	IS 15077 : PART 1 : 2019	Semiconductor Optoelectronic Devices for Fibre Optic System Applications : Part 1 Specification Template for Essential Ratings and Characteristics
181.	IS 15077 : PART 2 : 2012 (REAFFIRMED 2015)	Semiconductor Optoelectronic Devices for Fibre Optic Systems Applications : Part 2 : Measuring Methods
182.	IS 10322 : PART 1 : 2014 (REAFFIRMED 2019)	Luminaires : Part 1 General Requirements and Tests
183.	IS 10322 : PART 5 : SEC 1 : 2012 (REAFFIRMED 2017)	Luminaires: Part 5 Particular requirements Sec 1 General purpose luminaires
184.	IS 10322 : PART 5 : SEC 2 : 2012 (REAFFIRMED 2017)	Luminaires : Part 5 : Particular Requirements - Section 2 : Recessed Luminaires

Sr. No.	Standard No.	Title
185.	IS 10322 : PART 5 : SEC 3 : 2012 (REAFFIRMED 2017)	Luminaires : Part 5 : Particular Requirements - Section 3 : Luminaires for Road and Street Lighting
186.	IS 10322 : PART 5 : SEC 4 : 1987 (REAFFIRMED 2015)	Luminaires: Part 5 Particular requirements, Section 4 Portable general purpose luminaires
187.	IS 10322 : PART 5 : SEC 5 : 2013 (REAFFIRMED 2018)	Luminaires: Part 5 Particular requirements, Section 5 Flood light (superseding IS:1947)
188.	IS 10322 : PART 5 : SEC 6 : 2013 (REAFFIRMED 2018)	Luminaires : Part 5 Particular Requirements Section 6 Handlamps
189.	IS 10322 : PART 5 : SEC 7 : 2017	Luminaires : Part 5 Particular Requirements - Section 7 Lighting Chains
190.	IS 10322 : PART 5 : SEC 8 : 2013 (REAFFIRMED 2018)	Luminaires : Part 5 Particular Requirements Section 8 Emergency Lighting
191.	IS 10322 : PART 5 : SEC 9 : 2017	Luminaires : Part 5 Particular Requirements - Section 9 Rope Lights
192.	IS 12640 : PART 2 : 2016	Residual Current-operated Circuit-Breakers with Integral Overcurrent Protection for Household and Similar Uses (RCBOS) : Part 2 General Rules
193.	IS 12640 : PART 1 : 2016	Residual Current-operated Circuit- Breakers without Integral Overcurrent Protection for Household and Similar Uses (RCCBS) : Part 1 General Rules
194.	IS 14614 : 1998 (REAFFIRMED 2018)	Residual Current-operated Protective Devices (RCDs) for Household and Similar Use - Electromagnetic Compatibility
195.	IS/IEC 60898 : PART 1 : 2015	Electrical Accessories-Circuit-Breakers for Overcurrent Protection for Household and Similar Installations : Part 1 Circuit-Breakers for AC Operation
196.	IS/IEC 60898 : PART 2 : 2003 (REAFFIRMED 2017)	Electrical Accessories - Circuit-Breakers for Overcurrent Protection for Household and Similar Installations : Part 2 : Circuit-Breakers for AC and DC Operation
197.	IS 13961 : 1994 (REAFFIRMED 2014)	Insulating Poles (Insulating Sticks) and Universal Tool Attachments (Fittings) for Live Working
198.	IS 13961 : PART 2 : 2017	Live Working-Insulating Sticks and Attachable Devices : Part 2 Attachable Devices
199.	IS 3961 : PART 1 : 1967 (REAFFIRMED 2016)	Recommended current ratings for cables: Part 1 Paper insulated lead sheathed cables
200.	IS 3961 : PART 2 : 2017	Recommended Current Ratings for Cables : Part 2 PVC Insulated and PVC Sheathed Heavy Duty Cables
201.	IS 3961 : PART 3 : 1968 (REAFFIRMED 2016)	Recommended current ratings for cables: Part 3 Rubber insulated cables
202.	IS 3961 : PART 5 : 1968 (REAFFIRMED 2016)	Recommended current ratings for cables: Part 5 PVC insulated light duty cables
203.	IS 3961 : PART 6 : 2016	Recommended Current Rating for Cables : Part 6 Crosslinked Polyene Insulated PVC Sheathed Cables
204.	IS 3961 : PART 7 : 2017	Recommended Current Ratings for Cables : Part 7 Crosslinked Insulated Thermoplastic Sheathed Cables
205.	IS 2086 : 1993 (REAFFIRMED 2019)	Carriers and bases used in rewirable type electric fuses for voltages upto 650V (Superseding IS 8724)
206.	IS 13703 : PART 2 : SEC 1: 1993 (REAFFIRMED 2014)	Specification for Low-Voltage Fuses for Voltages not Exceeding 1000 V AC or 1500 V DC : Part 2 : Fuses for Use by Authorized Persons - Section 1 : Supplementary Requirements



Sr. No.	Standard No.	Title
207.	IS 13703 : PART 2 : SEC 2: 1993 (REAFFIRMED 2014)	LV fuses for voltages not exceeding 1000 V AC or 1500 V DC: Part 2 Fuses for use by authorized persons, Section 2 Examples of standardized fuses
208.	IS 13703 : PART 4 : 1993 (REAFFIRMED 2014)	Specification for Low-Voltage Fuses for Voltages not Exceeding 1000 V AC or 1500 V DC : Part 4 : Supplementary Requirements for Fuse Links for the Protection of Semiconductor Devices
209.	IS 12672 : 1989 (REAFFIRMED 2016)	Internal fuses and internal overpressure disconnectors for shunt capacitors
210.	IS 2672 : 1966 (REAFFIRMED 2015)	Code of practice for library lighting
211.	IS 4347 : 1967 (REAFFIRMED 2015)	Code of practice for hospital lighting
212.	IS 16665 : 2017	High Voltage Direct Current (HVDC) Substation Audible Noise
213.	IS 6665 : 1972 (REAFFIRMED 2015)	Code of practice for industrial lighting
214.	IS 4648 : 1968 (REAFFIRMED 2017)	Guide for Electrical Layout in Residential Buildings
215.	IS 900 : 1992 (REAFFIRMED 2018)	Code of practice for installation and maintenance of induction motors
216.	IS 3480 : 1966 (REAFFIRMED 2017)	Flexible steel conduits for electrical wiring
217.	IS 3837 : 1976 (REAFFIRMED 2017)	Accessories for rigid steel conduits for electrical wiring
218.	IS 3419 : 1989 (REAFFIRMED 2017)	Fittings for Rigid Non-metallic Conduits
219.	IS 9537 : PART 1 : 1980 (REAFFIRMED 2015)	Conduits for electrical installations: Part 1 General requirements
220.	IS 9537 : PART 2 : 1981 (REAFFIRMED 2017)	Conduits for electrical installations: Part 2 Rigid steel conduits (superseding IS:1653)
221.	IS 9537 : PART 3 : 1983 (REAFFIRMED 2017)	Conduits for electrical installations: Part 3 Rigid plain conduits of insulating materials (superseding IS:2509)
222.	IS 9537 : PART 4 : 1983 (REAFFIRMED 2017)	Specification for Conduits for Electrical Installations : Part 4 : Pliable Self-recovering Conduits of Insulating Materials
223.	IS 9537 : PART 5 : 2000 (REAFFIRMED 2015)	Conduits for Electrical Installations : Part 5 : Pliable Conduits of Insulating Material
224.	IS 9537 : PART 6 : 2000 (REAFFIRMED 2015)	Conduits for Electrical Installations : Part 6 : Pliable Conduits of Metal or Composite Materials
225.	IS 9537 : PART 8 : 2003 (REAFFIRMED 2013)	Conduits for Electrical Installations - Specification : Part 8 : Rigid Non-Threadable Conduits of Aluminium Alloy
226.	IS 14768 : PART 1 : 2000 (REAFFIRMED 2019)	Conduit Fittings for Electrical Installations - Specification : Part 1 : General Requirements
227.	IS 14768 : PART 2 : 2003 (REAFFIRMED 2018)	Conduit Fittings for Electrical Installations - Specification : Part 2 : Metal Conduit Fittings
228.	IS 14772 : 2000 (REAFFIRMED 2015)	General Requirements for Enclosures for Accessories for Household and Similar Fixed Electrical Installations - Specification
229.	IS 14927 : PART 1 : 2001 (REAFFIRMED 2017)	Cable Trunking and Ducting Systems for Electrical Installations : Part 1 : General Requirements
230.	IS 14927 : PART 2 : 2001 (REAFFIRMED 2017)	Cable Trunking and Ducting Systems for Electrical Installations : Part 2 : Cable Trunking and Ducting Systems Intended for Mounting on Walls or Ceilings
231.	IS 9537 : PART 1 : 1980 (REAFFIRMED 2015)	Conduits for electrical installations: Part 1 General requirements
232.	IS 9537 : PART 2 : 1981 (REAFFIRMED 2017)	Conduits for electrical installations: Part 2 Rigid steel conduits (superseding IS:1653)

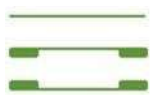
Sr. No.	Standard No.	Title
233.	IS 9537 : PART 3 : 1983 (REAFFIRMED 2017)	Conduits for electrical installations: Part 3 Rigid plain conduits of insulating materials (superseding IS:2509)
234.	IS 9537 : PART 4 : 1983 (REAFFIRMED 2017)	Specification for Conduits for Electrical Installations : Part 4 : Pliable Self-recovering Conduits of Insulating Materials
235.	IS 9537 : PART 5 : 2000 (REAFFIRMED 2015)	Conduits for Electrical Installations : Part 5 : Pliable Conduits of Insulating Material
236.	IS 9537 : PART 6 : 2000 (REAFFIRMED 2015)	Conduits for Electrical Installations : Part 6 : Pliable Conduits of Metal or Composite Materials
237.	IS 9537 : PART 8 : 2003 (REAFFIRMED 2013)	Conduits for Electrical Installations - Specification : Part 8 : Rigid Non-Threadable Conduits of Aluminium Alloy
238.	IS 3837 : 1976 (REAFFIRMED 2017)	Accessories for rigid steel conduits for electrical wiring
239.	IS 14768 : PART 1 : 2000 (REAFFIRMED 2019)	Conduit Fittings for Electrical Installations - Specification : Part 1 : General Requirements
240.	IS 14768 : PART 2 : 2003 (REAFFIRMED 2018)	Conduit Fittings for Electrical Installations - Specification : Part 2 : Metal Conduit Fittings
241.	IS 9537 : PART 1 : 1980 (REAFFIRMED 2015)	Conduits for electrical installations: Part 1 General requirements
242.	IS 9537 : PART 2 : 1981 (REAFFIRMED 2017)	Conduits for electrical installations: Part 2 Rigid steel conduits (superseding IS:1653)
243.	IS 9537 : PART 3 : 1983 (REAFFIRMED 2017)	Conduits for electrical installations: Part 3 Rigid plain conduits of insulating materials (superseding IS:2509)
244.	IS 9537 : PART 4 : 1983 (REAFFIRMED 2017)	Specification for Conduits for Electrical Installations : Part 4 : Pliable Self-recovering Conduits of Insulating Materials
245.	IS 9537 : PART 5 : 2000 (REAFFIRMED 2015)	Conduits for Electrical Installations : Part 5 : Pliable Conduits of Insulating Material
246.	IS 9537 : PART 6 : 2000 (REAFFIRMED 2015)	Conduits for Electrical Installations : Part 6 : Pliable Conduits of Metal or Composite Materials
247.	IS 9537 : PART 8 : 2003 (REAFFIRMED 2013)	Conduits for Electrical Installations - Specification : Part 8 : Rigid Non-Threadable Conduits of Aluminium Alloy
248.	IS 3419 : 1989 (REAFFIRMED 2017)	Fittings for Rigid Non-metallic Conduits
249.	IS 3043 : 2018	Code of Practice for Earthing
250.	IS/IEC 62305 : PART 1 : 2010 (REAFFIRMED 2015)	Protection Against Lightning : Part 1 General Principles
251.	IS/IEC 62305 : PART 2 : 2010 (REAFFIRMED 2014)	Protection Against Lightning : Part 2 Risk Management
252.	IS/IEC 62305 : PART 3 : 2010 (REAFFIRMED 2015)	Protection Against Lightning : Part 3 Physical Damage to Structures and Life Hazard
253.	IS/IEC 62305 : PART 4 : 2010 (REAFFIRMED 2015)	Protection Against Lightning : Part 4 Electrical and Electronic Systems Within Structures
254.	IS 13021 : PART 1 : 1991 (REAFFIRMED 2016)	AC supplied electronic ballasts for tubular florescent lamps: Part 1 General and safety requirements
255.	IS 13021 : PART 2 : 1991 (REAFFIRMED 2015)	AC Supplied Electronic Ballasts for Tubular Fluorescent Lamps - Specification : Part 2 : Performance Requirements
256.	IS 1258 : 2005 (REAFFIRMED 2015)	Bayonet Lamp holders
257.	IS 10418 : 1982 (REAFFIRMED 2016)	Drums for electric cables
258.	IS 2418 : PART 1 : 2018	Tubular Fluorescent Lamps for General Lighting Service : Part 1 Safety Requirements
259.	IS 2418 : PART 2 : 2018	Tubular Fluorescent Lamps for General Lighting Service : Part 2 Performance Requirements
260.	IS 2418 : PART 3 : 1977 (REAFFIRMED 2016)	Tubular Fluorescent Lamps for General Lighting Service : Part 3 : Dimensions of G-5 and G-13 Bi-Pin Caps



Sr. No.	Standard No.	Title
261.	IS 2418 : PART 4 : 1977 (REAFFIRMED 2017)	Tubular fluorescent lamps for general lighting service: Part 4 Go and no-go gauges for G-5 and G-13 bi-pin caps
262.	IS 418 : 2004 (REAFFIRMED 2019)	Tungsten Filament Lamps for Domestic and Similar General Lighting Purposes
263.	IS 1569 : 1976 (REAFFIRMED 2016)	Capacitors for use in tubular fluorescent high pressure mercury and low pressure sodium vapour discharge lamp circuit
264.	IS 2215 : 2006 (REAFFIRMED 2015)	Starters for Fluorescent Lamps
265.	IS 2418 : PART 1 : 2018	Tubular Fluorescent Lamps for General Lighting Service : Part 1 Safety Requirements
266.	IS 2418 : PART 2 : 2018	Tubular Fluorescent Lamps for General Lighting Service : Part 2 Performance Requirements
267.	IS 2418 : PART 3 : 1977 (REAFFIRMED 2016)	Tubular Fluorescent Lamps for General Lighting Service : Part 3 : Dimensions of G-5 and G-13 Bi-Pin Caps
268.	IS 2418 : PART 4 : 1977 (REAFFIRMED 2017)	Tubular fluorescent lamps for general lighting service: Part 4 Go and no-go gauges for G-5 and G-13 bi-pin caps
269.	IS 3323 : 1980 (REAFFIRMED 2017)	Bi-pin lamp holders for tubular fluorescent lamps
270.	IS 3324 : 1982 (REAFFIRMED 2018)	Holders for starters for tubular fluorescent lamps
271.	IS 9900 : PART 1 : 1981 (REAFFIRMED 2017)	High pressure mercury vapour lamps: Part 1 Requirements and test (Superseding IS:2183 and IS:7023)
272.	IS 9900 : PART 2 : 1981 (REAFFIRMED 2017)	High pressure mercury vapour lamps: Part 2 Standard lamp data sheets (superseding IS: 2183 and IS: 7023)
273.	IS 9900 : PART 3 : 1981 (REAFFIRMED 2017)	High pressure mercury vapour lamps : Part 3 Dimensions of lamp caps (superseding IS:2183 and IS:7023)
274.	IS 9900 : PART 4 : 1981 (REAFFIRMED 2017)	High pressure mercury vapour lamps : Part 4 Go and no-go gauges of lamp caps (superseding IS:2183 and IS:7023)
275.	IS 16463 : PART 11 : 2016	Low-Voltage Surge Protective Devices : Part 11 Surge Protective Devices Connected to Low-Voltage Power Systems - Requirements and Test Methods
276.	IS 16463 : PART 12 : 2017	Low-Voltage Surge Protective Devices : Part 12 Surge Protective Devices Connected to Low-Voltage Power Distribution Systems - Selection and Application Principles
277.	IS: 3070-3/1993, IS: 2309- 1989, IEC-62305	Lightening Arrester
278.	IS: 1248- 1983	Analogue Electrical Measuring Instruments
279.	IS: 2147	Degree of Protection
280.	IS: 2834	Shunt Capacitor for Power Station
281.	IS: 2705 .	Current Transformer
282.	IS: 3231	Electrical Relays for Power System
283.	IS: 13779	Digital Meters
284.	IS: 2551 - 1982	Danger Notice Boards
285.	IS: 3871/IS: 4293	Earth Leakage Circuit Breaker
286.	IS: 374 - 1979	Electric Ceiling Fan
287.	IS: 11037 - 1984	Electronic Fan Regulator
288.	IS: 10002-1981	Diesel Engine
289.	IS: 4889	Electrical Machines
290.	IS: 13364 - 1992	Alternator Voltage Regulators
291.	IS: 4722 - 2001	Electrical Rotating Machines
292.	IEC: 61347-2-13/EN: 61347-2-13/ IS:15885 (Part-2/Sec.-13)-2012	LED Driver Safety Requirements- Lamp control gear; particular requirements for DC or AC supplied electronic control gear for LED modules.

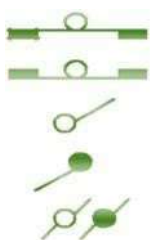
Sr. No.	Standard No.	Title
293.	IEC:62384/IS:16104-2012	LED Driver Performance Requirements-DC OR AC supplied electronic control gear for LED modules performance requirements
294.	IS:14700 (Part-4/Section-2)	Standard Testing of LED Driver
295.	CISPR-15/IS:6573, IEC:61547	EMI/EMC tests for LED Driver
296.	IEC: 62031/ IS: 16103 (Part- 1 & 2)- 2012	LED Modules for general lighting- Safety Requirements and Performance Requirements.
297.	IS: 16101-2012	General Lighting-LED/LED module – Terms and Definitions
298.	IS: 16102 (Part-I &II)-2012 & IEC/PAS 62612	Self-Ballasted LED Lamps for General lighting Services (Safety Requirements & Performance Requirements).
299.	IS: 16104-2012	Electronic Control Gear for LED modules – Performance Requirements
300.	LM-80/IS:16105-2012	Approved Method for Measuring Lumen Maintenance of LED Light Source
301.	LM-79/IS:16106-2012	Approved Method for Electrical and Photometric Measurements of Solid State LED Lighting Products.
302.	L-70 (IEC-60081-1997)/IS:16107-Part—2	LED Life Expectancy
303.	IEC: 60068-2-38	Environmental Testing/ Humidity Cycle Test
304.	IEC:60332-1/IS: 11000	Luminaries-Fire Retardant Test
305.	IEC:60081-1997 (Annexure-B,C &D)/ANSI_NEMA_ANSI C78.377-2008	Ra (Colour Rendering Index) Measurement Test
306.	IEC:60529	Luminaries- Ingress Protection Test.
307.	IEC: 60598-2-1/ 60598-1	Fixed General Purpose Luminaries/ Luminaries- General Requirement & Tests
308.	IEC: 61000-3-2	EMC (Electro Magnetic Compatibility)- Limits for Harmonic Current Emission
309.	IS: 513	Specification of Cold Rolled Low Carbon Steel Sheets and Strips
310.	IS: 4905	Method of Random Sampling
311.	IS: 10322 (Part-5/Sec.-1)- 2012 & Part-1	Requirements of fixed general purpose LED Luminaries
312.	IEC: 61373	Electric shock Testing

Conventional Signs & Symbols for Electrical Installation



- General wiring
- Wiring on the surface
- Wiring under the surface

WIRING IN CONDUIT



- Conduit on surface
- Concealed conduit
- Wiring going upwards
- Wiring going downwards
- Wiring passing vertically

FUSE BOARDS

LIGHTING CIRCUIT FUSE-BOARDS



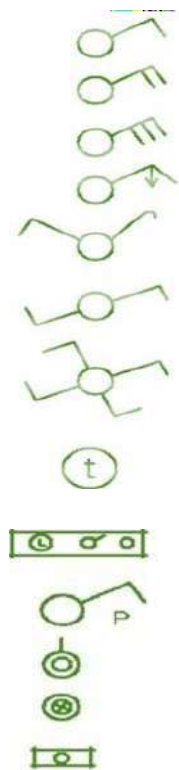
- Main fuse-board without switches
- Main fuse-board with switches
- Distribution fuse-board without switches
- Distribution fuse-board with switches

POWER CIRCUIT FUSE-BOARDS



- Main fuse-board without switches
- Main fuse-board with switches
- Distribution fuse-board without switches
- Distribution fuse-board with switches

SWITCHES & SWITCH OUTLETS ONE WAY SWITCH



Single pole

Two pole

Three pole

Single pole pull switch

Multi-position switch (for different degrees of lighting)Two-way switch

Intermediate switch

Period limiting switch

Time switch

Pendant Switch

Push button

Luminous push button

Restricted access push button

SOCKET OUTLETS



Socket-outlet, 5A

Socket-outlet, 15A

Combined switch& socket-outlet, 5A

Combined switch & socket-outlet, 15A

Interlocking switch& socket-outlet, 5A

Interlocking switch & socket-outlet, 15A

LAMPS AND LIGHTING APPARATUS



Lamp or outlet for lamp

Group of three 40W lamps

Lamp mounted on a wall

Lamp mounted on a ceiling

Counter-

weight lamp fixture

	Chain lamp fixture
	Road lamp fixture
	Lamp fixture with built-in-switch
	Lamp fed from variable voltage supply
	Emergency lamp
	Panic lamp
	Bulk head lamp
	Water-tight lighting fitting
	Batten lamp holder
	Projector
	Spot light
	Flood light
	Fluorescent lamp
	Group of three 40W
	Fluorescent lamp

ELECTRICAL PRACTICE FOR GENERAL POWER SUPPLY AT RAILWAY STATION

1.0 FOREWORD:

This document covers guidelines on Electrical practice for power supply system at platform/station. The purpose of these guidelines is to improve the reliability of power supply scheme and to eliminate the possibility of safety hazard by adopting sound Electrical Engineering practices.

2.0 GENERAL WIRING REQUIREMENTS:

In general, wiring scheme will conform to following provisions of IS, Codes and manuals:

1. Code of practice for electrical wiring IS-732(1989) or latest.
2. Code of practice for installation and maintenance of power cable upto and above 33KV IS-1255 (1983)
3. code of practice for fire safety of buildings (general) electrical installation IS-1646 (1997)
4. National Electrical Code of India -2011.
5. National building code of India part-8 for building services electrical.
6. General Specifications for Electrical Works part-1 Internal-2013 published by CPWD.
7. General Specifications for Electrical Works part-IV Sub Station-2013 published by CPWD.
8. Electric Installation Guide-2015 issued by Schneider Electric
9. Energy conservation building code-2017
10. IS3419-1989 second revision or latest for fitting of rigid non metallic conduit.
11. IS 3043-1087 first revision reaffirmed in 2016 or latest: Code of Practice for earthing.
12. IS 1293-2005 or latest: Plug and socket- outlets of rated voltage upto and including 250 volt and rated current upto and including 16A.
13. IS 3854-1997 second revision reaffirmed in 2002 or latest: switches for domestic and similar purpose.

3.0 GENERAL SCHEME FOR POWER SUPPLY SYSTEM:

- 3.1 The Single Line Diagram (SLD) for typical power supply arrangement at Railway Station is shown in annexure-A. Provision of single bus coupler has been shown in the SLD however if complexity of power supply system demands segregation of loads in more than two segments then more bus coupler may be provided.
- 3.2 Single line diagram for general power supply arrangement should be displayed at convenient location in substation.



- 3.3 SLD for every distribution board should be displayed inside the front cover of respective DBs.
- 3.4 DB number is to be marked in bold letters over the DB as per SLD.
- 3.5 In case of space constraint or for indoor substations, Zonal Railways may use compact substations with dry type transformer.
- 3.6 The Electrical distribution sub-station feeding power supply to Railway Station receives HT power supply normally at 33/11KV from distribution company or from main receiving sub-station of Railways.
- 3.7 In case of indoor/compact substation the switch gear at HT side will preferably be vacuum circuit breaker. The relays shall be microprocessor based numerical relays with Overload, Earth fault and Short circuit protection. Tripping relays shall be used for tripping of circuit breaker.
- 3.8 In case of outdoor substations drop out fuses with GOS (Gang Operated Switch) and DOLO fuse unit fixed in enclosed cubicle at ground level with locking arrangement shall be used.
- 3.9 In the substations feed with LT supply the incoming cable should be connected to distribution board through MCCB/MCB.
- 3.10 Various distribution boards should include Energy meters for recording energy consumption. The specification of the energy meter should be compatible with specification mentioned in Railway Board letter no. 206/Elect(G)/150/7 dated 09.03.17.
- 3.11 The distribution boards feeding supply to critical electronic loads should include SPDs Class II as per IEC 61643-1, at the terminals of incoming cables for external surge protection. Internal Surge protection (SPDs) shall consist of three MOV type arrestors connected from + ve and – ve terminal to earth (Via Y arrangement) for higher withstand of the continuous PV-DC voltage during earth fault condition. SPD shall have safe disconnection & short circuit interruption arrangement through integrated DC in-built bypass fuse (parallel) which should get tripped during failure mode of MOV, extinguishing DC arc safely (created by inbuilt thermal disconnection) in order to protect the installation against fire hazards. Nominal discharge current (I_n) at 8/20 microseconds shall be minimum 10 KA with maximum discharge current (I_{max}) of minimum 20 KA at 8/20 microseconds with visual indication (through mechanical flag) in all modules to monitor the life of SPD. The I_{scwpv} (Short Circuit current withstands capacity of arrester) would be at least 10% more than Nominal output current from the distribution board.
- 3.12 The power trunking or bus bar arrangement for power distribution in lieu of insulated wire run under platform shelters with adequate size of MCBs should be selectively used based on site requirements after getting clearance from PCEE.
- 3.13 RLC based power conditioners/ Savers may be used at locations having electronic equipments to reduce harmonic effects.
- 3.14 In case building is equipped with addressable automatic fire prevention and suppression system, the distribution boards should have separate



address and sensors for detecting initiation of fire. Firefighting equipment such as fire extinguisher and fire buckets should be provided at easily accessible location.

- 3.15 Decision may be taken by Zonal Railways for providing SCADA system for remotely monitoring critical parameters based on complexity of power supply system at particular station.
- 3.16 All the items used in electrical wiring shall be ISI marked. In general no temporary connection should be used. However in exceptional cases if temporary connections are to be used it should be used with spikes.
- 3.17 Substation building should structurally meet the requirements mentioned in National Building Code.
- 3.18 The fire rating of electrical Distribution Boards, Panels, Cables, Wire, Bus Bar should be governed by National Electrical Code.

4.0 DESIRABLE FEATURES OF LT SWITCH GEARS AT MAIN DISTRIBUTION BOARD AND SUB-DISTRIBUTION BOARD

- 4.1 If total load requirement of particular distribution board is more than 800Amp, then incoming cable should be connected to distribution bus bar via Air Circuit Breaker (ACB). ACB should have microprocessor based relays for LSIG (Long-time + Short-time + Instantaneous + Equipment Ground-fault Protection), Over voltage/under voltage, over frequency/under frequency, unbalance voltage and phase sequence protection.
 - 4.1.1 If total load requirement at substation/Main distribution board is less than 800Amp, MCCB with microprocessor controlled tripping mechanism having overload, short circuit, earth fault protection with adjustable range between 40-100% of rated current and provision of time delay should be used for incomer cable connection.
- 4.2 If individual outgoing feeder at sub-station distribution board have total load current from 63Amp to 125Amp MCCB should preferably be used. The MCCB for load more than 125Amp should be microprocessor based releases with Over Current and Short Circuit protection.
- 4.3 MCCB for sub-station panel should have double break, positive isolation connectivity, load line reversibility, shock and vibration proof with draw out design and horizontal cum vertical mounting features.
- 4.4 If individual feeder current is less than 63 Amp then MCB may be used for protection of feeder.
- 4.5 In case of feeder is supplying power to base kitchens of canteens/multifunctional complexes, MCCB may be replaced by RCCB/RCBO.

5.0 SETTING RANGE OF PROTECTION RELAYS:

- 5.1 Overload protection shall have adjustable setting from 40% to 100% of the rated current in step of 10% and adjustable time setting from 3 to 18 milisecond.
- 5.2 Short circuit protection shall have adjustable current setting from 4to 8 times of rated current. The short circuit setting and adjustable time



delay setting for fault discrimination should be from 50 to 500 milisecond.

- 5.3 Earth fault protection should have adjustable current setting from 20% to 100% of rated current and adjustable time setting from 100 to 400 milisecond.

6.0 DISTRIBUTION BOARDS:

- 6.1 The switchboard shall be floor mounted free standing totally enclosed and extensible type. The switch board shall be dust & vermin proof and shall be suitable for the climate conditions as specified. The design shall include all provisions for safety of operation and maintenance personnel. The general construction shall conform to IS 8623:1993 for factory assembled switch board. The panel should be powder coated with seven tank process.
- 6.2 It is recommended that distribution board should be minimum IP-66 if there is any chance of water entry into distribution box. If DB is installed at indoor locations where chances of water falling are less, then DB may be IP-43.
- 6.3 Electrical distribution boards/panels at stations should be located at a place having adequate clearance, ventilation and accessibility.
- 6.4 It is recommended to provide cable entry and exit points at the bottom side of distribution board.
- 6.5 It is recommended to provide residual current device (RCD) of 300 mA rating as part of the main board at the entry of the building and of 30 mA rating as part of the sub distribution board.
- 6.6 All opening in the housing for panel and distribution board should be sealed to check entry of reptile, lizard, rats etc. and possibility of foreign body like paper, Bidis, etc. being inserted by public (in case of distribution board installed in public area). Suitable glands/gasket should be used to fill up gaps in the opening of holes (for entry of cable, bus-bar etc.) and in the cover.
- 6.7 Electrical separation will be governed as per the requirement of IEC 61439.

7.0 CO-ORDINATION OF PROTECTION SYSTEM

An MCCB/MCB should be provided at the origin of each circuit. The purpose of MCCB/MCB is to cut-off the current in a time shorter than that given by the i^2t characteristic of the circuit cabling, but allowing the maximum load current I_B to flow indefinitely. The characteristics of insulated conductors when carrying short-circuit currents can, for periods up to 5 seconds following short-circuit initiation, be determined approximately by the formula: $i^2t = k^2S^2$

Which shows that the allowable heat generated is proportional to the squared cross-sectional-area of the conductor.

Where:

- t : Duration of short circuit current (seconds)
- S : Cross sectional area of insulated conductor (mm^2)



- I : Short circuit current (A.R.M.S.)
- k : Insulated conductor constant

for a given cable, the maximum permissible current varies according to the environment. For instance, for a high ambient temperature ($\theta_{a1} > \theta_{a2}$), I_{z1} is less than I_{z2} (see Fig. 2). θ means "temperature".

Note:

I_{sc} : 3-phase short-circuit current.

I_{SCB} : Rated 3-ph. short-circuit breaking current of the circuit breaker.

I_n : Nominal current level.

I_z : Maximum permissible current that circuit can carry indefinitely.

I_{cu} : Fault current rating of the circuit.

I_s : Maximum load current.

I_2 : MCB over current trip setting.

I_B : Maximum load current.

GENERAL RULES:

MCCB/MCB functions correctly if; (fig: 1&2)

- its nominal current I_n is greater than the maximum load current I_B but less than the maximum permissible current I_z for the circuit, i.e. $I_B \leq I_n \leq I_z$.
- Its tripping current is less than $1.45 I_z$.
- The 3 phase short circuit breaking current of the MCB should be greater than fault current rating of the circuit.

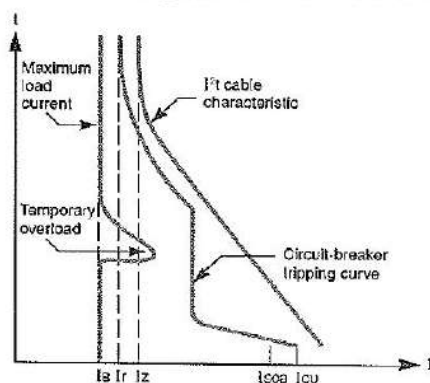


Fig:1, Circuit Protection by Circuit Breaker

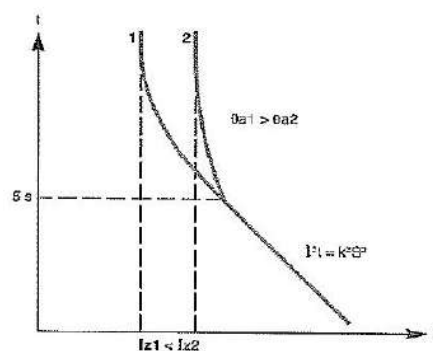


Fig: 2, I^2t characteristic of an isolated conductor at two different ambient temperatures

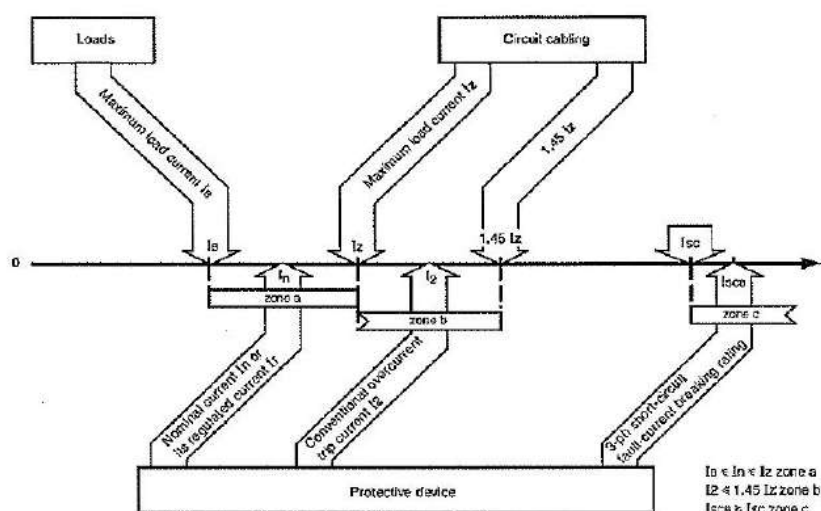


Fig:3, Current levels for determining circuit breaker or fuse characteristics

The three phase short circuit breaking capacity of MCCB should be greater than maximum anticipated short circuit current on dead short circuit of all three phases.

Example: For a 11kV/433V 250 kVA Transformer,

Maximum load current I_{FL}	$\approx 334A$.
% Impedance of T/F ($\%Z_{TR}$)	$= 4.5\%$ (say).
Impedance of T/F (Z_{TR})	$= \%Z_{TR} \cdot 10 \cdot kV^2 / kVA \approx 0.0337\Omega$.
Anticipated short circuit current (I_{sc}) in kA at any point on T/F secondary	$= 1.06 \cdot \text{Line Voltage} / [(Z_{TR} + Z_{CABLE}) \cdot \sqrt{3} \cdot 1000]$ (with 6% voltage tolerance at load end)
Max. anticipated short circuit current on dead short of all 3 Φ (worst possible fault) at T/F secondary	$= 7.86 \text{ kA}$ ($Z_{CABLE} \approx 0\Omega$)
Min. desirable rated service short circuit breaking capacity (I_{scB}) of MCCB at T/F secondary.	$= 2 \cdot \text{Anticipated } I_{sc} \approx 16 \text{ kA}$

Similar grading in the downstream system to be followed.

8.0 APPLICATION OF PROTECTION CO-ORDINATION PRINCIPLE

Protection by MCB/MCCB: By virtue of its high level of precision the current I_L is always less than $1.45 I_n$ so that the condition $I_L \leq 1.45 I_L$ will always be fulfilled.

9.0 Cable:

A) General specification:

- The LT cables shall be 1100 V grade, armoured, XLPE cable conforming to IS: 7098 Part - I (amendment 1 or latest) with improved fire retardant performance test for category C-2 as stipulated in appendix A of IS:7098 part-I (amendment 1 or latest).
- Halogen-free, low smoke, low toxicity.
- Flame retardant

- iv) Fulfills IEC 60332-1 requirements. Accredited lab test report/ Manufacturer's test report shall be verified while procuring.
- v) Conductor class IEC 60228 class 5. Accredited lab test report/Manufacturer's test report shall be verified while procuring.

B) SIZE SELECTION OF CABLE:

- i) The cross selection area of conductor should be such that cable can carry 1.45 times of maximum anticipated load current continually. Selection of cable size, voltage grade, no. of core, dielectric medium has to be most judiciously so as to be of sufficient capacity to carry 1.45 times the full load current.
- ii) For proper size selection of cable, the current rating of XLPE cable and distance up to which different size of cable can be used for different peak load current to limit voltage drop up to 8 volts has been shown in table 1 & 2 of annexure-B. These tables may be referred while selecting cables.

10.0 WIRING SCHEME:

- a. The wiring shall be done on a distribution system through main and/or branch distribution boards. Main distribution board shall be controlled by a circuit-breaker and each outgoing distribution circuit or sub-main circuit from main distribution board to sub distribution boards shall be provided with MCCB. The incomer at secondary distribution boards shall be controlled by a MCCB with microprocessor based tripping mechanism having Over Load, Short Circuit and Earth Fault Protection. Each outgoing circuit from secondary Distribution Board shall be provided with a MCCB on the phase or live conductor. The branch distribution board will have MCCB/MCB as incomer and MCB as isolating switch for each independent circuit.
- b. The neutral conductors (incoming and outgoing) shall be connected to a common link (multi-way connector) in the distribution board, the wiring throughout the installation shall be such that there is no break in the neutral wire except in the form of a linked switchgear.
- c. There shall be at least two circuits with distinct distribution board
 - i) One for light current (known as light power),
 - ii) Another for heavy current (known as heavy power) 16A socket outlets.

To connect heavy current appliances such as air conditioner, water pump, blower, heater etc. high current wiring shall be kept separate and distinct from low current wiring beyond the branch distribution boards. Lights and fans shall be wired in the light current circuits.

- d. Wiring shall be done only by the "Looping System". Phase or live conductors shall be looped at the switch boxes and neutral conductors at the point outlets. All joints in the conductors shall be made by means of approved mechanical connector in suitable and approved junction boxes.



- e. The balancing of circuits in three wire or poly phase installations shall be ensured.
- f. Distribution boards should preferably be located as near as possible to the centre of the loads they are intended to control. This will minimize the length and cost of final circuit cables. Location of DBs should be selected keeping in mind operation and maintenance convenience. Care must be taken to ensure IP-65/IP-66 protection for the units exposed to rain water.
- g. When more than one branch distribution board is fed from a single sub main cable it is advisable to provide local isolation near each distribution board.
- h. Fans and lights may be wired on a separate circuit. Power sub-circuits shall be designed according to the load and number of outlets on each sub circuit shall not be more than the current carrying capacity of the feeding conductor.
- i. The circuits for lighting of common area shall be separate. For large halls, 3-wire control with individual control and master control shall be made for effective conservation of energy.
- j. In bigger station it is advisable to employ branch distribution boards to save cable and to prevent voltage drop at the more distant points (lamps, fans or other appliances). In such cases, the main distribution board controls the distribution circuits to each sub-distribution board from which the final circuits to loads are taken
- k. The risk of spread of fire shall be minimized by selection of an appropriate material and proper erection. Components of wiring system such as conduit, cable ducting, cable trucking, bus-bar or bus-bar trunking etc. should have sufficient degree of flame retardants /fire resistant properties.

11.0 EARTHING AND BONDING

- a. Adequate number of earthing kits complying to IS: 3043 – 1987 should be installed. Earthing and bonding scheme should be in accordance with IS: 3043 – 1987.
- b. To keep Touch and Step Potential at substation within the limits specified in IS 3043-1987 earth mesh shall be provided if required.
- c. The individual earth resistance value of the earth pits should be as per following table:

Center	Earth value (Max.)
Power station	0.5 ohm
Substation major	1.0 ohm
Substation minor	2.0 ohm
Distribution transformer	5.0 ohm
Transmission line	10 ohm
Single isolate earth pit	5 ohm
Earthing mesh	0.5 ohm



The earthing system should be designed such that the minimum earth resistance value is less than 2 ohm for substation and for all other installations it is less than 5 ohm. Depending upon soil resistivity it may be necessary to use more than one number of electrode connected in parallel to achieve this value. In general, if earth resistivity is up to 50 ohm per meter, single electrode will be enough and in case earth resistivity is more than 50 ohm per meter then multi electrodes may be required to achieve this value.

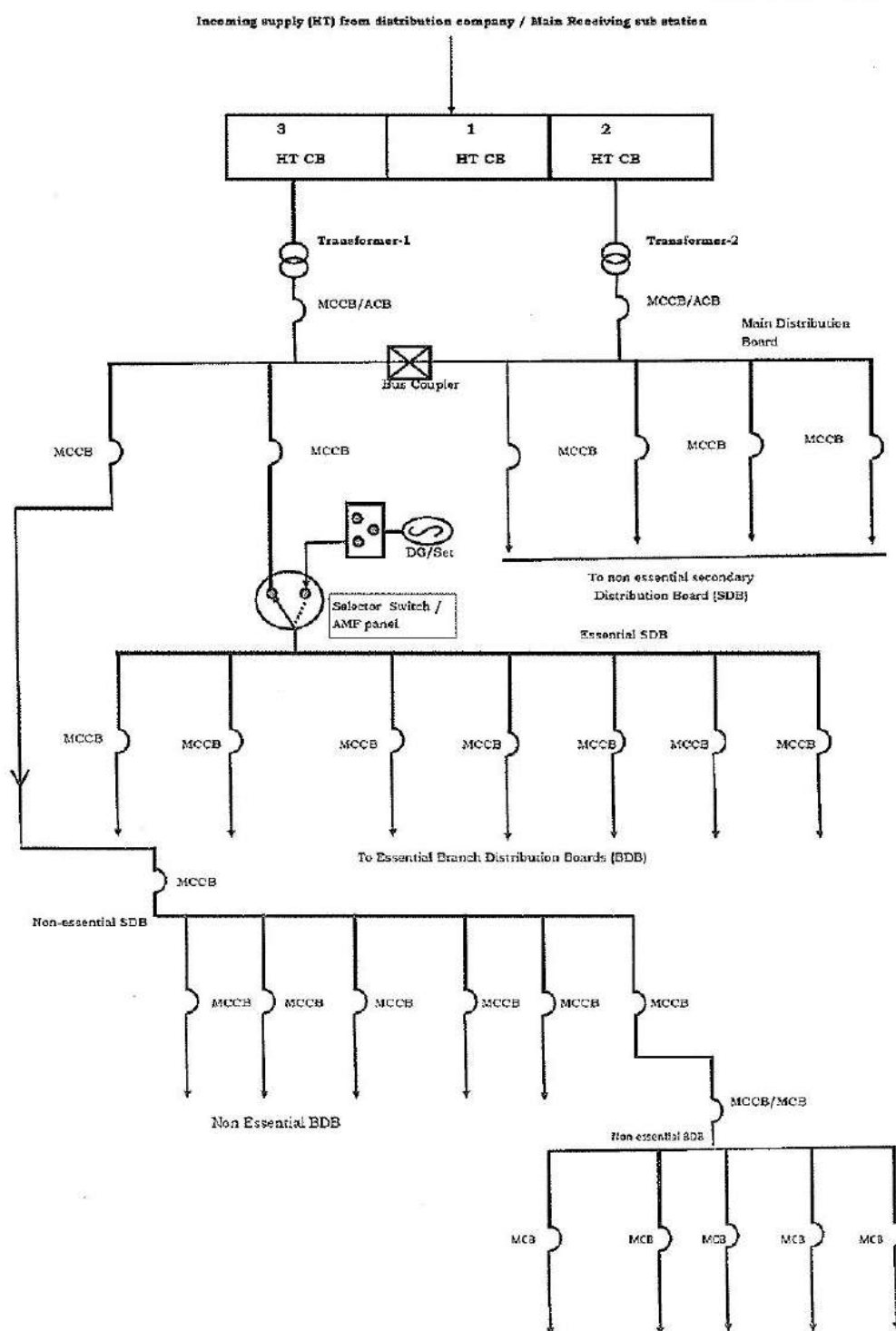
- d. For the system upto 250 voltage one distinguished earth and for the medium or high voltage system, two separate and distinguished earth to be provided. No short cut by means of mixing with other earth electrodes in the vicinity should be allowed.
- e. Each substation building should have lightning protection in accordance with the requirements specified in IS/IEC 62305. A separate earth electrode should be used for lightening protection.
- f. Connection to earth of those parts of installation which require to be earthed shall be made by means of an earth-continuity conductor which may be a separate earth conductor, the metal sheath of the cables or the earth continuity conductor contained in a cable, flexible cable or flexible cord. The sizes of earth-continuity conductors should not be less than half of the largest current carrying conductors'. The sizes of galvanized iron and steel earth-continuity conductors, should be sufficient to carry earth fault current without melting.
- g. The neutral conductor shall not be used as earth wire.

12.0 Maintenance:

- 12.1 For proper maintenance of electrical installations, the following items of work shall be carried out regularly as per periodicity stated below and a proper record of such work shall be maintained:
 - a. Earth testing: once in year
 - b. Insulation test: once in year
- 12.2 Gaskets of all distribution boards should be checked yearly.
- 12.3 Maintenance of switch gear/relays is to be done as per manufacturer's guidelines.
- 12.4 Relay setting are to be readjusted with respect to increase/decrease of connected load whenever there is major connection/disconnection of loads.
- 12.5 Yearly calibration of relay at sub-station should be done.
- 12.6 Temperature at cable connection terminal may be recorded by using infra red thermometer annually.



Annexure-A



Annexure-B

Chart showing the Distance upto which Different Sizes of UG Aluminium Conductor Cables can be used for Different Peak Load Current Ratings for 8 Volts Drop when Laid in Ground (PVC Insulated, PVC Sheathed, 3 core or 4 core) when Cable Grading is 1.1 KV

(Maximum Conductor Temperature - 70 deg C)														
S.No.	Current	Distance in mtrs for the following cable sizes in sqmm												
	Amp	6	10	16	25	35	50	70	95	120	150	185	240	300
1	5	165	260	415	725	895	1300	1925	2360	3065	3555	4300	5770	6460
2	10	80	130	205	360	450	650	980	1180	1530	1775	2150	2885	3230
3	15	55	85	140	240	300	430	640	785	1020	1185	1430	1920	2155
4	20	40	65	100	180	225	325	480	590	765	890	1075	1440	1615
5	25	30	50	80	145	180	260	385	470	610	710	860	1150	1290
6	30	25	40	70	120	150	215	320	390	500	590	715	960	1075
7	40	20	30	50	90	110	160	240	295	380	445	535	720	805
8	50	—	25	40	70	90	130	190	235	305	355	430	575	645
9	60	—	—	35	60	75	110	160	195	255	295	355	480	535
10	70	—	—	30	50	65	90	135	165	215	255	305	410	460
11	80	—	—	—	45	55	80	120	145	190	220	265	360	405
12	90	—	—	—	40	50	70	105	130	170	195	235	320	360
13	100	—	—	—	35	45	65	95	115	150	175	215	290	320
14	110	—	—	—	—	40	60	85	105	140	160	195	260	290
15	120	—	—	—	—	35	55	80	95	125	145	180	240	270
16	130	—	—	—	—	—	50	75	90	115	135	165	220	250
17	140	—	—	—	—	—	45	70	80	110	125	150	205	230
18	150	—	—	—	—	—	—	65	75	100	115	140	190	215
19	160	—	—	—	—	—	—	60	70	95	110	130	180	200
20	170	—	—	—	—	—	—	55	70	90	105	125	170	190
21	180	—	—	—	—	—	—	50	65	85	100	120	160	180
22	190	—	—	—	—	—	—	—	60	80	90	110	150	170
23	200	—	—	—	—	—	—	—	60	75	90	105	145	160
24	225	—	—	—	—	—	—	—	—	65	80	95	125	145
25	250	—	—	—	—	—	—	—	—	—	70	85	115	130
26	275	—	—	—	—	—	—	—	—	—	—	80	105	115
27	300	—	—	—	—	—	—	—	—	—	—	70	95	105

Note 1 : PVC Insulated electrical cable for voltage grade upto 1.1 KV is based on 8 volts drop.

- 1 This table is based on current and resistance as given in M/s Incab's table for cables (April 1964, Table No.17 and 33)
- 2 The distances are given in meters and after rounding.
- 3 The condition of installation of cable is ground temp.15 degree C.

Note 2 : For Temperature Correction please see as detailed below:

- 1 When the voltage drop and length is constant then to find the size of cable for following current ratings of the chart to obtain the calculated load current by the following factors and then see the size according to that ratings which was multiplied by the temperature factor.

Ground Temp:	20 Degree C	25 Degree C	30 Degree C	35 Degree C
Rating Factors:	0.95	0.9	0.85	0.8

Table:1



Annexure-B**Current Rating (in Ground) for XLPE Insulated 1.1 KV Grade Cables**

Nominal Area of the Conductor	Aluminium Conductor				Copper Conductor			
	Single Core		Multi Core		Single Core		Multi Core Unity	
mm ²	PVC	XLPE	PVC	XLPE	PVC	XLPE	PVC	XLPE
10	51	55	46	50	65	71	60	65
16	66	74	60	68	85	95	77	87
25	86	98	76	90	110	125	99	115
35	100	118	92	108	130	150	120	138
50	120	137	110	126	155	175	145	161
70	140	172	135	158	190	220	175	202
95	175	204	165	187	220	260	210	239
120	195	234	185	215	250	301	240	276
150	220	262	210	240	280	336	270	308
185	240	298	235	273	305	381	300	350
240	270	344	275	316	345	441	345	405
300	295	387	305	355	375	496	385	455
400	325	458	335	420	400	586	425	538
500	345	495	-	-	425	635	-	-
630	390	555	-	-	470	710	-	-
800	440	625	-	-	-	-	-	-
1000	490	685	-	-	-	-	-	-

RATING FACTORS FOR VARIATION IN AMBIENT AIR TEMPERATURE			
Air Temperature (°C)	40	45	50
Rating Factor (XLPE)	1.00	0.94	0.88
Rating Factor (PVC)	1.00	0.90	0.81

Table: 2



