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UNIT-2

2.1 INSTALLATION OF TRANSMISSION AND DISTRIBUTION LINE:

- A transmission line should have
    i. Sufficient current carrying capacity
    ii. Its supports and cross arm should have sufficient mechanical strength
    iii. It must be strong enough to give satisfactory service over long period.
- Transmission lines are normally of following types
    a) Steel poles
    b) Rail poles
    c) RCC poles

Following are some key features to be kept in mind while installing overhead line

1. Conductor should not energized the power lines or equipment.
2. Each bare conductor should be grounded properly.
3. Reel handling equipment should be in safe operating condition, must be leveled and aligned.
4. Load rating of pulling lines, conductor grips, load bearing hardware and accessories shold not be exceeded.
5. A reliable two way communication should be maintained between the reel tender and the pilling rig operator.
6. It should be ensured that no worker is under a tower.
7. Except during some emergency, work should be discontinued during bad weather conditions.
8. Line clearance shall maintain.
9. Ladders, platforms and aerial devices must not be brought closer to an energized part.

2.2 ERRECTION OF STEEL STRUCTURE

Steel has a high strength/weight ratio. Thus, the dead weight of steel structure is relatively small. This property makes steel a very attractive structural material for

a. High-rise buildings
b. Long span transmission lines
c. Structures located on soft ground
d. Structure located in highly seismic area

2.2.1 Methods of erection of steel towers

A. **Built up method:** a tower is built up member by member. Light derrick pole is used for raising member into position. People engaged in erection climbs up the erected tower and assemble the members, galvanized steel nut-bolts, washers, spring washers are used.
B. **Prone method:** tower is assembled completely on ground. Suitable packing's are usedon the ground. After assembly the complete tower is titled by means of derrick and is fixed on the stub. Helicopter may be used for lifting and shifting.
C. **Modern method:** Major sections are assembled on the ground to form major subassemblies. Some members are assembled individually and some sub assemblies are assembled to form the tower. Sometimes the complete face is assembled on the ground and is raised. The bracing angles are fitted to all the four sides to complete the erection.

The steel structures used for installation of transmission and distribution lines are of many types

- Lattice steel guyed/self supporting towers
- V-type suspension tower
- Self supporting tower
- Tension tower
- End frame
- Tubular tower
- Avalanche tower
- Wood poles
- Wood pole H-frame

The lattice and tubular types poles which are commonly used are shown in figure below

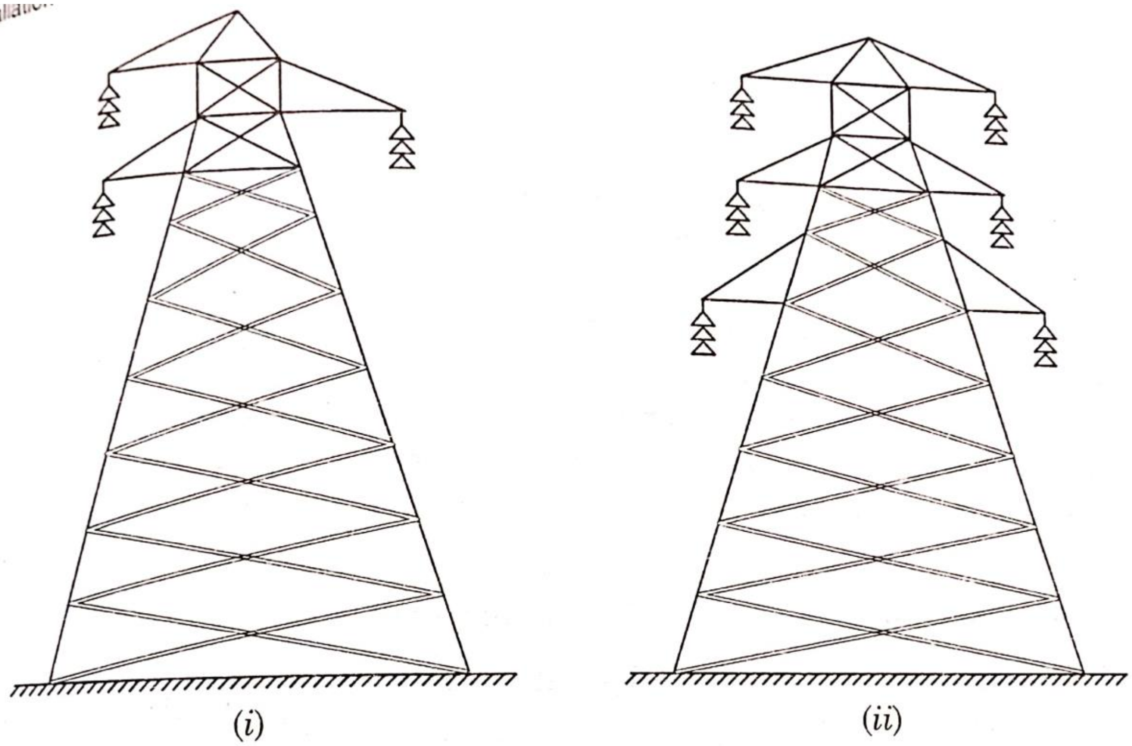

Fig. 2.1 : Lattice steel towers with suspension type insulators
(i) Single circuit (ii) Double circuit

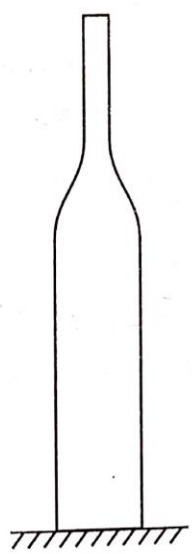

Fig. 2.2 : Tubular Poles

Some important points to be kept in mind are

1. The choice of appropriate design values for wind loads in the temporary erection condition.
2. Stability analysis during erection.
3. Design reviews and transmission of data.
4. Change to the agreed safe method of work.

Whenever there are significant forces likely to occur, and these are associated with a corresponding risk of instability, the designer should give careful consideration to

i. The design wind speed to adopt, bearing in mind
ii. The relevant need for adequate robustness and communicating
iii. Stability analysis during erection
iv. Careful thought needs to be given to the wind forces, forces arising from 'out of plumb' and project specific forces

Designers should have clear guidance in respect of

I. Design wind speed adopted
II. Any specific limitation/requirements.
III. A clear indication in case of columns
IV. The specific requirements and layout restrictions.

2.2.2 Erection of pole supports

- After excavation of pits is completed the supports to be erected may be brought to the pits location. Then the pole may be erected inside the pit. Wooden support may be utilized to facilitate lifting of the pole at the pit location.
- Having lifted the pole, the same should be kept in a vertical position with the help of ropes as a temporary anchor.
- After ensuring that the vertically and alignment are all right, concreting is to be done.

2.2.3. Erection of D.P. Structure for Angle Location

1. Generally, for angle of deviation more than 200 double pole structures of spacing 1.5 meters may be erected.
2. After the poles are erected, the horizontal/cross bracings should be fitted and the supports held in a vertical position with the help of temporary guys of manila rope of at least 25mm dia.

3. Before lifting the pole in the pit, concrete padding of not less than 75mm thickness may be put for the distribution of the distribution of the load of the support on the soil.
4. After the concerting is done, the pit may be fitted with earth after the curing of the concrete is completed.
5. Four stays along the line, two in each direction and two stays along the bisection of angle of deviation are to be provided.

2.3 CONNECTING OF JUMPERS, TEE OF POINTS, JOINTS AND DEAD ENDS

A jumper is an electrical connection between two points. Jumpers are used for making continuity of circuits across the poles/towers.

2.3.1 Types of jumpers

a) **Jumper connector:** The non tension jumper connector are of tubular type and suitable for jointing two ends of the jumper conductors.
b) **Jumper terminal:** The non tension jumper terminal are suitable for making jumper connection for making bolted connection between two ends of the jumper conductors, to facilitate disconnection whenever required.

Figure:

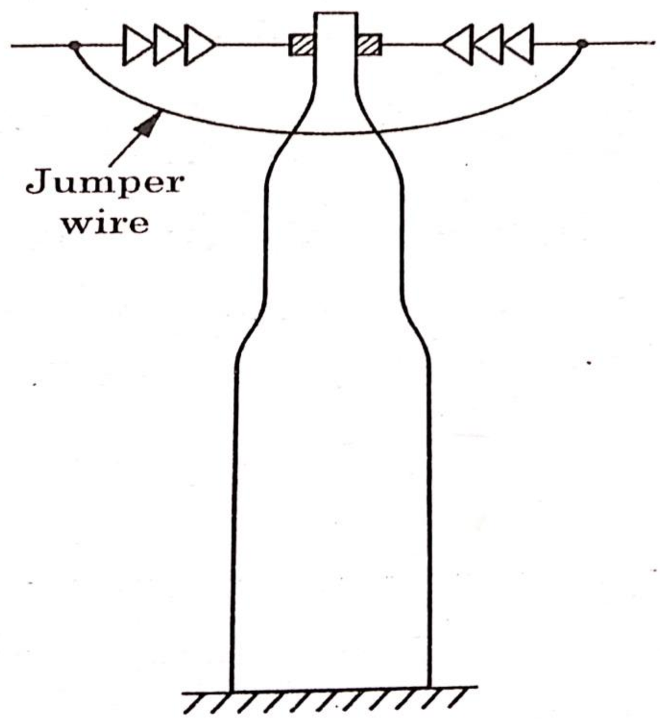

Fig. 2.3 : Connection showing jumper wire

2.3.2 TEE-OFF POINTS:

It is a branch transmission circuit which joins a main circuits and which is protected as part of the main circuit. A circuit showing Tee-off point is shown in figure below

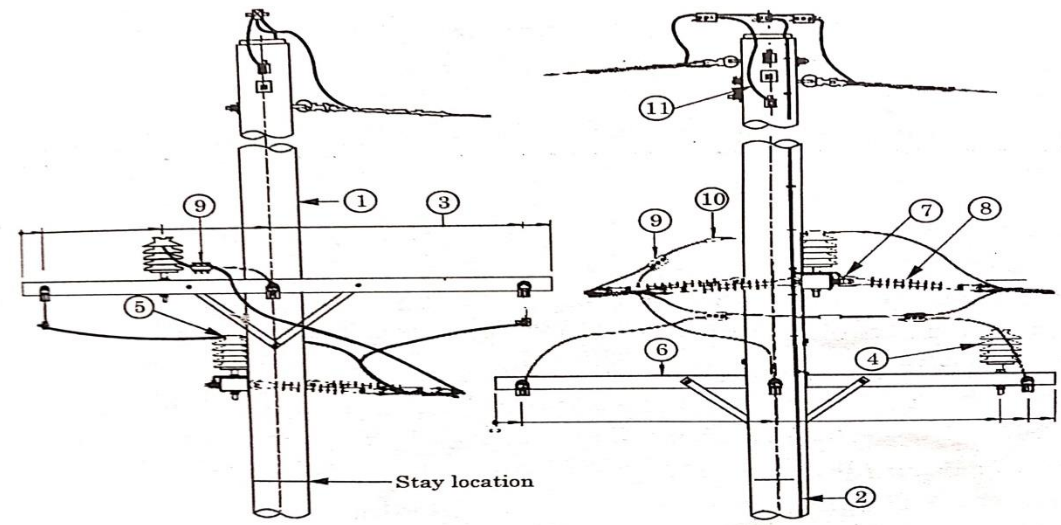

Fig. 2.4 : Standard Construction 33KV through termination Tee-off construction with overhead earthwire

1	Pole- Timber
2	Earthing- arrangement, timber
3	Crossarm- Mounting galvanized steel
4	Insulator- 33kv and pin arrangements
5	Tie- conductor high voltage support arrangement
6	Crossarm- mounting galvanized steel
7	Earthwire- overhead
8	Insulator- 33kv longrod string arrangement
9	Clamp- Parallel groove, 3 bolt
10	Joint- Non tension, compression
11	Earthwire- overhead, tee off arrangement

2.3.3 JOINTS :

1. **Aluminium joint:** Joint shall be made by cold pressure butt welding and shall withstand a stress of not less than the breaking strength of individual strand guaranteed.

2. **Steel Wires:** There should be no joint of any kind in the finished wire entering into the manufacture of the strand. There should be no strand joints in any length of the completed stranded steel core of the conductor.

3. **Mid span compression joint:** Mid span compression joint shall be used for joining two length of the conductor. The joint shall have a resistively less than 75% of the resistivity of equivalent length of the conductor. The joint shall not permit slipping off, damage to or failure of the complete conductor.

4. **Repair sleeve:** Repair sleeve of compression type shall be used to repair conductor with not more than two strands broken in the outer layer. The sleeve shall be manufactured from 99.5% pure aluminum and shall have a smooth surface.

5. **Parallel groove clamp:** When ate of line to be connected with an existing line the connection is made with the help of PG (parallel groove) clamp as shown in figure

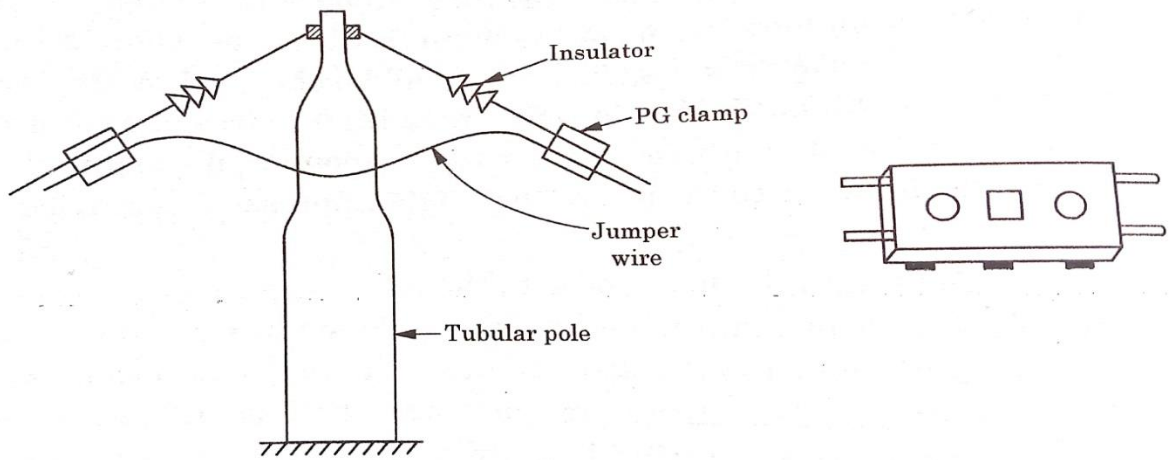

Fig. 2.5 : PG clamp (*i*) Connection (*ii*) Detailed view.

6. **Joint sleeve:** It is used to joint two conductors. The sleeve is made up of aluminium and wrapped around conductor to be joined in the figure

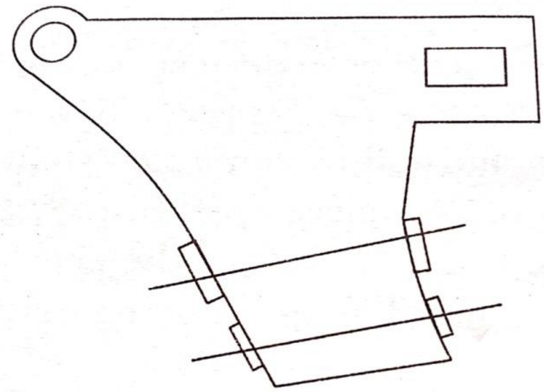

Fig. 2.7(*a*) Tension clamped for connecting dead ends

2.3.4 DEAD ENDS:

Two types of clamps used for dead end on is tension type and another one is compression type. The dead end conductor as heavy angles are attached to the insulators with the help of tension and compression as shown below

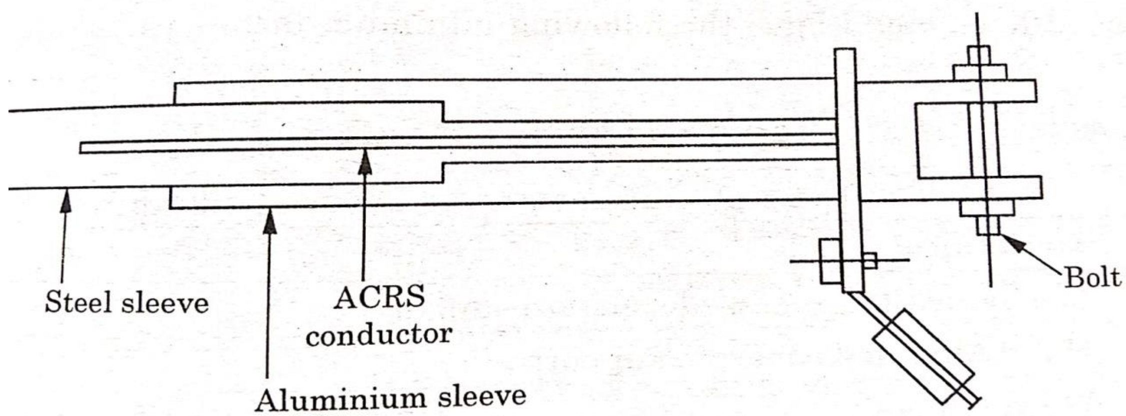

Fig. 2.7(*b*) Compression type dead end clamp

2.3.5. Clearance:

Clearance is provided for electrical apparatus so that sufficient space is available for easy operation and maintenance without any hazard to the operating and maintenance personal working near the equipment and for ensuring adequate ventilation.

Clearance for overload lines for HV and EHV installations

Voltage level(KV)	Ground clearance (in meters)
11	2.75
33	3.7
66	4.0
132	4.6
220	5.5
400	8.0

All conductors of overhead lines should have a breaking strength of not less than 350kg. where the voltage is low and the span is of less than 15m a conductor having an actual breaking strength of not less than 150kg is used.

Overhead line should have the following minimum factors of safety is

S.No.	TYPE OF SUPPORT	FACTOR OF SAFETY
1	Mechanical	1.5
2	Mechanically processed concrete support	2.0
3	Hand moulded concrete support	2.5
4	Wood support	3.0

The load should be

i. In case of latticed steel or other compound structure, factor of the safety should not be less than 1.5 under such broken wire conditions.
ii. The minimum factor of the safety for stay-wires, guard- wires or bearer wires shall be 2.5 based on the ultimate tensile strength of the wire.
iii. The minimum factor of the safety for conductor is 2, based on their ultimate tensile strength.

Percentage of the ultimate tensile strength of the conductor

Initial loaded tension	35%
Final loaded tension	25%

2.3.5.1 Crossing of Roads:

It is normally ensured that normal services are not interrupted nor damaged during stringing operations where roads, channels, telecommunication lines, power lines and railway lines have to be crossed. However, shut down can be obtained when working at crossings of overhead power lines. Arrangements are made for the proper handling of the conductor, earthwire and accessories in the field whe conditions like crossings take place.

I. At all important road crossings, poles are fitted with strain type insulators and the ground clearance at the roads under maximum temperature and in still air is kept such that even with conductor broken in adjacent span, **ground clearance of the conductor from the road surfaces will not be less than 5.8 meters.**

II. **HT road crossing guarding** The Gurading consists of guard cross arms of length 2.5 meters made out of 75x40x6 mm MS angles. The clamps are suitable for 9.5 meters long steel tubular poles. Guarding are erected with ground & line clearness as per the I.E. rules.

III. **Road crossing** At all important road crossings, the towers shall be fitted with single suspension or tension or double tension insulator strings depending on the type of towers and the importance of the road being crossed but the ground clearance at the roads under maximum temperature and in still air shall be such that even with conductor broken in adjacent span, the ground clearance of the conductor from the road surface will not be less than 8.0 meters.

2.3.5.2 Streets:

A. Clearance above ground of the lowest conductor

1. **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 values given in table 2.5

Table2.5 : Clearance above ground of the lowest conductor erected across a street

S.No.	Voltage Level	Distance
1	Low and Medium Voltage	5.8 meters
2	High Voltage	6.1meters

2. No conductor of an overhead line, including service lines, **erected along any street** shall at any part thereof be at a height less than values gives in table 2.6
    a) For low and medium voltage lines 5.5 meters.
    b) For high voltage lines 5.8 meters.
3. No conductor of in overhead line including service lines, **erected elsewhere than along or across any street** shall be at a height less than

    Table 2.6: Clearance above ground of the lowest conductor erected along a street

4. For extra-high voltage lines the clearness above ground shall not be less than 5.2 meters plus 0.3 meter for every 33,000 volts or part thereof by which the voltage of the line exceeds 33,000 volts. Provided the minimum clearness along or across any street shall not be less than 6.1 meters.

2.3.5.3 Power/Telecommunication lines:

a) Power Line Crossings

Where this line is to cross over another line of the same voltage or lower voltage, provisions to prevent the possibility of its coming into contact with other overhead lines shall be made in accordance with theIndian Electricity Rules, 1956 as amended from time to time. All the works related to the above proposal shall be deemed to be included in the scope of the Contractor except if modifications

S.No.	Type of Voltage Level	Height
1	For bare conductors of voltages upto 11KV	4.6 meters
2	For insulated conductors of voltages upto 11KV	4.0 meters
3	For voltages above 11KV	5.2 meters

and required to line below, in which case, the conditions to be agreed upon.

b) Telecommunication Line Crossing

The angle of crossing shall be as near to 90 degree as possible. However, deviation to the extent of 30 degree may be permitted under exceptionally difficult situations. When the angle of crossing has to be below 60 degree, the matter will be referred to the authority in charge of the telecommunication system. On the request from the Contractor, the Purchaser may obtain the permission of the telecommunication authority.

Following conditions apply where Telecommunication lines and power lines are carried the wires.

i. Every overheads Telecommunication line erected on supports carrying a power line shall consist of conductors such having a breaking strength of not less than 272.16 Kg.
ii. Every Telephone used on a Telecommunication line erected on supports carrying a power line should be suitably guarded against lightning and protected by cut outs.
iii. Where a Telecommunication line is erected on supports carrying a high or extra high voltage power line arrangement shall be made to safeguard any person using the telephone against injury from contact, leakage or indication between such power and telecommunication on lines.

c) Power Line Crossings

Where this line is to cross over another line of the same voltage or lower voltage, lattice type tower with suitable extensions shall be used. Provision to prevent the possibility of its coming into contact with other overhead lines shall be made in accordance with the Indian Electricity Rules,1956. In order to reduce the height of the crossing towers, it may be advantageous to remove the ground wire of the line to be crossed .

d) Telecommunication Line Crossing

The angle of crossing shall be as near to 90 Deg. As possible. However, deviation to the extent of 300 may be permitted under exceptionally different situation. When the angle of crossing has to be below 600, the matter will be referred to the authority in charge of the telecommunication system. On a request from the contractor permission of the telecommunication authority will be obtained by the owner.

<u>2.3..5.4 Railway Crossing:</u>

The details regarding overhead transmission lines crossing railway line is as follows:

i. The crossing should normally be at right angle to the railway track.
ii. No crossing should be located over a booster transformer, traction switching station, traction sub-station or a track cabin location in an electrified area.

iii. **Lines crossing or approaching each other**

1. Where an overhead line crosses or is in proximity to any telecommunication line, either the overhead line or the telecommunication line, whoever lays the line later, should arrange to provide for protective devices or guarding arrangements.
2. 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 should give one months notice of his intention so to do along with the relevant details of protection and drawing to the owner of the existing line.
3. Where an overhead line crosses or is in proximity to another overhead line. Guarding arrangements shall be provided so as to guard against the possibility of their coming into contact with each other.
4. Where an overhead line crosses another overhead line, clearances shall be as give in table 2.10.

Table .10: Minimum clearance in meters between lines crossing each other

S.No.	Voltage Level	Clearance (in meters)
1	11-66KV	2.44
2	110-132KV	3.05
3	220KV	4.58
4	400KV	5.49
5	800KV	7.49

Provided that no guarding are required when an extra high voltage line. Crosses over another extra-high voltage, medium or low voltage line or a road or a tram subject to the condition that adequate clearances are provided between the lowest conductor of the extra-high voltage line and the top most conductor of the clearances as stipulated in rule 77 from the topmost surface of the road is maintained.

5. A person erecting or proposing to erect a line. This may cross or be in proximity with an existing line, may normally provide guarding arrangements on his own line or require the owner of the other overhead line to provide guarding arrangements.
6. In all cases referred to in the preceding sub-rules the expenses of providing the guarding arrangements or protection devices shall be borne by the person whose line was last erected.

7. Where two lines cross, the crossing shall be made as nearly at right angle 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.
8. 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.
9. All work required to be done by or under this rules shall be carried out to the satisfaction of the Inspector.

<u>2.3.6 Earthing of Transmission Lines and Guarding:</u>

Guard structures are installed to prevent the conductor or overhead ground wires. Which are being pulled from coming into contact with existing overhead electric supply lines, communication line.

Guarding a transmission line involves covering, fencing enclosing, or otherwise protecting by means suitable covers or casings, barrier rails, screens, mate, platforms, designed to minimize the possibility under normal condition of dangerous approach or accidental contact by persons or objects.

Rules88. Guarding

i. Every guard-wire shall be connected with earth at each point at which its electrical continuity is broken,
ii. Every guard-wire shall have an actual breaking strength of not less than 635kg and if made of iron or steel, shall be galvanised.
iii. Lines crossing trolley-wires-In the case of a crossing over a trolley-wire the guarding shall fulfil the following conditions, namely'
   a) Where there is only one trolley-wire, two guard-wire shall be erected
   b) Where there are two trolley-wire and the distance between them does not exceed 40 cms, two guard-wires shall be erected
   c) Where there are two trolley wires and the distance between them exceeds 40 cms but does not exceed 1.2 meters, three guard-wires shall be erected
   d) Where there are two trolley-wires and the distance between them exceeds 1.2 meters, each trolley-wire shall be separated guarded.
   e) The rise of the trolley boom shall be so limited that the trolley leaves the trolley-wire, it shall not foul the guard-wires; and
   f) 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.

Galvanised Steel barbed wire used for fencing purpose is manufactured as per I.S. 278-1962

a) Materials

i. The wire is manufactured from steel made by the open hearth and electrical process should not contain sulphur and phosphorous exceeding 0.065% each.

ii. The general conditions relating to testing, inspection and supply of materials will be in accordance with I.S. 1387-1959.

The galvanised steel barbed wire is of the following types.

Table 2.12 Dimensions of galvanised steel barbed wire

S.No.	Diameter of wire (mm)		Distance between two barbs
	Line wire	Power wire	
1	2.5	2.24	75
2	2.5	2.24	150
3	2.24	2.24	75
4	2.24	2.24	150

The barb wire generally has following properties

1. The barbed wire shall be formed by twisting together two live wires, one containing the barbs. The sizes of the line and point wires and barb spacings are given in table above.
2. Tolerances –The permissible deviation from the nominal diameter of the line wire and the point wire shall not exceed +0.08 mm.
3. The barbs shall carry four points and shall be formed by twisting two point wires, each two turns, tightly round one live wire making altogether four complete turns. The barbs shall be so finished that the four points are set and locked at right angles to each other. The barbs shall have a length of not less than 13 mm and not more than 18 mm. the points shall be sharp and cut at an angle not greater than 35 degree to the axis of the wire forming the barbs

b) Details of barbed wire

Coating Test: The uniformity of zinc coating shall be testing by the method of specified in I.S. 429-1954 methods for testing weight and uniformity of coating on galvanised iron and steel wires and steel sheets. The line and point wires number of dips specified below in table 2.13.

Table 2.13 Number of dips

Type of wire	Size of wire	1-Minute Dip	½Minute
Line wire	2.5mm	3	1
Point wire	2.24	1	-

2.3.7 Spacing and Configuration of Conductors:

An example of spacing of conductors is shown in fig. 2.7 and explained in table 2.14 below.

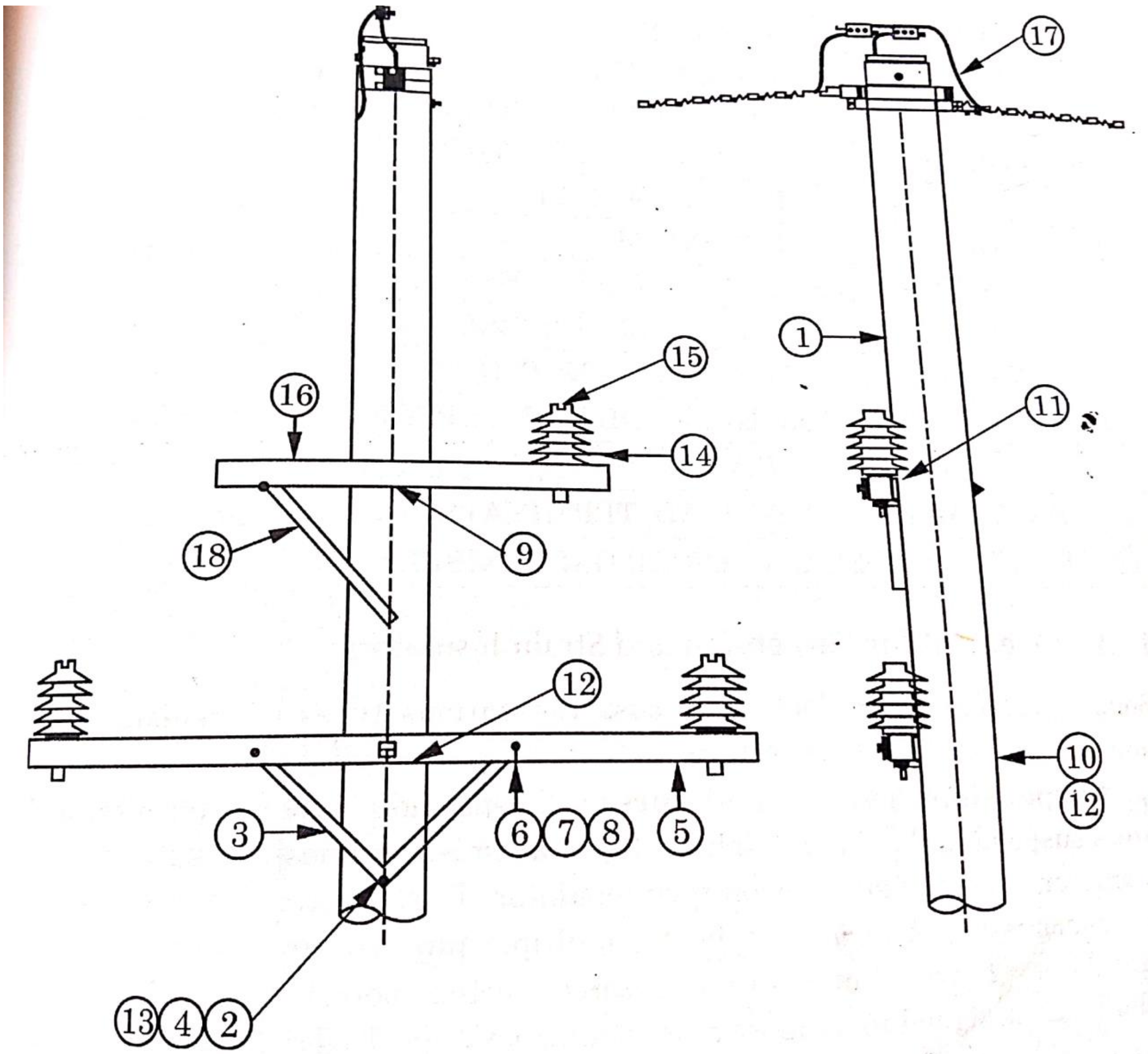

Fig 2.7 : Spacing of conductors

Table 2.14

1	Pole-concrete
2	Screw-set stainless
3	Brace-crossarm, flat, galvanized
4	Washer-flat-stainless steel
5	Crossarm
6	Bolt & nut-galvanised

7	Washer-flat galvanized
8	Washer-conical, stainless steel
9	Bolt & nut- galvanised(length to suit pole)
10	Washer-square galvanized
11	Block-gain aluminium
12	Washer-conical, stainless steel
13	Washer-spring, stainless steel
14	Insulator-33KV pin arrangement
15	The conductor, high voltage support arrangement
16	Crossarm hardwood
17	Earthwire-overhead, termination
18	Brace-crossarm angle galvanized

Arrangement for Suspension and Strain Insulators

Before proceeding first let us discuss the various tyes of insulator used in transmission and distribution system.

1. **Suspension Type Insulators:** Suspension type transmission line insulators suspend and support high voltage transmission lines. Fig.2.8 (i) to fig.(iv) shows different views of suspension type insulator. They are cost effective for higher voltage transmission, typically replacing multiple pin type insulators. Suspension type insulators have a number of interconnected porcelain discs, with each individual unit designed to support a particular voltage.

2. **Strain Type:** Insulators train type insulators are horizontally suspended suspension insulators. Fig.2.9 shows strain type insulators. They are used to handle mechanical stresses and take the pressure off a conductor at the end of the transmission line, at a sharp corner or curve or over long river crossings. Strain insulators are typically used for higher voltage transmissions.

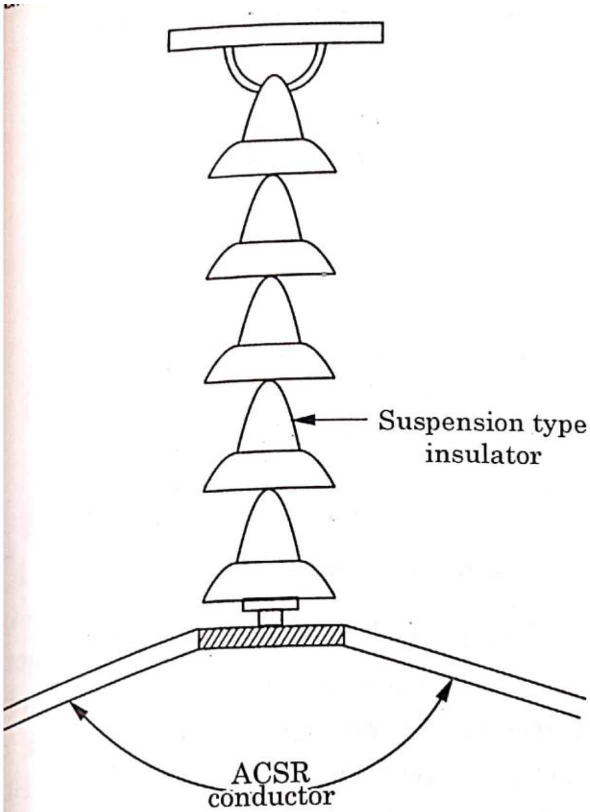

Fig. 2.8(*i*) Suspension type insulator (Vertically suspended)

Fig 2.8(*ii*) Suspension type insulator

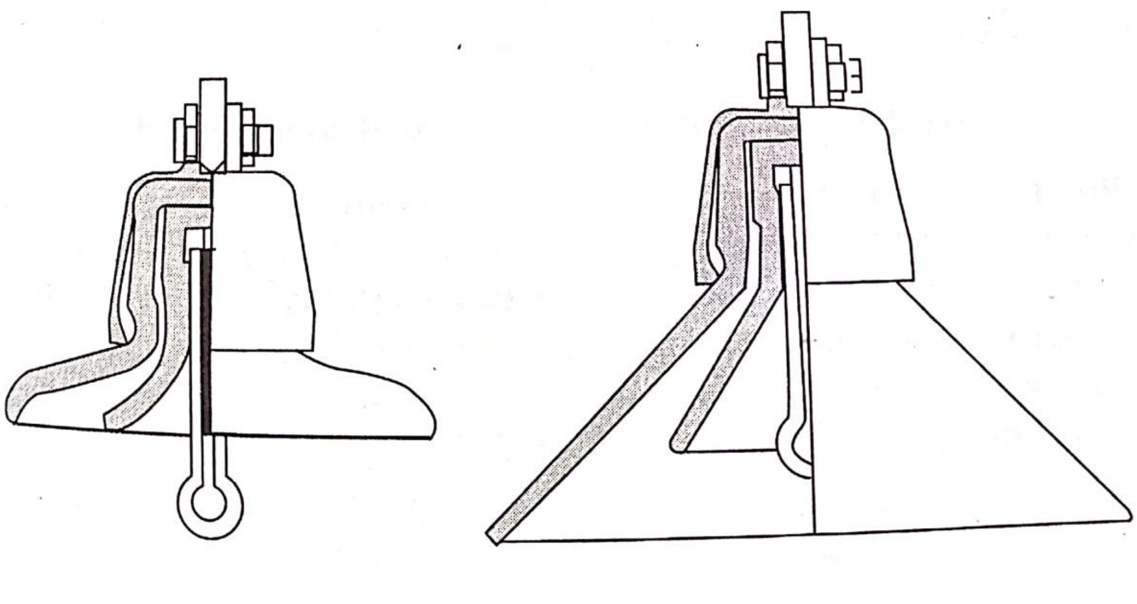

Fig 2.8 (*iii*) Cross-sectional view of suspension type insulator

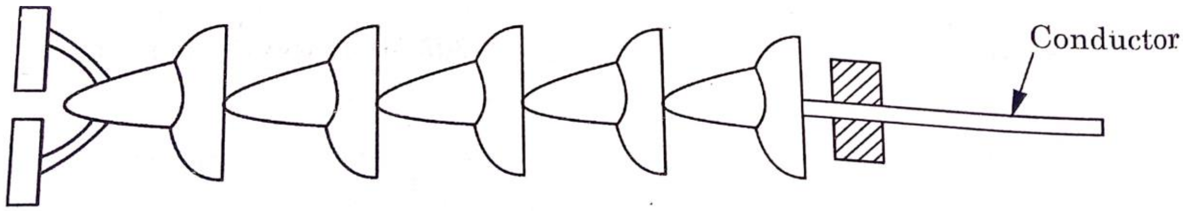

Fig. 2.9 : Strain type insulator (Horizontally suspended)

3. **Pin Type Insulators:** Pin type insulators are used for the transmission of lower voltage. Fig.2.10 shows a pin type insulator. A single pin type insulators is used to transmit voltage up to 11KV (kilovolts) and higher voltages require two three or four-piece pin insulators. They are not economically feasible for 33 KV and higher transmission lines. Pin type insulators are secured with steel or leads bolts onto transmission poles. These are typically used for straight running transmission lines.

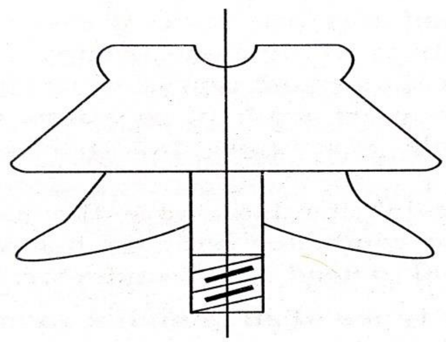

Fig. 2.10 : Pin type insulator

4. **Shackle Type Insulators:** Shackle type insulators, similar to strain type insulators, are used on sharp curves, end poles and in section poles. However, unlike strain insulators, shackle insulators are designed to support lower voltages. These insulators are single, round porcelain parts that are mounted horizontally or vertically. Fig.2.11 shows shackle type insulator.

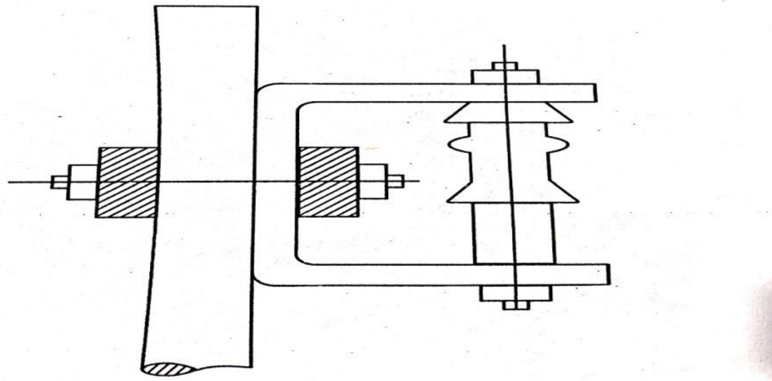

Fig. 2.11 : Shackle type insulator

5. **Stay Insulators:** Stay insulators, also called egg insulators, are primary used to prevent stay wires from becoming energized from accidentally broken wires. They, therefore, function to provide insulation between stay clamps transmission poles. Stay insulators are mounted at a height of at least 3 meters ground level. “Suspension” and “Strain” insulators are the same thing. When used in the vertical position they are called suspension and when used in the horizontal to dead –end a conductor, they are called strain.

   There are two basic types of suspension insulators:

   a) Unipart were first developed in the 1910s and are the common style still in production today. Each unit has a single glass shell bonded to a steel cap and steel. The modular units connect with each other cap-to-pin, forming a chain or string.

   b) Multipart are no longer produced, and original units are rare today. These are only two known styles: Cochrane and Byllesbly, both dating from thr late 1910s.

2.3.9 Bird guards:

The bird guard is a device to protect electrical insulators. It comprises on:

- A central shaft
- A clamp attached to an end of the shaft to secure the device to a transmission tower.
- A top and bottom cover to shield transmission towers insulators and
- Bearings to allow the guard to rotate in order to frighten birds away from the insulators.

There devices have been used successfully as part of the National bird project. These are

a) Bee Tee bird guard
b) Mission Bird guard
c) Naledi Bird guard

To reduce the risk of birds nesting over power lines and their urine or dropping shorting out line insulators, bird nesting platforms are sometimes constructed in pylons safely below the level of the line insulators. Fig.2.13, 2.14 and 2.15 shows in different types of bird guards

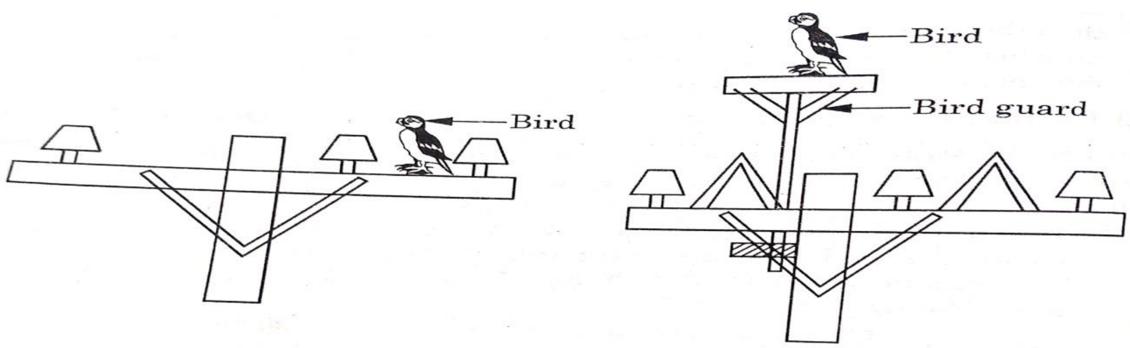

Fig. 2.13 : An example of bird guard

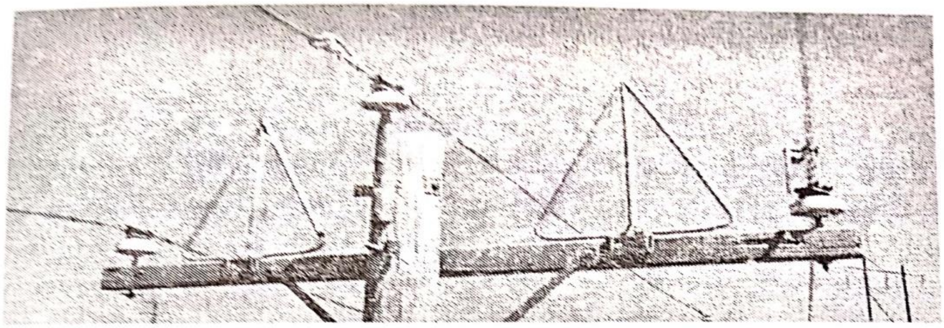

Fig 2.14 : Bird guard

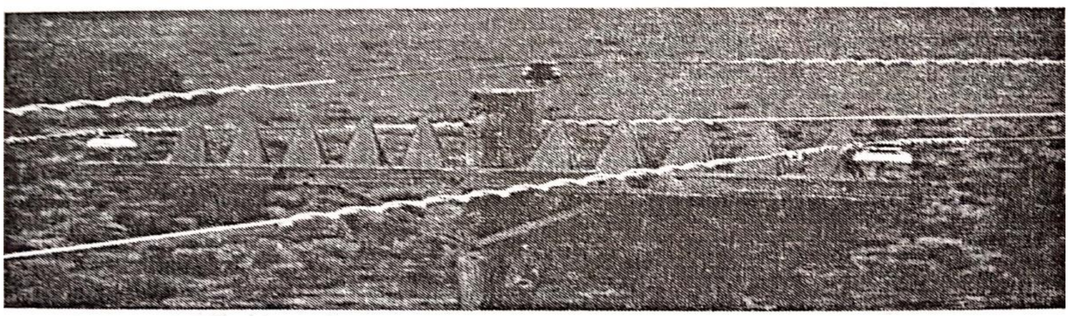

Fig 2.15 : Bird guard

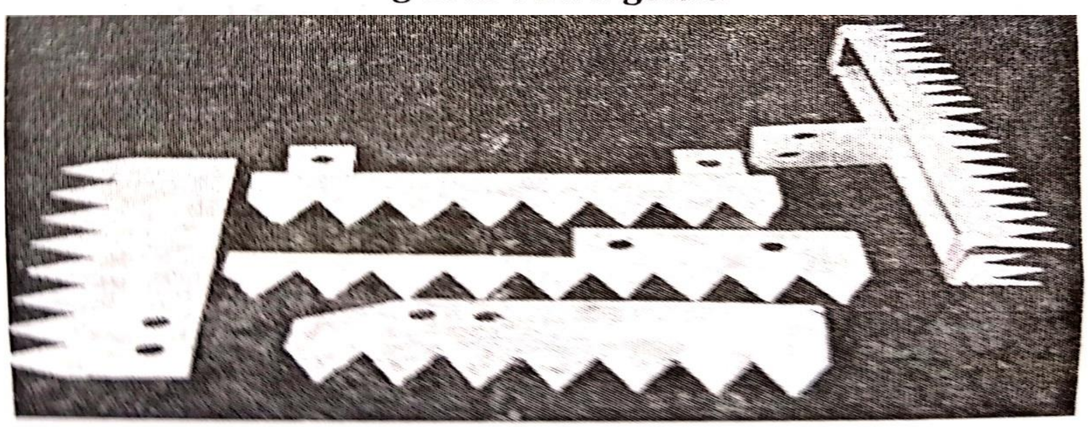

Fig 2.16 : Different types of bird guards

Bird guards are the most effective equipment to ward of birds sitting on lines. The birds sitting on lines can cause short circuit or any kind of mishap. The bird guards are designed to shield electric towers and substations from such kind of mishap. Made from MS sheets of optimum thickness, they can disrupt the vital supply of electricity. With extremely fine edges, these hangers can effectively help in fluent transmission of power through electric lines.

2.3.10 Anti-Climbing Devices and Danger Plates:

Anti-climbing devices are provided to prevent persons to gain entry at the places which are usually maintained at higher potentials. It is normally provided with G.I. Barbed wire and installed around the poles. The barbed wire conforms to Indian Standard IS-28. The barbed wires are given chromating dip as per procedure laid down in IS1340. All towers are filled with anti climbing devices at a height depending upon the voltage level. Normally the height is between 2.5 to 3.5 meters from ground level. Two diagonally opposite legs on each tower are provided with steps not more than 35 cm centres starting immediately above the anti climbing device and continuing to the top line conductor.

A danger notice plate confirming to Indian Standard IS 2551 – 1990 is also installed along with the anti-climbing devices. Notice plates are made as per IS: 2551-1963.

Two sizes of danger notice plates are recommended:-

(a) For medium voltage installation 200 x 150 mm
(b) For high voltage & extra high 250 x 200 mm

The plate should be made from mild steel at least 1.6mm thick and enameled white with letters, figures and the conventional skull and bones in signal red colour. The rear side of the plate should also be enameled.

1. All lettering should be centrally.
2. All dimension for the words in district language are mainly for guidance. However, care should be taken to space them centrally between the edges and the area of the skull and bones.
3. The location of the fixing holes shall be left to the user.
4. The corners of the plates should be rounded off.
5. Danger plate for high and extra voltage as per I.S.

Danger, Number & Phase Plates

i. The provision for fixing Danger, Number and Phase Plate is made on transverse face of the tower during development of the structural drawing. The arrangement for fixing these accessories should not be more than 4.5m. above the ground level and shall be provided above anti-climbing device.
ii. The letters, figures and the conventional skull and bones mark of danger plate shall conform to IS: 2551-1963 and shall be in a signal red colour on the front of the plate.

2.3.11 Sizes of Conductors:

ACSR has long been the backbone of overhead transmission and distribution systems. It has altogether replaced older types of overhead conductors made of copper, which are now a days used only to meet specific demands.

ACSR offers optimal strength for live design. It consists of Aluminum Conductor stranded around a core made of steel wires of high tensile strength. Variable steel core stranding enables desired strength to be achieved. These conductors are "bare", meaning that there is no insulation or jacket covering the conductor.

a) **Overhead Conductors**

b) **Conductor size**

   i. Gauge sizes decrease as the wire increases in size.

   ii. Number of stands=$3n^2-3n+1$
   Where n=number of layers including the single central strand.

   iii. The following conductors are used.

      a) AAC-all aluminum conductor
      b) AAAC-all aluminum alloy conductor
      c) ACSR-aluminum conductor steel reinforced
      d) ACAR-aluminum conductor alloy reinforced

2.3.12 Laying of Service Lines:

A service line connects the supply from poles to that of consumer premises. Bulk consumers are supplied electrical power at higher voltages at 11 KV or 33KV through HV feeders and 3 phase circuits. Domestic consumers are supplied electric power through 3 phase 4 wire system at low voltage. A circuit in Fig. 2.20 shows an example of service line.

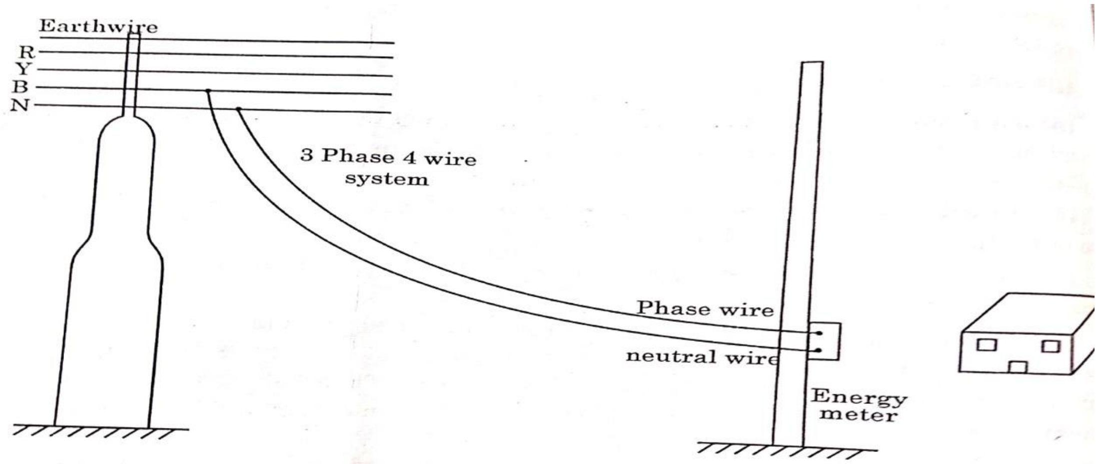

Fig. 2.20 : An example of service line for a domestic consumer

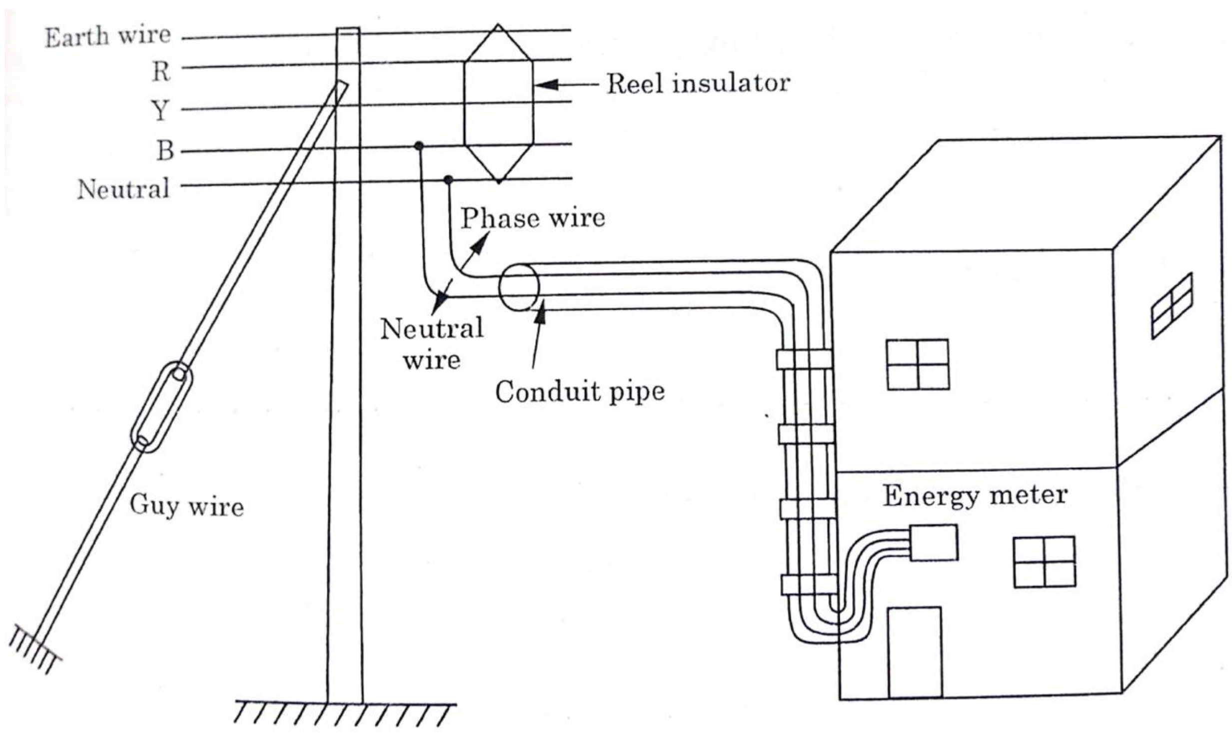

Fig. 2.21 : Service line connection for two storeyed house

2.3.13 Earthing:

In electrical installation the phase conductor should not come into contact with the metallic parts. If this happens then anybody coming in contact with it will experience severe shock and it may ever prove fatal. For safety purpose it is essential that in case of faults the circuit breakers operate instantaneously and cuts off the electrical supply. Also, for safety it is essential to provide a least resistance path to earth. Earthing of all such parts ensures safe operation of the transmission lines installations.

All equipments including frame of metals, metal conduits, transformer tank, generator and motor frames, switch boxes etc should be connected to ground or properly earthed. Table 2.16 gives the value of earth resistance for different types of substations.

Table 2.16

S.No.	Types of Substation	Resistance
1	Small substation	2 ohm
2	Large substation	0.5 ohm
3	Lattice steel towers	3.0 ohm
4	Major substation	1.0 ohm
5	Factory substation	1.0 ohm

2.3.13 Provision of Service Fuses:

Service fuses are provided on all poles/towers in order to protect these from the faults which may occur in the line provided to the customer premises.

2.3.14 Installation of Energy Meters:

The proper installation of an energy meter is an essential element for the accurate indication of the measured values of electric power or electric energy. Normally, differences can occur between single-phase and three-phase systems. There are two possible connections, one for single-phase systems and another for three phase systems

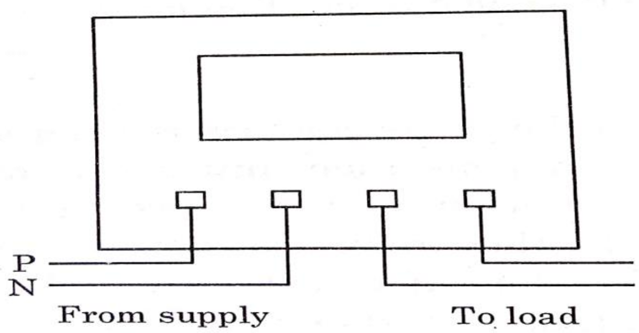

Fig 2.22 : Connections of single phase energy meters

In case the installed power or demand power are higher then current transformers are inserted in the measuring circuit for each phase. For application at higher voltages then the circuit includes voltage or potential transformers also.

In each situation, two corrections must be realized

1. Scale correction for the voltage and measured power ,and
2. Phase correction

In case of air transformer it does not shift the input signal phase. After installing the energy meter it is compulsory to seal all the elements that could influence the measuring values, in order to prevent possible changes of wiring by unauthorized persons.

Following points should be kept in mind while installing an energy meter

I. Meter should be ordinarily fixed outside the premises in such a manner that it is protected from the elements and can be read from outside without the need of meter reader to get the premises unlocked or opened for this purpose. The consumer should run the wiring from such that meter reading counter/display window is at eye level.
II. Energy meters should be installed in a tamper-proof meter box.
III. In case of semi-permanent house the meter is properly fixed on wall and is accessible to the meter reader. In case there is no good quality wall for fixing the meter, then it is to be fixed on the pole or in a pillar box. The earthing of the installation should be done.
IV. In case meter is installed inside the premises the meter and other equipments are placed very near to the point of entry of suppliers line, so that the metering unit is visible from outside the premises and independent/ unobstructed entry to the meter or metering

cubical can be provided. Whenever required the consumer should provide and maintain at his expense a locked and weatherproof enclosure.

V. Whenever new meter/metering equipment is installed the meter should be properly sealed on behalf of and in the presence of representatives of both the parties. The seal, name plates and distinguishing numbers or marks affixed on the meter and metering equipment should not be broken, erased altered or in any way.

VI. The consumer is responsible for safe custody of Meter(s), cut-outs/MCB/CB etc.

2.4 LAYING OF UNDERGROUND CABLES:

2.4.1 Inspection, Storage, Transportation and Handling of Cables:

Cable drums must be handled with care. Improper handling procedures or handling equipment can easily cause damage like broken drums or visible or invisible damage of the cable itself. Main danger comes from invisible damages leading to unusable cables. Therefore some base guidelines should be followed. The cable itself must always be protected and must not be touched improperly during transport and storage. A drum, damaged by handling or showing signs of wear or

rotting must be checked. Special handling procedures are necessary· If a wooden drum is handled and/or stored properly it ensures the safety of the cable. The temperature range and possible special requirements for transport and storage should be followed during transportation of cables.

1. Drum must be protected against rolling away.
2. On pallets drums must be fixed in upright position
3. Drums may never be laid on flanges or piled up
4. Lifting cables with a fork lify is only allowed from the “flange side”.

Following are the some guidelines to be follow

1. The fork of a fork lift may only support drum flanges, never the cable or its protection itself.
2. Use suitable loading equipment, never drop down.

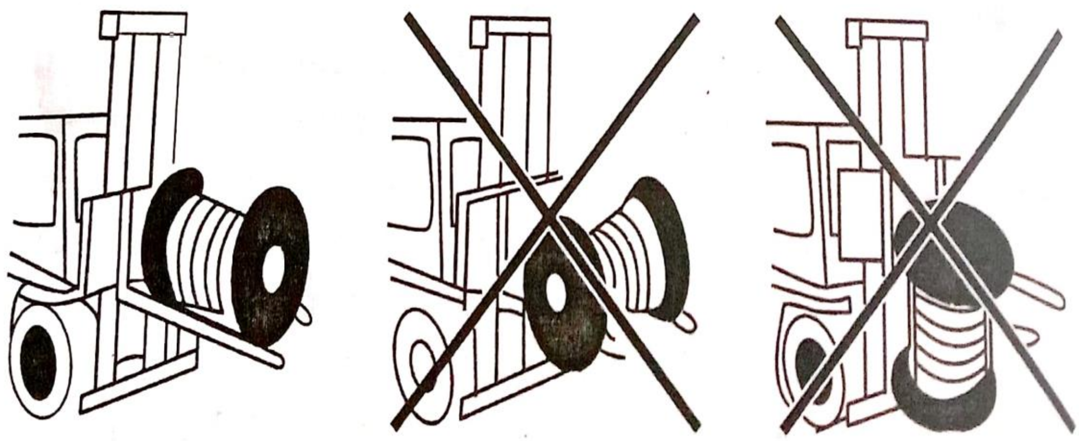

Fig. 2.23 (*i*) : Handling of cable by fork lift

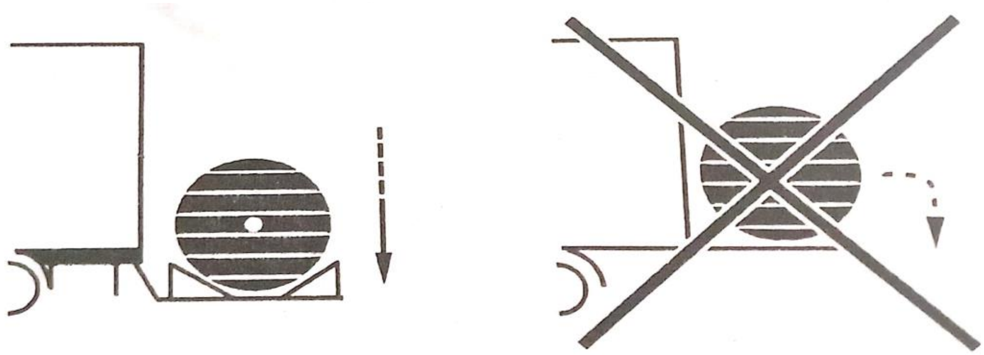

Fig. 2.23 (*ii*) : Handling of cable drum in truck

Cables should only be transported with suitable vehicles and must be fixed so that they cannot shift during transportation. The same applies in case cable are transported in a container.

- During transport and storage drums shall always be m upright positon.
- Drums must be protected against rolling away
- Use only crane with axle spreader.
- All screws holding the flanges must be checked.
- In case of dry and hot weather screws have to be tightened with a torque wrench.
- Drums with cables may only be rolled over short distances.
- Each drum is identified with an unique drum number.

Fig 2.23 (*iii*) : Protection of drums against rolling away

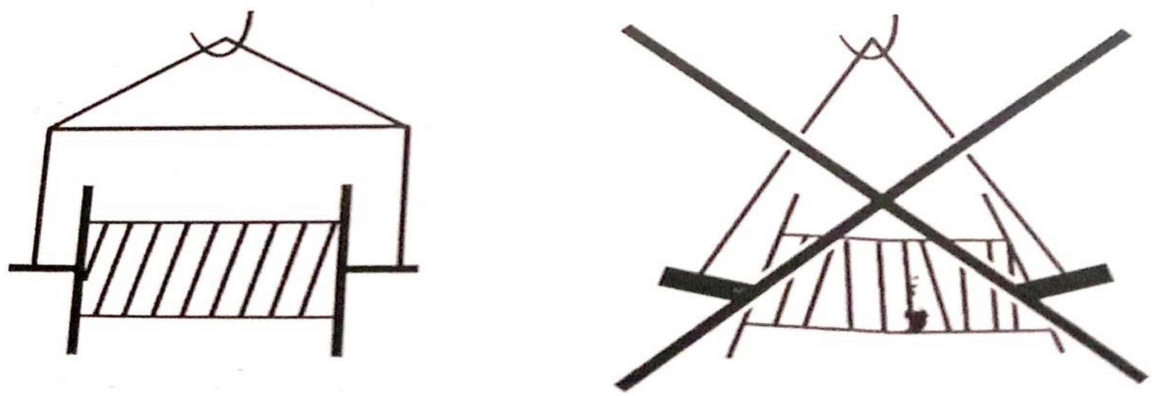

Fig. 2.24 : Handling of drum by crane

STORAGE:

- A damage drum should be checked.
- Cable for indoor use shall be stored indoor and outdoor use may be stored outside.
- All cables on drum shall be protected with suitable protection packages, such a black plastic sheeting, lagging etc.
- Cables exposed to direct sunlight will become warmer than the ambient temperature.
- Cable end must be fixed on the drum to avoid getting loose during transport, handling or storage.
- Cable end shall be sealed, stored in area without influence of light of high heat or we can say stored in secure and suitable area.
- Drums must be protected against rolling away while stored.

- It never be transported or stored lying on a flange.

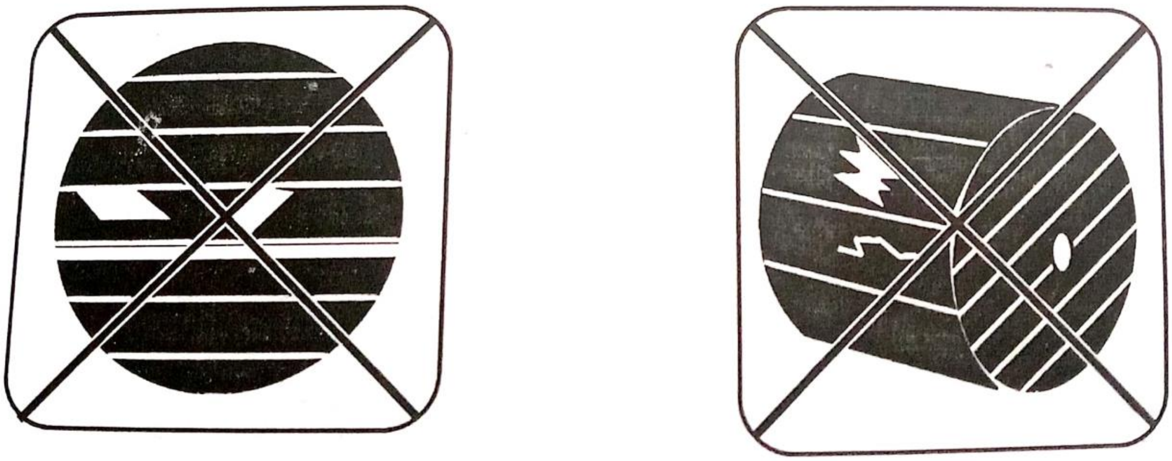

Fig. 2.27 : Handling of Drum

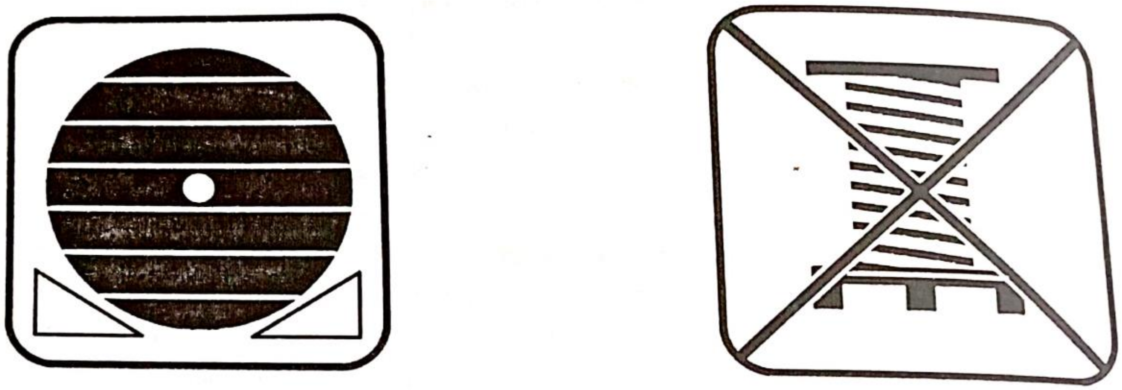

Fig. 2.28 : Protection of Drum

On pallets drums must be fixed in upright position

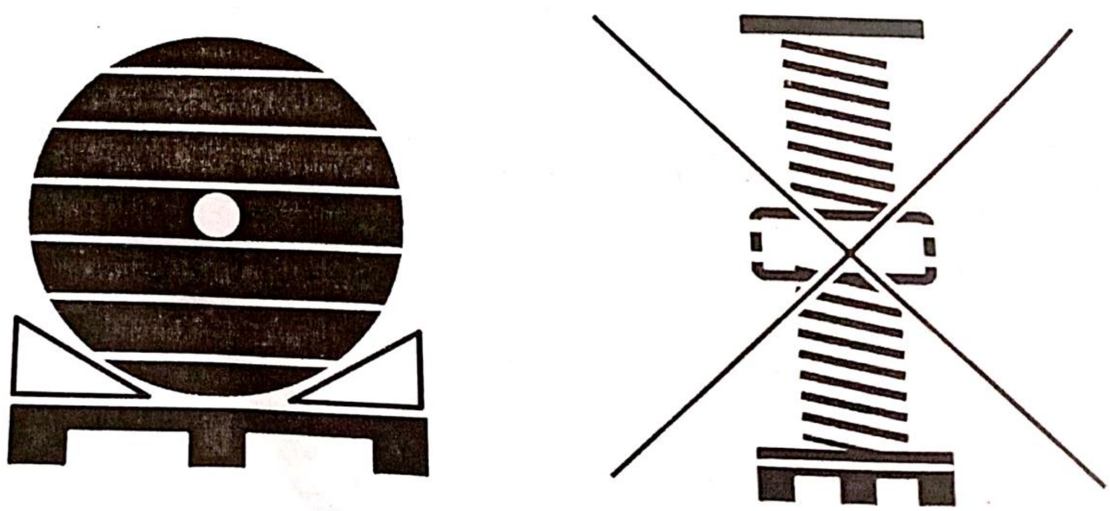

Fig. 2.29 : Positioning of Drums

2.4.2 CABLE HANDLING EQUIPMENT:

It is used in many places in industry, including oil and gas, utilities, mining, government and military applications.

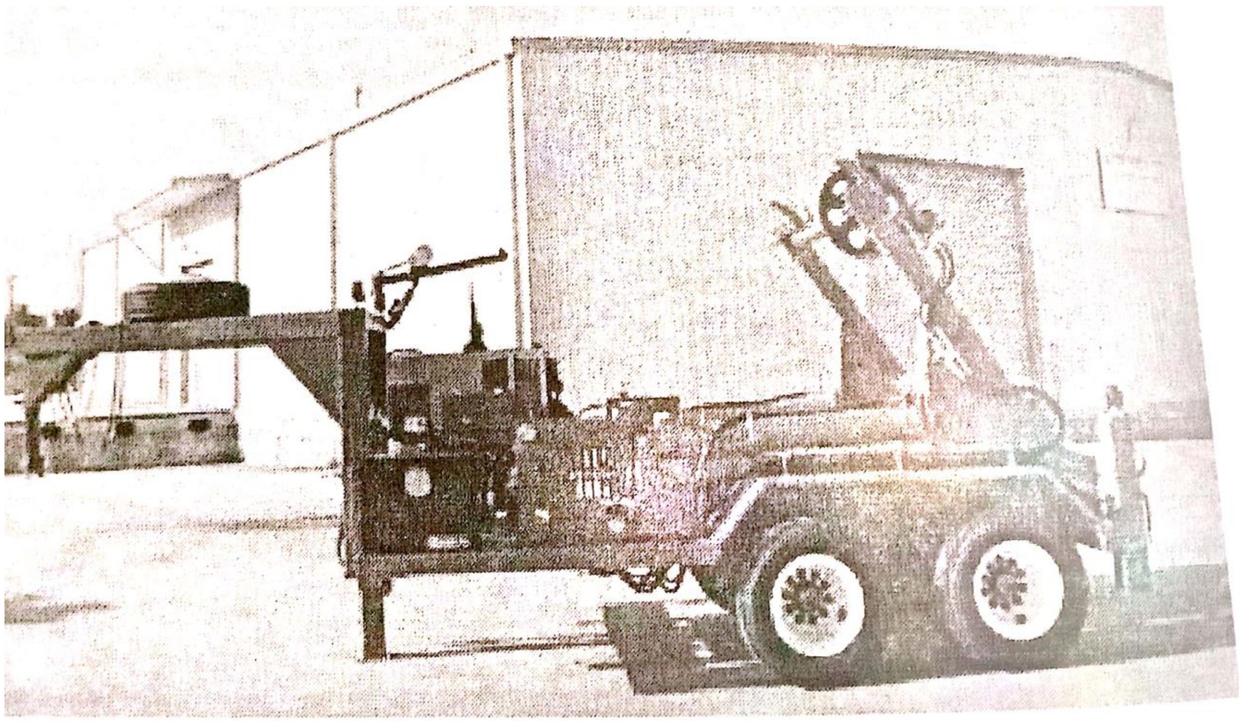

Fig. 2.31 : Hydraulic cable jack set

1) **Hydraulic cable jack set:** It is lightweight hydraulic drum jacks, versatile and easily adjustable within second to accommodate a vast range of drum. Excellent all around stability. Fitted with wheel to allow easy movement by one person. Supplied complete with spindle and collars.
2) **Jack towers:** Designed for drums lifts up to 20 tonnes. Heavy duty high grade steel construction with spindle block, plate and 10 tonne hydraulic jacks.

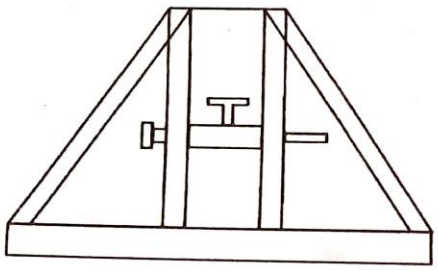

Fig. 2.32 : Jack Tower

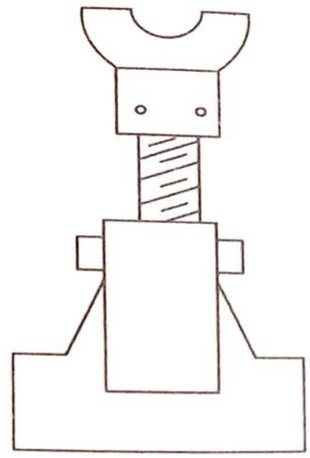

Fig. 2.33 : Screw Jack

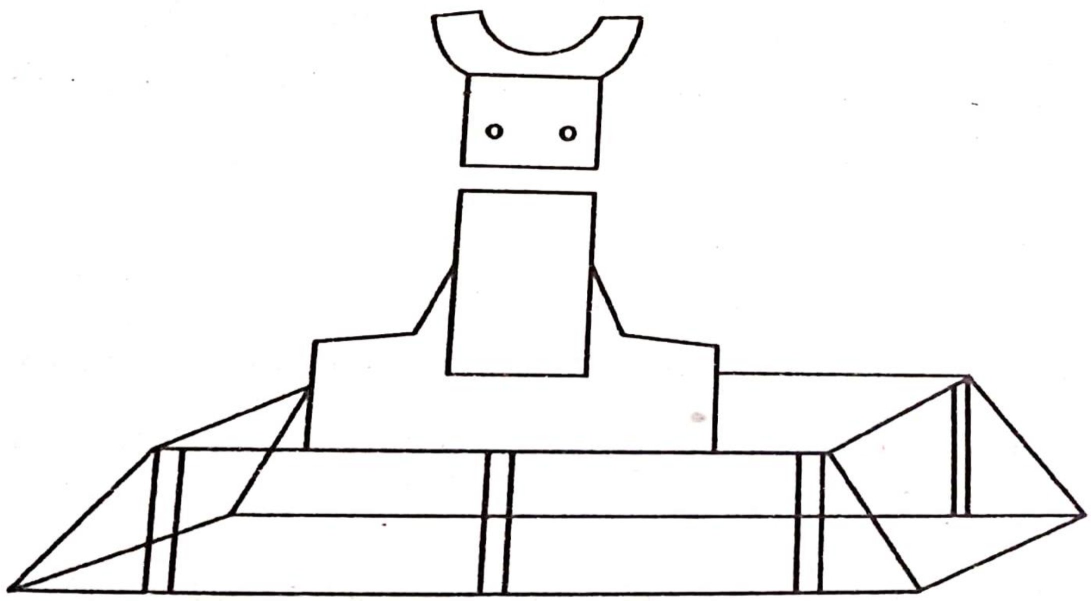

Fig. 2.34 : Jack plinth

2.4.3. **Cable laying depth and clearances from other serevices such as**

i. Water
ii. Sewarage
iii. Gas
iv. Heating and other mains

v. Telecommunication lines

Follow when laying an underground cable

a. Route should be as short as possible
b. Cable should be laid along road and railway tracks
c. Corrosive soil should be avoided.
d. The consideration should be given to the existence, alteration and growth to the other services.
e. The hard and expensive surface of the road should be avoided.
f. There will be a proper coordination with developing areas.
g. Authority should be taken from the authority like
- Municipal or local authorities
- Traffic authorities
- Highway and railway department
- Post trust authorities

h. In case of road crossing following rules should be followed
- Cable should be laid through G.I. pipes
- Depth of the pipe should be 1m in depth and slope slightly from road.
- Life of the pipes should be at least 20 years
- No joining in the middle of the road

Guidelines for national highways, bridge culverts and flyover, railways and open gutter crossing

1) **Along national highways:**
   - Taken permission from the authority
   - Cables should be laid at least 457cm from the centerline of the road and depth not less than 120cm from the surface
   - Save the cable from the roots like things.
2) **Along over bridges and culverts and flyover**
   - Culverts should be should be paid by a concrete channel of 12”.
   - In case of small bridges, the piers should be extended beyond the width of the road
   - In case of long bridges and flyovers, in present practice have a concrete channel 20 to 30 cm in depth 90 cm in width along the footpath with removable covers.

3) Along railways

- Side of the track should be in consultation with proper railway authorities if the alignments fall within 3 to 5.5 m from the centerline of any railway track.
- Excavation and reinstatement for any underground cable within 3m of the center of any railway track should be done with consultation of railway staff.

4) Railway crossing

- Railway track should be crossed by G.I. pipes of 75 mm dia.
- Minimum depth of G.I. pipes 1.25m
- The length of the pipes should be sufficiently long at least 4.5m from the center of the last track.

5) **Open gutter crossing**

It should be preferable to recommend to the local authorities to provide a small 25 to 30mm dia. Crossing G.I. pipes below the bed of the drainage opposite each multi storied building.

Some common wrong practice and their remedies:

1) Crossing water pipes:

- Whenever water exit at a insufficient depth and the contractor lays the cable over it cause
  - unequal stress on the cable
  - a sheath crack on it and consequently failure of circuit.
- Under such condition contractor should
  - Lay the telecom cable through G.I. pipes
  - Lay below the water pipes with a soft earth cushioning between pipe and cable
  - Cable made with water proofing insulating outer layer

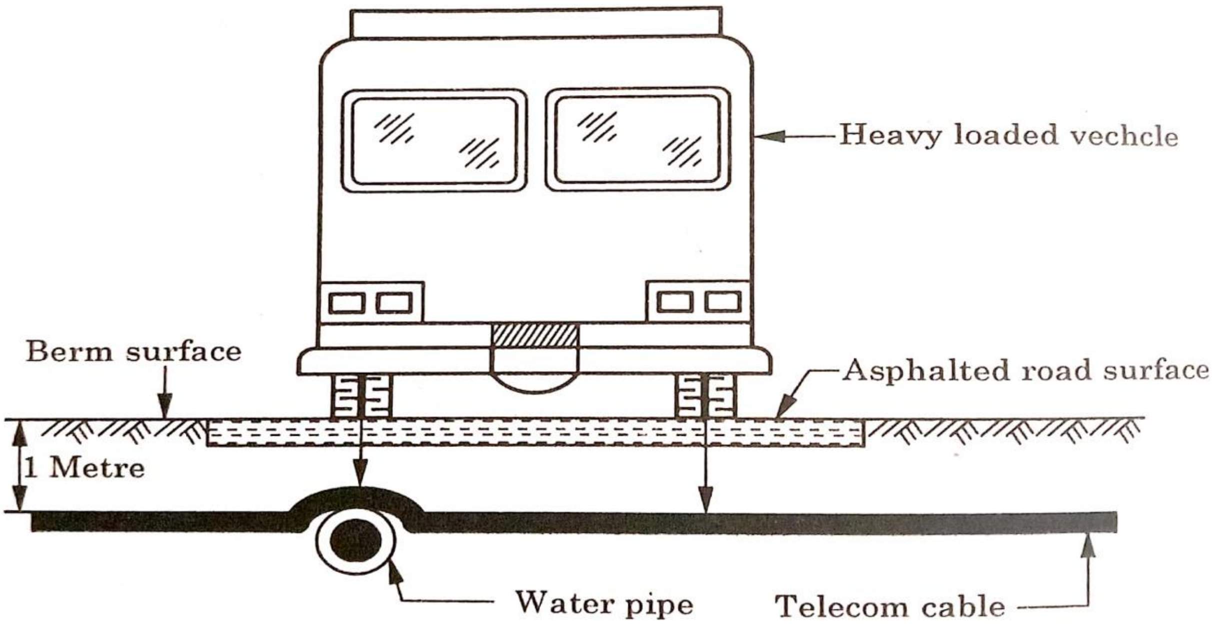

Fig. 2.35 : Laying of cable while crossing pipes

2) Crossing culverts:

- ➢ While laying cable across the culverts, G.I. pipes cut at the end in V-shape on the outer surface and bend downward. This apart from weakening the strength of G.I. pipes, damage the outer sheath of the cable due to abrasion. Moreover, the pipe broken itself at the weak spot whenever vehicle run over it.
- ➢ The V-cut also make a cause for
- Inner volume reduction
- Mud enter into the pipe which block it
- Further drawl of the cables not possible
- ➢ The use of 45 degree bend of same size by necessary coupling and sealing at the end after all cables are drawn through it, it preferable. The pipe further enclosed inside the parapet wall by dismantling.
- ➢ Sealing the ends of the pipes in both cases is avoid accumulation the mud and prevent of entry of harmful rodents, rats etc. Instead of parapets, can be enclose the GI pipes along with cable in cement concrete through the length of the culverts as shown in fig

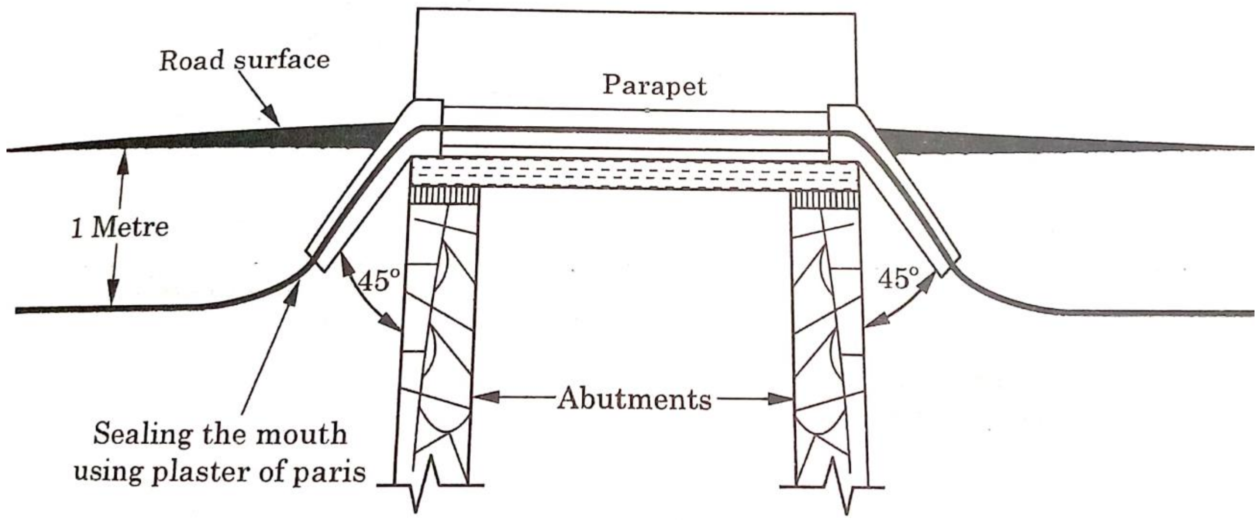

Fig. 2.36 : Layoing of Cable while crossing wieves

3) Crossing 11Kv electric cables:

- When 11Kv electric cables exist in parallel with proposed telecommunication route, take cable horizontally at least 0.6m above the earth surface for reducing the interference.
- The absence of sheath and armour continuity and improper earthing make a cause for AC induction.
- When the parallelism is more than 0.8 km the cable route should be referred to power telecom coordination committee for recommendation of protection measures. In case of crossing the angle between both is 90 and vertical clearance about 0.6 m but not less than 0.3m.
- However if 11kv cable exit in any route electricity board should be consulted and correct the location, crossing location etc before starting telecommunication cable laying as shown in fig.

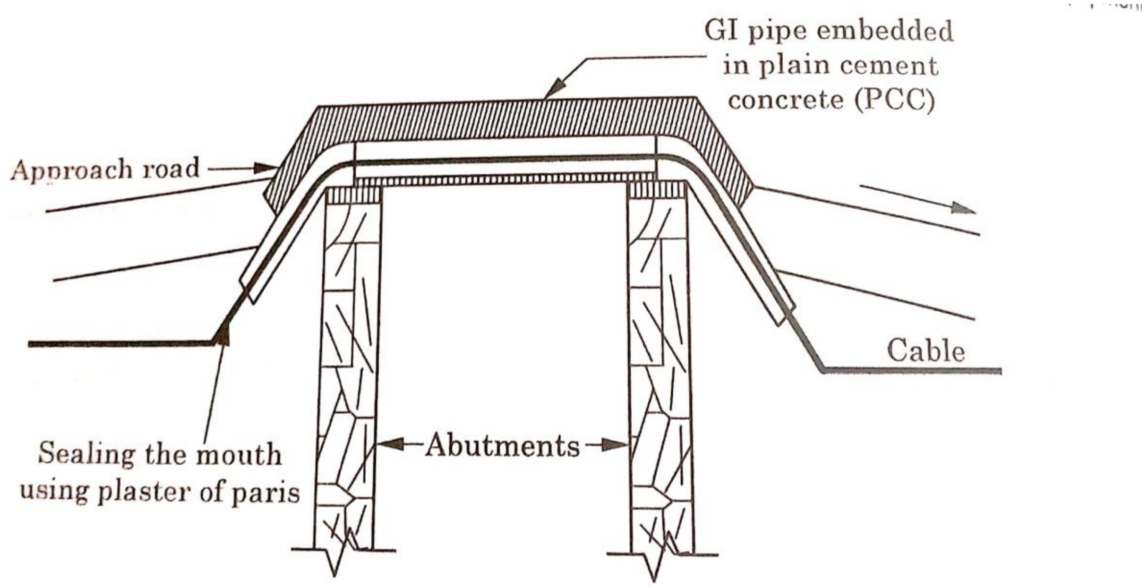

Fig. 2.37 : Laying of cable when crossing 11 kV electric cables

- Derating factor of the cable depand upon the following factors
  - Cable laying depth
  - Ambient temperature
  - Ground temperature
  - Parallel cable distance

2.4.4 Excavation of trenches

At the time of the trenching operation coordination with the following authorities is usually maintained

i. Electricity board
ii. Water works
iii. Gas pipe lines
iv. Sewage system

Trenching: following points are kept in mind et the time of the trenvhing

i. Top of the cable should not be less than 60cm from the soil surface.
ii. The alignment should be straight at least 50m at a stretch.
iii. It should be at least 0.3m away from the boundary walls.
iv. The depth of the trench should be 1.2m.

v. The width of the trench should be between 30cm to 40cm minimum.
vi. A separation of 0.6m should be maintained when cable is laid parallel to electric cable.
vii. At the crossing of the electrical cable, the telephone cable should be laid solid in between for 90cm on either side.

2.4.5 DIRECT CABLE LAYING

i. Laying of cable from drum
ii. Laying of cable in trench
iii. Backfilling of trench with earth, sand or layer of bricks

A. Direct in the ground

This method is employing in the following cases

1. Where road is narrow
2. Where the number of cable is few.
3. Where the road digging is easy.

This is the cheap and suitable method of initial investment. It involves

i. Digging the trench as per IS standard
ii. Digging can be done by manually or by thrust boring.
iii. Preparation of bedding of 5cm high above the soil.
iv. Thorough checking of cable which is to be laid.
v. Laying the cable in the trench with the help of the cable wheel.
vi. At the time of laying out, there should be not any twist in the cable, laying should be straight and there must not any criss cross of the cables.
vii. Cable rollers at every 10m in straight section.
viii. The best method of laying of the cable depends on the type of the cable and working conditions-
   a) One simple method is to lay the cable straight from a cable truck running along the side of the trench.
   b) Another way is to carry the cable. The distance between each man and the next is 3 – 10 meters, depending on the weight of the cables.

B. Special laying

In case cable are installed in special places where there are bridges or railways, special laying method are employed as follows;

1) When a cable crosses a river or canal, cables are attached to the bridge. In the absence of the these, an exclusive bridge should be built or submarine laying should be adopted.
2) In case of crossing the railway, there are two method; one is digging through the railway bed and the other is piercing from the side of the railway by using a excavator.

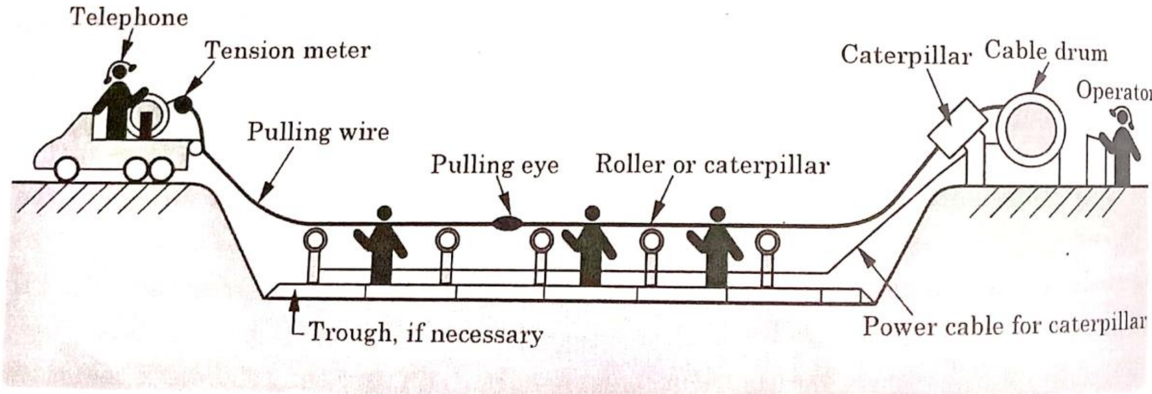

Fig. 2.38 : Cable Laid Direct in Ground

C. Cross bonding

- ✓ In cross bonding sectionalizing the cable screen into minor section and cross connecting them so as to neutralize the total induced voltage in three consecutive sections.
- ✓ The route is split up into groups of three drum length and earthed together at both ends.
- ✓ The purpose is to allow a standing voltage between screen and earth in each major section but eliminate circulating currents.
- ✓ With this, the current carrying capacity is enhanced for large conductor size.
- ✓ When cables are laid in flat formation, balance of induced voltage in the screen because of equal relative proximity of each single core cable with respect to each other.

2.4.6 LAYING OF CABLE INTO PIPES, CONDUITS AND WITHIN BUILDING

Laying of power cables in underground ducts or tunnel

This is employed in following cases-

1. Where the number of cable are many or expected to be increased in near future
2. Where digging is difficult due heavy traffic
3. In case of hard pavement

Underground duct install in congested area where excavation work is difficult, old cable can be removed and new cable can be installed without further excavation. When new cable is pulled from the duct then current rating affected, the current rating for cable in underground duct should be lower than the cable laid direct underground.

Electrical failure arises due to cable failure. At work places 80% of cable is laid in underground. Also being a coastal region the water is found inside the earth after digging even by 0.5m. Now there is a upcoming difficulties of water seepage inside the buried/reinforced concrete trenches during either laying of new cable or during attending some maintenance problems.

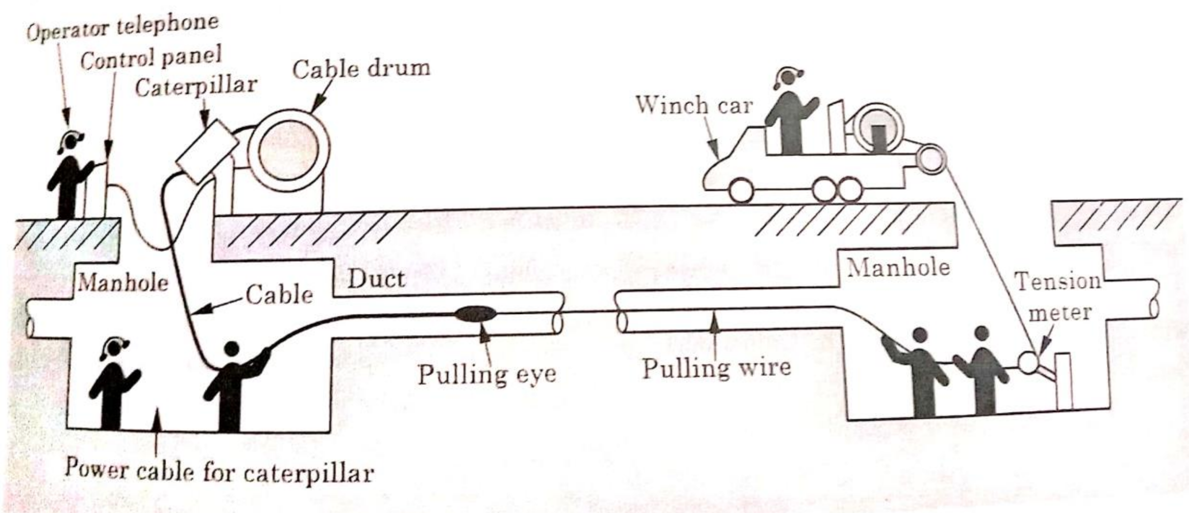

Fig. 2.39 (*a*) : Cable Laid in Duct

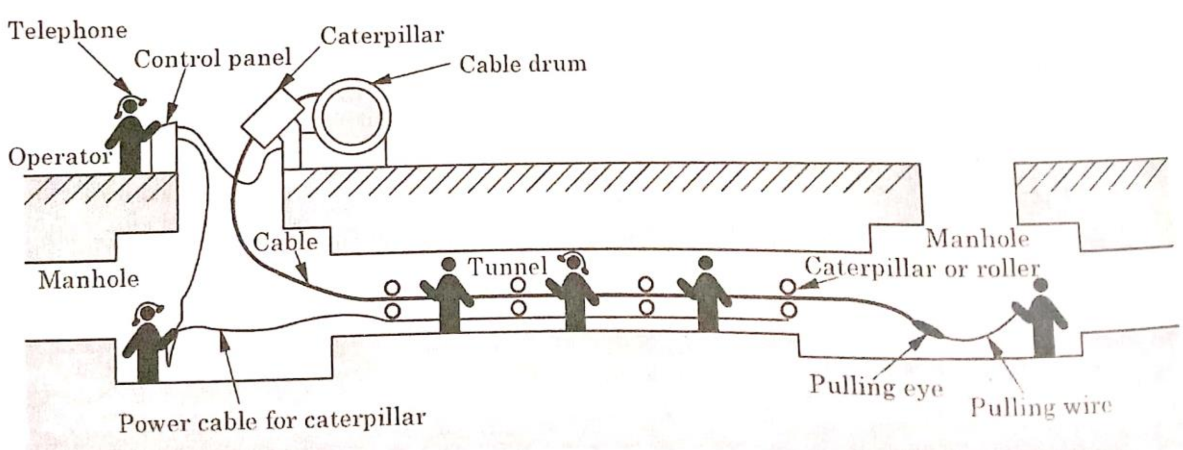

Fig. 2.39 (*b*) : Cable laid in tunnel

Guidelines for installation and maintenance of underground power cable up to and including 220KV XLPE cables

Power cables are designed to render a trouble free service for long period, say a minimum of 40 years. The life of the cable reduced due to several factors apart from the manufacturing deficiencies. These are following-

a) Cable is used by seeing the load condition, the **selected size** also meet the short circuit ranging.
b) In case of 11kv to 33kv, three core cable used recommended a **single core** cables, which can be provided non-magnetic armouring protection wherever required.
c) Depending upon the voltage grade, **the insulation** could be either PVC, impregnated kraft paper (PILC) or solid extruded dielectric, such as PE, XLPE, or EPR
d) Armoring of galvanized steel wire/steel **strips** are generally provided on 3 core cables. However for single core cables, non magnetic materials such as aluminum alloy are used.
e) Factors to be considered during installation of cables-
    i. Laying direct to the ground and protecting from the tiles.
    ii. Laying in ducts and pipes.
    iii. Laying on racks in trenches or in air.
    iv. Trefoil formation and flat formation are used for installation.
f) **Sheath** potential limiters (SVL) are provided for protecting the system against damage in case of surge or short circuit current.
g) Protection to be taken by the users are
    i. The **cable drums should be stored** in a yard with a firm surface preferably on concrete flooring and under shade away from direct sun rays.
    ii. Cable laying
    For cable pulled with stocking
    PVC and XLPE armoured cables $P = 7\ D^2$

PVC and XLPE unarmoured $P = 5D^2$

PILC armoured power cables

Belted and H type cables

Belted and H type $P = 3D^2$

HSL cables $P = 1D^2$

Where P = pulling force in newtons (0.133 kg)

D = outer dia of cable in mm.

h) The minimum depth of laying from the ground surface are- b

S.NO.	Types of Cable	Depth of Laying
1	L.V. cable and control cable	0.77m
2	H.V. cable 3.3 to 11 KV	0.9m
3	HV cable 22 KV and 33 KV	1.05m
4	EHV cables 66 KV and above	Min 1.2m
5	Cables at roads crossing	1.00 m upto 33 kv
6	Railway crossing	1.5 m above 33 kv

i) **Single core cables** used for A.C. distribution should not be laid in magnetic magnetic material such as steel or CI pipes or RCC pipes unless all the 3 phases are laid in the same pipe.

j) Three methods are used for **earthing and bonding**

i. Single point earthing

ii. Single point earthing at mid point

iii. Cross bonding

2.5 TRANSFORMER:

2.5.1. Inspection and Handling of transformer

- ✓ Before a permanent mounting of transformer final inspection should be made. Before energizing the transformer, alert all personal installing that lethal the voltage inside it. Personal should be instructed for unit service, opened lines, safety locks and tags applied.
- ✓ A careful examination should be made to ensure that all electrical connections have been properly carried out and that the correct ratio exits between the low and high-voltage windings.
- ✓ Any control circuit, if any, should be checked to make sure they function correctly. These include the operation of fans, motors, thermal relays and other auxiliary devices.
- ✓ All winding should be checked for continuity. You should arrange for an insulation resistance test to be carried out to make certain that no windings are grounded.

Standard transformer tests performed for each unit include the following

i. Ratio, for voltage relationship
ii. Polarity for single phase and three phase unit
iii. Phase relationship for three phase unit
iv. Excitation current, which relates to efficiency and verifies that core design is correct.
v. No- load core loss, which also relates to efficiency and verifies that core design is correct.
vi. Resistance, for calculating winding resistance and R component of the winding loss.
vii. Load loss, which again directly relates to the transformer's efficiency
viii. Regulation, which determine voltage drop when load is applied.
ix. Applied and induced potential, which verify dielectric strength.

The additional tests are

i. Impulse, sound and temperature rise to the coil.
ii. Corona of medium and high voltage.
iii. Insulation resistance and insulation power factor, which is done at initial insulation and every few years thereafter.

2.5.2 **Pole** Mounted **Substation**

It is the distribution substation placed over head on pole structure in open area. These types of station are designed for handling extra high voltage (upto 200KVA) and low voltage.

Following are some main characteristics of this

i. This type of sub-station consists of junction pole. Subsidiary pole and street pole are avoided except some cases where it is avoidable.
ii. The mounting pole should be sufficiently away from the street.
iii. Special care must be taken to maintain proper climbing space and avoid crowding of wirs and equipments.
iv. The pole should be strong enough to carry the weight of transformer and its protection system like G.O.link
v. **H-type pole mounted sub-station:** A transformer is mounted on cross-arm fixed between two pole and is securely fastened to the pole upto 200KVA.

vi. **Platform mounting:** A platform of steel structure is made on a 4-pole for placing transformer. It is suitable for Hazardous places.

vii. The pole should be straight, have double cross arm members.

viii. All the high tension bushing, connection should be opposite of platform. Name plate, breather and oil level gauge should be on front side.

ix. The wheel base shall be suitable locked.

x. Proper earthing, incoming and outgoing connection shall be made securely by competent person.

xi. Anti climbing device, caution board number plate should be fixed.

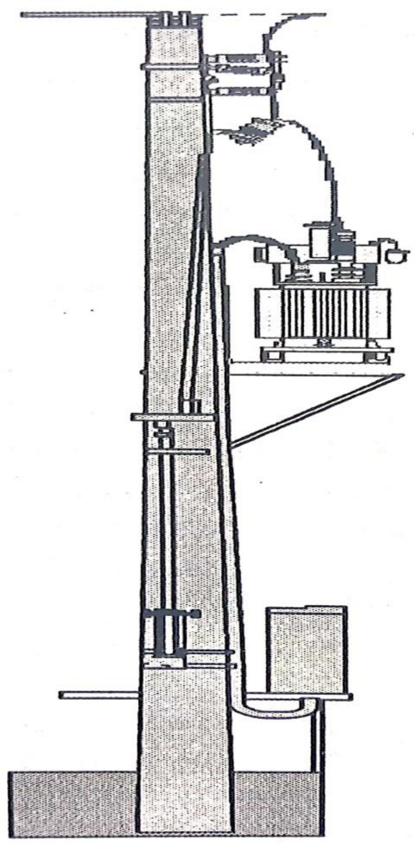

Fig. 2.42 : Pole Mounted Substation

2.5.3 Plinth Mounted substation:

Ground mounting and Plinth mounting: The main advantage of this type of mounting is its simplicity, ease of erection, ease of maintenance and elimination of the support structures. An added advantage is that in indoor substations, there is the reduction in the height of the building. A disadvantage however is that to prevent danger to personal, the circuit breaker has to be surrounded by an earthed barrier, which increase the area required. The layout of plinth mounted substation is

Transformer of the capacity above 500 KVA is made plinth or foundation mounted. These transformers are heavy and hence cannot be installed on poles. In the indoor type of plinth mounted substation the transformer, switch gear etc. are installed inside the building. The clearance between walls and equipment should also be adequate.

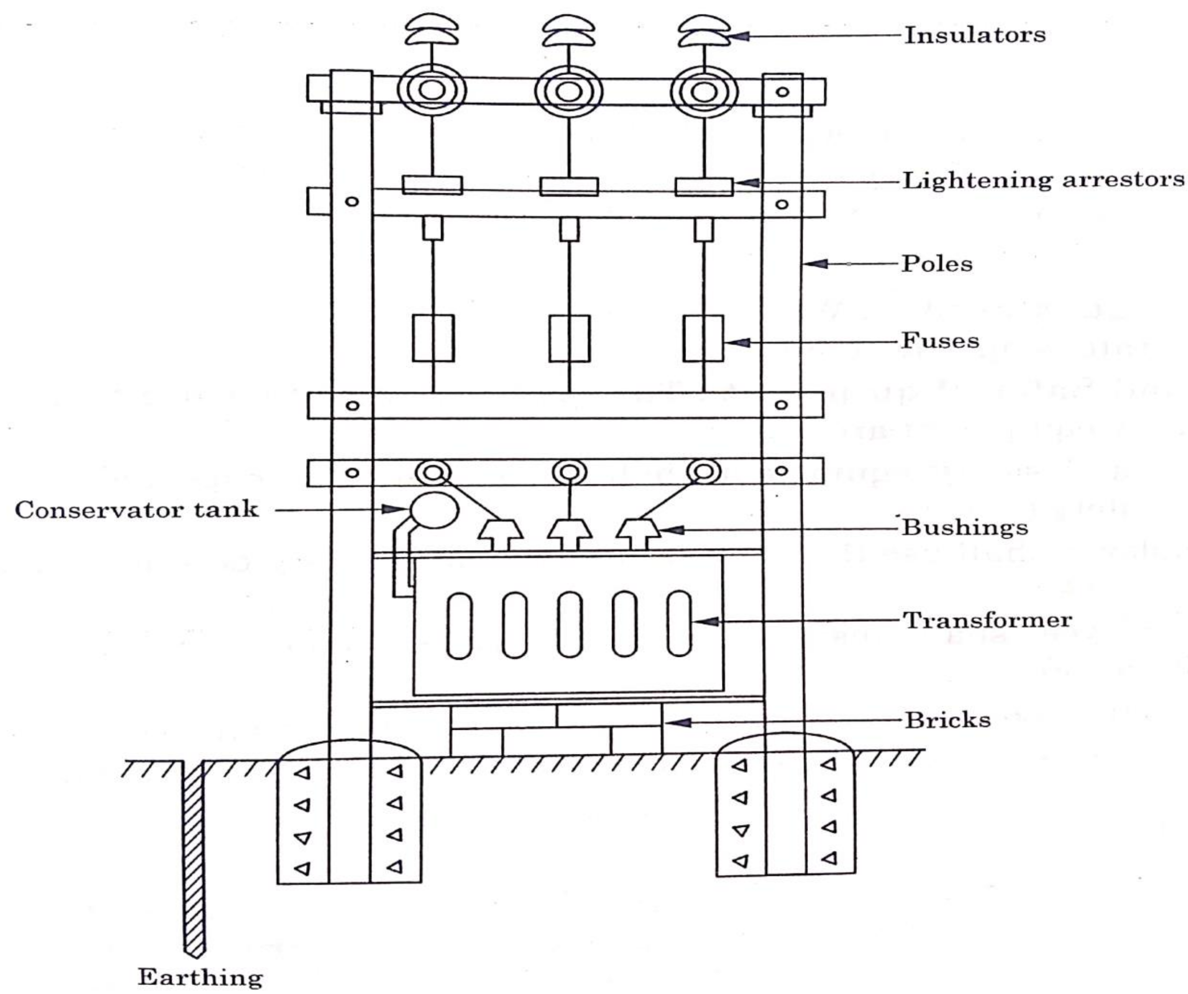

Fig. 2.43 : Plinth Mounted Substation

2.5.4 Grid Substation:

Access into substation: An employee should not enter an area in an electrical station where there are live exposed high voltage conductors unless the employee

a) is authorized to enter the area
b) is accompanied by a person who is authorized to enter that area
c) has been specifically instructed by an authorized person as to the area that an be entered.

Work on Substation: work in substation should be in accordance with the network operator's approved procedures.

Tools and safety Equipment: The employer should ensure that the appropriate tools and safety equipment are used:

- ✓ All tools and safety equipment shall be periodically inspected and tested to ensure their safety for use.
- ✓ The employee shall use the appropriate tools and safety equipment provided by the employer
- ✓ The employee shall inspect tools and safety equipment to check their serviceability before use
- ✓ The employee shall not use any suspected defective tool or equipment. It shall be withdrawn from service.

2.5.5 Busbars:

Busbars are made up of copper material having rectangular strips of sufficiently thickness depending upon how much current is to be carried by it.

Bars are source of infinite electrical power from where supply to different feeders is provided.

2.5.6 Isolators

These are essentially off load device although they are capable to dealing with small charging current of busbars and connections. The design of isolators is closely related to the design of substances. Isolator design is considered in the following aspect

- ✓ Space factor
- ✓ Insulation security
- ✓ Standardization
- ✓ Ease of maintenance
- ✓ Cost

Some type of isolators include

- ✓ Horizontal isolation type
- ✓ Vertical isolation type
- ✓ Moving bushing types

2.5.7 VOLTAGE AND CURRENT TRANSFORMER

- ✓ These are also known as instrument transformers. These are used for measuring and control purpose. These provide current and voltage proportional to the primary but there is less danger to instilment and personal.
- ✓ Those transformer which are used to step down voltage are known as voltage/potential transformer and used to step down current are known as current transformer

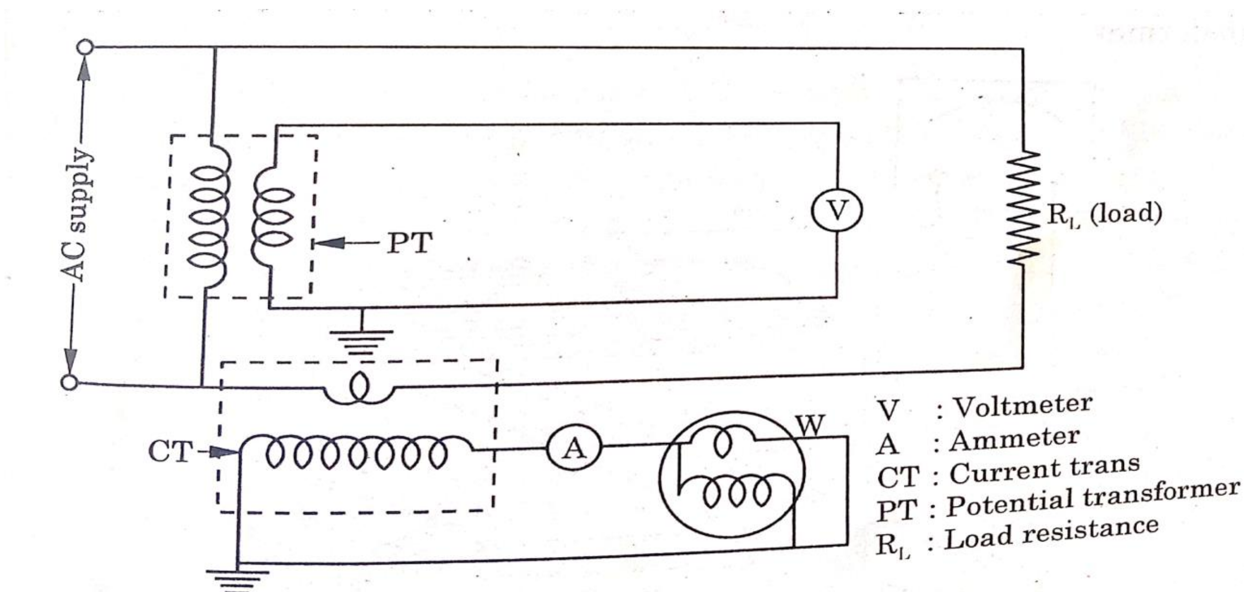

Fig. 2.44 : Connections of PT and CT

Potential transformer:

- ✓ These are used with voltmeter, watt-meter, watt-hour meter, frequency meter, power factor meter, synchroscope, protecting and regulating relay and under voltage & over voltage trip coil of circuit breaker. One PT can be used for many instruments.
- ✓ The secondary terminal should never be short circuited because a heavy current will result which can damage the windings.

Current transformer:

- ✓ The primary of a CT typically has only one turn. It is just a conductor or a bus going through the center of the core.
- ✓ The primary never has more than a very few thus while the secondary have many turnd depending upon how much current has to be step down.
- ✓ Current transformer are used with watt meter, power factor meters, protective and regulating relay, trip coil of the circuit breakers and ammeter etc.
- ✓ One CT can be used to operate several instruments.

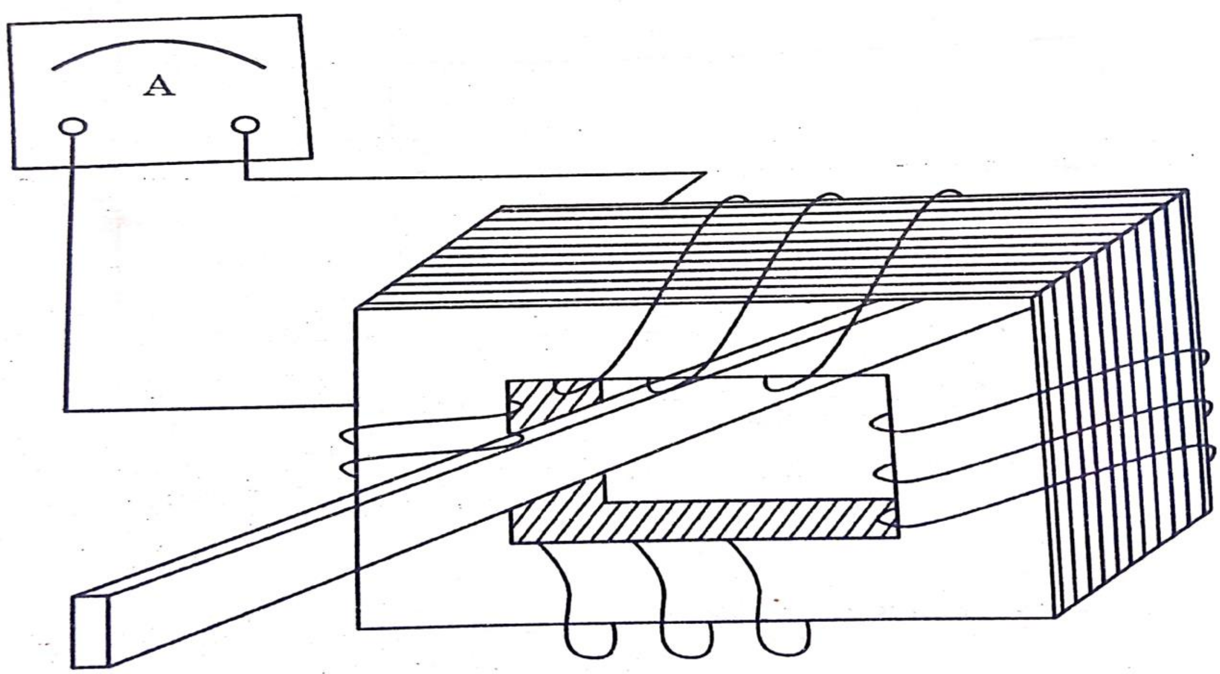

Fig. 2.45 : Current Transformer

2.5.8 Lightning Arrestors

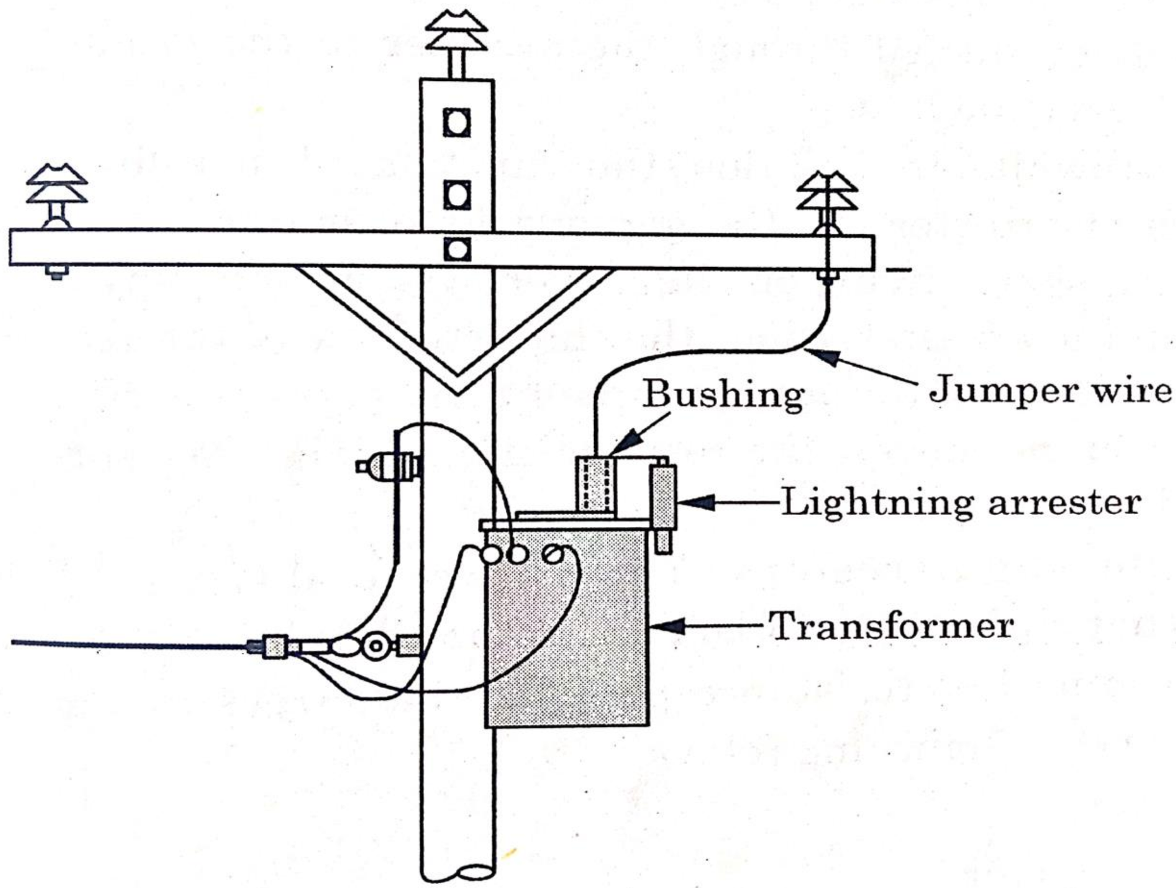

Fig. 2.46 : Lighting Arrestor

- ✓ LA provides a means by which lightning current may enter or leave without passing through circuitry to be protected. If it is absent then normal operation of instrument is not affected but when it is present and voltage goes up then LA activate.
- ✓ The earthing screen and ground wires protect well but they fail to provide protection against travelling waves, which may reach the terminal apparatus.

The action of the LA or surge diverter is as under-

i. Under normal operation, the LA is off the line i.e. it conducts no currents to earth or the gap is non-conducting.
ii. On the occurrence of over voltage, the air insulation across the gap breaks down and an arc is formed providing the low resistance path for the surge to the ground.

iii. It is worthwhile to mention the function of non-linear resistor in the operation of arrester. As the gap spark over due to over voltage, the arc would be a SC on the power system and may cause power- follow current in the arrester.

Types of the LA

1. Rod arrester
2. Horn gap arrester
3. Multigap arrester
4. Expulsion type LA
5. Valve type LA

2.5.9 Control & Relay Panels, HT/LT circuit breaker, LT switches

- ✓ Control and relay planes are used in substation for controlling protecting the transmission and distribution line as well as the transformer.
- ✓ These panels consist of the metering instrument for nothing down the valves of voltage, current, frequency etc.
- ✓ Also relay which are connected ensures that during a fault condition they trip the circuit thereby preventing damage to the electrical equipments
- ✓ HT/LT circuit breakers also disconnect the circuit from the main supply in the event of any fault. These operate at higher voltage as compared to the relays.
- ✓ Measures are taken that during make & break of the high potential circuit the arc developed between the terminals across the circuit breaker do not extend beyond permissible limits.

2.5.10 INSTALLATION OF POWER/Distribution TRANSFORMER:

- The successful operation of the transformer is dependent on proper installation as well as good design and manufacture.
- For installation of transformer first select a good location and then for the foundation evaluate the soil characteristics & concrete work.
- When placed inside or top of a building, the structural capabilities should be considered because a transformer represent a highly concentrated load.

Following are the step taken while installing a transformer-

a) **Preliminary inspection upon receipt of transformer:** when received. a transformer should be inspected for damage during shipment. Examination should be made before removing it from the railroad car or truck, if any damage is evident or any indication of rough handling is visible, a claim should be filed with the carrier at once and the manufacturer notified.

b) **Handle and lift with care:** transformers are designed with provision of lifting, jacking and /or rolling. This provision will vary depending upon the weight, size and mechanical configuration of the unit. You may lift the transformer with enclosures having lifting lugs by using appropriate slings or chains.
c) **Plans of prevention of contaminants:** Develop a procedure for inventory of all the tools, hardware and any other object used in the inspection, assembly, and testing of transformer. A check sheet should be used to record all items, verification should be made that these items have been properly accounted for upon completion of work.
d) **Making connection that work:** when you start to making the connection between transformer and incoming & outgoing conductors, the name plate's instruction should be followed carefully. Checks all the taps jumpers for all tightness and proper location. Retighten all cable retaining bolt after the first 30 days of service.
e) **Controlling sound level:** when testing a transformer for sound level, you should recognize that all transformers, when energized, produce an audible noise. Although there are no moving parts in transformer, the core does generate sound. The location of the transformer relates directly to how noticeable its sound level appears.
f) **Make sure transformer is grounded:** grounding is necessary to remove static charges that may accumulate and also is needed as a protection should the transformer winding accidentally come in contact with the core or enclosure

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2.5.11 Dehydration:

It is the slow build up of oxidation products as a result of chemical reaction with oxygen and moisture from environment under prevailing condition and physical ingress of polar molecules.

Dehydration of transformer: Moisture removal can be done by several methods using various combination factors. Benefits of this is

- ✓ Minimize partial discharge effect from inadequate oil impression.
- ✓ Removal of unwanted oxygen
- ✓ Removal of combustible gases
- ✓ Extremely dry oil

The machine are used for dehydrating the transformer oil consist of following steps-

i. **Oil transfer and circulating system:** Many consist of inlet, outlet pump and necessary valves and piping to ensure easy operation and maintenance. It is made vacuum tight to have a leak-proof operation.
ii. **Heating system:** I is capable of heating the oil 25 to 80 centigrade. It contain insulated heat exchanger with indirect low watt density bobbin type electric heaters. Oil temperature is controlled with thermostat. Suitable oil distribution system is provided to ensure uniform flow of oil over heaters.
iii. **Filtration system:** It is suitable for removing suspended particle such as colloidal carbon, oxidation sludge, dirt, dust, scale upto < 1micron. It consist of pre filter and fine filter.
iv. **Pre filter:** It is a metallic strainer with magnet. It removes magnetic and coarse suspended particle and to protect inlet pump from damage due to abrasion.
v. **Fine filter:** Remove all suspended particle upto <1 micron. Filter element either non-hygroscopic molded cellulose cartridges or cleanable edge type filter candles.
vi. **Degassing & dehydration chamber:** it is designed to remove large portion of dissolved impurities from oil. Rasching ring trays and oil dispersing system are provided to have sufficient exposure of oil to vacuum during filtration. Oil level is controlled with float switch.
vii. **Vacuum system:** Rotary oil-sealed vacuum pump or combination of mechanical booster pump and rotary oil-sealed pump is get proper working vacuum during filtration. Necessary valves for easy operation and maintenance of the plant.

2.5.12 Earthing system

Substation earthing: calculation for earth impedances and potential are based on site measurement of grounded resistively and system fault levels. A grid layout with particular conductor is then analyzed to determine the effective substation earthing resistance, from which the earthing voltage is calculated.

Earthing and bonding: The function of these are to provide an earthing system connection to which transformer neutrals or earthing impedance may be connected in order to pass the maximum fault current. Earthing system also ensure that no thermal or mechanical damage occur on the equipment within the substation, thereby resulting in safety to operation and maintenance personal.

In designing the substation three voltage have to be considered-

i. **Touch voltage:** difference in potential between the surface potential and potential at an earthed equipment.
ii. **Step voltage:** this is the potential difference when a man bridges a distance of 1m with his feet while not touching any other earthed equipment.
iii. **Mesh voltage:** This is the maximum touch voltage that is developed in the mesh of the earthing grid.

Earthing materials:

i. Bare copper conductor is used for substation earthing grid.
ii. Connection to the grid and earthing joints should not be soldered, it must be bolted.
iii. The earthing grid must be supplemented by earthing rods.
iv. Switchyard fence earthing practices are possible and are used by different utilities.

Earthing and electrical protection:

Earthing and electrical protection system shall be designed and installed to safely manage abnormal network condition likely to be experienced.

GENERAL: Earthing and protection system shall be designed and install to ensure

- ✓ The reliable passage of fault current
- ✓ The reliable passage of Single Wire Earth Return (SWER) load current to ground and/or source.
- ✓ Appropriate coordination with other utilities system
- ✓ Suitability from the environment and earthing conditions
- ✓ Mechanical stability and integrity of connection.

2.5.13 FENCING OF YARD:

Fencing of yard is done to prevent unauthorized persons from gaining access to the substation or transformer. This ensure safety of the equipments as well as person/animal who may accidently come into contact with the high voltage electrical appliances and may receive a fatal shock.

<u>2.6. Testing of Various electrical Equipments</u>

I. Electrical Motor

The various tests conducted on electrical motor are as follows

a) **Types Tests:**
   i. Measurement of stator and rotor resistance.
   ii. Open circuit voltage ratio test.
   iii. No load current, voltage, power input and speed.
   iv. Locked rotor test.
   v. Heat run test for determing temperature rise.
   vi. High voltage test.
   vii. Overhead test.
   viii. Reduced voltage test at no-load.

b) **Special Tests:**
   i. Shat voltage measurement.
   ii. Vibration severity test.
   iii. Sound level measurement.
   iv. Stability of motor to PWM (Pulse width modulation) supply.

c) **Routine Tests:**
   i. High voltage tests.
   ii. Insulation, resistance measurement.
   iii. Locked rotor test.
   iv. Open circuit voltage.

Few of the above tests are explained below.

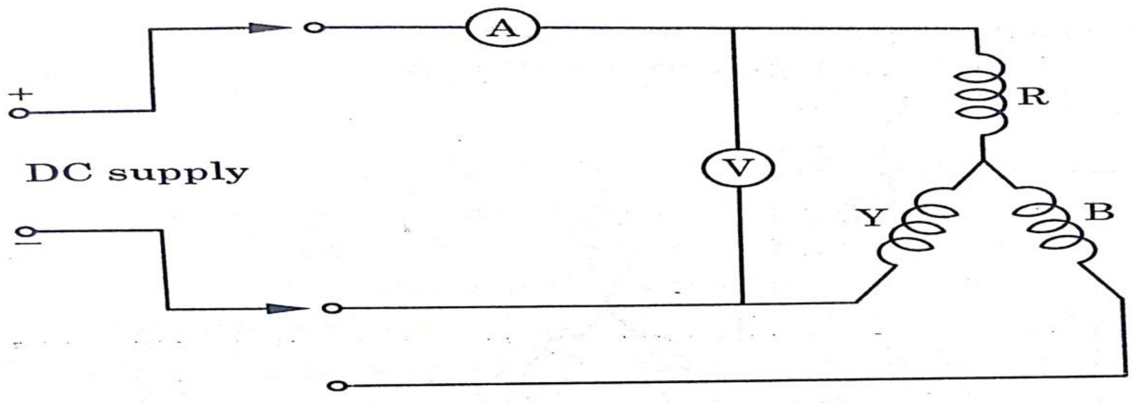

Fig. 2.47

1. **Measurement of Stator and rotor resistance:** Fig.shows an arrangement for determining the stator and rotor resistance motor windings. The resistance is measured by applying de voltage across two windings at a time say first de voltage is applied across R and Y windings and the current flowing thorough the two windings is noted with the help of ammeter. The value of de resistance will be

$$\mathbf{R_{de}} = \frac{V}{2I}$$

2. **Open circuit voltage ratio test:** Open circuit voltage ratio test in conducted on slip ring induction motors only, rated voltage and frequency is applied to the stator windings of the motor and voltage is measured between the slip rings. The circuit is shown in Fig. below

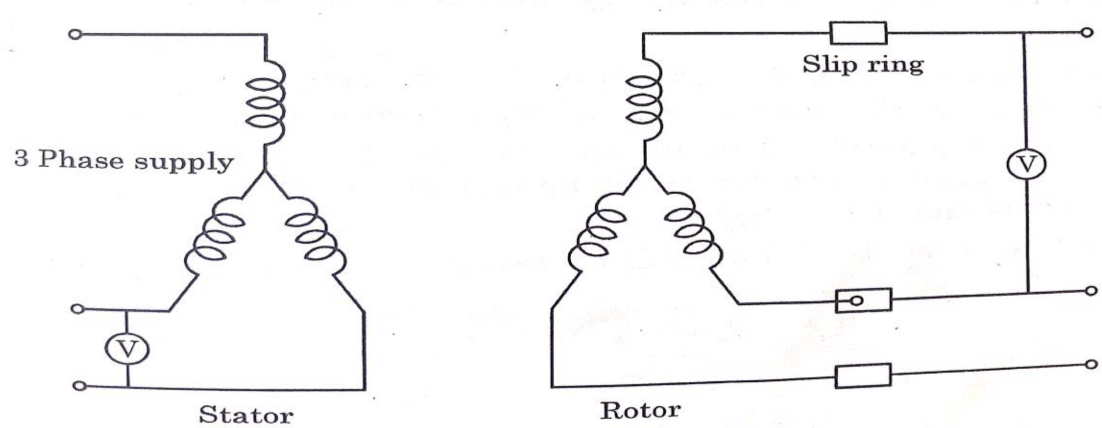

Fig. 2.48 : Open Circuit Voltage Ratio Test

3. **No Load values:** The motor is run without any load connected across the motor. The current, voltage and power drawn by the motor is recorded. The circuit for the is shown in Fig below.

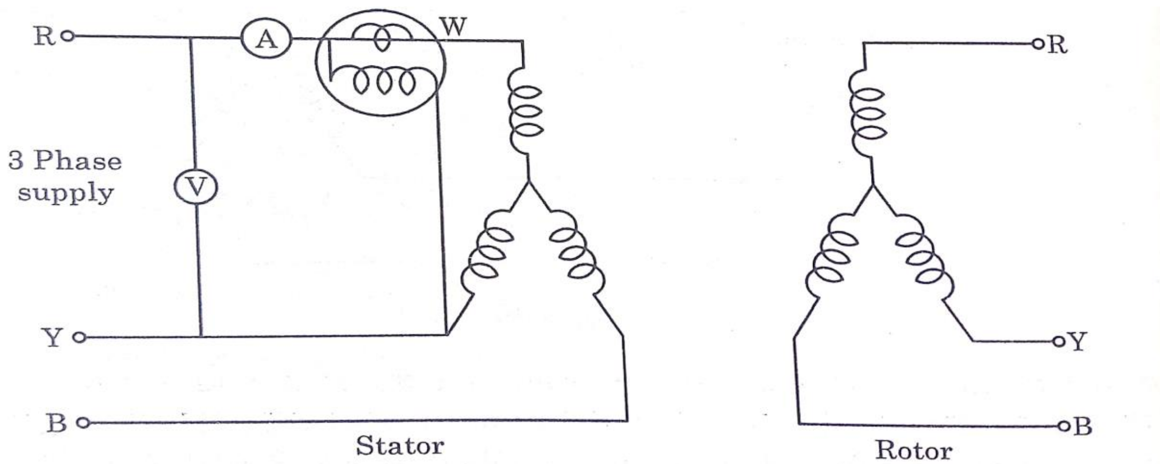

Fig. 2.49 : No Load Valves of Motor

4. **Locked Rotor Test:** This test is conductor for determining the copper losses of the motor. The stator winding of the motor is given reduced 3 phase supply and is increased slowly while keeping the motor flocked. When the motor carries rated current the power drawn by the motor is noted down. This value represents the copper losses of the motor assuming the iron losses to the negligible.
5. **Heat run test:** This test in done to determine the temperature rise for the motor. Following three methods are generally used for conducting this test:
   - Thermometer method
   - Temperature detector method by embedded instruments
   - Resistance method

   The first two methods are conventional where temperature is determined by nothing the values of thermometer. In the resistance methods the temperature rise of the windings is determined by increase in the resistance of the windings.

   The resistance value depends upon the surrounding temperature, hence, the temperature correction factors must be applied. The change is resistance due to temperature rise fromT_1 to T_2 in calculated by the following formula

$$\frac{R_2}{R_1} = \frac{T_2 + 235}{T_1 + 235}$$

Where R_1=Initial resistance at room temp say 20°C

R_2 =Final resistance at final temperature

T_1 =Initial temperature

T_2=Final temperature

6. **High voltage test:**
   - ✓ The high voltage test is applied between the windings and the frame with the core connected to the frame and to the windings not under test and shall be applied only to a new and completed motor with all its parts in place under conditions equivalent to normal working conditions. The test is carried out at the maker's works.
   - ✓ Motors with normal voltage above 1KV, when both the ends of each phase are individually accessible, the test voltage shall be applied between each phase and the frame, with the core connected to the frame and to the other phases and windings not under test.
   - ✓ The test voltage at power frequency and should be as near as possible to sine wave from. The voltage is increased to full value steadily or in the steps of not more than 5% of the full value.
   - ✓ Test made on windings should not be repeated.
   - ✓ Completely rewound wings is tested at the full test voltage for new motors.

7. **Insulation Resistance Test:** The insulation resistance when the high voltage test is applied shall be not less than one megohm. The insulation resistance shall be measured with an a.c. voltage of about 500 volts applied for sufficient time for the reading of the indicator to become practically steady, such voltage being taken from an independent source or generated in the measuring instrument.

II. **Transformers**

Following tests are conducted on transformers

a) **Type Tests:**
   - i. Phasing out
   - ii. DC resistance
   - iii. Polarity test
   - iv. Voltage ratio
   - v. Core loss

vi. Magnetising current
vii. Copper loss
viii. Temperature rise test
ix. Impulse voltage test
x. Partial discharge test

b) **Routing test:**

i. Ratio test
ii. Break down value of oil
iii. No load test
iv. Insulation resistance
v. Vector group test
vi. Inducted over voltage test
vii. High voltage test

c) **Special tests:**

i. Short circuit test
ii. Vibration/earthquake test
iii. Measurement of zero phase sequence impedance

Few of the above tests are explained below

1. **Polarity test:** The HV and LV terminal of 3 phase and 1 phase transformer is done as per IS 2026-1962. The same is shown in fig. below

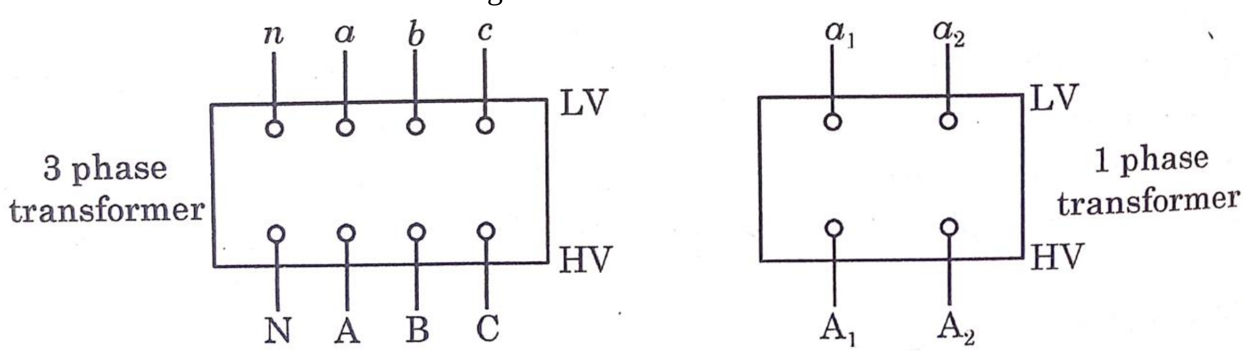

Fig. 2.50 : Polarity Marking

2. **Ratio test:** The ratio test is done as per the circuit shown in fig.2.51 below

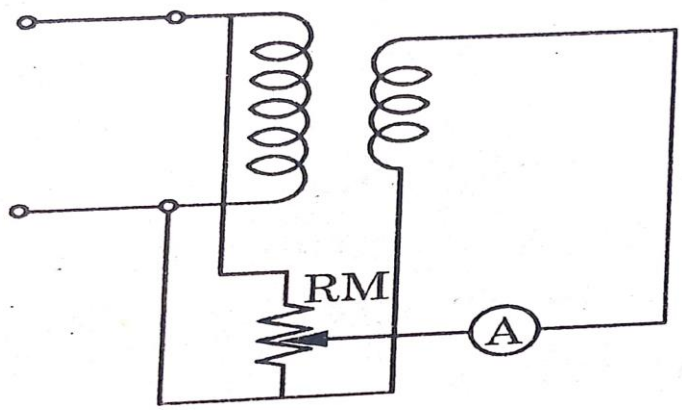

Fig. 2.51 : Ratio Test

In case of LV transformers a direct measurement with voltmeter on no load gives the value of voltage ratio directly. The meter reads the value of ratio directly when the ammeter A reads zero value.

3. **Windings resistance test:** the circuit for determining the winding resistance is shown in fig. The method is known as voltmeter/ammeter method

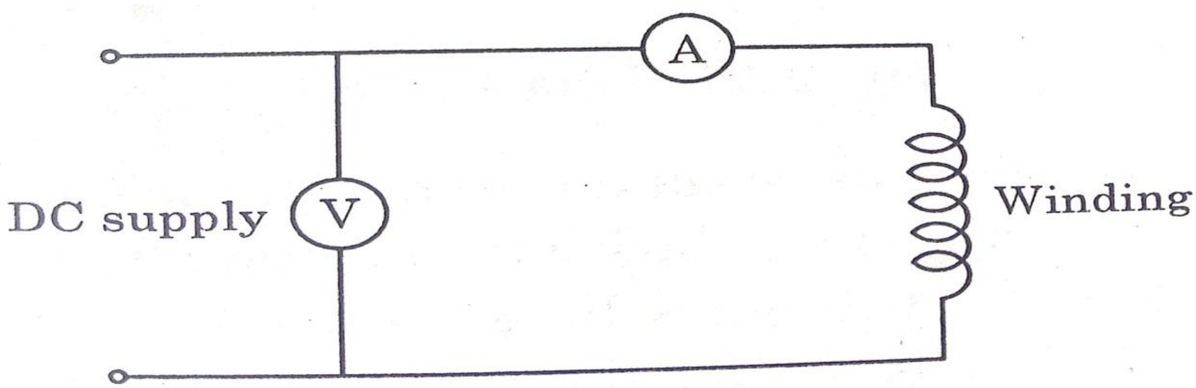

Fig. 2.52

DC voltage is applied across the terminals of the winding. The value of current flowing through the winding is noted and value of de resistance is determined as

$$R_{de} = \frac{V}{I}$$

4. **Insulation resistance:** The value of insulation resistance is determined with the help of meggar. Insulation resistance is measured between conductor and insulation and also between conductors.

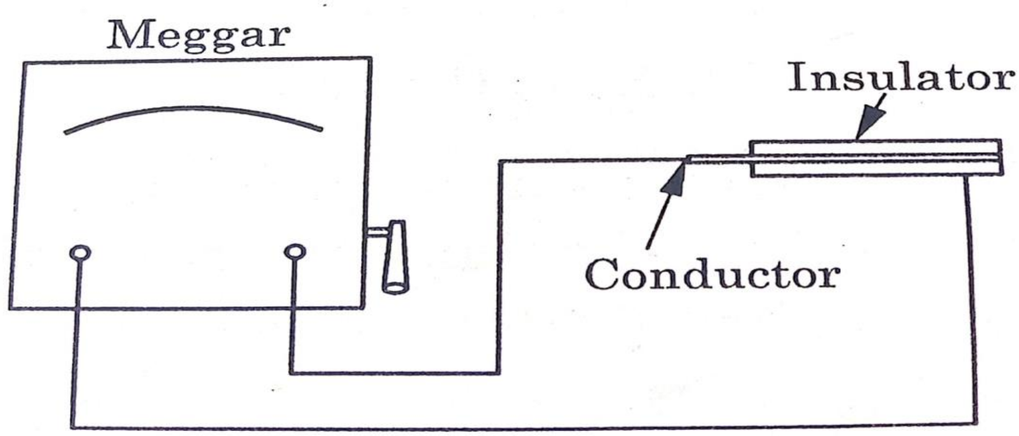

Fig. 2.53 : Insulation Resistance Test

5. **Polarity test:** The polarity test is done on transformer in determine the polarity so that when connecting two transformers in parallel the polarities of the windings can be connected market properly. A dot shown in the winding represents the positive polarity

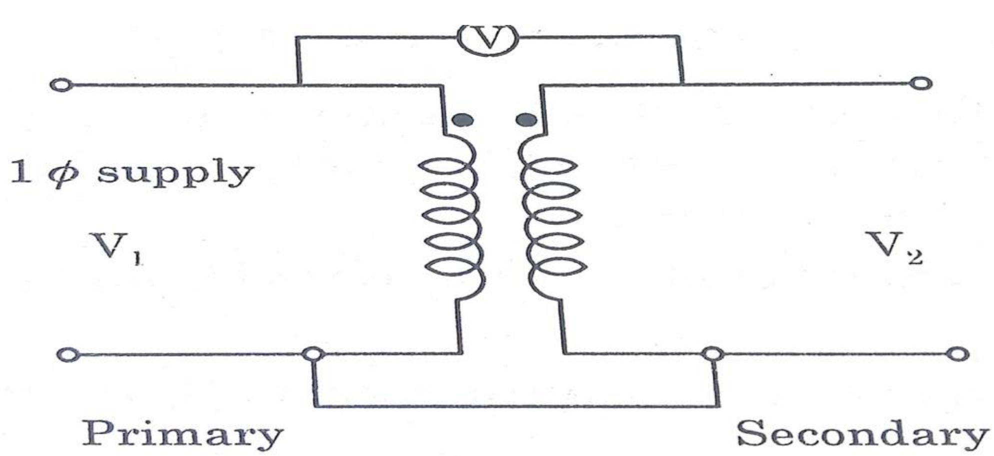

Fig. 2.54 : Polarity Test

V_1 and V_2 are the primary and secondary voltage respectively. If the voltmeter indicates zero readings it means the polarity is as shown in fig, and is correct. If the voltmeter is not correct twice the voltage will be shown by the voltmeter. Care should be taken white conducting this test that the voltmeter should be twice the value of the transformer voltage rating.

6. **High Voltage Test:** In this test high voltage as per IS standard is applied to one winding and the other winding as well as core of the transformer is earthed. This test determines the insulation strength for surges and over voltages.

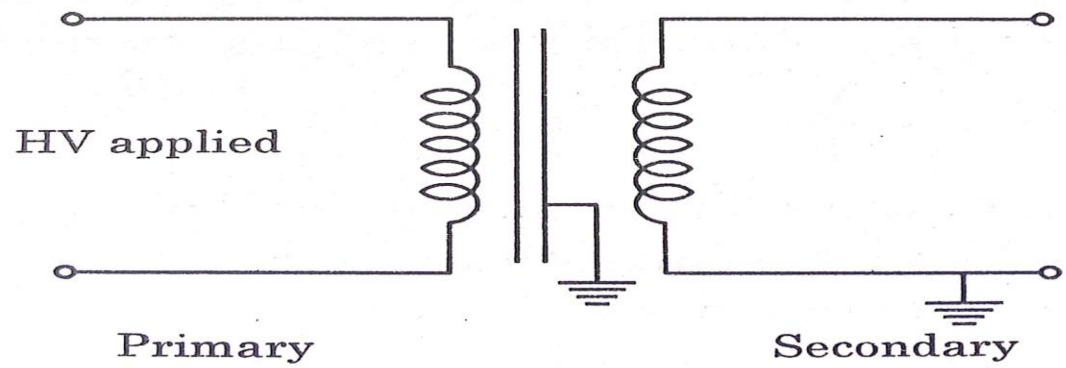

Fig. 2.55 : HV Test

7. **Open circuit test:** This test is done to determine the no load losses i.e. eddy current and hysteresis losses. The circuit is shown in fig.2.56

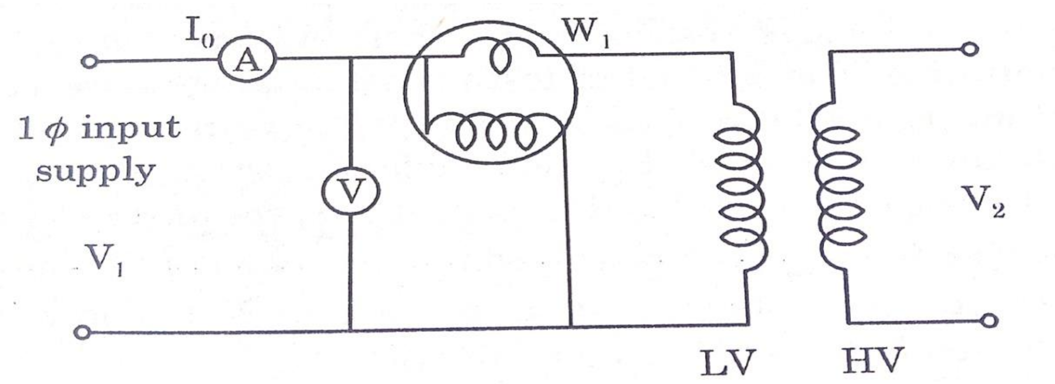

Fig. 2.56

Related voltage is applied in the LV winding of the transformer at no load and the reading of voltage, current and is noted.

Let I_o = no load current

V = rated voltage of LV winding

W_1= no load power

The value of W gives the value of no load losses directly.

8. **Short circuit test:** This test is done to determine the copper losses. This test as conducted from the high voltage winding side. A reduced voltage is given to HV winding of the transformer and LV winding is short circuited.

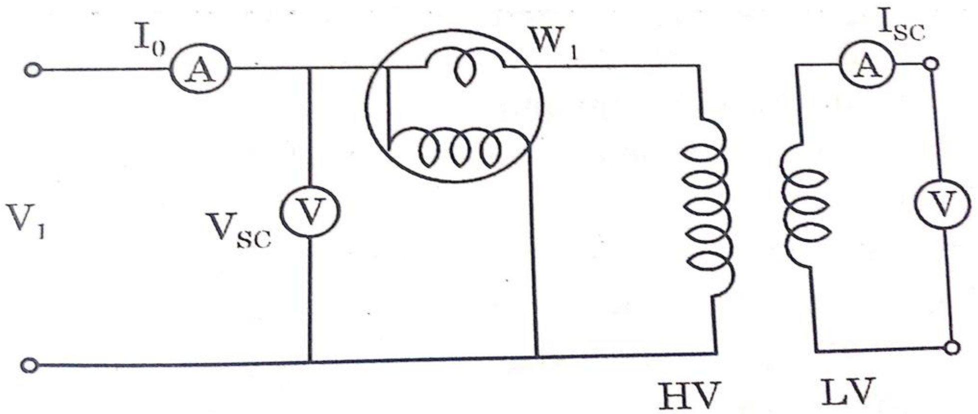

Fig. 2.57 : Short Circuit Test

The input voltage is increased till the ammeter connected across LV winding indicates the rated current. When the value of Isc becomes equal to the rated current of the transform the value of W_1 gives the value of copper losses

III. Cables

For any engineering product especially those of high value and of durable life like Power Cable, intensive testing before their shipment from the works is of paramount importance. The concept of testing has undergone several changes over the years based on performance feed-back and we have now broad classification of such tests that taken into account the predictable life for these products in respects of their Electrical, Physical, Thermal and Chemical stresses during their life time.

For cable the tests have been classified in the following four broad categories.

i. **Routine Tests:** Tests carried out on each cable to check the requirements. Which are likely to vary during production.
ii. **Type Tests:** Tests carried out to prove conformity with the specification. These are interned to prove the general qualities and design of a given type of cable.
iii. **Acceptance Tests:** Tests carried out on samples taken from a lot for the purpose of acceptance of the lot.
iv. **Optional Tests:** Special tests to be carried out when required by agreement between the purchaser and the supplier.
v. **Electrical Tests:** The major tests covered in this category are High Voltage Tests, Conductor Resistance Tests, Partial Discharge Tests, Impulse Tests, Dielectric Power Factor Tests and Insulation Resistance Tests.

1. **High Voltage Tests:** The insulation material in a cable is used to isolate the conductors from one another and from ground, as well as provide the necessary mechanical strength. The fundamental requirement of the insulation in an electric cable is that it withstands the voltage imposed on it service. It is necessary that an evaluation of the condition of the insulation be made by imposing a higher voltage stress for a short duration.
2. **Conductor Resistance Test:** Accurate control of resistance is necessary to meet system design parameters. Resistance is influenced by conductor dimensions and construction, processing, conditions, temperature and resistively. It is expressed in terms of Ohms per kilometer corrected to 20°C.
3. **Partial Discharge Test:** Partial Discharge in voids remain unnoticed in the normal high voltage test and could be harmful to the life of the insolent. Extruded dielectric tends to deteriorate very fast due to the discharges in small voids and cavities. It is, therefore, necessary that such voids should, as far as possible, be avoided in the extrusion process. Still certain minute voids are unavoidable and these remain in the insulation.
4. **Impulse Test:** Insulating material used in high voltage electric cable may be subjected to transient over voltages resulting from nearly lighting strokes. The ability of the insulating materials to withstand this transient voltage is important in establishing the reliability of the cable insulation and the design of the cable.
5. **Dielectric Power Factor Test:** The power factor of the dielectric should be small in order to reduce the heating of the dielectric material and to minimize its effect on the rest of the network. The power factor is dependent on both voltages gradient and temperature. The power factor test is a sensitive test to check the dielectric of a cable for inclusion of impurities and mechanical imperfections or voids.
6. **Physical Tests:** The major tests covered in this category are Tensile Test for Aluminium Wires, Wrapping Test for Aluminium Wires, Annealing Test for wires used as conductors, Dimensional Test, Tensile Strength & Elongation at Break of Thermoplastic & Electrometric Insulation & Sheath, Tensile Strength & Elongation at Break of armouring materials, Torsion Test on galvanized steel strips for armouring and Bending Test.
7. **Tensile Test for Aluminium Wires:** This test is performed on conductor material to determine, the strength of the material when subjected to tensile stress. Since cable conductors to be pulled from one end along

trenches are subjected to considerable force during pulling as well as manufacture, it is necessary to ensure that the conductor material has adequate tensile strength.

8. **Wrapping Test for Aluminium Wires:** This test brings out the properties of the material, which makes it suitable for winding and twisting. Cable conductors during the process of manufacture as well as during installation are subjected to torsion due to axial twist and might breaks, if material is not sufficiently ductile.
9. **Annealing Tests for Wires used as Conductor:** As the conductor of a cable is subjected to twisting and bending, it is necessary that it should he flexible enough to taken any desired bend without breaking.
10. **Dimensional Test:** The dimensions of the various components of cables such as thickness of insulation or sheath, diameter or thickness of armour wires etc, have been specified on the basis of voltage stress and or mechanical force the cable is expected to withstand in service. Measurement of such dimensions determine their limitations to ensure that the requirement of the specifications are full met.
11. **Tensile Strength and Elongation at Break of thermoplastic and Electrometric Insulation and Sheath:** During the process of manufacture and during insulation electric cables are unavoidably subjected to mechanical stresses particularly bending. Thermoplastic or Electrometric insulation and sheath in the cable are also subjected to these stresses and strains.
12. **Tensile Strength and Elongation at Break of Armouring Materials:** During laying, cables are pulled from one end along trenches. In certain type of installations, cable in mine shaft, bridges, vertical runs, etc., the cables, by virtue of there supporting methods, are subjected to permanent tensile stress.
13. **Torsion Test on Galvanised Steel Stripes for Armouring:** During the armouring process and subsequently during laying of the cables, the armour wires are subjected to tensional stresses. This test evaluates the torsion resistance of the wires.
14. **Winding Test on Galvanised Steel Stripes for Armouring:** These tests one to ensure that the Zinc coating sufficiently adherent on to the basic.
15. **Bending Test:** All electric cables are subjected to bending operation during handling and installation. The minimum radii are specified in the relevant specifications.

16. **Thermal Test:** The major tests covered in this category are Loss of Mass Test, Thermal Ageing in air, Shrinkage Test, Ozone Resistance Test, Heat Shock Test, Hot Deformation Test, Cold Bend Test, Cold Impact Test, Hot Set Test, Heating Cycle Test and Flammability Test.

Recommendations for installation of cables: Following are some of the related points which should be kept in view during installation of cables. For detailed reference in 1255 should be referred.

1. Before laying, the insulation of the cable should be checked with meggar on a preliminary check against any probable damage. The cable end should be plumbed back after checking.
2. The drum should be always rolled in the "direction of rolling" marked on the drum. In the absence of any such mark, the drum should be rolled in the direction same as that of that of inside end of the cable and opposite in that of the outside end.
3. Where the cable is to be joined with an existing cable, the sequence of cores at the two ends to be joined should be in the opposite direction, i.e. if at one end it is the clockwise direction, at the other end it should be in anticlockwise direction.
4. The minimum bending radius for cable should not be less than the value as recommended in IS 1255 and whenever possible 25% higher values should be adopted.
5. When the cable are necessarily laid and joined in very cold region, both the cable and the ambient temperature should be above 0°C and have remained so for previous 24 hours. If necessary cables can be warmed up to reduce the stiffness of insulating compound. During such conditions the cable should also not be bent to very small radii.
6. Single core cables should be transposed at joints which in turn should be clearly marked to indicate circuit and phases.
7. Accessories and Jointing Materials: Jointing materials and accessories like conductor ferrules, solder, insulating and protection tapes, insulating compound, protective filling compound, lead or copper sleeves, joint boxes etc. of right quality and sizes should be procured.
8. Unless unavoidable, the cables should be joined core to core having the same identification number or colour. Core should not be crossed while jointing.
9. Before jointing, paper insulation near to conductors and lead sheath should be tested for moisture bt immersing pieces of paper tapes one by one in hot insulating compound or paraffin wax at temperature 120° to 140°C.
10. Earthing: All joints, terminations, lead sheath and armour wires should be connected to earth. Precautions should be taken to prevent chemical bimetallic corrosion of earth connectors and clamps.

11. Testing After installations: Immediately after laying and jointing is completed.

Introduction to Maintenance

Maintenance is a process of keeping machinery in good running condition. Good maintenance keeps the efficiency of the machine high. Maintenance process differs from machine to machine. The process has to be scientifically designed.

The benefits of good maintenance are:

- Enhanced life of the equipment
- Higher efficiency
- Higher output of the equipment
- Improved safety conditions for operating personnel
- Less pollution
- Satisfaction

3.1 Types of Maintenance, Maintenance Schedules, Procedures

3.1.1 Maintenance Objectives:

- Maximising production or increasing facilities availability at the lowest and at the highest quality and safety standards.
- Reducing breakdown and emergency shutdown.
- Optimising resources utilization.
- Reducing downtime.
- Improving spares stock control.
- Improving equipment efficiency and reducing scrap rate.
- Minimising energy usage.
- Optimising the useful life of equipment.
- Providing reliable cost and budgetary control.
- Identifying and implementing cost reductions.

3.1.2 Types of Maintenance

(a) Run to failure Maintenance (RTF)
(b) Preventive Maintenance (PM)
(c) Corrective Maintenance (CM)
(d) Improvement Maintenance (IM)
(e) Predictive Maintenance (PDM)

(a)Run to failure maintenance (RTF): The required repair, replacement, or restore action performed on a machine, or facility to at least its minimum acceptable condition. The oldest type of maintenance subdivided into two types.

1. Emergency maintenance
2. Breakdown maintenance

Disadvantages:

1. Its activities are expensive.
2. Using this type of maintenance, the occurrence of a failure in a component can cause failure in other components.
3. Its activities are very difficult to plan and schedule in advance.

This type of maintenance is useful in the following situations:

i. The failure of a component in a system is unpredictable.
ii. The cost of performing run to failure maintenance activities is lower than the performing other activities of other types of maintenance.
iii. The equipment failure priority is too low.

(b) Preventive Maintenance (PM): It is a set of activities that are performed on plant equipment, machinery, and system before the occurrence of a failure.

Advantages

- The factors that affect the efficiency of this type of maintenance
- The need for an adequate number of staff in the maintenance department in order to perform this type of maintenance.
- The right choice of production equipment and machinery that is suitable for the working conditions.
- The required staff qualifications and skills, which can be gained through training.
- The support and commitment from executive management to the PM programme.
- The proper planning and scheduling of PM programme.
- The ability to property apply the PM programme.

Preventive maintenance is further subdivided into different kinds:

i. **Routine maintenance** which includes those maintenance activities that are repetitive and periodic in nature such as lubrication, cleaning, and small adjustment.
ii. **Running maintenance** those activities that are performed before the actual preventive maintenance activities take place.

(**c) Corrective Maintenance (CM):** In this type, such as repair, replacement, or restore will be carried out after the occurrence of a failure.

This type of maintenance is subdivided into three types:

i. **Remedial maintenance:** Which is a set of activities that are performed to eliminate the source of failure without interrupting the continuity of the production process.
ii. **Deferred maintenance:** Which is a set of corrective maintenance activities that are not immediately initiated after the occurrence of a failure but are delayed in such a way that will not affect the production process.
iii. **Shutdown corrective maintenance:** Which is a set of corrective maintenance activities that are performed when the production line is to total stoppage situation.

The ways to perform corrective maintenance activities is by conducting four important steps:

- Fault detection
- Fault isolation
- Fault elimination
- Verification of fault elimination

Corrective maintenance has several prerequisites in order to be carried out effectively.

- Accurate identification of incipient problems.
- Effective planning
- Proper repair procedure
- Adequate time to repair
- Verification of repair

(d) Improvement Maintenance (IM): It aims at reducing or eliminating entirely the need for maintenance.

i. **Design-out maintenance:** The maintenance point of view by redesigning those machinery and facilities which are vulnerable to frequent occurrence of failure and their long term repair or replacement cost is very expensive.

ii. **Engineering services:** Which includes construction and construction modification, removal and installation, and rearrangement of facilities.

iii. **Shutdown improvement maintenance:** Which is a set of improvement maintenance activities that are performed while the production line is in a complete stoppage situation.

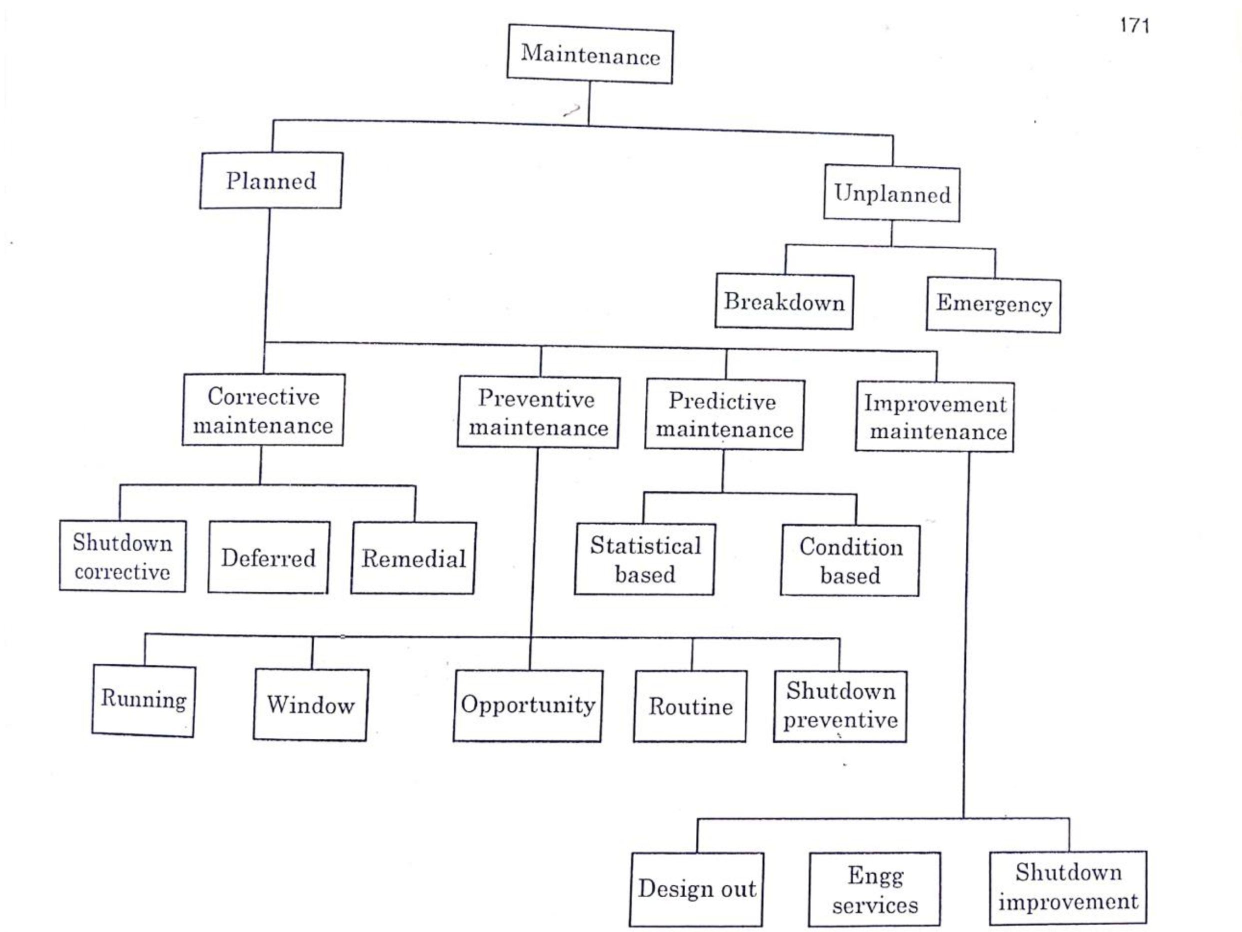

Chart 3.1 : Types of Maintenance

(e)Predictive Maintenance (PDM): Predictive maintenance is a set of activities that detect changes in the physical condition of equipment in order to carry out the appropriate maintenance of work. It is classified into two kinds.

- **Condition-based predictive maintenance**: It depends on continuous periodic condition monitoring equipment to detect the signs of failure.
- **Statistical-based predictive maintenance:** It depends on statistical data from the meticulous recording of the stoppage.

Advantages

- Increased component operational life/availability.
- Allows for pre-emptive corrective action.
- Decrease in equipment or process downtime.
- Decrease in costs for parts and labour.
- Better product quality.
- Improved worker and environment safety.
- Improved worker morale.
- Energy savings.
- Estimated 8% to 12% cost savings over preventive maintenance program.

Disadvantages

- Increased investment in diagnostic equipment.
- Increased investment in staff training.
- Savings potential not readily seen by management.

3.2.1 Authorized Persons, Danger Notice, Caution Notice, Permit to Work, Arranging of Shut Downs, Temporary Earths Cancellations of Permit, Restoration of Supply

Procedure for permit to work (Line Clear): A line clear is a permit to work on any electrical equipment or line. It is issued by an authorized person to another authorized person.

Procedure before issue of line clear

i. Approval of the competent authority for shut down of line/equipment should be verified.
ii. Line/equipment shall be switched off.
iii. No back feed certificates, wherever necessary shall be obtained.
iv. The issuer should personally see and ensure that all the blades of the AB switch are physically in open condition and locked.
v. The line/equipment shall be earthed by discharge rods.
vi. A ‘danger do not operate’ board should be exhibited on the concerned control panel and ‘men on line’ board should be exhibited on the outdoor AB/switch//equipment.

vii. All operations for issue of line clear should be done personally by the issuer.
viii. After following all the precautions the line clear book should be filled up carefully without leaving any column left unfilled.

Responsibilities of the receiver

i. The receiver should very clearly indicate the specific equipment/line which he wants to work when requisitioning for L.C. (line clear)
ii. If the receiver is at the same place as that of the issuer he should follow all the operations being conducted so as to ensure that line clears are being issued on the correct line/equipment.
iii. At the work spot, after receiving line clear, he should earth the line/equipment on either side of the work spot.
iv. In case if any other power lines are crossing near to work spot of the line on which LC is received he should also obtain LCs on all such line to avoid induction.
v. He should write down on the duplicate form the number of persons engaged on the work.

Rules to be followed when returning of LC

i. The persons who have received the LC only should return it.
ii. He should personally ensure that there are no men, material or earth on the line.
iii. He should inform all the workmen that it is no longer safer to work on the line as the line clear is being returned.
iv. The line/equipment should not be charged until the LC is cancelled.

Before cancellation of LC the following precautions should be taken.

i. The returned LC should be carefully examined. It should be ensured that all the certificates required are furnished.
ii. ‘Men on Line’ danger do not operate boards should be removed.
iii. It should be ensured that no other LC is pending. All men material removed; Earthing is removed.
iv. All no back fed certificates should be returned.
v. After charging the line/equipment check should be made for unusual sound/noise.
vi. All the workmen/supervisor should be permitted to leave the work spot only after the normalcy is restored.

3.2.2 Patrolling and Visual Inspection of Lines

Visual Inspection: A visual inspection of the electrical installation, which is not concealed is carried out prior to any testing. The inspection shall include a check on the condition of all electrical equipment and material and will take the following factors into account.

1. Safety
2. Wear and tear
3. Damage and corrosion
4. Overloading and overheating
5. Suitability and age
6. External influences
7. It shall be established that such circuit is adequately protected with the correct type and rating of fuse or circuit breaker.
8. The insulation and sheath of each conductor at a sample of termination points shall be inspected to determine its condition and correct installation.

The tree clearance shall be done, and all the minor defects like

1. Damaged insulator
2. Improper pin binding
3. Loose jumpering
4. Loose stays shall br rectified during the inspection itself.

3.2.3 Special Inspection and Night Inspections

The overhead lines should be inspected regularly for maintenance purposes in order to detect the faults witch may ultimate lead to breakdown of the lines, then by causing extensive damage to power supply. The cost of maintenance increases many fold is a major breakdown occurs in addition to loss electrical power supply to major electrical installation leading to production shutdown and disruption in emergency electrical services.

Patrolling of Overhead Lines: All overhead lines should be patrolled periodically at intervals of three months. In case of heavy show fall or thunderstorms it should be checked immediately for major breakdown.

Inspection of Over Line from Top: Special and emergency inspection as written below should also be carried out when over required.

i. Measurement of earth resistance
ii. Measurement of insulation resistance

iii. Measurement of strength of all supporting structures like cross across etc.
iv. Measurement of clearness in shape of jumpers.
v. Measurement of minimum clearance required of the lowest portion of overhead ACSR conductor.

3.2.4 Effect of Open or Loose Neutral Connections

Effect of open or loose neutral connections: Neutral wire is required for saking a closed path for operating any circuit. If the neutral wire gets open circuited then the circuit continuity gets broken and the appliances will stop working.

Identification of open neutral : If it is noticed that an outlet or perhaps a light switch that is not working, but other devices in the same room are, then it may be because of an open neutral, In order to verify this one needs to remove the plate that covers the wiring for that outlet.

Causes: The neutral wire could potentially disconnect from the receptacle for to a few reasons. One reason can be due to disturbance form vibrations.

Safety Concerns: The purpose of the neutral wore is to return the current from the device back to the source of the source of the electricity. If the neutral wire is not connected, or "open," it will allow a potentially large charge to be stored in the device it's connected to. If this is the case and if anybody touching that device would be electrocuted.

Ground and neutral: Since the neutral point of electrical supply system is often connected to earth ground, ground and neutral are closely related. Under certain conditions, a conductor used connect to a system neutral is also used for grounding (earthing) of equipment and structures.

Correct polarity : If a single-pole switch or fuse is connected in the neutral of the system rather than in the phase, a very dangerous situation may result as illustrated in fig.

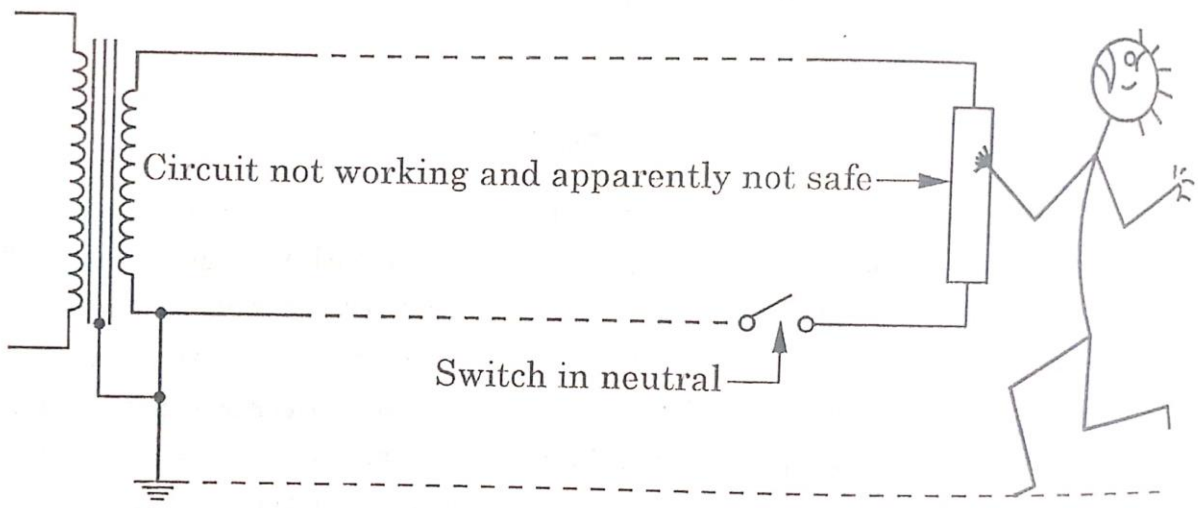

Fig 3.1 : The Danger of Breaking the Neutral of a Circuit

Special care in checking polarity is necessary with periodic tests of installation already connected to the supply, which must be switched off polarity testing. It is necessary to confirm correct connection of supply phase and neutral. Should they be transposed, all correctly-connected single-pole devices will be in the neutral, and not in three phase conductor.

3.2.5 Provision of Proper Fuses on Service Lines and their Effect on System

All the service lines provided whether overhead or underground are provided proper fuses. A simple circuit diagram showing overhead services connection to domestic supply is shown in fig.

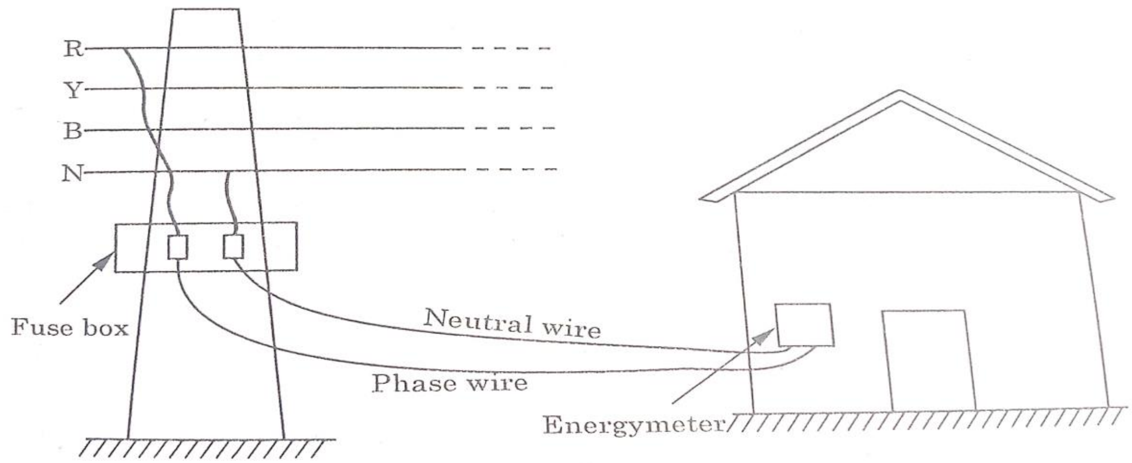

Fig. 3.2 : Service Connection to Domestic Installation

All the service connection are provided with proper fuses so that in case of a fault within the zone between fuse box and energy meter the supply through the main line being supplied remains infect by blowing of the fuse wire and the electrical prefect the main line from getting damaged.

3.2.6 Causes of Dim and Flickering Lights

The cause of dim or flickering lights can be because of partially open connection providing varying resistance and therefore intermittent voltage drop. This can be because of following reasons.

i. Bad terminal connection
ii. Burned or broken wire
iii. Bad or burned wire splice
iv. Bad or burned light switch
v. Bad breaker etc.

3.3 Maintenance of Distribution Transformers

3.3.1 Transformer Maintenance, Checking of Insulation Resistance

The insulation resistance with the help of Meggar. The insulation is completely dried up and all the moisture present is removed. The resistance of the insulation depends upon the temperature at which the test is being performed. For class A insulation the insulation resistance get halves for every 10c rise in temperature. The minimum value of insulation resistance is 2MQ for each thousand volt operating voltage at 60c temperature. The voltage generated by the generator during measurement of the value should be steady.

The insulation resistance value is low initially while measuring with Meggar but rises to high value as the windings gets fully charged and shows the correct reading of the insulation resistance.

3.3.2 Checking of Transformer Oil Level

The oil level of the transformer is checked by looking at the level indicated in the printed scale on the glass installed at the conservator tank. The conservator tank should always be full of oil so that the oil which providing cooling effect to the temperature rise due to current carried by windings also provides insulation between the two windings of primary and secondary as well as between core and winding.

3.3.3 BDV Test of Oil

Breakdown voltage test is conducted on the transformer oil to measure its dielectric strength. The test is performed on a standard oil test set. The sample oil is taken and laced between two electrodes of specified dimensions as per relevant is standard. The gap between these electrodes is usually kept at 2.5 mm. The voltage applied across these electrodes is gradually increased till a flash over takes place. The voltage level at which flash over takes place is the dielectric strength of the oil.

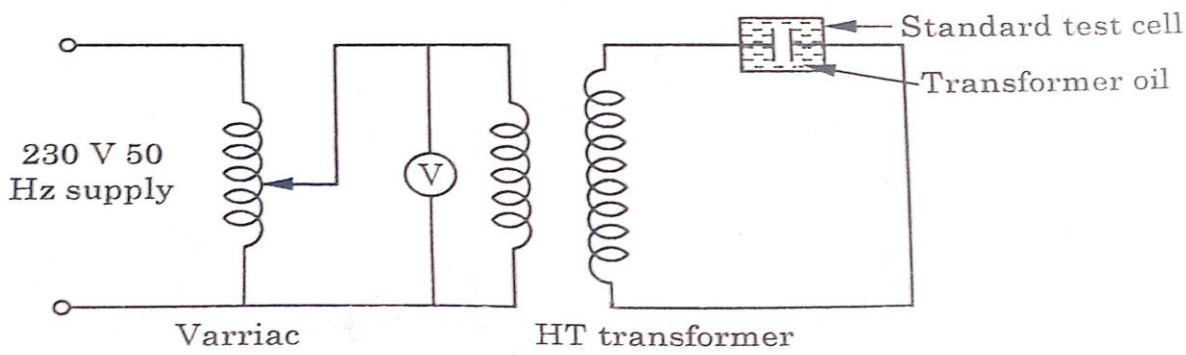

Fig. 3.3 : BDV test

3.3.4 Measurement of Earth Resistance

Full of potential method with an earth Meggar. The earth meggar is used for the measurement at earth electrodes or earthing system of small or medium extent such as single rod earth electrodes, strip earth electrodes. The earth electrodes, the probe and auxiliary electrode should all lie in a straight line as far apart as possible. The distance of the probe from the earth electrode tested should be at least 2.5 times the maximum extension of this electrode but not less than 20 m. the distance between the probe and the auxiliary should beat least 4 times the maximum extension of the electrode tested but not less than 40 m.

(Prepared By: Mr. Ashok Saini , Assistant Professor , ECE)

3.4 MAINTENANCE OF GRID SUBSTATION

3.4.1 Checking and Maintenance of

(i) Isolating switches

Table 3.2 : Maintenance Schedule for Isolators

S. No.	Work to be carried out	Periodicity	Action required if inspection shows unsatisfactory condition
1.	Isolator to be disconnected from the system and both ends earthed. Clear the salt, cement or the acid fumes if accumulated on the surface of the insulators. Clean the insulator thoroughly	3 Months	—
2.	Examine the contacts, inspect contact surfaces for correct alignment, any mark of corrosion or any abnormality.	– do –	If deep pitting or burning of contacts is found. the contacts should be immediately replaced. In case of minor pitting, contact surface should be smoothened with sand paper.

S. No.	Work to be carried out	Periodicity	Action required if inspection shows unsatisfactory condition
3.	Check the tightness of bolts, nuts, washers, cotter pins and terminal connections. The operating rods should be cleaned and lubricated. Check for simultaneous closing of all blades and making of contact fully in the closed condition of the isolator.	6 Months	—
	MECHANISM		
4.	Lubricate output shaft bearing, auxiliary switch linkage, pin of emergency handle guard.	1 Year	Fill up oil if required (only recommended lubricants should be used).
5.	Apply a thin film of contact lubricant to auxiliary switch contacts.	—	Replace the auxiliary contact if found defective.
6.	Check electrical components, ensure contactor operates freely. Check all electrical connections, fixing bolts, split pins etc. Check up functioning of all auxiliary relays inside the mechanism.	– do –	Remove and replace if any item is found defective.
7.	Check IR values of driving motors	– do –	—
8.	Measure contact resistance of each pole by passing DC current	– do –	Compare with test values and if high, adjust the contacts and contact pressure,
9.	Check pick-up values of operating coils.	– do –	Replace if necessary.
	EARTH SWITCH :		
10.	Check the tightness of earth connections, bolts, nuts, washers etc. The operating rods to be cleaned and lubricated.	6 Months	Tighten, if any bolt/nut is noticed loose.
11.	Clean the surface of insulators thoroughly to avoid possibility of flash over.	6 Months	Clean the surface with soft dry wiping rags, wet or paraffin soaked cloth. If these methods are ineffective, 10% strong HCL can be used. In this, necessary precautions for its use may be observed.

S. No.	Work to be carried out	Periodicity	Action required if inspection shows unsatisfactory condition
12.	Examine contacts, inspect contact surfaces for correct alignment, corrosion mark or any other abnormality.	-- do --	Remove and replace in case any contact is found damaged.
13.	Check for simultaneous closing of all blades and complete making of contact in the closed condition. Ensure that earth switch does not close when isolator is in closed condition	– do	---
14.	Check the working and alignment of auxiliary switches.	– do –	If necessary, make adjustments.
15.	Check mannual working of the isolator with hand lever.	– do –	---

(*ii*) HT/LT Circuit breakers

Table 3.3 : Maintenance Schedule for Minimum Oil Circuit Breakers

S. No.	Work to be carried out	Periodicity	Action required if inspection shows unsatisfactory condition
1.	Checking of oil level in each interrupter	Weekly	If the oil level is low, top up the oil
2.	Checking of visible oil leaks	– do –	If any oil leakage is observed attend to the same.
3.	Checking of heater function	3 months	Replace the damaged/defective heater
4.	Visual inspection of breaker and operating mechanism	– do –	Replace the damaged/broken parts, fix the loose parts properly. Exposed metal parts should be protected by a thin coating of rust preventing oil/grease after defrosting. If dust collection is excessive cleaning with non-fluffy cloth at the earliest opportunity is essential. For removing oil/grease and carbon deposit, use Acetone.

S. No.	Work to be carried out	Periodicity	Action required if inspection shows unsatisfactory condition
5.	Checking of breaker operation and removal of coating developed on current carrying parts	– do –	Breaker should be operated electrically from local and remote controls a few times on no load with isolators on both sides open. Tripping of breaker with mechanical push button should be checked. In this process any coating developed between the sliding surfaces will get removed.
6.	Cleaning of Porcelain bushings	– do –	Clean the bushings. Period may be reduced in case of highly polluted atmospheric conditions.
7.	Checking of oil leakage from oil dash pot in operating mechanism	– do –	Replace the damaged/ defective O-rings in the event of any oil leakage.
8.	Checking of dielectric strength of oil	Quarterly or after 4 major or 10 medium or 1000 interruptions at rated normal current	Filtering/replacement of oil is essential if withstand value is less then 40 KV.
9.	Checking of contacts burning.	– do –	If burning slight, removing the burn beads and polishing the surface are sufficient. Replace the tips and arcing ring when burning is heavy. Make sure that the contact surface at the joint is clean and loosening and tightening of tips a few times before final tightening is done.
10.	Checking of extinguishing chamber.	– do –	Extinguishing chamber should be removed from the breaking unit and rinsed with transformer oil keeping the rinsed with transformer oil keeping the chamber 'upside down'. If the condition of any part indicates severe burning dismantle the chamber replace the burnt/damaged parts.

S. No.	Work to be carried out	Periodicity	Action required if inspection shows unsatisfactory condition
11.	Cleaning and lubricating	Yearly	Clean the mechanism, base frames and link boxes (inside and outside) with non-fluffy cloth. Rust should be removed from the metal surfaces and unpainted steel surfaces should be smeared with grease of the grade recommended by the breaker manufacturer. The interrupter heads and insulators should be cleaned with non-fluffy cloth, oil, grease and carbon deposits be removed with Acetone. Lubricate all the points provided with grease nipples in the mechanism and breaker with grease of the grade recommended by the breaker manufacturer. Gear wheels should also be lubricated with the same grease, avoiding excessive lubrications. Care should be exercised to keep the friction clutch free from lubricants. Sliding parts, catches, rollers and operating magnets should be lubricated with the recommended lubricating oil.
12.	Checking of locking elements of the rod system, outer mechanism (on interrupter) and in the operating mechanism.	– do –	Replace the damaged locking elements with new ones. During assembly after overhaul all the locking elements coming in the moving Parts should be replaced even though they are not damaged.
13.	Checking/tightening of foundation bolts and all hardware in breaker and mechanism.	– do –	Satisfactory movement of links and arms should be checked after tightening the fixing bolts by slow operation. Remove earth connection before taking the breaker into service.
14.	Checking of control dimensions in a closed breaker.	– do –	If the control dimensions are deviating from the given values, corrective action should be taken by adjusting the gap with the help of the pull rods.

(iv) LT Switches

Table 3.5 : Maintenance Schedule for Lightning Arresters

S. No.	Work to be carried out	Periodicity	Action required if inspection shows unsatisfactory condition
1.	Reading of the surge counter	3 Months	Normal counting rate is 0 – 5 counts a year. More than 10 counts is abnormal but can be explained with a lot of known switching operations or increased contamination. In case of contamination each the arrester as soon as possible. Counts of the order of 100 per year indicate low spark over voltage due to internal arresters faults. In such cases the arrester have to be changed. But before replacing the L.A; health/correctness of the surge counter must be established.
2.	Cleaning of the surge arrester	6 Months	—
3.	Measurement of insulation Resistance	– do –	Measure insulation resistance after cleaning the surface of the insulater. The basic value should be more than 1000 M ohm with a 1000 V Megger. Any value below this should be deemed to be abnormal.
4.	Measure Earth resistance and check earth connections.	– do –	—
5.	Grading current measurement. Measure the grading current in the following ways :	Yearly	A change of grading current of more than 50% (at constant voltage) indicates faulty arrester which should be changed.
	(i) Check with current leakage meter.		
	(ii) In case current leakage meter is not available, connect a high ohmic (≥ 1 M. ohm) voltmeter across the surge counter which constitutes a capacitive shunt. The voltage to be measured is of the order of a few volts and is proportional to the grading current. However, a faulty surge counter may give rise to voltages of some KV at the arrester side of the surge counter. Therefore, always connect the voltmeter to the surge counter terminal with an insulated stick. Comparison		

S. No.	Work to be carried out	Periodicity	Action required if inspection shows unsatisfactory condition
	of this value should be made with the earlier measurements from the same arrester. Individual diverter may show great variations in grading current at normal phase voltage. For comparison of measured values always note the type of instrument used. The non-linear grading resistors cause great variations of current for small variations of current for small variations of line voltage. Therefore also note the actual line voltage and compare the grading current measurements at the same line voltage (a voltage change of 10% may cause current variation between 10-40%).		

(v)

Table 3.6 : Maintenance Schedule for Power transformers

S. No.	Work to be carried out	Periodicity	Action required if inspection shows unsatisfactory condition
1.	Check winding temp rise	hourly	Shut down the transformer and investigate if these are persistently higher than normal.
2.	Check oil temp. rise	– do –	
3.	Check load (Amperes)	– do –	Take remedial measures if values are above normal.
4.	Check voltage	– do –	
5.	Check oil level in transformer	daily	If low, top up with dry oil, examine transformer for leaks.
6.	Check relief vent diaphragm	– do –	Replace if cracked or broken.
7.	Check colour of active agent in dehydrating breather	– do –	If silicagel is pink, change by spare charge. The old charge may be reactivated for use again.
8.	Check indicating lamps and working of alarm/bazzar	– do –	Replace lamps if fused.
9.	Check oil level in bushings	monthly	If low, bring it to the correct oil level.
10.	Check N tank pressure and its leakage (if applicable)	– do –	If N pressure low, check leakage and recoup N pressure.
11.	Check oil level in oil cup of dehydrating breather.	– do –	Top up oil if required.

S. No.	Work to be carried out	Periodicity	Action required if inspection shows unsatisfactory condition
12.	Examine bushings for cracks and dirt deposits.	quarterly	Clean or replace.
13.	Check for dielectric strength and water content of oil in transformer and top changer.	– do –	Take suitable action to restore quality of oil.
14.	Check earth resistance	– do –	Take suitable action if earth resistance is high.
15.	(*a*) Check cooler fan and pump bearings, motors and operating mechanisms.	Half yearly	Replace burnt or worn out contacts or other parts.
	(*b*) Testing/Maintenance of oil cooler	– do –	
16.	Check control circuits independently half of onload tap changer driving yearly mechanism.	Half yearly	If faulty, take suitable action to set these right.
17.	Inspect all moving parts, contacts, brake shoes, motor etc. of onload tap changer driving mechanism.	– do –	Clean, adjust or replace as requred.
18.	Check insulation resistance	Yearly	Take remedial measures
19.	Check oil in transformer as per IS : 1866-1983 for following tests : 1. BDV 2. PPM 3. resistively 4. Acidity 5. Tan delta	Yearly (or earlier if T/F can conveniently be taken out for checking)	Filter or replace
20.	Test oil in oil filled bushings	– do –	Filter or replace
21.	Check gasketed joints	– do –	Tighten the bolts evenly to avoid uneven pressure
22.	Check relays, alarms, their circuits, AC/DC fuse, links etc.	do –	Clean the components or replace contacts and fuses, if necessary. Adjust the setting, if necessary
23.	Check pockets of temperature indicators	– do –	Oil to be replenished, if required.
24.	Check dial type oil gauge	– do –	Adjust, if required
25.	Inspect paint work	– do –	Any painting or retouching should be done, if necessary.

S. No.	Work to be carried out	Periodicity	Action required if inspection shows unsatisfactory condition
26.	Cleaning of arcing horns and checking clearance	– do –	Set the clearance if required
27.	Check operating of pressure relief valve, if applicable	Yearly	Set the value ckt. if required
28.	Check contacts of diverter switch of tap changer having non-arcing selector switch	– do –	Replace worn out parts
29.	Mechanical Inspection of Buchholz relays	Two Yrs.	Adjust floats, switches etc.
30.	Internal inspection of oil conservator	– do –	Should be thoroughly cleaned and gears of float arm and MOG set right..
31.	General inspection of non-arcing selector switch of on-load tap changer	3 Yrs or after 15,000 operations	Replace worn out parts, filter oil.
32.	Dissolved gas Analysis of oil	5 Yrs.	In case of excessive gas, analyse fault and rectify defect. Also subject oil to vacuum to bring Dissolved gas to accepted levels. Periodicity of this test may be reduced to one year after 15 years of service.
33.	Overall inspection including lifting of core and coils	7 to 10 Yrs.	Wash the winding and core with clean dry hot oil. Tighten all bolts, nuts, coil clamping screws.

3.5.1 Overhauling of Motors

1. **General Procedure for Overhauling of ac Motors:** Clean the motor with compressed air and inspect the following.
   a) **Condition of the coupling**
      - Coupling condition.
      - Check nut threads, fan fitness and seating.

   b) **Condition of foundation legs for foot mounted motors**

   c) **Rotate the motor by hand and observe the following**
      - Rotor moves freely or jammed
      - If the rotor is rotating with a sound then the source of sound has to be identified. The defective bearing or fan or some other loose part touching somewhere may be responsible for the abnormal sound.

d) **Coupling Removal:** Remove the coupling by coupling puller or hydraulie jack as per standard practice adopted in the plant.

e) **Inspection** After coupling removal, inspect and rectify the following

- **Condition of the shaft** If it is worn out then suitable repair action has to be taken.
- **Condition of the coupling and the key** If the inner surface of the coupling bore has been worn-out then the coupling has to be replaced.
- **Condition of the keyway** If the keyway is oversized then the same has to be repaired.

f) **Dismantling of the Motor**

- Dismantle the motor mounted blower or air-to-water heat exchanger where provided.
- Remove the non-driving end cover of the motor.
- Unscrew the loading screw of the fan then pull out the fan by suitable puller rod arrangement.
- Take out the outer dust seal.
- Remove the outer grease cup.
- With slight heating, the inner grease retaining ring has to be taken out.
- Unscrew the fixing bolts and take out the cover.
- Before removal of rotor it has to be seen that there will be no obstruction. If there is any internal cooling fan them it has to be removed.

g) **Removal of Rotor** Depending on the size and weight of the rotor and the facilities available, one of the following method may be applied.

- Use of a balance beam and suitable ratchet hoist.
- Use of two hooks of the crane and two pipes at both the ends.
- Use of single pipe in cantilever manner with manual labour to balance the weight of the armature at one end of the pipe.
- Use of moveable screw jack.

Inspection of Stator:

The following visual inspection has to be done and suitable repair action has to be initiated

- Condition of the Stator winding- if it is burnt. Repair or replace any damaged winding.

- Looseness of the cages of the slots and stiffeners of the overhang of the windings.
- Inspect carefully the high voltage terminal board with special emphasis on the terminal bushings.
- Condition of lead- Check the insulation condition of the outgoing leads from the windings particularly with respect to brittleness.
- Condition of end cover fixing, threaded holes & lifting hooks or eye bolts. Check the condition of legs.

Inspection of Rotor

- Check for any rubbing marks on the body
- Check the dimensional accuracy of bearing seat and coupling seal
- Check the rotor visually for any breakage in bars end rings and laminated core.
- It is always preferred to conduct growler test on the rotor to ensure its soundness
- Check looseness of balancing weights
- Looseness of bars in the cage & condition of S.C. ring

h) **Bearing Checking** Clean the bearing thoroughly with diesel/kerosene oil and check for its soundness. If found defective it has to be replaced with a new.

i) **Checking of Cooling System:** The cooling arrangement, either a cooling box separately attached or cooling water circulation tubes in case of water cooled stators should be thoroughly checked for any leakage at joints and jacket.

j) Inspect the end covers for mechanical soundness with special emphasis on the bearing housing. Any groove or change of dimensions has to be suitably repaired.

k) Inspect other parts namely grease cups, fans and other fittings for their mechanical soundness.

l) **Electrical test:** The electrical tests can be divided into two parts namely routine test and special test. Routine tests are carried out in all stators irrespective of its defect status whereas special tests are done for only repaired stator or for any specific defect.

3.5.2 Preventive Maintenance

The purpose of preventive maintenance is to avoid breakdown during the running of the plant. All motors are required to be overhauled from time to time in accordance with the

Plant Preventive Maintenance Schedule. The frequency of such overhauling and maintenance depends on the conditions under which the machine operates and as recommended by motor manufacturer.

Prior to dismantling of large motors, the defect reports generated during inspection should be compiled and the abnormalities and defects should be properly attended during maintenance.

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