Unit 4

Repair and Maintenance of Power Distribution Lines

171176CH04

Introduction

Repair and maintenance of lines is very important for uninterrupted supply of electricity. Maintenance is done primarily twice a year, once before monsoon and the next is done after monsoon to see if any breakdown has occurred in the line. Line patrolling, maintaining ground clearance, replacement of insulators, restringing of lines, replacement of burnt jumpers, replacement of damaged conductor, replacement of damaged pole, etc. are some of the cheeks performed during maintenance. Proper maintenance of line improves its life drastically.

Session 1: Preparation for Repair and Maintenance of Power Distribution Lines

Materials and Accessories used in Power Distribution

In this section, we will discuss some materials and accessories used in power distribution.

Poles (Supports)

The poles or supports are classified according to the material used for it:

- Steel
- Cement
- Wood

Fig. 4.1 Tubular Poles

Steel poles are further classified as follows

Rail Poles: These can be of L shape, rail type and tubular shape. They are better than R.C.C. poles, light in weight and cheaper in cost. The poles are affected by atmospheric moisture, rains, etc. Hence they are always painted or coated with chemicals to avoid rusting. These are normally used for 33kV lines.

Tubular Poles: Tubular poles are either of swaged section (built up sections) or stripped single unit type (jointless one casting). The action of wind pressure is very low because of their circular section as compared to plain section R.C.C. poles and can be erected easily by digging pits of diameter or section slightly greater than the pole's diameter. These are normally used in hilly areas (Fig. 4.1).

Fig. 4.2 RCC Poles

Cement poles are further classified as follows

R.C.C. poles: These poles are made by reinforcing (i.e. embedding) steel rods into concrete slabs of pole shaped cylinders. These poles are of permanent nature, have a long life, remain unaffected by rain, sunlight, etc. and are heavy in weight due to the presence of concrete and steel (Fig. 4.2).

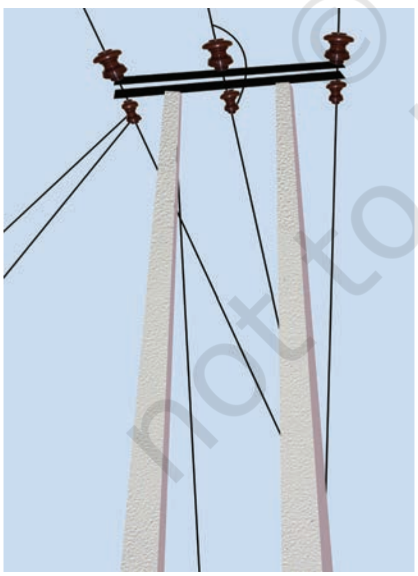


Fig. 4.3 PSC Poles

P.S.C. poles: Pre-stressed cement concrete poles are essentially made of concrete. A frame of high tensile steel wire is inserted into a mould and stretched to a certain level. Galvanised wire is used as earth wire inside the mould. A right proportion of concrete mix is poured in the mould and a vibrator is used to compress the concrete to produce high strength PSC poles (Fig. 4.3).

Wooden poles

Wooden poles are light in weight and cheap in comparison to all other types of poles, made up of wooden beams. These are easily affected and spoiled by atmosphere, rain water, white

NOTES

ants, soil moisture, etc. Therefore, they are used for temporary work and are coated with special chemical for permanent installations. The common impregnating material (coating) used is Creosote. These poles are normally used in hilly areas.

As per the CEA (Central Electricity Authority) Regulations 2010, Relating to Safety and Electric Supply, Clause 57(2), the supports should have the following minimum factor of safety as given in Table 4.1.

Table 4.1

S. No.	Types of Supports	Factor of Safety
1	Metal Supports	1.5
2	Mechanically processed concrete supports	2.0
3.	Hand moulded concrete supports	2.5
4.	Wooden supports	3.0

An Earthing arrangement is provided with a projected length of 50 mm at both ends of the pole, using 8 S.W.G G.I. wire embedded in concrete. In actual practice, it is convenient to use 8m poles for all purposes (instead of having different sizes) with minor adjustments in spans, if required. This avoids future replacement costs, omission or errors by workmen in transportation and selecting different poles for different locations. The selection of poles for erection of lines depends on a number of factors such as:

- Pole strength
- Type and size of conductor
- Maximum wind pressure
- Maximum line tension
- Snowfall
- Presence of fruit farms
- Guarding
- Different crossings like river, road, railway, telephone lines, etc.

The erection of power distribution lines involves only erection of different types of poles, such as steel, PSC, wooden poles, etc.

Conductors

Fig. 4.4 All Aluminium Conductors

Fig. 4.5 Aluminium Conductor Steel Reinforced

Fig. 4.6 All Aluminium Alloy Conductors

Aluminium conductors of different types and sizes are used for drawing overhead lines, whether they are LT or HT lines. These include:

AAC – All Aluminium Conductors: This type of conductor is made up of one or more strands of hard drawn 1350 aluminium alloy. The AAC conductors are used in low and high voltage overhead lines. AAC is used extensively in urban areas where spans are usually short but high conductivity is required (Fig. 4.4).

ACSR – Aluminium Conductor Steel Reinforced: It is a type of high-capacity, high-strength stranded conductor typically used in overhead power lines. The outer strands are high-purity aluminium, chosen for its excellent conductivity, low weight and low cost. The centre strand is of steel for additional strength to help support the weight of the conductor (Fig. 4.5).

Reinforced Conductors

AAAC – All Aluminium Alloy Conductors: These conductors are made out of high strength Aluminium-Magnesium-Silicon Alloy. These conductors are designed to get better strength to weight ratio and offer improved electrical properties, excellent sag-tension characteristics and superior corrosion resistance when compared with ACSR (Fig. 4.6).

Table 4.2 lists various specifications of different types of conductors used:

Table 4.2 Specifications of Different Types of Conductors

S. No.	Code Name	Nominal Aluminium Area (mm^2)	Equivalent nominal copper area (mm^2)	Stranding & wire diameter in mm of Aluminium (mm)	Stranding & wire diameter in mm of steel (mm)	Breaking load kg.	Weight of Cond. kg./km	Calculated Resistance at 20°C in ohms/ km	Current carrying capacity at 40°C above 30°C ambient temp.
1.	Gnat	25	16	7/2.21		485	73	1.071	85
2.	Ant	50	30	7/3.10		852	144	0.544	135
3.	Squirrel	20	13	6/2.211	1/2.11	771	85	1.394	75

4.	Weasel	30	20	6/2.59	1/2.59	1136	128	0.9289	102
5.	Rabbit	50	30	6/3.35	1/3.35	1850	214	0.5524	150
6.	Racoon	80	48	6/4.09	1/4.09	2746	318	0.3712	202
7.	Dog	100	65	6/4.72	1/4.72	3299	394	0.2792	250

The Gnat and Ant conductors (mentioned in S. No. 1 and 2) are generally used for LT Lines. The other types of conductors (mentioned from S. No. 3 to 7 are all ACSR Conductors and are commonly used on 11kv lines, except Dog conductors. As per CEA Regulations 2010 relating to Safety and Electric Supply, Clause 7, the minimum factor of safety for conductors have to be based on their ultimate tensile strength.

Insulators

Pin Type Insulators: These are commonly used on 11 kV Lines. The pins for pin insulators shall have a stalk length of 135 mm, shank-length of 125 mm and minimum failing load of 2kN. They should be forged. The pin type insulator is secured to the cross-arm on the distribution pole. There is a groove on the upper end of the insulator for resting the conductor. The conductor passes through this groove and is bound by the annealed wire made of the same material as the conductor. Pin type insulators can be of one part, two parts or three parts type, depending upon the application voltage. For example, in 11kV system, one part type insulators are used where the whole pin insulator is one single piece of properly shaped porcelain or glass (Fig. 4.7).

Fig. 4.7 Pin Type Insulators

Shackle Type Insulators: The shackle insulators are used in low voltage distribution lines (LT lines). They are also called spool insulators. These insulators are used to isolate the live conductor from pole and are mounted in every pole of electrical line. These insulators can be mounted either in vertical or horizontal positions (Fig. 4.8).

Fig. 4.8 Shackle Type Insulator

There are two types of shackle insulator fittings— strap type and u-clamp type fittings. Strap type fittings are for dead-end locations. On the other hand, u-clamp type fittings are for tangent locations or for service lines where the load is small. All fittings are to be galvanised.

Fig. 4.9 Disc Type Insulators

Disc Type Insulators: In higher voltage, such as beyond 33kV, it becomes uneconomical to use pin insulator as the size and weight of the insulator becomes more. Handling and replacing bigger sized single unit insulator is a difficult task. Suspension insulator was developed to overcome these difficulties. In suspension insulator, the number of insulators are connected in a series to form a string and the line conductor is carried by the bottom most insulator. Each insulator of a suspension string is called disc insulator because of its disc-like shape. Disc insulators are normally used in 11kV lines for dead-end locations (Fig. 4.9).

Fig. 4.10 Guy Strain Insulator

Guy Strain Insulators: These are only used for guy/stay wires. These are designed to work in mechanical tension or strain, as they are capable to withstand the pull of a suspended electrical wire or cable. The guy strain insulators are used in overhead electrical line. The strain insulator is inserted between stay wire to isolate the lower portion from electricity. It may also be used where a wire attaches to a pole or tower, to transmit the pull of the wire to the support while insulating it electrically (Fig. 4.10).

Pins for Insulators

Pins for pin insulators have to be of single-piece forged. All ferrous parts should be galvanized (Fig. 4.11). Helically formed pin insulator ties used for holding the conductor on the pin insulator have been standardised and should conform to the requirements of IS: 12048-1987. Types and dimensions of pins are as follows:

Fig. 4.11 11 kV GI Forged Pins for Pin Insulators

Table 4.3 Types and Dimensions of Pins

Voltage (kV)	Type	Stalk Length	Shank Length (mm)	Failing load minimum kN
33	Large Steel Head type L 300 N	300	150	10
11	Small Steel Head type S 165P	165	150	5

Guy Assembly

Guy assembly is needed for dead-end and angular locations to counter balance the load on the supports due to pulling of the conductors, so that supports remain straight in vertical position without bending in any direction. They are also provided at mid-span support as a protection against the wind load (Fig. 4.12).

Fig. 4.12 Guy Assembly

G.I. Wire

G.I. wires are used for protective guarding at the crossing of lines with roads, railway tracks, telecommunication lines, etc. These have to be of 3.15, 4 and 5 mm sizes. The wires shall be galvanised with "heavy coating". G.I. wires are used in reinforcement of aluminium conductors in distribution and transmission of electricity. ACSR wire is used for power fencing as this material is most suitable for electric conduction (Fig. 4.13).

Fig. 4.13 G.I. Wires

GO Switches

Gang operated switches or GO switches, as they are commonly called, are switching devices used in overhead power lines. They are called Gang Operated as they are operated in a Gang, all three switches together, using a single mechanism. The gang operated switches are also called Air Break Switches because air is used as the breaking medium. These are normally installed at the pole mounted distribution substation to isolate the transformer from HT line, so that the HT fuse replacement could be carried out for the restoration of supply. The GO switches are used in electrical lines with voltage of 5 kV. They can be mounted vertically or horizontally, and can be motorised and operated from a remote location.

11kV Cross-arms

The following types of cross-arms are used for 11kV Lines:

- **V cross-arms** for tangent locations with clamps are widely used in many electrical transmission lines, for effective and efficient distribution of power. They have the capacity to bear heavy electrical fluctuations and voltages (Fig. 4.14).
- **Double-channel cross-arm** for tension or cut point locations where D.Ps. are used. The conductors

Fig. 4.14 V Type Cross-arms

for the double cross-arm configurations are suspended from an adjustable tie plate which connects the two timber cross-arm members together. The cross-arm can be used to support up to three conductors, one mounted at the centre and one mounted one foot from either end of the cross-arm (Fig. 4.15).

Fig. 4.15 Double-channel Cross-arms

Fig. 4.16 L.T. Cross-arms

- **L.T. cross-arms** have been standardised for horizontal as well as vertical formation of conductor. They have a strong structure and high sensitivity (Fig. 4.16).

L.T. Line Spacers

Clashing of L.T. conductors in the mid-span very often takes place due to sag, wind and longer spans (Fig. 4.17). This results in faults and interruptions. In order to overcome this problem spacers are provided. As per REC Construction Standards two types of spacers are generally used:

- **Spiral** - made from high quality PVC. They should be circular with 13 mm diameter.
- **Composite** - made from poly-propylene in a single mould (except the clamping pieces). They should be rectangular strips of 25 mm × 12 mm dimensions.

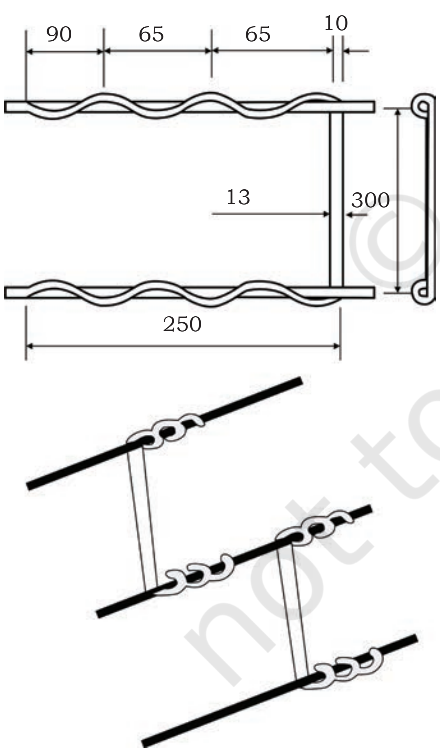
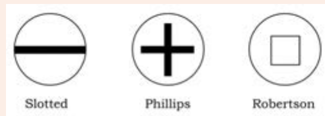


Fig. 4.17 Line Spacers

Fig. 4.18 Vertical Line Spacers

Tools to be used for distribution line maintenance

Name	Function	Image
Screwdriver	Used to turn, tighten or remove screws	 Screwdriver 
Wrenches	Used to allow rotary motion in only one direction and preventing the motion in opposite direction, Used to tighten nuts of various sizes	
Spanner	Used to provide grip to apply torque for turning objects such as nut or a bolt. A spanner with variable diameter to tighten nuts and bolt of various sizes	  Spanner (Top) and wrench (Bottom)

Survey and Right of Way (ROW)

Survey of the Proposed Route of Line

Initial survey should be carried out for construction of new lines. During line survey various type of crossings i.e. highway crossing, railway, river, telephone lines, E.H.V. lines etc. are to be taken into account. It should be seen that telephone line should not be parallel to power line for excessive length. The induction effect on telephone line will cause disturbance to telephone

NOTES

NOTES

communication and even damage equipment. It is necessary to obtain the approval of P and T Department (B.S.N.L.) for route of lines with voltages of 33 KV and above.

Any crossing should be at right angle i.e. 90 degrees, which enables to keep a short span and safe clearance. If possible, highway and railway crossings should be avoided. Railway authority gives permission for overhead crossing only for E.H.V. Lines. Low and medium voltage lines are to be crossed with underground cables.

Before finalising the route, the following parameters should be kept in mind

1. The shortest route possible.
2. As close as possible to the road for easy maintenance and approach during the construction.
3. Route should be in the direction of possible future load.
4. Angle points should be less.

The areas to be avoided as far as possible are

(a) Rough and difficult country side
(b) Urban development area
(c) Restricted access for transport vehicles
(d) Abrupt changes in line routes
(e) Difficult crossing — river, railway lines
(f) Proximity to aerodromes
(g) Natural hazards like steep valleys, hills, lakes, gardens, forests, playgrounds, etc.

The route selected for a distribution line shall be such that it will give the lowest cost considered over a period of years, consistent with accessibility for easy maintenance, etc. This includes many considerations such as original cost, tree trimming and compensation, freedom from vehicular damages, future development and availability for services. Transportation contributes to a major portion of construction cost. Hence while finalising the route alignment, it should be ensured that transportation cost should be as low as possible.

Transport of RCC/PSC poles pose greater problems as they are generally heavier than other types of supports for the same purpose. The RCC/ PSC poles are generally stronger on the longer axis than on the shorter axis. Care should be taken on this aspect while handling, to prevent excessive stressing of the pole at the time of transporting. The unloading of poles from truck or trailer should also be done carefully. Suitable skid boards must be used and on no account, the poles should be dropped. Several utilities have special trucks made with side loading arrangements for pole transportation or trailers should be used. It is preferable to provide a chain pulley block with a beam arrangement in the middle of the truck body to facilitate unloading/ loading of poles. The poles should not be dragged on a rough surface, but transported in small hand-cart.

NOTES

Detailed Survey

The survey of the overhead lines can be broadly divided into two heads:

(a) Preliminary 'Walk Over' survey
(b) Detailed survey

Having provisionally fixed the route, on the survey map, a preliminary 'Walk Over' survey is carried out, before conducting the survey with ranging rods. As far as possible, the line route is taken through areas with minimum tree growth. If there are alternative routes, all such routes are investigated for final evaluation of the most economic route.

Detailed survey can be carried out by the theodolite and angle points can be fixed and marked with survey stones. A route map to a scale of 1cm=0.5km can be prepared showing the various angles, approach roads, near the line, routes detail of railways, communication lines, EHT line crossing, river crossing, etc. But this is not necessary in case of small lines as the local staff usually is conversant with the topography and therefore marking of locations aligning the line with ranging rods is found to be satisfactory.

Right of Way

(a) Once the route of the line is fixed approval has to be obtained,
    (i) from the railway authorities for railway crossings,

Notes

(ii) from the competent forest authorities for routing of the line in forest areas, and

(iii) from the state level Power Tele-communication Coordination Committee (PTCC).

(b) In addition if urban development, airport and similar other areas fall in the route of the line, permission has to be obtained from those departments.

(c) Sometimes private gardens/orchards may fall on the route and require tree cutting. The details of trees are to be marked. Compensation is fixed by revenue authorities and paid to the owner.

Pole Locations

While locating poles on lines, the following general principles are to be kept in mind:

1. Keep spans uniform in length as far as possible.
2. Locate to have horizontal grade.
3. By locating the poles on high places short poles can be used and will maintain proper ground clearance at the middle of the span. In extremely hilly or mountainous areas, poles are located on ridges thereby increasing the spans without greatly increasing the pull on the conductor. This is possible because the sag can be made very large by maintaining the required ground clearance.
4. Poles should not be placed along the edges of cuts or embankment or along the banks of creeks or streams.
5. Cut-point for a section could be at a length of 1.6 km (except in special cases), where double-pole structures should be provided to take tension of the conductors. It may have been already estimated that 10 supports (locations) are mostly required for one km length of H.T. line and 15 supports for L.T. line.

Work permit

Rules regarding work permit and important notices/ information:

- Unless line-clear permit is issued by an authorised person, the worker should not climb on pole or apparatus. No one should go in the vicinity of bare conductor and work.
- Only shift engineer or operation in-charge is authorised to issue permit.
- The line-clear permit should only be issued to a person duly authorised for said work.
- The only competent authority to authorise a worker is the executive engineer of that division or superintending engineer. They should issue authorisation order in writing.
- The permit can only be issued or obtained by those authorised persons for the work and jurisdiction as prescribed in the written authorisation order by the competent authority.
- The written order by the competent authority should invariably be displayed on the notice board at the concerned sub-station, power house and distribution centres in a specific format.
- The consolidated authorisation should be kept at the office of the concerned superintending engineer.
- The superintending engineer (SE) or chief engineer (CE) of Circle/Zone can authorise persons other than stated above such as E.E. (Testing) or testing staff (or any other person who is competent to work in the views of concerned SE/CE).
- The area authority should include the names of such authorised persons in their list. The area officer should obtain the list of authorised persons of bulk consumers and area in the vicinity and also handover his list to them.
- Generally, the line inspector or persons of equivalent post are authorised for working on H.T. line/installations. However, division engineer may authorise the person/persons of lower rank, if he is confident about his skills.

Methods for issuing or obtaining and returning the permit:

- For obtaining line-clear permit, only an authorised person should apply. He should apply for line clear permit to the authorised person

Notes

Notes

only and such authority will issue the permit accordingly.

- Where it is not possible to obtain permit in writing then permit can be obtained on telephone. In such a case, the permit obtaining authority should confirm by repeating the matter with permit issuing authority over phone. The same should be noted in the permit book by both the persons. The duplicate copy of line clear permit after cancellation shall be sent to each other by post or in person as early as possible for record. This register should be inspected by area or divisional Officer from time to time.
- The permit book is an important record and should be preserved properly. The pages of permit book should be numbered serially. Pages from this book should not be taken out or torn or used for any other work. In case any page is torn or taken out by some person due to any reason, then the concerned person should sign on the same and make dated entry in the logbook of sub-station/ power house with signature.
- The person, who has taken the permit, should return it. In case where the permit issuing and obtaining authority is same, the self-permit should be taken in his name and cancelled after completion of work. This procedure should be followed strictly.
- In case the permit is taken in person, same can be returned on phone.
- While issuing or returning permit on phone, the code words should be used.

Precautions to be taken while issuing permit:

It is the duty of the shift engineer or person issuing the line clear permit to ensure that the sub-station/ feeder/equipment for which the permit is being issued, should be made dead, i.e., equipment/ feeder should be discharged and properly earthed. First, he should switch off the equipment/feeder as per the instructions laid down. Thereafter, he should adhere to the following instructions regarding grounding and locking of equipment:

- Power T/F should be opened (off position) and locked, at S/stn, respectively.
- Warning boards with following instructions should be tagged on handles of isolators/breakers:
  - Do not charge. Workers are working.
  - The line/equipment under permit - Don't charge.
  - Attention - work in progress - Do not charge the line/equipment.
- The same type of warning boards should be tagged on handles of control switchgear. The control circuit fuse of control panel should also be taken out and kept in the custody of the permit issuing authority.

Duties and Responsibilities of a Distribution Lineman

When the lineman is entrusted with the responsibility of construction (erection of lines, distribution substation, UG/AB cables):

- He shall be responsible for surveying HT lines and LT lines and report to his superiors any variation from the original estimates.
- He shall be responsible for executing the distribution lines and erecting transformers, underground and AB cables as per technical standards.
- He shall be responsible for all T and P issued for execution of work.
- He shall maintain the time rolls and mark the attendance regularly.
- He shall maintain a register showing the allocation of work every day and also write in the same register the progress of work against the allocation.
- He shall prepare pole schedules, after completing the work and handover the same to his superiors.

In case he is put in charge of contract work, he shall be responsible for proper supervision of work and see that the work is executed as per standards. Materials issued to the contractor shall properly be accounted:

- He shall maintain a dairy showing the day to day work done in detail and take the signatures of his next superiors once in a fortnight.

NOTES

NOTES

- He shall be responsible to ensure that the code of safety rules is followed by him and the staff working under him. A copy of the said code is already supplied to him. Any instances where the staff fails to use safety appliances as per the code shall be brought to the notice of his superiors immediately for taking disciplinary action.
- He shall be responsible for upkeep of T and P and safety appliances supplied to him and keep them in working order.

The lineman is entrusted with O and M (operation and maintenance) activities (lines, distribution substation and UG/AB cables):

- To restore power supply in an area as quickly as possible or make arrangements for alternate power supply till power is restored.
- To maintain LT, HT (Low tension, High tension) lines and equipment under his charge as per the schedule fixed up, as well as continuity of supply.
- To report any interruption beyond one hour on LT lines and restoring supply.
- To rectify HT and LT lines by following instructions from superiors for such rectification.
- To maintain distribution transformers/substations in his area of jurisdiction covering oil testing, checking of condition of breather, GO Switch operation, HT Fuses and LT side protection, earthing of transformer body, neutral, etc.
- To attend breakdown of HT and LT Lines in a time bound manner as per performance standards set by the State Electricity Regulatory Commission.
- To replace damaged transformers in a time bound manner as per performance standards set by the State Electricity Regulatory Commission.
- To make proper gradation of fuse in services and all other places where fuses are used.
- To maintain a register showing the allocation of work every day and also record the progress of work against the allocation.
- To supervise work under contract and see that all maintenance work is carried out as per maintenance schedule and as per standards.
- To follow the code of safety rules and encourage the staff working under him to do the same.
- To ensure security of T and P and safety appliances supplied to him and keep them in working order.

Check Your Progress

Notes

A. Fill in the blanks

1. Rail poles are __________ than RCC pole.
2. RCC poles are made by __________ steel rods into concrete slabs of pole-shaped cylinders.
3. Pin-type insulation are commonly used on __________ lines.
4. LT cross arms have been standardised for horizontal as well as __________ formation of conductors.

B. Multiple choice questions

1. Identify which is not a cement pole:
   (a) RCC pole
   (b) PSC pole
   (c) Wooden pole
   (d) Rail pole
2. Pin-type insulators are commonly used on:
   (a) 11 KV line
   (b) 33 KV line
   (c) 15 KV line
   (d) None of these
3. GO switches are used as:
   (a) Switching devices
   (b) Cutout devices
   (c) Controlling switches
   (d) None of these
4. LT line spacers are provided:
   (a) To keep distance between wires
   (b) For holding wires
   (c) For tying of wires
   (d) None of these

C. Match the columns

	Group A	Group B
1.	Distribution Lineman	(a) recruitment of various roles
2.	Electricity Act 2003	(b) concerned with grievances
3.	DISCOM	(c) construct LT, HT lines
4.	Escalation Matrix	(d) allows multiple licensing in distribution

D. Short answer questions

1. Why RCC poles are more preferred in erction of lines?
2. List the factors responsible for selection of poles.
3. Discuss the role of conductors and their types.
4. What is the role of Guy strain insulators?

Session 2: Specific Terminology in Distribution Line

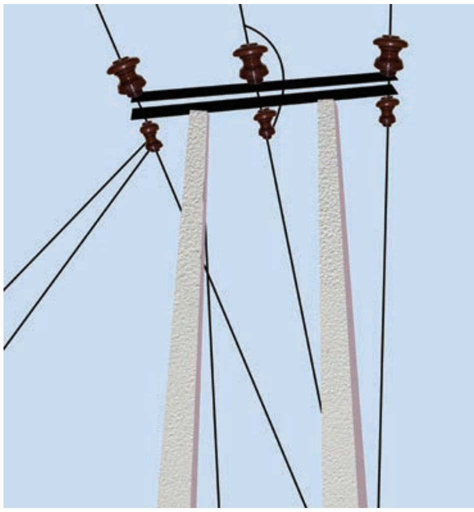


Fig. 4.19 Pole

Fig. 4.20 Tower

Low Tension (LT) Line and High Tension (HT) Line

A low-tension line is a low voltage line and a high-tension line is a high voltage line. In India LT supply is of 400 Volts for three-phase connection and of 230 Volts for single-phase connection. High tension or HT supply is applicable for bulk power purchasers who need 11 kilo-Volts or above.

Overhead Line

Overhead line means any electric supply line which is placed above ground and in the open air.

HT and LT lines upto 33 kV are erected on poles (Fig. 4.19). Extra High Volt i.e., EHV lines of 66,132, 220 and 440 kV are erected on towers (Fig. 4.20).

Peak Demand

It is the maximum load/demand which is recorded during the peak hours representing the simultaneous maximum demand of all the consumers at a particular point. It can be annual peak load, monthly peak load, weekly peak load and daily peak load etc. Peak load for a state is recorded by state load dispatch centre. For different categories of consumer peak/maximum demand will be recorded by the consumer energy installed at their premises.

Load Shedding

Load shedding is normally carried out when the power demand is more than the power availability at a given point of time to shed excess load on the generating stations. Load shedding is carried out on priority basis. Emergency services such as hospitals, fire services, important government office etc. are left out and load shedding is carried out phase by phase. Thus the switching 'OFF' of particular feeder (circuit breaker) to avoid total breakdown due to overload is called shedding.

Power system

The production of electricity and transmission and distribution in our houses, factory or piece of work involves a long process, which consists of operation of power machines and system network. The whole process is referred as the 'Power System" (Fig. 4.21).

Power system can be divided into three broad sections: generations, transmission and distribution and utilisation.

Power generation

Generation of power is done through various sources like thermal, hydro, non conventional as well as nuclear power station.

In thermal power station use of coal, gas and diesel is made for generation of power.

Similarly through hydro power station use of water as well as tidal energy is used for generation of power.

Non conventional energy uses solar, wind, bio fuel as well as agricultural waste.

Nuclear power station uses nuclear energy to generate power.

Transmission

Transmission system is used for transmitting the power for long distances and it consists of transmission lines and substation at extra high voltage and high voltage. In transmission system, two substations are connected at the same voltage.

In transmission, substation consists of transformers, bus bars, circuit breakers, isolators, protection and communication equipments and a control room.

Power Distribution System

Power distribution involves distribution of power received at HV substations to consumers through distribution system which operates at voltages at 33 KV and below. A distribution system consists of electrical sub stations, distribution transformers and distribution lines.

A distribution substation is located near or inside city/town/village/industrial area. It receives power

NOTES

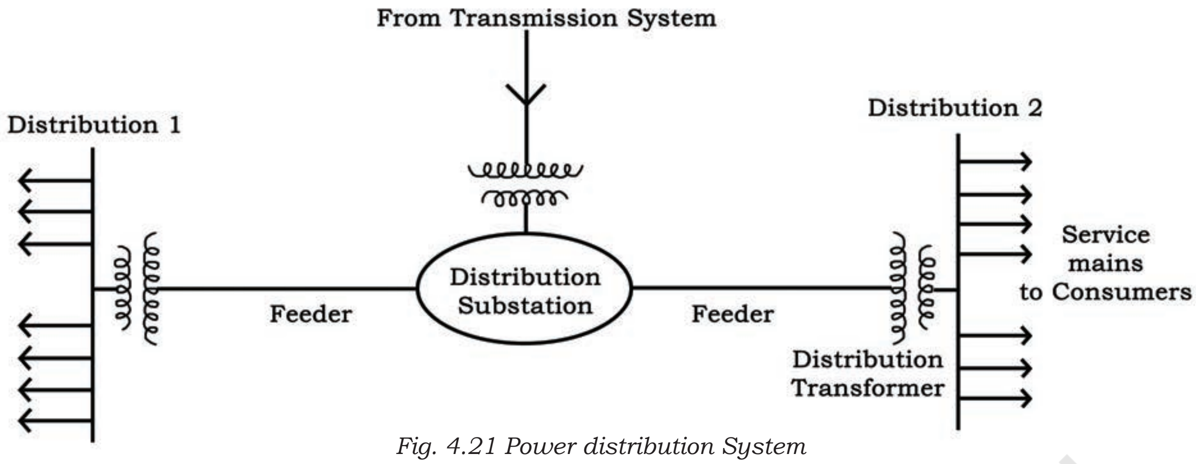


Fig. 4.21 Power distribution System

from a transmission network. The high voltage from the transmission line is then stepped down by a step-down transformer to the primary distribution level voltage.

- Primary distribution system: It connects the transmission system with secondary distribution network, at 33 kV or 11 kV voltage levels and form the backbone of the distribution system.
- Secondary distribution system: Supplies power to consumers at voltages of 415 volts and/ or 240 volts and constitutes the first contact of utility authorities with the consumers.
- Distribution lines: These include overhead lines and/or cables. The lines in rural areas are mostly radial in nature. The lines in city areas are mostly mesh-like networks often called 'ring mains', which are used to increase the reliability of supply and to meet the high density of loads (Fig. 4.22).

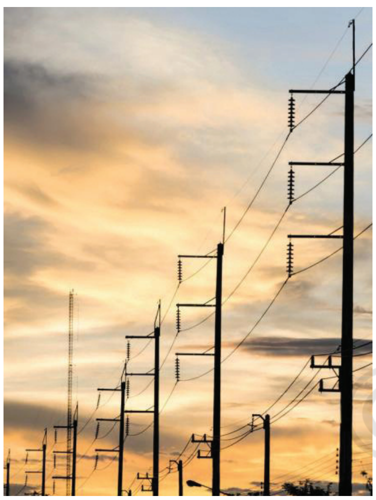


Fig. 4.22 HT Line

Utilisation refers to the process through which the electricity is put to different uses such as:

- Power for industrial units
- Power for different kinds of household appliances and gadgets
- Power for communication and electrical traction
- Use in medical equipment, electrolysis, etc.

We can say that the voltage of a local transmission line is 13,800 volts. This voltage is then lowered even further between 220 and 440 volts for industrial use and from 120 to 240 volts for commercial and residential customers.

Difference between Transmission and Distribution Line

Transmission line helps in the movement of electricity from a power plant or power station to the various substations whereas the distribution line carries electricity from the substation to the consumer's end.

In electric power distribution, a service drop is an overhead electrical line running from a utility pole, to a customer's building or other premises. It is the point where electric utilities provide power to their customers.

Common safety warnings

Power lines are not insulated and one should always avoid contact with them. It is quite possible for people to get electrocuted if you touch power lines.

The strongest magnetic fields are usually emitted from high voltage transmission lines — the power lines on the big, tall metal towers. To be sure that you are reducing the exposure levels to 0.5 milli gauss (mG) or less, a safety distance of 700 feet may be needed. It could be much less, but sometimes more.

Power lines produce low-to mid-frequency magnetic fields (EMFs). These types of EMFs are in the non-ionizing radiation part of the electromagnetic spectrum, and are not known to damage DNA or cells directly, according to the National Cancer Institute.

Is there a safe living distance from power lines? Hundreds of studies worldwide have shown that living next to high voltage power lines and other parts of the power transmission network increases your risk of cancer and other health problems. The closer you are the more you are bombarded with dangerous EMFs.

NOTES

NOTES

Check your progress

A. Fill in the blanks

1. ___________means any electric supply line which is placed above ground line and in the open air.
2. HT and LT lines upto _________33 kV are erected on poles.
3. The voltage of a local transmission line is __________ volts.
4. Transmission system is used for ___________the power for long distances.

B. Multiple Choice Question

1. Generation of power is done through various sources
   (a) Thermal,
   (b) Hydro,
   (c) Non conventional as well as nuclear power station
   (d) All the above
2. Extra High Volt i.e., EHV lines of ___________ kV are erected on towers.
   (a) 66
   (b) 32,
   (c) 220 and 440
   (d) All the above
3. The strongest magnetic fields are usually emitted from high voltage transmission lines are _________milli gauss
   (a) 02
   (b) 03
   (c) 04
   (d) 05
4. It is the ___________ load/demand which is recorded during the peak hours
   (a) Minimum
   (b) Maximum
   (c) Average
   (d) None of these

C. Short Answer questions

1. Differentiate between high and low tension line.
2. Define peak demand.
3. Discuss the importance of power distribution system.
4. Why house should not be made near high transmission line.
5. Differentiate between transmission and distribution line.

Session 3: Construction Activities

Construction

The construction activity of H.T. lines is divided into the following:

1. Pit marking, pit digging
2. Erection of supports and concreting
3. Providing of guys to supports
4. Mounting cross-arms, pin and insulators, and pin binding
5. Paying and stringing of the conductor
6. Jointing of conductors
7. Sagging and tensioning of conductors
8. Crossings
9. Guarding
10. Earthings
11. Testing and commissioning

Pit Marking and Digging Procedure

After surveying, the pole location should be marked with the peg. The pits should not be too large than necessary, as otherwise, after erection of the pole and filing there remains a possibility of tilting of the pole. For marking the pits, the dimensions of the pit and the distance from centre of the pits are required. Pits having a dimension of about 1.2m x 0.6m should be excavated with its longer axis in the direction of the line. The planting depth should be about 1/6 length of the support (1500 mm). Excavation is generally done by using pickaxe crow bars and shovel. Very hard or rocky soil may require blasting of rock by small charges of gun powder, etc.

Erection of Poles and Concreting

After excavation of pits is completed, the supports/poles to be erected are brought to the pit location by manual labour or by cart. Then the pole is erected inside the pit. Erection of poles can be done by using bipod/wooden horse made of 15 cm G.I. pipe and 6m long. The distance between the legs should be

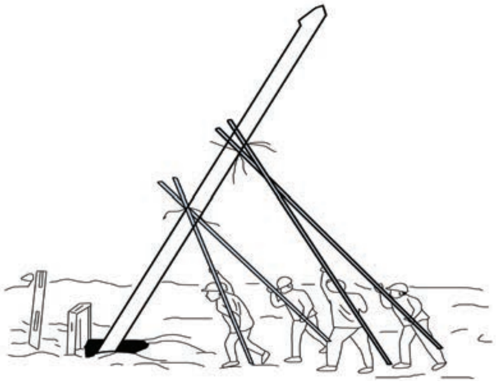


Fig. 4.23 Erection of pole

10 m. The tie wire for attachment of bipod to the pole is about 6 m long and is made of 7/10 SWG (3.15mm) stay wire and this wire should be attached to the pole at 8m. The pole is slid along the line route. The pole is tied with three ropes. The rope at the bottom prevents the pole from dragging in the direction of the pull. To prevent the support from the moving side from rising, two guy ropes are fixed on both sides and attached to a temporary anchor. For smooth sliding and prefect placement of pole in the pit, an inclined trench having 15.2 cm (6 in) width and 10.2 cm (4 in) length may be dug adjacent to the pit as shown in fig 4.23. A piece of M.S. channel is placed in an inclined position at the opposite end of the pit for enabling the pole to slip smoothly inside it. The trench would facilitate the pole to skid smoothly into the pit with jerks. The bipod is placed in position and attached to the pole by means of tie wire. The rope pulley is used to pull for lifting the poles. When the pole has reached at an angle of (35° to 40°) the derrick and bottom holding rope is slowly released. When the pole assumes the vertical position, the holding ropes should be tightened.

It should be ensured that during the time of erection, the two men shifting the bipod while raising the pole when it is free at a 40 degree angle, will also join the other two men who are holding the rope. The supervisor should be at a distance, guiding correct position so that in the event of breaking of rope, if the pole falls, it will not cause an accident.

Before the pole is put into RCC, padding or alternatively suitable base plate may be given below the pole to increase the surface contact between the pole and the soil. The padding will distribute the density of the pressure due to weight of the pole on the soil. After lifting the pole it should be kept in a vertical position with the help of manila rope of 20/25 diameter, using the rope as a temporary anchor. The alignment of the poles should be checked and set right by visual check. The verticality of the poles are to be checked with a spirit level. After the pole erection has been completed, and confirming that the verticality and alignments are all right, earth filling and ramming should be done (Fig.4.23).

In swamp and special locations, before earth filling, the poles are to be concreted up to the ground level of the pit. After poles have been set, the temporary anchors should be removed.

Erection of Double pole (DP) Structure for Angle Locations

Double pole structures are required in all the angle locations as well as in the tangent locations. DP is erected at a distance of every one kilometre as line DP. For angles of deviations more than 10°, DP structure should be erected. The pit digging should be done along the bisection of angle of deviation.

After the poles are erected, the horizontal/cross bracing should be fitted and the supports should be held in a vertical position with the help of temporary guys of Manila rope 20/25 mm diameter. Ensuring that the poles are held in vertical position (by spirit level) the concreting of poles with 1:3:6 ratio may be done from bottom of the pole to the ground level. Before lifting the pole in the pit, concrete padding of not less than 75 mm thickness may be put up for the distribution of the loads of the support on the soil or anchor plate should be used.

Concreting

The concreting mixture 1:3:6 ratios would mean 13 bags of cement 100 cft of stone and 50 cft of sand. It may be noted that while preparing the concrete mixture large quantities of water should not be used as this would wash away cement and sand.

Table 4.4 General proportions of Concrete Mixer

Material		Proportion 1:3:6	Proportion 1:2:4	Proportion 1:4:8
1.	1×1/4 Stone Metal	100 cft	100 cft	100 cft
2.	Sand	50 cft	50 cft	50 cft
3.	Cement	13 bags	20 bags	10 bags
4.	Water	484 ltr	484 ltr	484 ltr

NOTES

NOTES

11 kV Line

Normally 10 poles are erected within 1 km distance (average span length 100-105m).

Stays

After the pole erection is over, guying or putting stays is carried out. The following are different types of stays used in distribution lines (Fig.4.24).

1. Ordinary Stay
2. 'A' Type
3. Self Stay ("B" type)
4. 'Y' stay
5. Flying stay
6. Strut
7. Storm guys

Ordinary Stay: This type of stay is generally used. The size of stay rod, turn buckle and stay wires are to be used as per the line tension. Generally, for H.T. lines of 19 mm (3/4") diameter stay rod, 20 mm (5/6") size eye bolt, and 7/8 size stay wire are used and for L.T. lines of 15 mm (5/6") stay rod, 12.5 mm (½") eyebolt and 7/10 size stay wire are used. Stay insulator shall be used at a vertical height of 3 meter (10") from the ground.

'A' Type Stay: When the line tension is less and there is no sufficient space for stay, this type of stay is used. In cities, many times, there is no sufficient space for stay. At such places, the stay pit is dug at a short distance from the pole and hence cannot take adequate tension. A support angle is fixed to the pole. Arrangement is available to affix the stay wire to the angle. This is called "Stay out trigger". This type of stay looks like English 'A'.

Self Stay or 'B' Type Stay: When there is no space for stay, the lower portion of the stay wire is clamped by stay clamp to the lower portion of the pole. Such type of stay is called Self stay or 'B' type stay.

'Y' Type Stay: It is used for supporting guarding cross arm. It is also used for side brackets.

Flying Stay: When the line is on the roadside and there is no space for stay, pole piece of sufficient height is erected at the other side of the road and a stay wire is tied up between pole and pole piece. For giving tension to the pole piece, stay wire and stay rod are used.

Strut (Stud): When the pole is on the roadside and there is no space for stay, one pole is used as a support to the line pole from opposite side of the stay. The support pole is called "strut". Strut is fixed to line pole by a suitable clamp.

Storm Guys: When the line is straight and the distance from one cut-point to another is more, this type of stay is used. At mid-pole of the line, two stays at an angle of 60^0 on both sides are tied up. Such type of stay is called "Storm Guys". For angle location, stays are to be given in such a way that tilting of the pole due to conductor tension is avoided. Stay insulators are used to obstruct the leakage current.

Stay Binding: The stay should be linked with pole earthing and/or neutral wire using G.I. so that leakage current will pass through earthing or neutral to the ground. Such binding is called "Stay Binding".

Remember

1. if stay insulator is not provided, 8 S.W.G. G.I. wire shall be used near the stay clamp and link it to neutral conductor. The length of G.I. wire should be sufficient to join the stay wire to neutral of L.T. line or in case of H.T. line, to the H.T. earthing. This G.I. wire should be well bound to the earthing or neutral.
2. stay insulator should not be less than 10 ft from the ground.

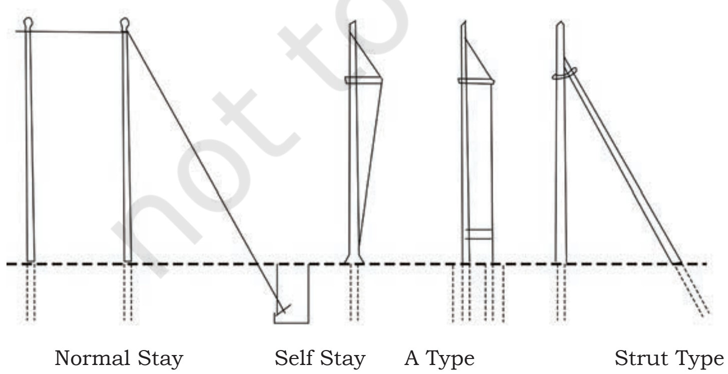


Fig. 4.24 Types of stay

Notes

3. While binding the stay, pole should not be tilted.
4. Thimble is necessary for stay binding. If the thimble is not available, the portion on stay wire on eye bolt should be binded properly.

REC construction G4 gives the details of various guys. The figure 4.25 gives the detail of stay set arrangement for 11kV/LT Line.

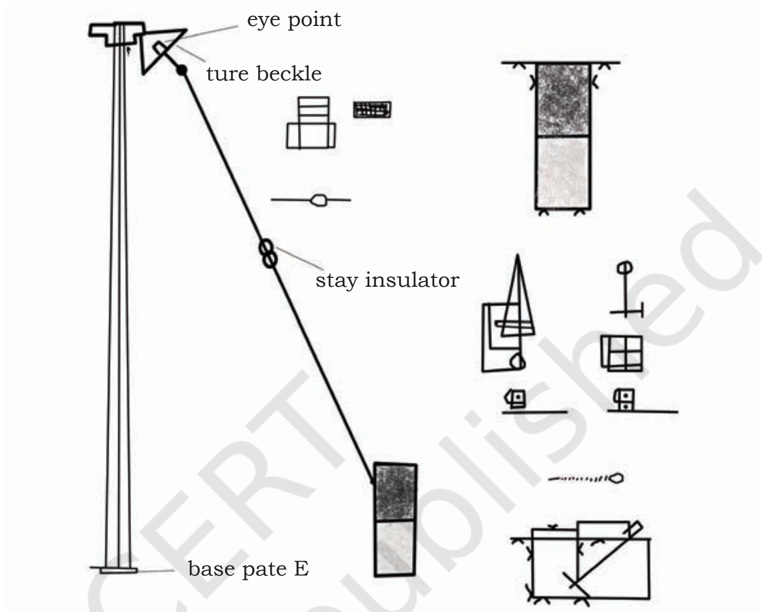


Fig. 4.25 Erection of stay

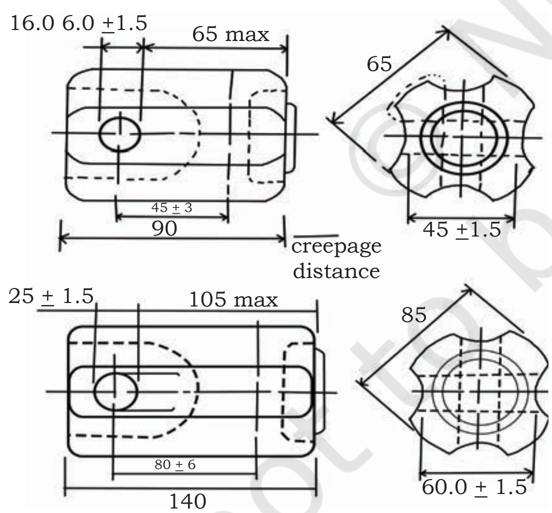


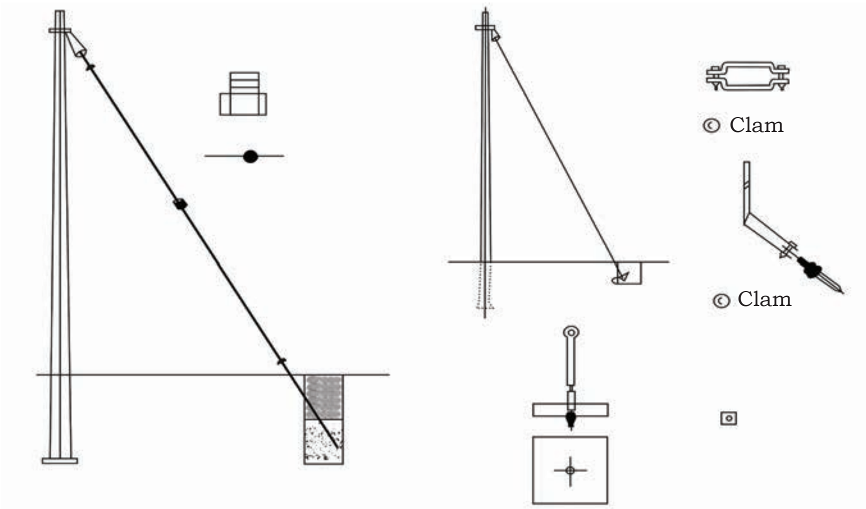
Fig. 4.26 Dimensions of stay

Fifteen locations are there within 1 km. Provision for 9 guy-sets is made with 7/3.15 stay-wire (5.5kg). The turn-buckle M.S. rod of 16 mm diameter concrete quantity at the rate of 0.2 cm per stay-set should be provided. Either base pad should be used or additional provision for base pad-concreting should be made (Figs. 4.26 and 4.27).

11 kV and LT Stay erection

Guy Strain Insulators

Guy strain insulators are placed to prevent the lower part of the guy from becoming electrically energised by a contact of the upper part of the guy when the conductor snaps and falls on them or due to leakage. No guy insulator shall be located less than 3.50 meter (vertical distance) from the ground.



Stay set Arrangement Anchor Rod & Plate

Fig. 4.27 Construction of various components of stay

Fixing of Cross-Arms and Top-brackets

After the erection of supports and providing guys, the cross-arms and top-brackets are to be mounted on the support with necessary clamps, bolts and nuts. The practice of fixing the cross-arms a bracket before the pole erection is also there. In case, these cross-arms are to be mounted after the pole is erected, the lineman should climb the pole with necessary tools. The cross-arm is then tied to a hand line and pulled up by the ground man through a pulley, till the cross-arm reaches the lineman. The ground man should station himself on one side, so that if any material drops from the top of the pole, it does not strike him. All the materials should be lifted or lowered through the hand line, and should not be dropped.

11 kV 'V' cross arm fixing

Insulators and Bindings

Line conductors are electrically insulated from each other as well as from the pole or tower by non-conductors, which we call 'insulators'.

There are 3 types of porcelain insulators

1. Pin type
2. Strain type
3. Shackle type

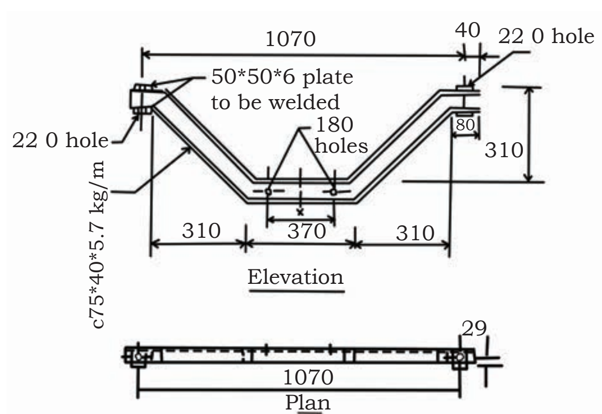


Fig. 4.28 11 kV 'V' cross arm specification

The pin type insulators are generally used for straight stretch of line. The insulator and its pin should be mechanically strong enough to withstand the resultant force due to combined effect of wind pressure and weight of the conductor in the span. The strain insulators are used at terminal locations or dead-end locations and at places where the angle of deviation of line is more than 10°. The shackle type of insulators are used for L.T Lines (Figs. 4.28 and 4.29).

The pins for insulators are fixed in the holes provided in the cross-arms and the pole top brackets. The insulators are mounted in their places over the pins and tightened. In case of strain or angle supports, where strain fittings are provided for this purpose, one strap of the strain fitting is placed over the cross-arm before placing the bolt in the hole of cross-arms. The nut of the straps is so tightened that the strap can move freely in horizontal direction (Fig. 4.30).

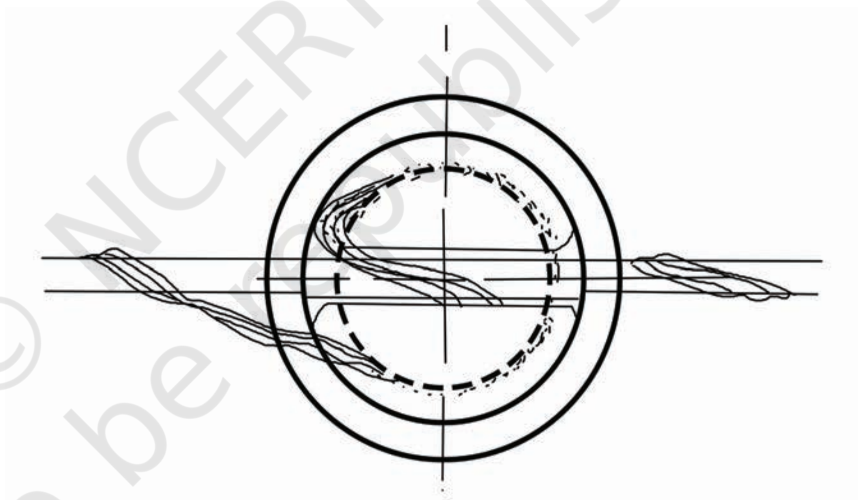


Fig. 4.29 Binding of pin insulator

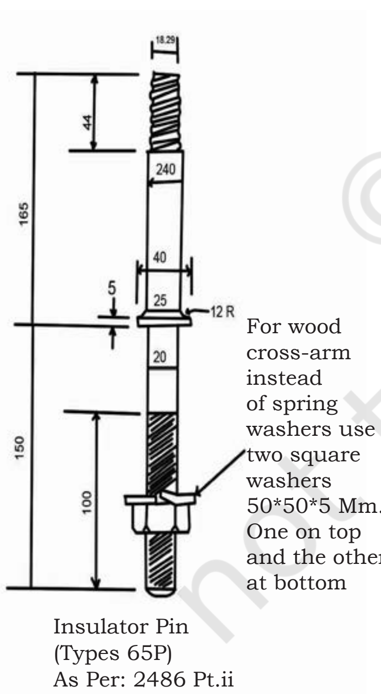


Fig. 4.30 Specification of GI pin

Tying of Conductor on Pin Insulators

Conductors should occupy such a position on the insulator so as to produce minimum strain on the tie wire. The function of the wire is only to hold the conductor in place on the insulator, leaving the insulator and pin to take the strain of the conductor.

In straight line, the best practice is to use a top groove insulator. These insulators will carry grooves on

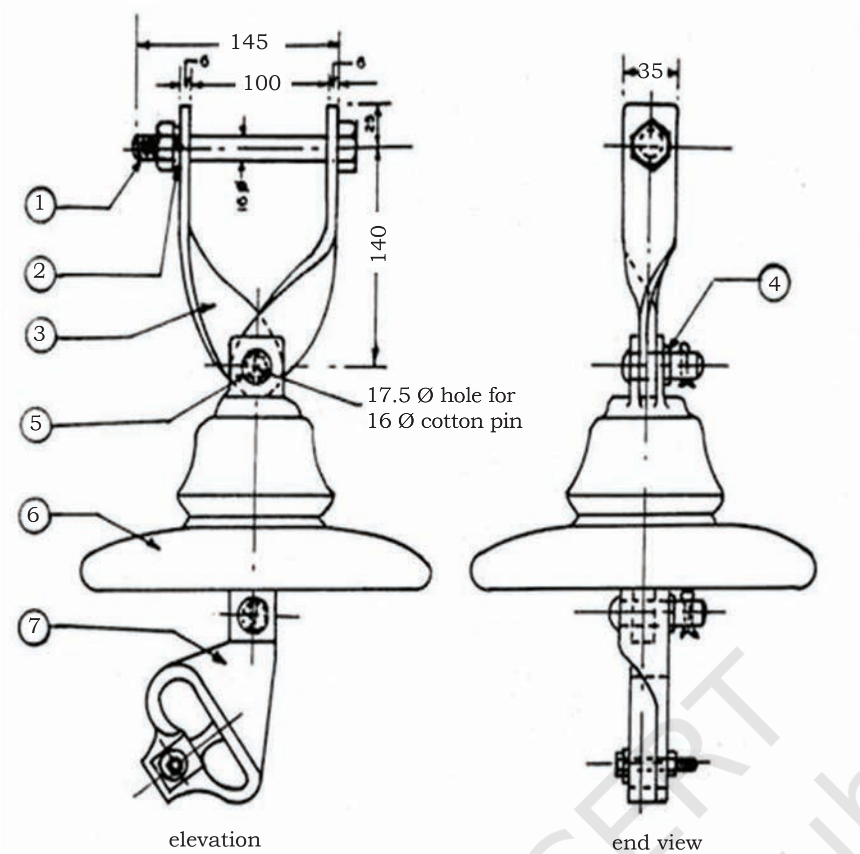


Fig. 4.31 Fixing of Disc Insulator

the side as well. When the conductor is placed on the top groove, the tie wire serves only to keep the conductor from slipping out (Fig. 4.31).

On corners and angles (below 5 deviations) the conductor should be placed on the outer side of the insulators. On the far side of the pole, this pulls the conductor against the insulator instead of away from the insulator.

Kind and Size of Tie Wire to be used

In general the tie wire should be the same kind of wire as the line wire i.e. aluminium tie wire should be used with aluminium line conductor. The tie should always be made of soft annealed wire so that it may not be brittle and injure the line conductor. A tie wire should never be used for second time. Good practice is to use number '6' tie wires for line conductor. The length of the

NOTES

wire varies from 1m for simple tie of small insulators (LT pin insulators) to 3 m (33 KV pin insulators).

Rule of Good Tying Practice

1. Use only fully annealed tie wire.
   (i) Use that size of tie wire which can be readily handled, yet one which will provide adequate strength.
   (ii) Use length of tie wire sufficient for making the complete tie, including an end allowance for gripping with the hands. The extra length should be cut from the end if the tie is completed.
   (iii) A good tie should:
      - Provide a secure binding between line wire insulators and tie wire.
      - Have positive contacts between the line wire and the tie wire so as to avoid shifting contacts.
      - Reinforce line wire in the vicinity of insulator.
   (iv) Avoid use of pliers.
   (v) Do not use the wire which has been previously used.
   (vi) Do not use hard drawn wires for tying.
2. Good helical accessories are available and can be used.

Conductor Sagging and Erection Stringing

Conductor erection is the most important phase in construction. The main operations are:

- Transportation of conductor to work site
- Paying and stringing of conductor
- Joining of conductor
- Tensioning and sagging of conductor

The conductor drums are transported to the location. While transporting, precautions are to be taken so that the conductor does not get damaged/ injured. The drum could be mounted on cable drum support, which generally is made from crow-bar and wooden slippers for small size conductor drums. The direction of rotation of the drum has to be according to the mark in the drum so that the conductor could be drawn. While drawing the conductor, it should not rub causing damage. The conductor could be passed over

Notes

poles on wooden or aluminum snatch block mounted on the poles for this purpose.

The mid-span jointing is done through compression crimping or if helical fittings are used the jointing could be done manually. After completing the jointing, tensioning operation can be started. The conductor is pulled through come-along clamps to string the conductor between the tension locations. Sagging of conductor has to be in accordance to the Sag Tension chart. In order to achieve it, it is preferred to pull the conductor to a tension a little above the theoretical value so that while transferring it from the snatch blocks to the pit insulators and to take care of temperature variation proper sag could be achieved. Sagging for 33/11 kV line is mostly done by 'sighting'. A horizontal strip of wood is fixed below the cross-arm on the pole at the required sag. The lineman sees from other end and the sag is adjusted by increasing or decreasing the tension. The tension clamps could then be finally fixed and conductor be fixed on pin-insulators. All fittings, accessories like guys, cross-arms, etc., could be checked as they

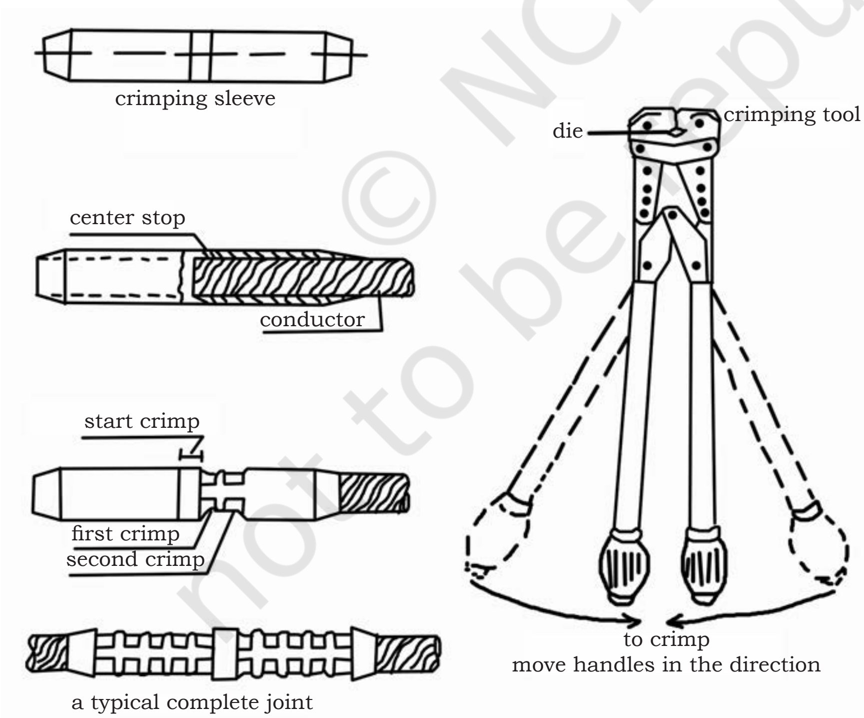


Fig. 4.32 Crimping of ACSR and AAC conductor

NOTES

should not have deformities. Along the overhead line where the conductor is to be strung, four number of wheel consisting of wooden circular base provided with vertical steel rod is placed, which is loaded with the conductor drums (as required). These conductors, say three in number are dragged using the 'come along' tool by either labourers, tractor or pulling machine along the line supports (Fig. 4.32).

This bunch of conductors is lifted up to the cross-arms by a man on the pole-top using a pulley and rope. And a handful of other labourers pull the other end of the rope. Thus, the conductor reaches the cross-arm. A similar procedure is followed for all the poles before sagging.

Ground Clearance

- Specified clearances are to be maintained at the lowest point of the span with maximum sag as per CEA Gazette Notification 2010
- Maximum sag is related to the temperature
- Tension of conductors is to be limited so that F.O.S. is 2

Keeping all these parameters in view, sag-tension charts are to be drawn for each conductor size, so that, while constructing the lines, these charts are referred for keeping proper sag and tension at the atmospheric temperature at that time. This will help in maintaining required clearance.

Maximum Clearance between Supports

The supports are designed to withstand certain working load. This governs the distance (span) between two supports. The load on the supports depends upon wind pressure on conductors, surface area of the support, fittings etc. The greater the wind pressure zone area the lesser the span. REC has issued Construction Standards for span for 11kV and LT Lines for various wind pressure zones i.e.50 kg/m, 75 kg/m and 100 kg/m. The span for 11kV for 50 kg/m is 107meters and it gets reduced at higher wind pressure.

Table 4.5 11 kV Line—Triangular Configuration (Rec Construction Standards)

Conductor size (Normal AI area)	Working load of supports	Maximum permissible span in meters in a wind pressure zone of		
		50 kg/m	75 kg/m	100 kg/m
Rabbit ACSR (equivalent AAAC 7/3.15)	140 kg	107 (107)	67.5 (72)	NR
	200 kg	NR	104 (107)	73.5 (78.0)
Weasel ACSR (equivalent AAAC 7/2.5)	140 kg	107 (107)	87.5 (90)	NR
	200 kg	NR	107 (107)	95 (98)
Squirrel ACSR(equivalent AAAC 7/2)	140 kg	107	107	NR
	200 kg	NR	107	107

LT lines (3 phase 4 wire) 8 m supports (3 phase – 4 wire) line vertical formation

(i) Above spans will suit for single phase lines also.

(ii) 3 phase-5 wire lines are required to provide street lighting in the inhabited areas where spans have to be limited to get normal intensity of light hence the details are not given.

Table 4.6 Maximum permissible spans with ACSR, AAAC and AAC Conductor

Conductor Size (Normal AI area)	Working load of Supports	Maximum permissible span in meters in a wind pressure zone of		
		50kg/m	**75kg/m**	**100kg/m**
ACSR Rabbit (equivalent AAAC 7/3.15)	140 kg 200 kg	99 (103) NR (NR)	62.5 (63) 93.5 (98)	NR (NR) 66.5 (69)
ACSR Weasel (equivalent AAAC 7/2.5)	140 kg 200 kg	99.5 (107) NR (NR)	77.5 (77) 99.5 (107)	NR (NR) 82.5 (83)

NOTES

ACSR Squirrel (equivalent AAAC 7/2)	140 kg 200 kg	100.5 (107) NR (NR)	91 (91) 100.5 (107.0)	NR (NR) 97 (99)
AAC (Ant)	140 kg 200 kg	71.5 NR	66.5 67.5	NR 63
AAC (Gnat)	140 kg 200 kg	73 NR	66 66	NR 59.3

Overhead Conductor Stringing

Along the overhead line where the conductor is to be strung, four wheels consisting of wooden circular base provided with vertical steel rod are placed, which are loaded with the conductor drums (as required). These conductors, say, three in number are dragged using the 'come along' tool by either labourers, tractor or pulling machine along the line supports.

This bunch of conductors is lifted up to the cross-arms by a man on the pole-top using a pulley and rope. A handful of other labourers pull the other end of the rope. Thus, the conductor reaches the cross-arm. The details are shown in figure 4.33. A similar procedure is followed for all the poles before sagging.

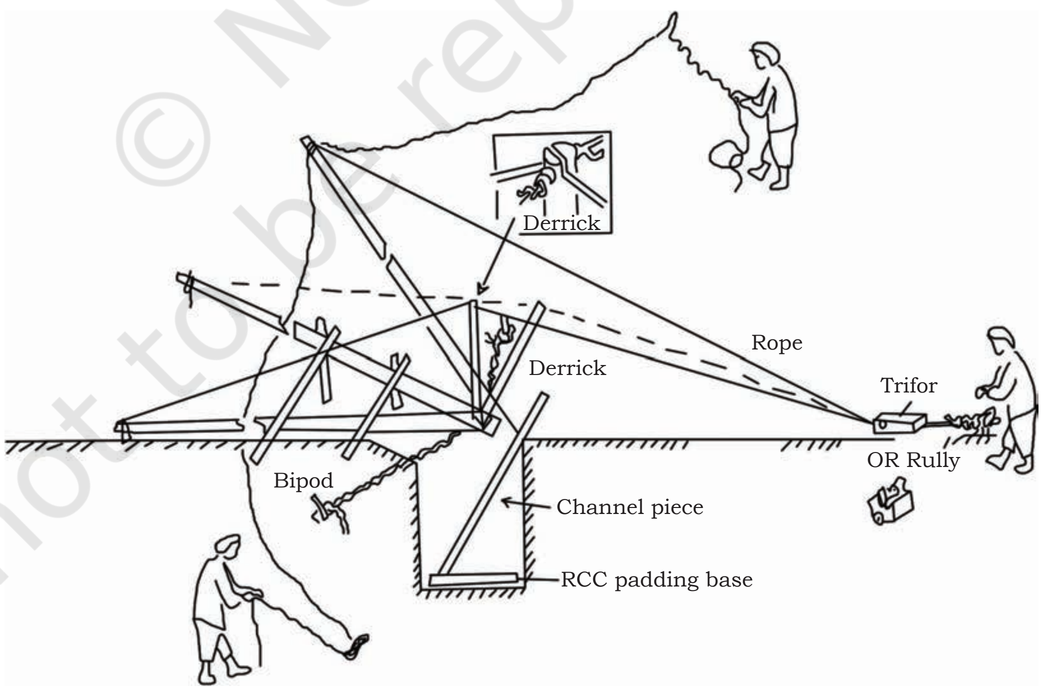


Fig. 4.33 Derrick Method

Sagging and Tensioning

The variation in the atmospheric temperature results in the increase or decrease of the length of the conductor of a section. In summer, when temperature is high, the length increases due to expansion and in winter, when the temperature is low the length decreases due to contraction. With increase in length, the conductor becomes loose, sag increases and tension reduces, while in winter the sag decreases, tension increases.

11 kV Fixing and binding of strain Insulator

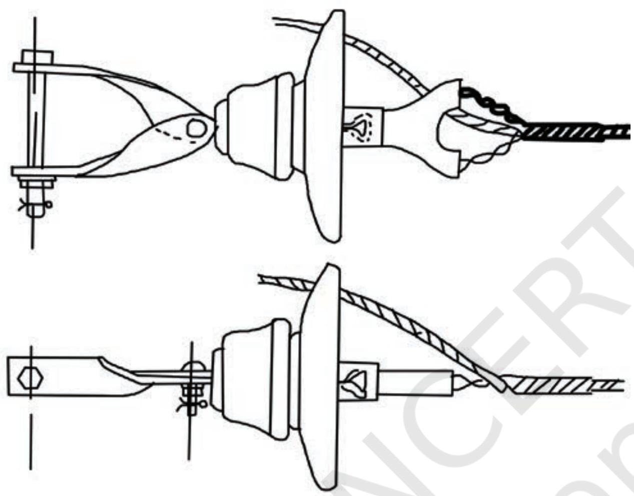


Fig. 4.34 Strain Insulator Assembly with Helically Formed Fittings

There are two important factors which affect the sag and tension:

- Elasticity of the conductor and
- Temperature

Sag is directly proportional to wind pressure load (W) and inversely proportional to temperature (T). If the length of the conductor increases due to temperature increase then sag will increase. This may be the case in summer, while it may be reverse in winter. The tension will accordingly decrease or increase.

In order to keep the sag and tension values under varied working conditions according to the regulations, Sag-Tension charts are prepared for different spans and temperatures for ACSR, AAAC and AAC conductor.

NOTES

Notes

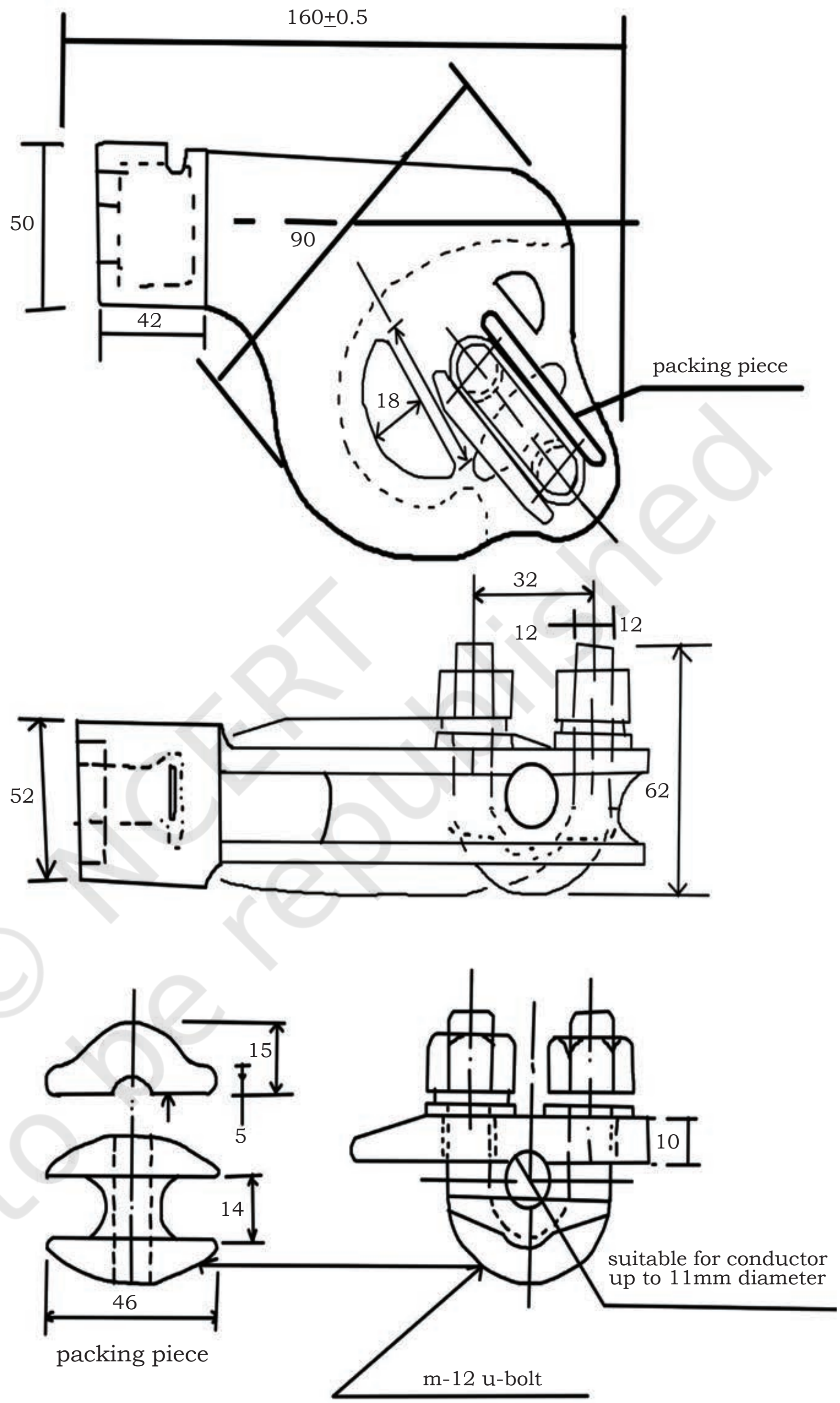


Fig. 4.35 11kV Strain Clamp for Ball and Socket type insulator

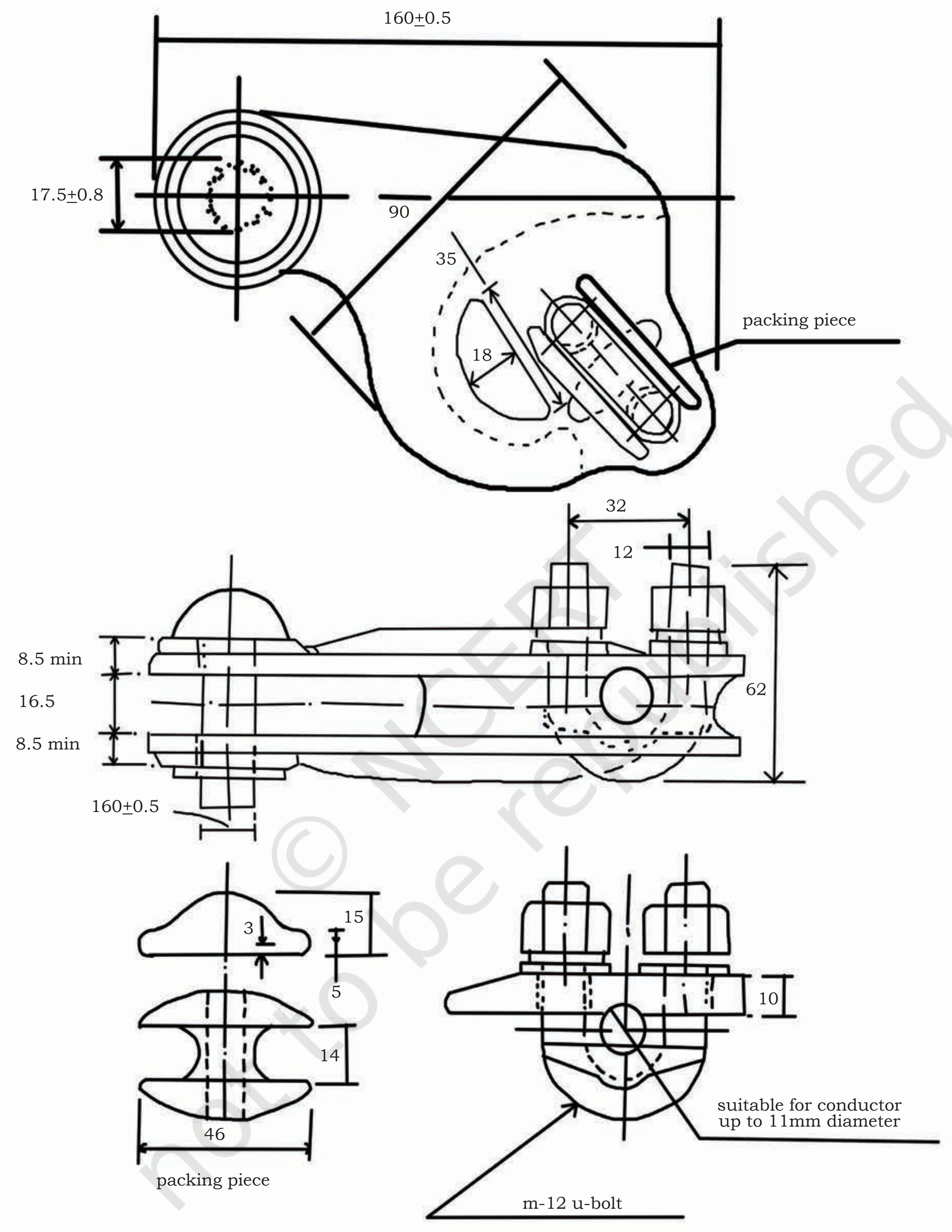


Fig. 4.36 Fixing of Disc insulator

Conductor Jointing

The length of distribution lines are in kilometers and one coil of conductor is not able to solve the length problem. Hence jointing the conductor is necessary.

Another necessity of jointing the conductor is breaking of the conductor for some reason.

Types of Joints

(1) Britannia, (2) Telephone, (3) Meried Joint, (4) 'T" joint, (5) Sleeve joints, (6) Compression joint.

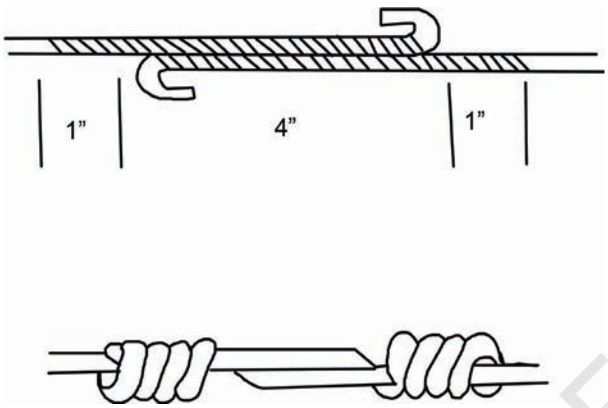


Fig. 4.37 Britannia Joint

Britannia Joint: This type of joint is made only on solid conductors and cannot be made on stranded conductor. Two conductors of length 6 inches (150 mm) are brought in front of each other to be joined . Then both conductors should be cleaned to make sure that they are rust free. If the conductor is of copper; it should make good electrical connection. Then ends of both the conductors are bent through half centimetre and placed on each other. The length of the contact portion should be minimum 100 mm. This joint should be bound by 14 mm copper wire as shown in the figure (Fig. 4.37).

Telephone Joint (Western Union): This joint is used only for solid conductors. It is used for conductors of size 8 SWG or higher size. First, they are bent at 100 to 125 mm from the edges and are placed over each other. Then each one is twisted with another conductor.

Married Joints: This joint is made between copper conductors having central strand of G.I. wire. This joint should not be made between Al conductors. Approximately 175 to 200 mm of conductor strands are unwound. The G.I. strand of both conductors should be broken up to a length of 175 mm. Both conductors should be brought in front of each other and their strands should be woven with each other. The strand of one conductor is twisted on another conductor, and the strand of the other conductor is twisted on the first.

Likewise all the strands are twisted and then soldered. This is used only for small span length (Fig. 4.38).

'T' Joint: This joint is made with stranded conductor. This joint cannot take tension. It is used for jumper or tapping in sub-station. The conductor strands to be separated up to 100 mm. Then middle steel strands are cut. Then it shall be placed to horizontal conductor with three strands each on either side and shall be twisted over the horizontal conductor (Fig. 4.39).

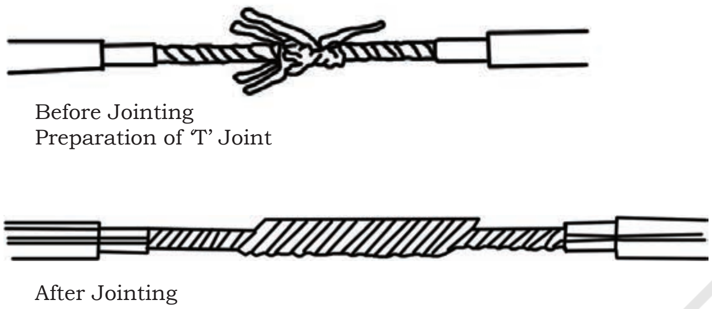


Fig. 4.38 Married Joint

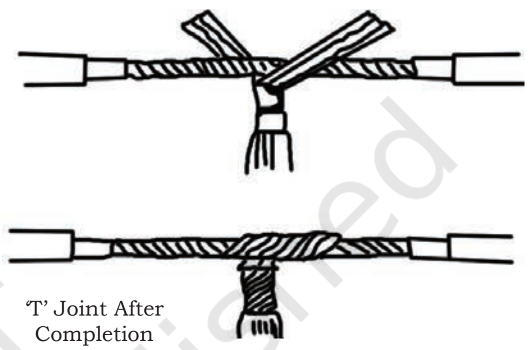


Fig. 4.39 'T' Joint

Sleeve Joint: It can be made with any type of aluminium conductor. Graphite grease is applied over the conductor and as shown in figure 4.40 two Al sleeves should be taken. These sleeves should be placed on the conductor as shown. Sleeves should be twisted by twisting wrench. This joint is made for L.T., H.T., ACSR, AAC conductor up to 0.06 cm^2 (Fig. 4.40).

Fig. 4.40 Sleeve Joint

Compression Joint: This joint is used for conductors of more than 0.06 cm^2 sizes. For preparing these joints, two different sleeves are used. There are two holes in Al sleeve. Rebating is done through these holes. Slide aluminium sleeves are slid over one conductor. It is slid until only the working length protrudes. The next step will be cutting of the aluminium strands for installation of the steel sleeve. It is measured back from each end of the conductor and then a distance equal to half the length of the aluminium sleeve is marked. The cut

Notes

line is then marked. The marked location for cutting should be taped. The outer strands are cut with a rotating tool until the layer becomes loose. To prevent nicking, the core inner layer should not be cut. The wire in the inner layer is removed by hand. It is extremely important to note that a small cut on the core should not be disturbed while cutting the aluminium strands. If this happens, the ultimate strength of the joint will be reduced. Repeat the above process with another conductor. Insert the conductor's core into the steel sleeve, making sure that the ends butt solidly against the center stop. Also, ensure the distance from the end of the barrel to the aluminium strand. Lubricate the sleeves with solid lubricating wax. Remove the tape from the ends of the aluminium strands. Set the steel sleeve into the compressing tool. Choose a proper size of the die for steel sleeve. Make initial die compression at the centre of the steel sleeve. Make compression on both sides of the centre compression. Overlap successive compressions by approximately 0.5 inches. Choose one side and compress it to the end. Repeat the same process to the other side also. The aluminium sleeve extrudes beyond the steel sleeve. Remove and clean the steel sleeve. Now change the die in compressing tool for the aluminium joint compression. Slide the aluminium sleeve over the steel sleeve until the end of the barrel aligns with the marks placed on the conductor. Inject the filler compound through holes. This filler compound protects the steel barrel from corrosion, cleans the strands by removing oxides while compressing. Now make the initial compression on either side of the splice beginning at the start mark. Continue making compressions on one side to the end. Complete the compression on the other side also. The centre portion of the splice is not compressed.

Jumpering

Connecting two conductors or wires is called Jumpering.

1. Jumper should not be connected to main conductor. The jumper should always be connected by P.G. clamps as shown in Fig 4.41.

Notes

2. When the jumpers are near metallic portion, all such jumpers are covered with alkathene pipe.

Fig. 4.41 Jumpering

3. Conductor joints are marked on A.C.S.R. conductor when dispatched. Mid span joint should be made before stringing because the steel strand is not kept continuous. Hence it is necessary to replace the company joint.
4. Care should be taken that mid span joint will not be less than 40 feet from pole.
5. Every joint should be done carefully.
6. Where conductor strands are cut, repair sleeve is used.
7. Conductor joint strength should be 95% that of conductor, and resistance should be that of main conductor.

Guarding

Guarding is an arrangement provided for the lines, by which a live conductor, when accidentally broken, is prevented to come in contact with other electric lines, telephone or telegraph lines, railway lines, roads, and persons or animals and carriages moving along the railway line or road, by providing a sort of cradle below the main electric line. Immediately after a live conductor breaks, it first touches this cradle guard of G.I. wires before going down further. This, in turn, trips the circuit breakers or H.T./L.T. fuses provided for the H.T./LT. lines, and the electric power in the conductor or the line is cut off, and danger to any living object is averted.

Guarding is not required for crossings of 66 kV and higher voltage lines where the transmission line is protected by fast acting relay operated circuit breaker of modern design with a tripping time of even less than the order of 0.25 seconds from occurrence of fault to its clearance. For all other crossings, like railway tele-communication lines and major road crossing guarding is essential.

The minimum height between any guard wire and live crossing conductor shall not be less than 1.5 m in case of a railway crossing (Fig. 4.41).

Types of Guarding

(i) P.V.C. Guarding
(ii) Levice Guarding

P.V.C. Guarding

This is mainly used for L.T. Lines passing through agriculture field. This is used where formation of line is vertical. The upper end is tied in shackle bolt and lower end is tied to the neutral. A G.I. wire frame is prepared so that there will be horizontal G.I. wire piece at equal distance below every conductor. The vertical wires of the frame are insulated with P.V.C. pipe. Even during conductor swings, it will not be earthed due to P.V.C. pipe. In case of snapping of conductor, it will make contact with the G.I. wire and get earthed, resulting blowing of the fuse (Fig. 4.42).

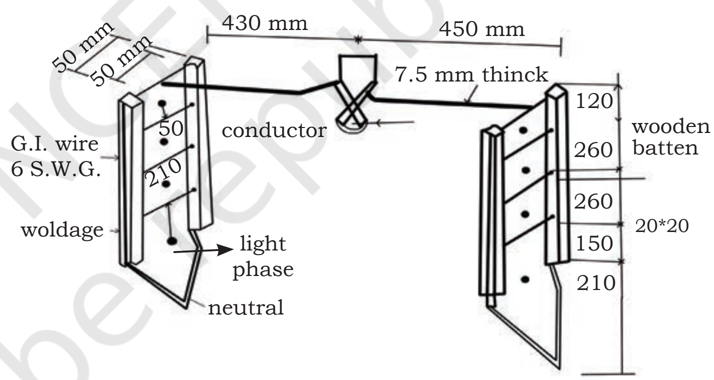


Fig. 4.42 Vertical Type Guarding

There are two types of guarding according to the formation. A). To use in case of 'D' clamps. (B) Direct shackle type.

Levice Guarding

This is of the following types:

(i) Carpet guarding
(ii) Cradle guarding
(iii) Box type guarding

There are two, three or four guard wire for levice guarding. These are bound with cross arm. The horizontal laces at a specific distance are tied up to the above wires. This guarding is used up to 33 KV lines.

(i) Carpet Guarding: The specific length cross arms are fixed on the poles. Four G.I. wires are used for guard wire. Lacings are tied up at specific distance. This type is used for power line crossing or power and telephone line crossing (Fig. 4.44).

(ii) Cradle Guarding: It consists of 6 guard wire. Four are on lower side and two on the upper side. Cross lacing is done from three sides. It is also called Tray guarding. Even though the conductor while snapping jumps up drastically, it will not go out of the cradle guarding. This is used for railway or L.T. to 33 KV guarding in residential area, for road crossing or along the road lines (Fig. 4.43).

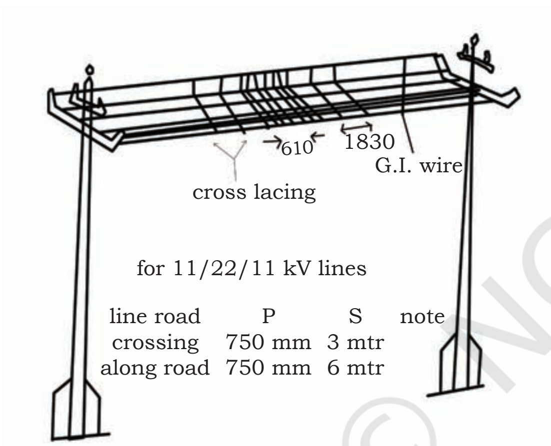


Fig. 4.43 Cradle Type Guarding

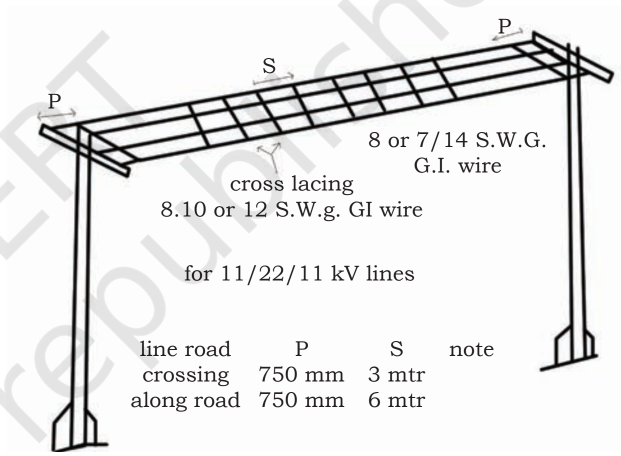


Fig. 4.44 Carpet Guarding

(iii) Box Type Guarding: This is used for composite lines. By fixing cross arms to the lower line, carpet guarding is done and also for the upper line, the upper guard wire is fixed to the lower by vertical lacing.

Road crossing and guarding

(a) As far as possible road crossing should be at right angle, but not less than an angle of 60 degrees.

(b) Cradle guarding is used for road crossing of power line or along the line.

(c) G.I. wire of 10 W.S.G. for L.T. line and 8 W.S.G for 11 KV to 33 KV lines is used for guarding.

Notes

(d) The first lacing should be at a distance of 750 mm from the pole. Other lacing is tied at a distance of 3 meter from each other.

(e) The vertical distance between conductor and guarding in mid span should be minimum 610 mm for L.T. and 1220 mm for H.T line.

(f) The vertical distance between L.T. line guarding cross arm and neutral should be 610 mm (2 ft.) and the length of cross arms should be 750 mm (2½')

(g) The clearance between line and guarding cross arm for 11 KV, 22 KV and 33 KV line should be 650 mm (2 ¼'), 750 mm (2 ½') and 840 mm (2 ¾') respectively.

(h) There is no need of guarding for lines above 66 KV, as their circuit breakers are sensitive. The breaker trips when conductor snaps thereby isolating the line.

Presently, due to electrification of railway-tracks, 11kV and L.T. crossings have to be done through underground cables.

Special Instructions

(a) Power lines should always be guarded as above.

(b) The distance between guard-wire and telephone line should be minimum 920 mm.

(c) The telephone crossings for 66 KV and above are done by Telephone Department. The clearance between the power line and telephone line shall be as below :

66 KV and 132 KV - - 2750 mm (9')
220 KV and 400 KV -- 4575 mm (15')

Fitting Accessories on H.T./L.T. line

It is essential to fix accessories after pole erection. Line accessories are of two types.

(a) Conductor accessories
(b) Pole accessories

a. Conductor Accessories

1. Binding Tape: Binding tape is used for binding pin insulator, shackle or Line insulator to the conductor. The tape is wound on the conductor. The metal of binding tape should be same as that of conductor. The first layer is wound along the wire in direction of twist of wire and second layer is in opposite the twist. The portion on which the binding wire is to be wound should be taped 25mm more from either side. This tape is used for avoiding conductor snapping due to friction.

2. Binding Wire: It is used for binding insulator to the conductor.

3. P.G. Clamp: It means parallel groove clamp. This is used for joining jump wire. Line tension cannot be given on P.G Clamps. Bi-metallic P.G. clamp is made out of two different metals and the conductor of the same metal is used in the same type of metal groove of P.G. Clamp

4. T Clamp: T clamps are used in substation to connect the jumps and cannot sustain tension.

b. Pole accessories

The main pole accessories are cross arms, clamps, insulators, aluminum bobbins, nuts and bolts, stay clamp, etc.

Earthing

Earthing shall generally be carried out in accordance with the requirements of CEA regulations for measures relating to safety and electricity supply, dated 20th September 2010 and the relevant regulations of the Electricity Supply Authority concerned and as the following:

1. All metal supports, fittings etc. shall be permanently and efficiently earthed. Either a continuous wire may be run with earthing arrangements at 4 points in 1.609 km or each independent structure should be efficiently earthed.
2. Similarly at consumer's premises a suitable earthing point would be provided. Consumer has to make arrangement for independent earthing.
3. Sub-stations structures etc. should be provided with two independent earthing points. This should be interconnected or matting in the sub-station area could be laid-down for connecting to the earth points.

NOTES

Notes

4. For RCC/PCC poles the metal cross-arms and insulator pins shall be bonded and earthed at every pole for HT lines and at every 5th pole for LT lines.
5. All special structures on which switches, transformers, fuses, etc., are mounted should be earthed.
6. The supports on either side of the road, railway or river crossing should be earthed.
7. All supports (metal, RCC/PCC) of both HT and LT lines passing through inhabited areas, road crossings and along such other places, where earthing of all poles is considered desirable from safety considerations should be earthed.

In special locations, railway and telegraph line crossings, special structures, etc., pipe/rod earthing should be done. At other locations the coil earthing may be adopted. The coil earthing consist of 10m length of 8 SWG G.I. wire compressed into a coil 450 mm length and 50 mm diameter and buried 1500 mm deep.

Earthing and its types

It is very important to earth the line and electrical equipment. It will be electrically unsafe without earthing. The pole/ body of equipment connected solidly to earth are called earthing.

1. For Electrical supports and equipment

In case of short circuit or leakage, current will pass with minimum resistance to earth so that maximum current will flow through effected circuit so that fuse will blow or circuit breaker to trip. This will isolate the faulty line or equipment from live circuit.

2. Transformer neutral earthing

(a) The leakage or unbalanced current will have path with minimum resistance.

(b) Sensitive protecting equipment works properly. (Earth Fault Relay)

(c) It prevents the lines being charged to excessive high voltage due to lightening or switching surges.

(d) By connecting resistance in the neutral earthing, fault current is controlled.
(e) It helps for keeping neutral voltage always zero.

3. For Lightening Arrestor

The lightening arrestor or earthing, discharges the lightening charge with very low resistance, which prevents possible damages to the infrastructure. For this, very low earth resistance is necessary. This quality can be achieved by piercing the earth electrode deep in the ground till the wet soil.

Earth tester measures earth's resistance and its unit is ohm.

It is very important to earth the line and electrical equipment. It will be electrically unsafe without earthing. The pole/body of the equipment connected solidly to earth is called earthing.

Methods of Earthing

As per REC Construction Standards there are two types of earthing:

1. REC Construction Standard J-1 Coil Earthing (Fig. 4.45)
2. REC Construction standard J-2 Pipe Earthing or Spike Earthing (Fig. 4.46)

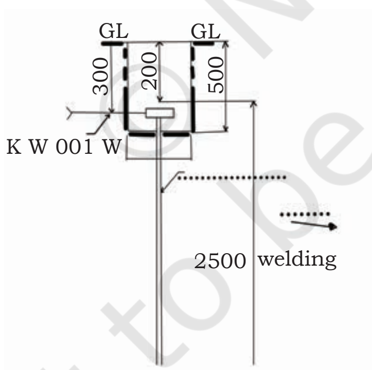


Fig. 4.46 Pipe Earthing

Notes:

1. All dimensions are in mm
2. Earth terminal should be made of G.I
3. Manufacturing tolerance
4. Clamp is to be welded to spike
5. The whole assembly is to be hot dip galvanised (BIS: 2629 and 4759)

Notes

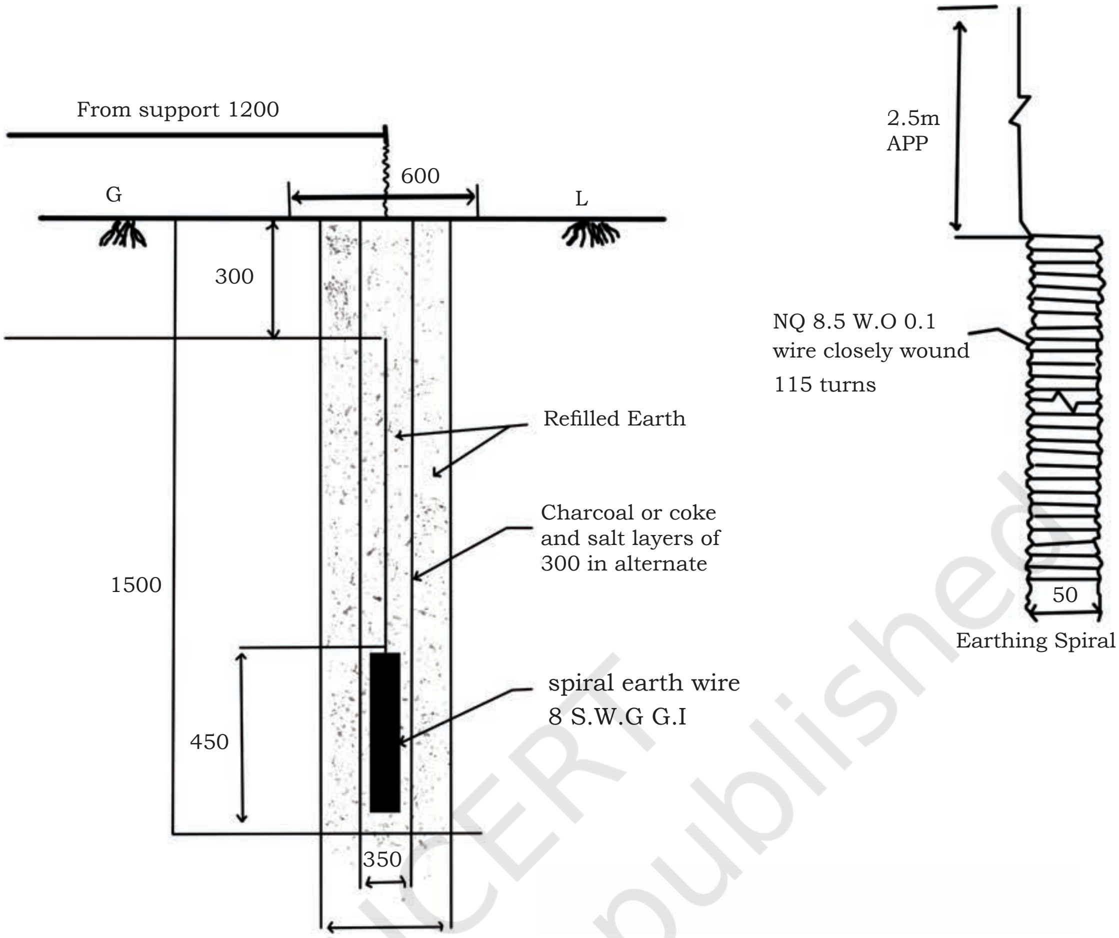


Fig. 4.45 Coil Earthing

6. All ms (mild steel) parts should be as per BIS: 2062
7. Weight mentioned is for packing and forwarding purpose only

Earth Resistance

(a) Earth resistance is depended on following factors:
   (i) Type of soil
   (ii) Temperature of earth
   (iii) Humidity in earth
   (iv) Minerals in earth
   (v) Length of electrode in the earth
   (vi) Electrode shape and size
   (vii) Distance between two electrodes
   (viii) Number of electrodes

(b) Maximum earth resistance allowed is as below:

  (i) Major power station 0.5 ohms
  (ii) Major sub-stations 1.0 ohms
  (iii) Minor sub-station 2 ohms
  (iv) Neutral bushing 0.2 ohms
  (v) Service connection 4 ohms
  (vi) L.T lightening arrestor 4 ohms
  (vii) L.T. pole 5 ohms
  (vii) H.T. pole 10 ohms
  (viii) Tower 20-30 ohms

If earth's resistance is more than the above values, the following treatments can be made for minimising resistance.

(i) Oxidation on joints should be removed and joints should be tightened.
(ii) Sufficient water should be poured in earth electrode.
(iii) Earth electrode of the biggest value should be used.
(iv) Electrodes should be connected in parallel.
(v) Earth pit of more depth and width-breadth should be made.

Anti-climbing Devices

In order to prevent unauthorised persons from climbing any of the supports of HT and LT lines without the aid of a ladder or special appliances, certain anti-climbing devices are provided to the supports. Two methods generally adopted are:

(i) barbed wire binding, for a distance of 30 cm to 40 cm at a height of 3.5 m to 4 m from ground level,
(ii) clamps with protruding spikes at a height of 3 m to 4 m.

Testing and Commissioning

When the line is ready to energise, it should be thoroughly inspected in respect of the following.

1. Poles — proper alignment, concerting and muffing.
2. Cross-arms — proper alignment.

Notes

NOTES

3. Binding, clamps and jumpers — To check whether these are in reach.
4. Conductor and ground wire — Proper sag and to check whether there are any cuts, etc.
5. Guy — To check whether the Guy wire is tight and whether the Guy insulators are intact.

Earthing System: In order to check whether the earthing connections support and the fittings are intact the following steps should be taken. Measure earth's resistance with a earth tester. After the visual inspection is over and satisfied, the conductor is tested for continuity/ground, by means of a Megohmmeter or megger. At the time of testing through the megger, a person should not climb on the pole or touch the guarding, conductor, guy wire etc.

1. Before charging any new line, it should be ensured that the required inspection fee for the new line is paid to the electrical inspector and approval obtained from him for charging the line.
2. The line should be energised before the authorised officer.
3. Before energising any new line, the officer-in-charge of the line shall notify to the workmen that the line is being energised and that it will no longer be safe to work on line. Acknowledgement of all the workmen in writing should be taken in token of having intimated them.
4. Wide publicity should be made in all the localities through which the line is to be energised will be passing. It s necessary to Intimate the time and date of energising and warning the public against the risk in meddling with the line.
5. The Officer-in-Charge of the line shall personally satisfy himself that the same is in a fit state to be energised.

Principle of Operation of Fuse

Heating effect of electric current is used in the operation of the fuse (Fig. 4.47). Any increase in an electric current in the circuit results in the increase in the rate of heat generation which will increase the temperature of the fuse wire. If this temperature happens to be above the melting point of the material of fuse wire, fuse must have operated.

Regulators used in distribution system are voltage regulators which are used to adjust voltage at distribution end. The step type voltage regulator takes an incoming voltage that will vary with load conditions and maintains a constant output voltage. As the loading increases along the distribution feeder, the voltage will drop. This reduction in voltage reduces the amount of power used by the lighting portion of the load. There are two types of regulators: single phase regulator and three phase regulator (Fig. 4.48).

Fig. 4.47 Fuse

Fig. 4.48 Voltage Regulator

Auto Re-closer

(a) A Re-closer is a protection device (Fig. 4.49):
  – For overhead power lines
  – It is a circuit breaker designed to handle fault currents
  – Designed to Re-close on to a fault

Fig. 4.49 Auto Re-closer

Sectionaliser

(a) A Sectionaliser is a load break switch:
  – It is used in conjunction with a "re-closer" or "circuit breaker".
  – It counts the interruption created by a re-closer during a fault sequence.

Check Your Progress

A. Fill in the blanks

1. Double poll (DP) strutures are required in all the angle___________
2. In 11 KV lines ___________ poles are erected within 1 km distance.
3. Guy strain insulators are placed to ___________ the lower part of the guy.
4. Connecting to conductors or wires is called ___________.
5. Cross arms and ___________ are mounted on the support with ncessary clamps, bolts and nuts.

B. Multiple choice questions

1. Which type of joint is made with Aluminium conductors?
   (a) Compression (b) Meried
   (c) Sleeve (d) Britannia

NOTES

2. Which of these is not a type of porcelain insulator?
   (a) Pin type (b) Strain type
   (c) Britannia (d) Shackle type
3. While binding the stay, pole should not be tilted.
   (a) False
   (b) True
4. The diamond guarding is used for
   (a) LT Line (b) HT Line
   (c) Both HT and LT (d) None of the above
5. Average span of 11 KV line is
   (a) 50 meter (b) 2. 60 meter
   (c) 3. 75 meter (d) 4. 100 meter

B. Short answer questions

1. Discuss the importance of guarding. Explain the types of guarding.
2. List the factors on which earth's resistance is dependant
3. How do lightening arrestors help in earthing?
4. Explain the types of joints used in conductor jointing.

Session 4: Distribution Line Maintenance

The lines and equipment should be inspected by the competent authority. Following points need to be taken care of during inspection:

1. For existing substation, the work should be done as per the layout approval.
2. Statutory clearances have to be ensured, while inspecting the following crossings:
   (a) Railway crossings
   (b) P and T crossings
   (c) Junctions
   (d) Road Crossings
3. Make sure that proper clearance is obtained for the lines with different voltages operating on the same support.
4. DPs and cut points should be inspected based on need and approvals.
5. Adequate safety and clearances should be ensured while running the lines at domestic colonies.

6. There should be appropriate earthing.
7. Any crossing should be at right angles, to the extent possible.
8. Proper cross arms, extension cross arms should be ensured as per the requirement.


Fig. 4.50 Power Distribution Lines

Maintenance

When an overhead line trips on a sustained fault, it should be inspected to find out the nature of fault such as loose sag, snapping of conductor, tree branches touching the lines, conductor falling on cross arms (Fig. 4.50). An improvement with a view to avoid re-occurrence of such faults in future should be arranged and carried out soon (Fig. 4.51). Complaints regarding no current/failure of power supply, voltage fluctuation, and load shedding and scheduled outages shall be addressed by the senior lineman as per the provisions of the regulations. Problems related to current such as no current or failure of power supply in premises could occur due to various reasons such as:


Fig. 4.51 Mitigating Bird Hazards to Overhead Lines

- Fuse blown out/tripping of MCB
- Burnt meter
- Broken service line
- Service line snapped from pole
- Fault in distribution mains
- Distribution transformer failure
- Fault in HT system
- Problem in grid (33 kV or 66 kV) substation
- Planned/scheduled/emergency maintenance work
- Load shedding
- Street light complaint

Pre-monsoon Inspection

The inspection carried out with the overhead lines without supply is called pre-monsoon inspection. It should be planned in advance with proper tools and equipment (Figs. 4.52 and 4.53).

Pre-monsoon inspection involves the following

1. Tree cutting should be properly executed.
2. Sagging of lines should be minimised.
3. Leaned poles should be rectified.
4. Lines should be properly aligned by tightening with proper bolts and nuts.
5. Earthing should be checked.
6. Torn insulators/flash over insulators should be replaced.
7. Jumpers at cut points should be checked up.
8. Stay wires should be properly aligned.

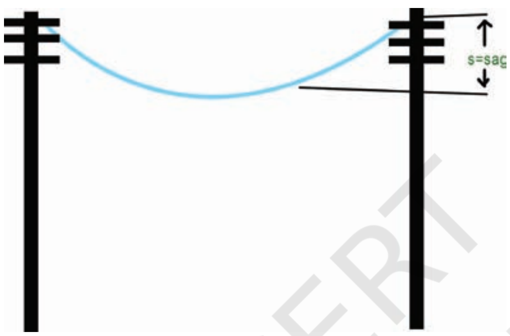


Fig. 4.52 Sag in Overhead Distribution Lines

Fig. 4.53 Inspection of Power Distribution Lines

11 kV Lines Maintenance

11 kV Lines maintenance is required to minimise interruptions and improve the efficiency of power supply. The overhead lines should be inspected periodically to detect any fault which may lead to break down of electric supply. When an overhead line trips, it should be inspected to find out the nature of fault.

Fig. 4.54 Low Tension Distribution Lines (LT)

Low Tension (LT) Line Maintenance

LT Line (Fig. 4.54) maintenance includes:

1. Alignment of poles
2. Replacement of damaged service wire
3. Removal of bird nests
4. Tree clearance
5. Checking of pole fittings and street light brackets
6. Careful examination of damages to L T conductor such as black spots on conductor

Ground Patrol

The periodic patrolling (not exceeding a month) of overhead lines at ground level, while, the line is live, is called **ground patrol** (pole to pole inspection) poles maintenance. The following should be checked:

- Leaning of pole (Fig. 4.55)
- Sinking of earth around the pole
- Corrosion of metal at ground level (RSJ Poles)
- Cracks in Pre stressed Cement Concrete Poles (PSCC).

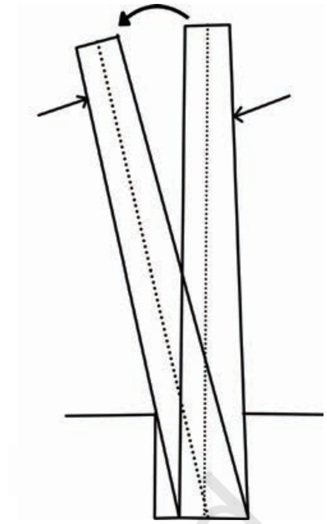


Fig. 4.55 Leaning of Pole due to loose foundation.

Cross Arms

The following should be checked while maintaining cross arms:

- Tilting of cross arms
- Rusting of cross arms
- Bird nest or creeper on cross arm (Fig. 4.56)

Bindings

The looseness and cutting of bindings should be carefully observed while patrolling.

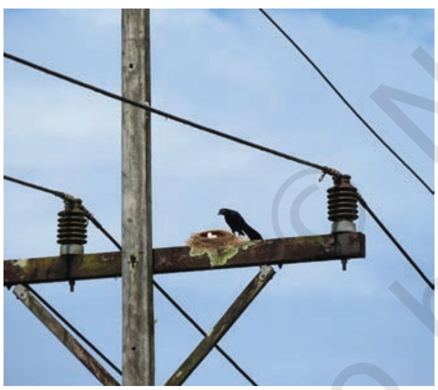


Fig. 4.56 Bird's Nest on Cross Arm

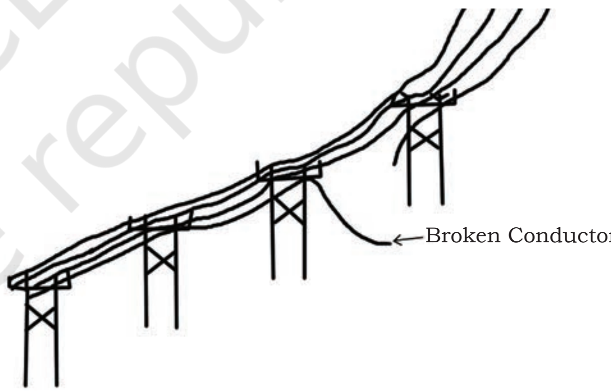


Fig. 4.57 Conductors Distribution System

Conductors

The following should be checked while maintaining conductors (Fig. 4.57):

- Cut strands, burnt marks and corrosion
- Breakage/Looseness of conductors
- Spotting kites, green creepers on the conductors

Fig. 4.58 Stay Wire

Stay Wire

The following should be checked while maintaining stay wire (Fig. 4.58):

- Corrosion of guy rod and stay wire
- Guy wire tightness
- Creeper on the stay wire

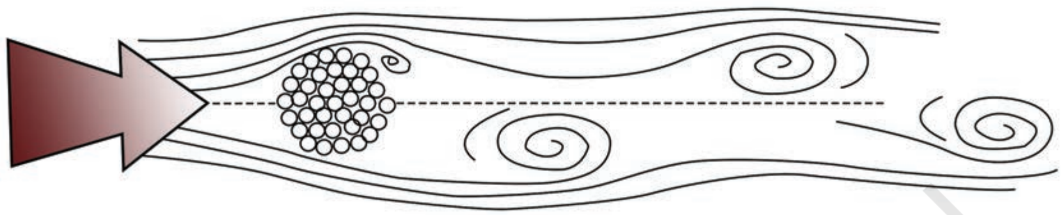


Fig. 4.59 Aeolian Vibration

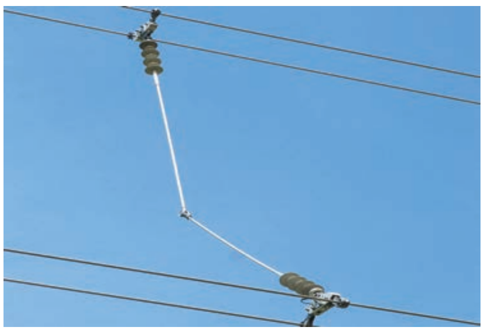


Fig. 4.60 Power Line Galloping

Causes of Conductor Damage

Aeolian vibration: It is one of the most important problems in power transmission lines because it represents the major cause of fatigue, failure of conductor strands or of items associated with the support, use and protection of the conductor during high wind pressures (Fig. 4.59).

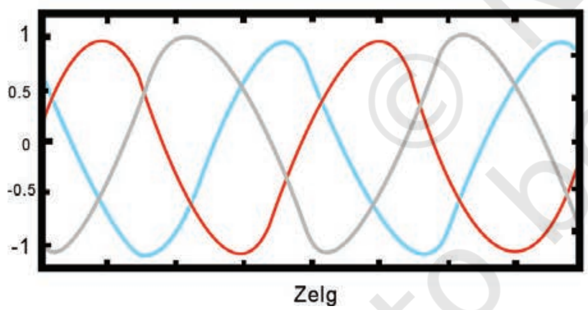


Fig. 4.61 Voltage Balance

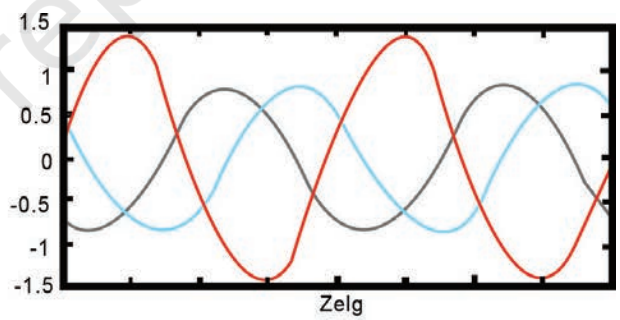


Fig. 4.62 Voltage Imbalance

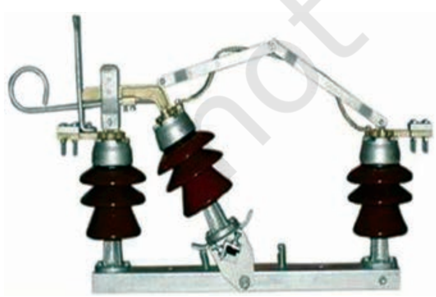


Fig. 4.63 Air Break Switches

Galloping: The high-amplitude, low-frequency oscillation of overhead power lines is due to wind. Sway oscillation and gallop tend to short circuit between lines thus damage is caused due to arcing. PG clamp maintains equal distance across the lines by maintaining the sag to protect from sway oscillation (Fig. 4.60).

Unbalance loading: Major line failures are due to unbalance load when one phase conductor gets overheated and snapped (melted down) due to excessive current (Figs. 4.61, 4.62 and 4.63).

Overloading: When a line is loaded beyond the maximum current carrying capacity the conductor gets overheated and snapped.

Air Break (AB) switches need maintainance to check:

- Defect in closing of the AB switch
- Missing of the lock
- Damage of earth wire
- Dust accumulation on the insulators
- Blades/contact burnings

11 kV Cable and Cable Boxes

- Proper supporting of cable and cable boxes
- Damage to insulator and compound leakage from the box
- Intactness of terminal connections with overhead lines and earthing

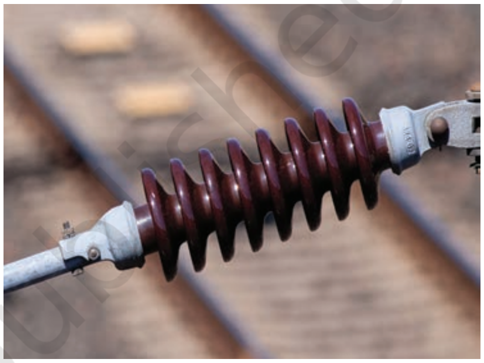


Fig. 4.64 Disc Insulators used in Power Lines

Insulator Discs

Due to moisture and dust particles on the surface of insulator the resistance is reduced. This leads to flash over marks in case of lightning (Fig. 4.64).

Causes of Insulator Damage

1. Due to difference in temperatures and hot and cold season, there is extra stress on both conductor and insulators of entire overhead network (Fig. 4.65).
2. During rainy season dust over the insulator becomes conductive and forms fine hair crack which further develops to fretting due to load and lightening.
3. Excessive tightening of PG clamps causes extra strain to disc insulator, pin insulator and conductor through-out up to end points and causes tensile breaks of conductor and abrasion, fatigue on pin insulators.

Fig. 4.65 Wire Insulation Damage

Fig. 4.66 Megger

Fig. 4.67 Earth

Fig. 4.68 Equipment Calibration

4. Though lightning arresters (LA) are the most effective means of protecting electrical lines against lightning and switching, failure of LA directly impacts the insulators damage due to spark.

Line conductors are electrically insulated from each other as well as from the pole 'insulators'. The insulator and its binding should be mechanically strong enough to withstand the resultant force due to combined effect of wind pressure and weight of the conductor in the span.

Material Testing Equipment

Line conductors are electrically insulated from each other as well as from the pole 'insulators'. The insulator and its binding should be mechanically strong enough to withstand the resultant force due to combined effect of wind pressure and weight of the conductor in the span.

Proper calibration and working of equipment should be double checked before using them for testing and repair activity (Figs. 4.66, 4.67 and 4.68). In case tools used in testing are not properly working and calibrated, then it will not lead to proper adjustment of equipment which in turn would result in malfunction of the total connected system. All the equipment which are meant for testing and repair activities should be kept separately from other equipment, and should be tested for their accuracy and workability according to defined standards.

Table 4.7: Line Patrol Log Sheet

Item No.	Points to be checked during inspection and defects noticed	Location Nos.			Action taken for Rectification	Inspection Officer's Remarks
	General					
1.	Adequate clearance to conductors and poles are available from trees, shrubs, bushes etc.		Yes	No		
2.	Vertical and horizontal clearance from the neighbouring structures under construction etc., are adequate		Yes	No		

3.	Any new road, channels, earth embankment are constructed near or below the lines reducing clearance		Yes	No		
	Poles					
4.	The pole is leaning and if so whether stay is required to make it plumb		Yes	No		
5.	Earth around the pole has sunk or eroded		Yes	No		
6.	The metal is corroded at ground level		Yes	No		
7.	Any cracks have been developed in PCC/RCC poles		Yes	No		
8.	The pole is intact and free from mechanical injury due to vehicles dashing against them		Yes	No		
	Cross Arms					
9.	Any bird nest, or creeper observed on cross arms		Yes	No		
10.	The cross arm is tilted		Yes	No		
11.	The cross arm is rusted		Yes	No		
	Binding/Clamps/Jumpers					
12.	The bindings/jumpers are cut,		Yes	No		
	Loose, Charred or Burnt		Yes	No		
13.	Visible indications for heating of the PG clamps are observed		Yes	No		
14.	Visible dangers like cut strands, and burn marks, corrosion etc. observed		Yes	No		
15.	The conductors are loose, increasing the sag		Yes	No		
16.	Kites or green creepers are observed on the conductors		Yes	No		
17.	The conductor/ground wire has sufficient clearance over roads, rivers, channels, railways and telecommunication circuits, haystacks etc.		Yes	No		
18.	The guarding and earth, provided for conductors are intact		Yes	No		
	Guys					
19.	Corrosion of guy rod and stay wire is observed		Yes	No		
20.	The guy wire is tight		Yes	No		

21.	The guy insulators provided are intact		Yes	No		
22.	Any green creepers on the stay wire		Yes	No		
23.	Guy pits have been washed away/ sunk		Yes	No		
24.	The sleeve concreting is in order		Yes	No		
	AB Switches and Fuse					
25.	There is any visual indication for the defective closing of the switch		Yes	No		
26.	The lock is missing		Yes	No		
27.	The earth wire is cut or damaged		Yes	No		
28.	There is too much of dust accumulated on the insulators		Yes	No		
29.	The blades/contacts/arcing horns are burnt out or charred		Yes	No		
	Lightning Arresters					
30.	The porcelain is damaged		Yes	No		
31.	The line and earth connections are intact		Yes	No		
32.	There is any external indication to show the lightning arresters have been punctured		Yes	No		
	11 kV Cable and Cable Boxes					
33.	The cable and cable boxes are properly supported		Yes	No		
34.	The insulators are damaged and compound leaking from the box		Yes	No		
35.	The terminal connection with the overhead line is intact		Yes	No		
36.	The earthing lead from the cable box is intact		Yes	No		
	Earthing System					
37.	The earthing connections of the metal supports and fittings are intact		Yes	No		
	Schedule of Periodical Routine Inspection of Lines Lightning Arresters					
38.	The porcelain is damaged		Yes	No		

39.	The line and earth connections are intact		Yes	No		
40.	There is any external indication to show the lightning arresters have been punctured		Yes	No		
	11 kV Cable and Cable Boxes					
41.	The cable and cable boxes are properly supported		Yes	No		
42.	The insulators are damaged and compound leaking from the box		Yes	No		
43.	The terminal connection with the overhead line is intact		Yes	No		
44.	The earthing lead from the cable box is intact		Yes	No		

Schedule of Periodical Routine Inspection of Lines

The lineman should adhere to the time limits as per the performance standard prescribed by the State Electricity Regulatory Commission.

The following table indicates the time standards as prescribed by the Delhi Electricity Regulatory Commission (DERC):

Table 4.8 Schedule for Inspection of Lines

Nature of Cause of Power Supply Failure	Maximum Time Limit for Power Restoration
Fuse blown out or MCB tripped	• Within three hours for urban areas. • Within eight hours for rural areas
Service line broken, snapped from the pole	• Within six hours for urban areas. • Within 12 hours for rural areas.
Fault in distribution mains	• Temporary supply to be restored within four hours from alternate source, wherever feasible. • Rectification of fault and thereafter restoration of normal power supply within 12 hours.
Distribution transformer failed/burnt	• Temporary restoration of supply through mobile transformer or another backup source within eight hours, wherever feasible. • Replacement of failed transformer within 48 hours.
HT mains failed	• Temporary restoration of power supply within four hours wherever feasible • Rectification of fault within 12 hours.

Problem in grid 33 kV substation	• Restoration of supply from alternate source, wherever feasible within six hours. • Roster load shedding may be carried out to avoid overloading of alternate source. • Repair and restoration of supply within 48 hours.
Failure of power transformer	• Restoration of supply from alternate source, wherever feasible within six hours. • Roster load shedding may be carried out to avoid overloading of alternate source. • Replacement action to be intimated to the Commission within 72 hours and replacement of power transformer within 20 days.
Burnt meter	• Restoration of supply by bypassing the burnt meter within six hours. • Replacement of burnt meter within three days
Street light complaint	• Restoration within 72 hours.

Check Your Progress

A. Fill in the blanks

1. Resistance opposes __________ flow and inductance opposes __________ flow.
2. Load shedding is normally carried out when the power __________ is more than the power __________ at a given point of time to shed excess load on the generating station.
3. __________ is used for cutting, removing insulation, jointing and twisting the electric wires and cables even on live line.
4. Bench vice is use to __________ the object.
5. The flow of current towards an undesired path or abnormal stoppage of current is termed as a __________.

B. Multiple choice questions

1. The selection of poles for erection of lines depends on a number of factors such as:
   (a) Distribution of power
   (b) Pole strength
   (c) Type and size of conductor
   (d) wind pressure
   (e) All of above
   (f) Only (a) and (c)

2. What are the causes of insulator damage?
   (a) Due to difference in temperatures
   (b) Improper calibration
   (c) Broken service line
   (d) None of the above
3. Current transformers are:
   (a) Small transformer
   (b) Supply low values of current
   (c) Used where the current or voltage is too high
   (d) (a) and (c)
   (e) (a) and (b)
   (f) (a), (b) and (c)

C. Match the columns

Group A		Group B	
1.	AAC	(a)	high-capacity, high-strength stranded conductor
2.	ACSR	(b)	made out of high strength Aluminum-Magnesium-Silicon Alloy
3.	AAAC	(c)	made up of one or more strands of hard drawn 1350 aluminum alloy
4.	Shackle Insulator	(d)	mounted axially

D. Short answer questions

1. Why maintenance is important?
2. What maintenance should be done during pre monsoon inspections?
3. What are the causes of insulation damage?
4. Why material testing equipment is required? Explain with reasons.

Notes

Live Line Maintenance

AEROPOWER SERVICES

ALL SERVICES

POWER LINE PATROL

POWER LINE METHODICAL INSPECTION

LIVE LINE INSPECTION & TESTING

LIVE LINE MAINTENANCE

OTHER POWER LINE SERVICES

ASSET MANAGEMENT SOLUTIONS

AERIAL LIFTING

SPECIALISED TRAINING

nsulator Washing

ɘropower's helicopter live line insulator washing system is one the most efficient and cost-effective available. Comprising a 'belly' mounted ɩnk, water pump and a 5.5m non-conductive boom, the Aeropower wash system was developed in-house, and has been refined over 25 yea

ɘropower's insulator wash system uses a stream of high pressure, demineralised water to remove pollutants from glass and porcelain insul

ıe helicopter is flown adjacent to the insulator string and positioned by the pilot to enable the line worker to direct a high-pressure stream ater onto and under each insulator. The swirling motion created by the water flow removes pollutants such as dust and dirt, salt, and bird oppings. The insulator washing is conducted in line with IEEE 957: Guide for Cleaning Insulators which specifies water quality requirements e 'hot-end to cold-end' wash and then rinse method.

ıe Aeropower live-line insulator wash system is suitable for washing horizontal and suspension type insulator strings. Whilst wash time will ıe voltage/string length and how dirty the string is, the Aeropower helicopter based approach enables a string to be typically washed in 15 conds.

support washing operations and to improve operational efficiency, Aeropower has developed a truck mounted mobile helipad with fuel a ater tanks which enables the aircraft to be refuelled and to take on board additional water close to the power-line, minimising ferry flight ti

ɘropower's live line insulator washing operations are conducted in accordance with the Aeropower Live Line Work Manual and conform to ustralian and International Live Line standards:

- AS 5804 High-Voltage Live Working
- IEEE 516 Guide for Maintenance Methods on Energised Powerlines
- ESAA Helicopter for Live Line Work Guidelines
- IEEE 957: Guide for Cleaning Insulators

ardware Repair & Replacement

ɘropower's MD500 helicopters can be fitted with an approved 'platform' that provides a safe and stable workspace from which the linework ɘrform a range of live line maintenance tasks including:

- Conductor / earth-wire repairs
- OPGW Maintenance / installation
- Installation / removal of aerial marker balls
- Installation / removal of bird diverters
- Installation / maintenance of dampers
- Installation of helical wraps

ıe platform can accommodate a range of tools and other equipment, as well as components and parts.

orking as a team, the pilot and lineworker complete a range of tasks with the helicopter moving to assist the lineworker.

ɘropower's live line maintenance operations are conducted in accordance with the Aeropower Live Line Work Manual and conform to Austr ıd International Live Line standards:

- AS 5804 High-Voltage Live Working
- IEEE 516 Guide for Maintenance Methods on Energised Powerlines
- ESAA Helicopter for Live Line Work Guidelines

Live-line working

In electrical engineering, **live-line working**, also known as **hotline maintenance**, is the maintenance of electrical equipment, often operating at high voltage, while the equipment is energised. Although this is more hazardous for personnel than working on electrical equipment with the power off, live-line maintenance techniques are used in the electric power distribution industry to avoid the disruption and high economic costs of having to turn off power to customers to perform essential periodic maintenance on transmission lines and other equipment.

A lineman wearing equipment for hot glove work

The first techniques for live-line working were developed in the early years of the 20th century, and both equipment and work methods were later refined to deal with increasingly higher voltages. In the 1960s, methods were developed in the laboratory to enable field workers to come into direct contact with high voltage lines. Such methods can be applied to enable safe work at the highest transmission voltages.[1]

Background

In general, it is impossible to determine visually whether electrical equipment is energized; in any event, it is often necessary to maintain or repair circuits while they are in operation. In addition, at high voltages, it is unnecessary to come into direct contact with charged equipment to be shocked because an arc can jump from the equipment to a tool or part of the body. Materials such as rubber, while excellent insulators, are also subject to electrical failure at high voltages.

Methods

In general, there are three methods of live-line working which help workers avoid the considerable hazards of live line working.[2] In various ways, they all serve to prevent current flowing from the live equipment through the worker.

Hot stick or Live Line Tool
: Hot sticks are used in live line work by having the worker remain at a specified distance from the live parts and carry out the work by means of an insulating stick. Tools can be attached to the stick, allowing work to be performed with the worker safely away from the live conductors.

Insulating Gloves or Rubber Gloves
: A live line worker is electrically protected by insulating gloves and other insulating equipment, and carries out the work in direct mechanical contact with live parts.

Barehand or Potential
: The barehanded approach has a live line worker performing the work in direct electric contact with live parts. Before contact, the worker's body is raised to the same electric potential as the live parts, and then held there by electric connection, while maintaining suitable isolation from the surroundings which are at different potentials, like the ground, other people or trees. Because the worker and the work are at the same potential, no current flows through the worker.

Unearthed or De-energised

Some organizations additionally consider working on unearthed de-energised equipment to be another form of live-line working. This is because the line might become inadvertently charged (e.g. through a back-charged transformer, possibly as a result of an improperly connected, inadequately isolated emergency generator at a customer facility), or inductively coupled from an adjacent in-service line. To prevent this, the line is first grounded via a clamp known as a bond or drain earth. Once this is in place, further work is not considered to be live-line working.

Working under tension from an electrically insulating platform in a medium voltage network

Hot stick

Hot-stick working appeared in the second decade of the 20th century, when insulating poles made from baked wood were used for tasks such as replacing fuses, replacing post insulators, and transferring lines onto temporary supports.[2] The sticks enabled the linemen to carry out the work without infringing on the minimum clearance distances from live equipment. As experience with the techniques developed, then the operating voltages at which the work was performed increased. With the advent of fibreglass poles in the late 1950s, which neither split nor soaked up rainwater, utilities were prepared to carry out hot-stick working to their highest operating voltages, perhaps 765 kV.[2]

Tools, such as hooks or socket wrenches can be mounted at the end of the pole. More sophisticated poles can accept pneumatically or hydraulically driven power tools which allow, for example, bolts to be unscrewed remotely. A rotary wire brush allows a terminal to be scoured clean before a connection is made. However, a worker's dexterity is naturally reduced when operating tools at the end of a pole that is several metres long.[3]

Insulating glove or rubber glove working

Usually applied for work above 1 kV AC 1.5 kV DC The primary classes are:

- Class 00 - phase to phase working voltage 500 V
- Class 0 - phase to phase working voltage 1.0 kV
- Class 1 - phase to phase working voltage 7.5 kV
- Class 2 - phase to phase working voltage 17 kV
- Class 3 - phase to phase working voltage 26.5 kV
- Class 4 - phase to phase working voltage 36 kV

Gloves protect the worker from exposure to the live part being worked upon sometimes referred to as the 1st point of contact; the point where current would enter the body should an inadvertent contact be made. Covers of insulating material such as blankets and linehose are employed in rubber glove working to protect the worker from exposure to a part at a different potential sometimes referred to as the 2nd point of contact; the point where current would leave the body should an inadvertent contact be made.

Bare hand

Bare-hand, or potential working involves placing the worker in direct electrical contact with an energized overhead line. The worker might work alongside the lines, from a platform that is suspended from them, or may sit or stand directly on the line itself.[3] In all cases, the worker's body is maintained at the same voltage as the line. It is imperative that the worker maintain appropriate and adequate limits of approach to any part at a different potential. Such techniques were first used in 1960.[2]

There are a number of ways in which the worker can access the live parts:

- The worker can access from a specialist type of mobile elevating work platform (MEWP) termed an insulating aerial device (IAD) which has a boom of insulating material and which all conductive parts at the platform end are bonded together. There are other requirements for safe working such as gradient control devices, a means of preventing a vacuum in the hydraulic lines, etc.
- The worker can stand on an insulating ladder which is maneuvered to the line by means of non-conductive rope.
- The worker is lowered from a helicopter and transfers themself to the line.
- The worker is brought alongside the wire in a hovering helicopter and works from that position.

As the worker approaches the line, an arc will form between the line and the worker as they are being charged. This arc can be debilitating, and the worker must immediately bond themself electrically to the line to prevent further arcing.[3] A worker may use a conducting wand during the approach to first make the connection. Once on the line, the worker is safe from shock as both the lineworker and the wire are at the same electric potential, and hence no current passes through their body. This is the same principle as that which allows birds to safely sit on power lines.[3]

When the work is completed, the process is reversed to remove the worker safely from the wire. Barehand working provides the lineworker with greater dexterity than the hot stick method, and may be the preferred option if conditions permit it.[4] With this technique, insulator strings, conductor spacers and vibration dampers can be replaced, or lines spliced, without any loss of supply.[4]

The strong electric field surrounding charged equipment is enough to drive a current of approximately 15 μA for each $kV \cdot m^{-1}$ through a human body.[5] To prevent this, hot-hand workers are usually required to wear a Faraday suit. This is a set of overalls made from or woven throughout with conducting fibers. The suit is in effect a wearable Faraday cage, which equalizes the potential over the body, and ensures there is no through-tissue current.[6][7] Conducting gloves, even conducting socks, are also necessary,[8] leaving only the face uncovered.[3]

There is little practical upper voltage limit for hot-hand working, and it has been successfully performed at some of the highest transmission operating voltages in the world, such as the Russian 1150 kV system.[9]

Helicopter

A lineworker wearing a Faraday suit can work on live, high-power lines by being transported to the lines in a helicopter. The worker can perform maintenance sitting on an outrigger platform attached to the helicopter while the aircraft hovers next to the line. When approaching the line a long wand is touched to the line to equalize the potential of the aircraft to that of the line, then a breakaway bonding wire connected to the helicopter's frame is attached to the line during work. Alternatively the worker can transfer to the wires from the helicopter and crawl down the wires, then be picked up by the helicopter after the work is completed.[10]

Eye protection

An electric arc is extremely bright, including in the ultraviolet, and can cause arc eye, a painful and potentially blinding condition. Workers may be provided with appropriately tinted goggles that protect their vision in the event of a flash, and provide defence against debris ejected by an arc.

See also

- Lineworker

References

1. Gorur, Ravi (2017-08-26). "Live Line Working and Insulators" (http://www.inmr.com/live-line-working-insulators-2/). *INMR : Independent T&D Information Resources*. Retrieved 2019-03-10.
2. "Live Work Guide for Substations" (http://mydocs.epri.com/docs/public/000000000001008746.pdf) (PDF). EPRI. October 2004. Retrieved 8 December 2008.
3. Stix, Gary (September 1988). "Working hot: life at 765 kV" (http://www.simson.net/ref/1988/IEEE_Working_Live.pdf) (PDF). *IEEE Spectrum*. **25** (9): 54–56. doi:10.1109/6.7169 (https://doi.org/10.1109%2F6.7169). ISSN 0018-9235 (https://www.worldcat.org/issn/0018-9235).
4. Miller, R.H.; Malinowski, J.H. (1970). *Power System Operation* (https://books.google.com/books?id=6tk6yXzu62IC&pg=PA178). McGraw-Hill Professional. pp. 178–180. ISBN 978-0-07-041977-3.
5. Krawulski, Andrzej; Niejadlik, Tomasz (7–9 June 2006). "Live wire work on 400 kV and 220 kV OHL" (http://www.vde-kongress.de/NR/rdonlyres/0B8B61EF-2ACC-4C29-8E66-1CFF652E1BEB/20815/etg_1_09.pdf) (PDF). *Proceedings of the 8th International Conference on Live Maintenance*. Prague: ICOLIM 2006.
6. Bosonetto, Doriano; Iulita, Mario (7–9 June 2006). "The development of conductive suits: the Italian experience" (http://www.vde-kongress.de/NR/rdonlyres/5D1FB137-884E-41F0-88E2-B257717C84F6/20907/etg_3_12.pdf) (PDF). *Proceedings of the 8th International Conference on Live Maintenance*. Prague: ICOLIM 2006.
7. Davies, John (1988). *Performance of Protective Clothing* (https://books.google.com/books?id=RvVWcAbHI10C&pg=PA813). ASTM International. pp. 813–832. ISBN 978-0-8031-1167-7.
8. *Electrical Times* (https://books.google.com/books?id=Z2rP5ie2uSsC). Vol. 156. July 1969. p. 58.
9. Krylov, S.V.; Timashova, L.V. "Experience of live-line maintenance on 500-1200 kV lines in Russia". *Transmission and Distribution Construction and Live Line Maintenance*: 359–368.
10. Head, Elan (April 2015). "High-value cargo" (https://verticalmag.com/features/highvaluecargo/). *Vertical Magazine*. pp. 80–87. Retrieved 24 June 2021.

OVERHEAD LINE EQUIPMENT

PUBLISHED 29 MAR 2017

Overhead Line Equipment – Suppliers Of Medium & High Voltage Electrical Equipment

Thorne & Derrick International, are Specialist Distributors of an extensive range of **Overhead Line Equipment** used to erect, construct and maintain LV-HV power lines.

We service UK DNO's, global utilities and their contractors involved in the installation and maintenance of Overhead Transmission and Distribution power lines with electrification equipment including **33kV joints, terminations and connectors** and **arc flash clothing** to protect linesmen and jointers against the risks and hazards associated with arc incident.

Need Products Quick?

T&D can source all your **Overhead Line Equipment** – we

FEATURED MANUFACTURER

Nexans
ELECTRIFY THE FUTURE

FEATURED BLOG ARTICLES

66kV 72.5kV | Power Cables Accessories for Offshore Windfarms

PUBLISHED 08 DEC 2022

Power Cable Accessories Nexans Power Accessories is the leading European innovator and manufacturer of…

Supplying Cable

GET QUOTE

T&D, Largest **CATU Electrical** Stockist

CUTTING & CRIMPING TOOLS

Copper ♦ Aluminium ♦ ACSR ♦ ACC ♦ AAAC ♦ **Cutting & Crimping Tools**

Hydraulic heads and battery tools for power line cutting and compression of **crimping connectors**, terminals and joints used in high voltage electrical transmission and distribution.

T&D, **Cembre** Stockist

HIGH VOLTAGE JOINTS & TERMINATIONS

Cable Joints ♦ Cable Terminations ♦ Sealing Ends ♦ Surge Arresters

MENU

CALL US | GET QUOTE | CONTACT

INSULATORS

Pin Insulators (11kV 33kV Porcelain) ♦ Insulator Pins (Line & Pilot Pins) ♦ Cap & Pin Disc Insulators ♦ Staywire Insulators 11kV 20kV 33kV ♦ Low Voltage Insulators – Coachscrew & Reel ♦ Conductor Rail Insulators – Porcelain ♦ Toughened Glass Cap & Pin Disc Insulators

INSULATOR FITTINGS

Ball Ended Fittings ♦ Socket Ended Fittings ♦ Overhead Line Shackles ♦ Yoke Plates ♦ Links & Plates ♦ Arcing Horns ♦ Sag Adjuster Sets

MENU

CALL US | GET QUOTE | CONTACT

Credit Nexans – contact us for **HV Cable Joints, Terminations & Connectors**

Credit ABB – Joint, Terminate & Connect Medium & High Voltage Cables

THORNE & DERRICK

T&D are UK distributors and worldwide exporters of LV, MV & HV Cable Installation, **Cable Jointing**, **Duct Seals**, Substation & Electrical Equipment – we service UK and

MENU

CALL US | GET QUOTE | CONTACT

FURTHER READING

TD – LV, MV & HV Cable Installation, Jointing, Substation & Electrical Equipment
Size: 3.25 MB

RELATED PRODUCTS

Phase Comparators (LV MV HV 11kV 33kV)
View product

Voltage Detectors | LV MV HV EHV 11kV 33kV 66kV 132kV up to 765kV
View product

Insulating Gloves (LV MV HV 11kV 33kV Electrical Gloves)
View product

Insulating Matting (LV MV HV 11kV 33kV Switchgear Mats)
View product

MENU

CALL US | GET QUOTE | CONTACT

Overhead Line & Underground Cable Tools For Transmission & Distribution
View product

Portable Earthing Kits – Short Circuit & Portable Earths For Substations & Overhead Lines
View product

NAVIGATION PRODUCT CATEGORIES ADDRESS

MENU

CALL US | GET QUOTE | CONTACT

Electrical PPE & Protection Kits

Cable Cleats, Clamps & Hangers

Cable Cutting & Cable Crimping Tools

Cable Duct

Cable Lugs & Connectors (Mechanical Shearbolt & Crimp Types)

Cable Protection

Cable Protection Covers

Cables

Cold Shrink

Cut Outs & Isolators

Overhead Transmission Lines Maintenance Explained

OHTL maintenance is one of the major parts in my work. We are responsible for maintenance of 11KV

We do all our maintenance with power off, when it comes to live maintenance, we hire a qualified team to do it for us.

In this article I will answer some important questions about overhead transmission line (OHTL) maintenance.

Table of Contents

What Is Transmission Line Maintenance?

The process of replacement damage insulators, periodic inspection and repair the Overhead Transmission lines towers, conductors and accessories is called the transmission line maintenance.

This process includes insulators cleaning, joints tightening and hot spots clearing.

As the overhead transmission line (https://www.electrical4uonline.com/overhead-power-lines-faults/) comprise of three main components i.e., conductor (https://www.electrical4uonline.com/aluminum-conductor/), insulator, and the towers (and the supporting materials), the process also refers to the replacement of electric equipment used in the overhead transmission lines.

https://www.electrical4uonline.com/product/cracked-insulator/
(https://www.electrical4uonline.com/product/cracked-insulator/)Cracked Overhead Power Line Insulator

This equipment includes the broken insulators, worn-out cables and the wooden cross-arms.

A checkup of the foundation of every tower, its earthing, power conductor and earth wire conductor is also done.

A calculation based on corona effect is also performed.

The dust and dirt on the transformers (https://www.electrical4uonline.com/electric-transformers-faults-a-complete-guide/)bushings may lead to flash-over and poor efficiency of the system of power transmission. So, cleaning transformers is also an essential part of the OHTL maintenance (https://www.electrical4uonline.com/electrical-maintenance-all-types/).

Now, let’s move to another question and discuss OHTL maintenance (https://www.electrical4uonline.com/electrical-maintenance/)types.

What Is Transmission Line Maintenance Types?

There are 2 types for the maintenance of transmission lines.

- **Cold Line maintenance**
- **Hot Line maintenance**

The cold line maintenance has another name i.e., “In-Operative Method” of transmission line maintenance.

While the hot line maintenance (https://www.electrical4uonline.com/overhead-power-line/) is also known as “line-in Operation” of maintenance of transmission lines.

To choose one of these options, the guidelines have been issued by Institute of Electrical and Electronics Engineering (IEEE (https://www.ieee.org/)).

You should have the knowledge of voltage levels, that is being transmitted by the line, before choosing one of these options for maintenance types.

> *We use cold maintenance in my workplace for short period non periodic maintenance, when the cost of down time is not high.*
>
> *While the company prefers live maintenance for long period regular maintenance, while the cost of stopping loads will be costly.*
>
> — In my workplace

Overhead Transmission Line Maintenance Procedure

In the transmission line maintenance work we do replacement of burnt jumpers, insulators, maintaining the ground clearances, replacements of damaged poles, re-stringing of the cables and line patrolling.

As a short procedure list :

- Prepare all work permits from the authorized departments.
- Prepare a good work plane with all details and parts that need maintenance.
- Make sure that the all crew members know their rule and what they are expected to do.
- Check all hand tools, PPE equipment, and all trucks and vehicle.
- Make a pre-work meeting to discuss all points with the team to make every thing clear, specially safety precautions.
- If the work is cold maintenance, check and double check power isolation procedure before work.
- Recheck power with test tools.

- Make sure to use grounding rods and cables for all lines to protect the workers from any unexpected power connection.
- Go ahead with great caution and make sure that only qualified workers are involved in the job.
- After completing all tasks as planned, never ever connect power before direct contact with all members to ensure that no body still on the towers.
- Connect power and check loads.

OHTL Maintenance Tasks

- Ground Inspection: The first step of maintenance is ground inspection of the cables and towers. The surveyor walks along the transmission lines (https://www.electrical4uonline.com/overhead-power-lines-faults/) and checks if the line is cut or not.
- The tower foundation, nut-bolts, beam, cross-arms, waist, main legs, horizontal and diagonal members are checked. The anti-climbing parts of towers are set if damaged.
- The nut-bolts are replaced if hey become useless.
- The insulators and vibration dampers should be also checked.
- If the tower body is damaged, on the basis of the magnitude of damage, it is either replaced or

repaired.

- Insulators inspection is carried out. The insulators are checked to make sure that there is no damage is done to them by flashover events or if they are broken or contaminated.
- The sag between two poles is also measured to see if the line between the poles has loosened or not.
- Conductor (https://www.electrical4uonline.com/electrical-conductor/)condition and spacing from the adjacent conductor is checked.
- Corona Inspection: Corona can be really catastrophic in the overhead line transmission system. The detection of corona is carried out by the "Thermal Vision Scanning". In corona, a reasonable amount of heat is emitted. So, the thermal vision scanner is the instrument used to detect the heat coming from the cables and the joints.

In all of these methods the crew is completely insulated from the live lines using different materials except for the bare-handed procedure.

In bare-handed procedure, the crew members are on the same potential as the line is. There is a reasonable distance of the line from the ground.

So, there is no worrying of completing a circuit that could harm the line man. In the others methods, the crew members wear the insulating suits that is a complete shield from the electric field, potential and absolute potential.

What Does A Live Power Line Mean?

The energized line of the overhead transmission system is called a live power line. Energized means the power in the cable is present.

A live power line (https://www.electrical4uonline.com/how-electricians-work-on-live-circuits/)has no visual signs that you can count on to know if the line is energized or not.

A rule of thumb is , “If you don’t know, its energized” i.e if you are about to work on a power line, you should suppose it’s energized unless you are 100% sure its not a live line.

I usually use **a medium voltage tester or a medium voltage multimeter** to check the power line.

What Does OHTL Live Maintenance Mean?

OHTL live maintenance, preparing the line to replace a cutout fuse

Live power line maintenance means, inspecting and repairing the transmission lines while the power is not isolated.

For this kind of maintenance, the system is not shut down and the line has a live voltage.

Conductors and insulators are checked, repaired, and replaced if required, without de-energizing the line. It is also known as Hot-line maintenance.

Why To Use Live Maintenance?

The main reason for using this process is not to interrupt the power transmission by the power lines to keep loads working.

This method is suitable for critical loads, and loads that cost much if stopped.

If the lines are de-energized, the end systems are affected because power is not being supplied continuously.

Live line maintenance (https://www.electrical4uonline.com/maintenance-essential-best-practices/)is a successful method that is applicable for any kind of live lines ranging from the Low Voltage live lines (69 kV) to Ultra High Voltage live lines (1 MV).

Process Of Live Line Maintenance Methods:

- **Bare-hand method**
- **Insulating gloves**
- **Hot Stick**

Bare-Hand Method

In Bare-hand method that is also known as the Potential method. The worker has the same potential as the line has. He comes in direct contact with the line.

Workers may stand/sit on the line or choose to stand on a platform suspended from the line or a separate platform of the same potential.

To access the line, the worker is provided one of these facilities.

1. A platform of the helicopter is maintained at the same height as the line. It is an expensive way to maintain to the power line.
2. An insulated ladder that can move back and forth along the line.
3. A mobile elevating work platform or an IAD (insulating aerial device) is provided. Bothare insulated.
4. The worker may be hanged through the helicopter to reach the line level.

When using a platform, the worker must take care of the arc forming while energizing himself to the level of the cable.

For this purpose, a wire or a wand can be used to make an electric bond to prevent more arcing that may lead to damage. This step zeroes out the probability of current running through the body of the worker.

Reverse the process after completion of maintenance (https://www.electrical4uonline.com/maintenance-andr-energy-efficiency/). Remove the worker from the line and the IAD is closed down.

Insulating Gloves Method

In this method, the worker is covered with an insulating suit, after wearing the insulating suit, he is allowed to work on the line using his hands covered with the rubber or insulating material. Note that the worker should be isolated from contacting any grounded parts and tools.

The worker must be aware of the type of insulator that is needed for maintenance. On the basis of the magnitude of the voltage, gloves are classified into some classes.

- **Class-00:** These gloves are used for low voltages. Usually, the line voltage up to 500 V can be dealt with easily using these gloves. It has Beige color.
- **Class-0:** These gloves are used for dealing voltages ranging from up to 1kV. This class is red in color.
- **Class-1:** These gloves are better than class 0, have a voltage dealing capacity ranging from up to 7.5kV. This category is painted white.
- **Class-2:** These gloves are used for dealing voltages up to 17kV. The color it is painted is yellow.
- **Class-3:** Voltage that has a magnitude of 26kV is dealt with the class 3 insulating gloves. These gloves are green in color.
- **Class-4:** The voltage of magnitude 36 kV is dealt with class 4 insulators and they are painted with orange color.

(The voltages in the above section are the line-to-line voltages)

Hot Stick Method

The hot stick method is carried out using a pole. This pole is generally made of the fiberglass and as it is a fiberglass it is an insulator.

This pole is used to make it sure that the lineman is out of danger. This method is carried out while the line is energized.

The pole plays its role to open/close switch, lay insulating sleeves, test the voltage of the line, replace the fuses and some other tasks depending on the nature of task needed to be performed.

Who Can Perform Live OHTL Maintenance?

The linemen of the particular department of power distributions of a country perform the live overhead transmission line maintenance. The lineman must have some skills like:

- Proper knowledge of OHTL.
- Proper knowledge of insulators, vibration-dampers, conductors.
- Know how to operate the IAD (insulating aerial device).
- The method that is to be used at the particular voltage of the line.
- Experience of maintenance by himself or the experience of maintenance under the supervision of a senior.

Advantages/Disadvantages Of Maintenance OHTL

Advantages	Disadvantages
The maintenance may add up to 40-50 years in the age of the lines.	High cost, specially live maintenance

The risk of losses decreases.	High risk tasks, including: working at height and electrocution risk
The risk of interruption of power is lesser than the non-maintained lines.	Needs long time to make maintenance for all lines
Power losses such as corona losses can be checked and we can get rid of them.	

Advantages/Disadvantages of maintenance OHTL

How Do You Know If A Power Line Is Live Or Not?

Without testing you can't tell if the power line is energized or isolated.

If you have no testing equipment, you should suppose the line as energized.

There are different ways to tell whether the line is live or not using the voltage testers.

- HVNCVT-1: for the voltage from 50V to 1.5kV.
- HVNCVT-2: for the voltage from 1.5kV to 1.32MV.

These non-contact voltage testers are attached to the fiberglass pole and have a knob to select the range.

YOU MIGHT ALSO LIKE

(https://www.electrical4uonline.com/overhead-power-lines-faults/)

Overhead Power Lines Faults (Causes

Voltage Drop Demystified: How Distance Can Impact Electrical Systems (Https://Www.Electrical4uonline.Com/Voltage-Drop-And-Distance/)

23/02/2023

(https://www.electrical4uonline.com/overhead-power-lines-6-answers-for-beginners/)

(https://www.electrical4uonline.com/overhead-power-line/)

Overhead Power Lines, Types Inspection And

And Solutions) (Https://Www.Electrical4uonline.Com/Overhead-Power-Lines-Faults/)

09/12/2021

Overhead Power Lines: Answers For Beginners (Https://Www.Electrical4uonline.Com/Overhead-Power-Lines-6-Answers-For-Beginners/)

24/09/2021

Maintenance (Https://Www.Electrical4uonline.Com/Overhead-Power-Line/)

03/03/2021

TAGS: OHTL (HTTPS://WWW.ELECTRICAL4UONLINE.COM/TAG/OHTL/)

• • •

Safe Work Practices on High Voltage Cables

Summary

This document supports the Power System Safety Rules and its requirements detailed under 'High Voltage Transmission Cables' Category 7.

It covers safe work practices on High Voltage Cables and Pilot Cables to ensure the safety of workers where it is possible for induced voltages and transfer of earth potentials to occur.

It also sets down the method of identifying cables and requirements for safeguarding cables when working on associated oil or gas systems.

Document Control

Revision no:	2	**HP TRIM no:**	D2005/01698	**Approval/ Review date:**	11/03/2020
Business function:	Manage Health And Safety			**Document type:**	Corporate Work Instruction
Process owner:	Head/Health, Safety and Environment				
Related Procedure/s:	Power System Safety Rules				
Author:	Kitchener Morris, PSSR Manager				
Reviewers:	Megan Calvert, HSE Systems Manager Mark Dorahy, Cables Officer Chris Kezik, Delivery Manager James Mason, Training Designer				
Approver:	Michael Gatt, EM, Works Delivery				

Contents

1. **Purpose** 4
2. **Scope** 4
   2.1 Document Location 4
3. **Definitions** 5
4. **Work on HV Cables - General** 5
   4.1 Work with HV Transmission Cables in Service 5
   4.2 Work with HV Transmission Cables Isolated Only 5
      4.2.1 Types of Work requiring a cable isolated 5
      4.2.2 Access procedure for work related to an isolated only cable 5
   4.3 Work with HV Cables Isolated and Earthed 6
   4.4 Work on HV Transmission Cables as Disconnected Apparatus 6
5. **HV Transmission Cable Hazardous Situations** 7
6. **Basic Principles for Determining Safe Working Methods** 8
   6.1 Bonded Earth Conditions 8
   6.2 Insulated Working Conditions 9
   6.3 Safe Work Methods 10
7. **Identification of HV Cables and Pilot Cables** 12
   7.1 General 12
      7.1.1 HV Transmission Cables 12
      7.1.2 Pilot Cables 12
   7.2 High Voltage Cable Identification 12
   7.3 Pilot Cable Identification 12
   7.4 Precautions 13
8. **Routine Maintenance** 13
   8.1 Sheath Repairs 13
   8.2 Work on Link Boxes 13
   8.3 Work on Oil System Equipment 14
   8.4 Work on Cable Pressure Monitoring Equipment 14
   8.5 Use of Instruments and Testing Equipment 14
9. **Non-Routine Maintenance** 14
   9.1 Cutting a Cable 14
      9.1.1 Cutting a HV Cable or Pilot Cable 14
   9.2 Making a Joint in a Cable 14
      9.2.1 Making a Joint in a Pilot Cable 15
   9.3 Breaking Down a Joint in a HV Cable 16
   9.4 Constructing a Sealing End on a HV Cable 16
   9.5 Breaking down a Sealing End in a HV Cable 19
   9.6 Terminating a Pilot Cable 19

9.6.1 Terminating in Pilot Isolation Kiosks 19
9.6.2 Terminating at Locations other than in Isolation Kiosk (including Cable Road Pits) 20
9.7 Metallic Part Repairs of HV Cables or Pilot Cables 20
9.7.1 Metallic Part Repairs Utilising Insulated Working Conditions 20
9.7.2 Metallic Part Repairs Utilising Bonded Earth Mat Conditions 21
10. Installation of HV Cables and Pilot Cables 21
10.1 General 21
10.2 Advice to Controller 21
10.3 Positioning of Oil Plants and Other Equipment 21
10.4 Pulling of HV Cables and Pilot Cables 22
10.4.1 Cable Pulling Requirements 22
10.4.2 First Joint Bay-Insulation of Cable Metallic Parts 23
10.4.3 Cable Sealing Ends – Working Methods 23
10.4.4 Cable Sealing Ends – Isolation from Substation Earth 23
10.4.5 Field Jointing 23
10.5 Pilot Cable Terminations and Jointing 23
11. Accountability 23
12. Implementation 24
13. Monitoring and Review 24
14. Change from previous version 24
15. Reference Documents 25
16. Attachments 25

1. Purpose

This document supports the Power System Safety Rules and its requirements assembled under 'High Voltage Transmission Cables' Category 7. The document describes safe working practices on High Voltage (HV) cables and pilot cables.

2. Scope

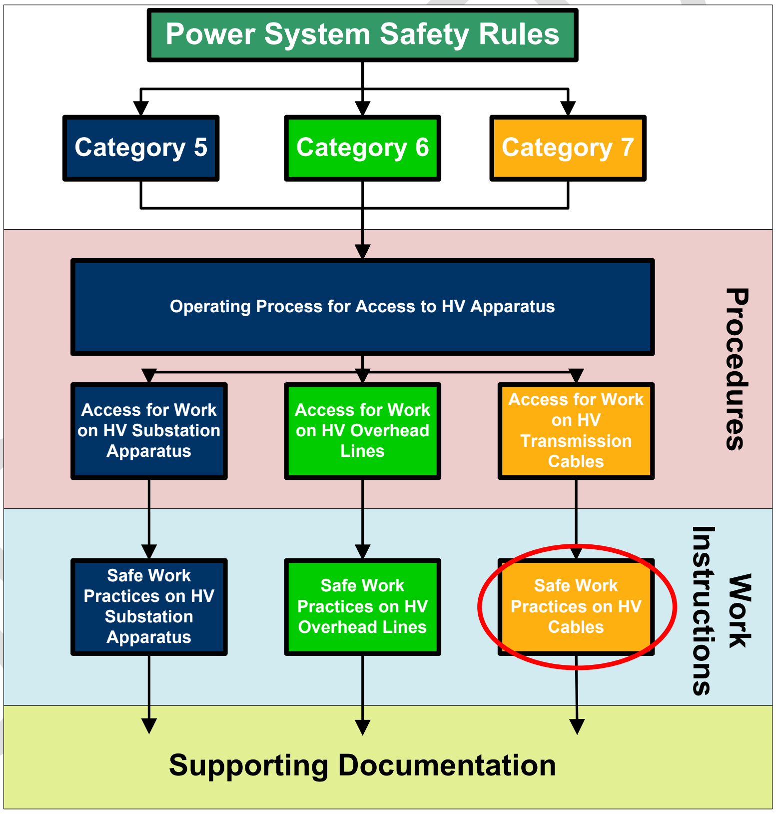
This document applies to all persons working on HV cables and pilot cables.

It covers safe work practices on High Voltage Cables and Pilot Cables to ensure the safety of workers where it is possible for induced voltages and transfer of earth potentials to occur. It also sets down the method of identifying cables and requirements for safeguarding cables when working on associated oil systems.

This is in addition to the requirements of any Legislation, Codes of Practice or Guidelines, as applicable.

2.1 Document Location

The following diagram shows the relationship between this and other relevant PSSR procedures.



Warning: A printed copy of this document may not be the current version. Please refer to the Wire to verify the current version.

3. Definitions

Term	Definition
17kV ac	Means a voltage of 17kV ac applied for a one minute test
Metallic Part	The metallic part of a cable is the armour, metallic sheath, reinforcing tapes, metallic screen and cores, or any metallic part connected to one of these.
HV Transmission Cable	HV Cable 22kV and above interconnecting two substations.

4. Work on HV Cables - General

For all work associated with HV Cables, in the charge of a controller, an RFA shall be submitted in accordance with Section 2 of the Power System Safety Rules.

4.1 Work with HV Transmission Cables in Service

Certain work may be carried out with a cable in service and without the issue of a Cable Access Authority. The work allowable and the applicable conditions are set down in 7.1.3 of the PSSR.

4.2 Work with HV Transmission Cables Isolated Only

4.2.1 Types of Work requiring a cable isolated

Although work is permitted with a cable in service under Rule 7.1.3, the practicalities of certain types of work mean that it will be necessary to have the cable isolated. The types of work in this category are:

(a) Work on oil panels and external pipe work if there is risk of causing oil to drain from the cable. Pipe work is insulated from metallic parts of a cable installation, but loss of oil affects the integrity of the cable insulation.

(b) Connection and reading of pressure gauges along a cable route. This will be required during work to find the location of oil leaks. Pressure readings are more accurate when the cable is in a stable thermal condition, which is best achieved with the cable off load.

(c) With oil filled cables it is preferred that the cable be isolated even for slight movements, even though this is not specifically required by the PSSR.

(d) When there is interference with a cable trench (e.g. excavation works) there might be a fault on or obvious damage to one cable and the suspicion of damage to another cable in the same trench. Whilst work is being carried out on the faulty cable the suspect cable should be isolated.

(e) Where it is required to manage induced currents and voltages.

4.2.2 Access procedure for work related to an isolated only cable

Work requiring a HV Transmission Cable to be isolated will be performed under a LV/MECH Access Authority in accordance with the following procedure.

(a) Requests for Access with the cable isolated shall be made on a Request to Access form with LV/MECH specified in "Access Required" column. Recall arrangements must be made during the outage assessment process to ensure workers will be available to effect the recall. To enable recall, workers on site are to remain in close contact with the Controller during the outage.

(b) The isolation of the cable and the clearance to issue the LV/MECH Access Authority shall be managed by the Controller through a HVPRI.

(c) On completion of the day's work the cable maintenance worker holding the LV/MECH Access Authority is to suspend or cancel the LV/MECH Access Authority as per the requirements in the Access for Work on LV/MECH Apparatus procedure.

4.3 Work with HV Cables Isolated and Earthed

HV Cable work that requires the cable be made safe for work shall have an Access Authority issued in accordance with TransGrid's 'Power System Safety Rules' and 'Access for Work on HV Transmission Cables'. A summary is set out below:

> A HV Access Authority (HV Substation Cables);
> A HV Testing Access Authority (Testing HV Substation Cables);
> A Cable Access Authority (HV Transmission Cables); and
> A Cable Testing Access Authority (Testing HV Transmission Cables).

Concurrent Access Authorities may be issued on the one cable provided the Controller is satisfied that adequate isolation can be achieved between any section of metallic sheath to be tested and all apparatus being worked on by other parties. This will allow:

> Concurrent high voltage testing on different sections of sheath on the same cable;
> Concurrent high voltage testing on sections of the cable sheath and work on the main conductor of the cable. (Cable dielectric provides sufficient insulation to allow testing voltages to be applied to the cable sheath while workers are working on the isolated and earthed primary conductor); and
> Concurrent high voltage testing, in the field, of a section of insulated metallic cable sheath and work in terminating switchyards.

4.4 Work on HV Transmission Cables as Disconnected Apparatus

If a long outage of HV transmission cables is proposed it may be possible to disconnect it temporarily from the system prior to working on it without an Access Authority. In such a case, the PSSR requirements for 'Making Disconnected HV Cables Safe for Work' Rule 7.5.5 and the document 'Work on Disconnected Apparatus' Section 5 must be complied with.

5. HV Transmission Cable Hazardous Situations

The following table lists typical situations encountered when working on or in the vicinity of HV transmission cables and the controls to be implemented.

Situation	Hazards	Controls	Reference
Excavation of underground cables	Buried Services	An excavation permit or equivalent document outside a substation; A cable access authority (unless specifically precluded under rule 7.1.3)	Excavation Permit WorkCover Guide 'Work Near Underground Assets' 2007
Working in the vicinity of a cable sealing end	Exposed HV conductors	Safe approach distances shall be maintained for persons and plant	PSSR – Attachment B
Removal of Earth Connections	Dangerous Voltages	Earth connections between cable sheaths and the earthing system shall not be removed while the cable is in service.	PSSR 7.1.1
Cable testing	Capacitance	Equipment shall be fully discharged before working on the apparatus after electrical testing has been performed.	PSSR 7.4.1
Identifying HV Cables and Pilot Cables	Incorrect identification of Cables.	Work must not commence on HV Cables and Pilot Cables or accessories until the equipment which it is safe to work on has been positively identified.	This document Section 7
Cable maintenance	Dangerous Voltages	Bonded earth mat or Insulated working conditions established depending on work	This document Sections 8 and 9
Installation of HV Cables and Pilot Cables	Switchyard Earth Grid Voltage Rise & Transferred Earth Potentials	Equipment that may be subject to transferred earth potentials shall be either insulated, isolated, or otherwise rendered safe.	This document Section 10

6. Basic Principles for Determining Safe Working Methods

It is essential when developing safe working procedures to carefully assess the possibility of hazardous voltage rises occurring at the work site and where appropriate, give consideration to the following basic safe working principles:-

(a) When working on a HV cable conductor (including a metallic sheath, armouring, oil line, etc., which can be subject to dangerous voltage rise, 'bonded earth mat working conditions' should preferably be employed. Where this is not possible, 'insulated working conditions' must be adopted.

Note: Due to the practical difficulties in maintaining insulated working conditions in field situations, use of this method should be limited to only those times where bonded earth mat working conditions are not able to be used.

(b) Remote earths should not be introduced to the local work site earth mat situation where practical. Therefore, where the PSSRs allow it, all remote earths connected to the conductors being worked on need to be disconnected. Also precautions need to be taken to isolate all incoming electric leads (e.g. for lighting and power tools) connected to a remote earth by the use of an isolating transformer. Also any oil equipment etc., must be isolated by use of insulating hoses or connectors.

(c) Conductors being worked on should be kept as short as possible by disconnecting phase conductors and/or cable sheath sectionalisation.

(d) The maximum number of continuous and earthed parallel conductors should be maintained at all times to maximise the shielding effect. See Appendix F for further information

6.1 Bonded Earth Conditions

Bonded earth conditions comprise an equipotential area made from conductive material, such as 25mm galvanised wire mesh. The conductive material shall be continuously bonded with multiple bonds and shall cover the floor, walls and ceilings, as necessitated by the conditions of any areas which can be touched from the working position. An earth stake shall be driven to a minimum depth of 600mm at each end of the working area and the two stakes bonded together or, alternatively, a single earth stake may be driven and used in conjunction with the existing earthing system of the cable installation.

Side driving of an earth stake is acceptable at locations that are at least 600mm below the surface.

Regardless of the earthing arrangement used, the overall resistance between the equipotential conductors and the surrounding earth must be less than 10 Ohms.

WARNING: Extreme care must be taken when driving earth stakes to ensure no damage is caused to the cable or to other services.

All earth connections from the bonded earth mat or from other exposed metalwork shall be made effectively and solidly to the earth stake with a conductor of minimum size 16mm2 or equivalent. All exposed and lightly insulated metal objects within the equipotential area shall be bonded to the earth stake or covered with a material insulated to withstand 17kV ac.

A barrier to prevent persons contacting the bonded earth mat shall be erected at least one metre from the edges of the working area or associated metallic tent frame. Where this cannot be achieved, this distance may be reduced at the discretion of the authorised person issuing the Cable Access Authority and or the APIC for the Cable Access Authority, subject to other control measures being implemented.

Access to the bonded earth mat shall be made via a non-conductive ladder or staircase and an insulated platform or mat suitable to control step potential effects. Refer to figure below.

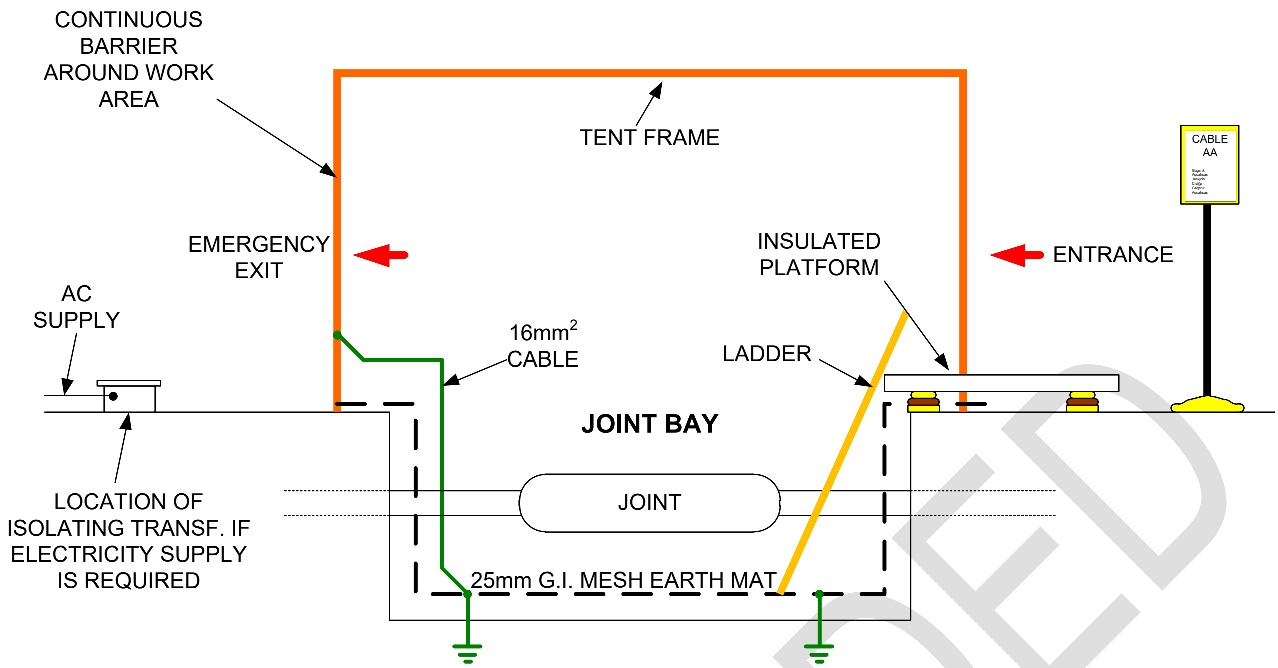


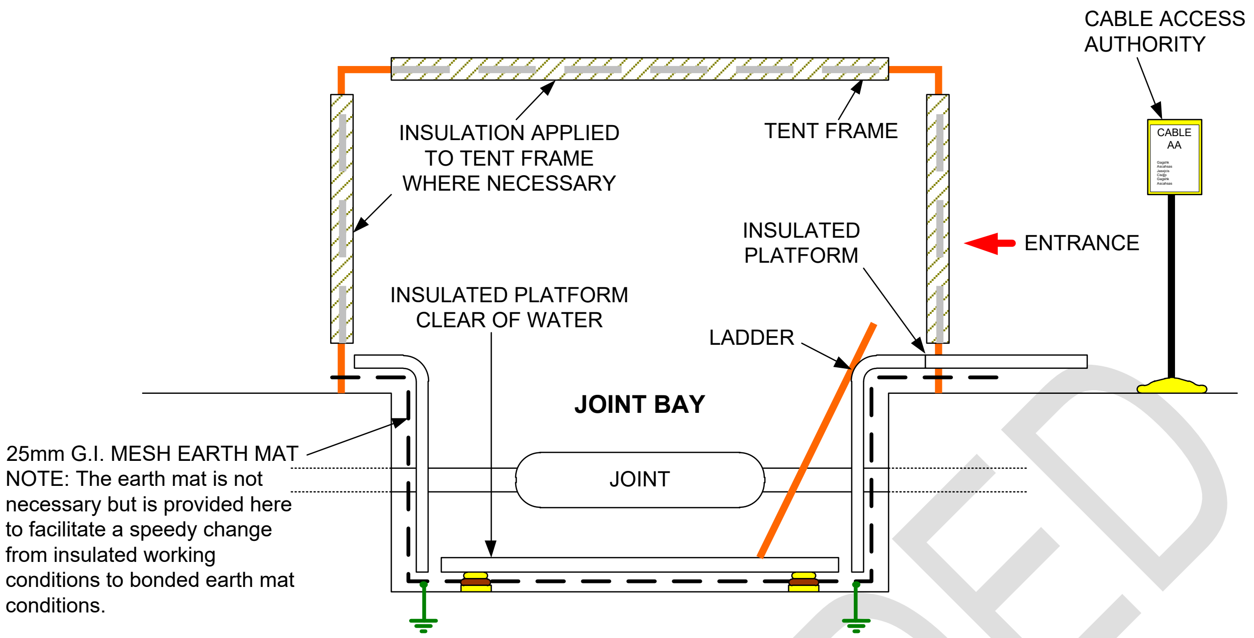
Figure 1: Typical arrangement of bonded earth connections for a joint bay

6.2 Insulated Working Conditions

Insulated working conditions means that an insulated platform shall be used within the work zone, and all insulated parts shall be kept as clean and dry as possible. All exposed metallic parts of cables and pipes or any other earthed material which can be touched from the insulated platform whilst in contact with the unearthed metallic parts of the cable to be worked on, shall be covered with a material, insulated to withstand 17kV ac, which shall be maintained in as clean and dry a condition as possible. All connections to the earth stake shall be made with a conductor of minimum size 16mm^2 or equivalent, insulated to withstand 17kV ac. Refer to figure below.

Any person on the insulated platform must not accept materials from or make personal contact with any person not on the platform or touch any earthed object while in contact with the unearthed metallic parts of the cable.

A barrier to prevent unauthorised entry shall be erected at least one metre from the edges of the working area. Where this cannot be achieved, this distance may be reduced at the discretion of the authorised person issuing the Cable Access Authority or the Authorised Person In Charge of the Cable Access Authority, subject to other control measures being implemented.

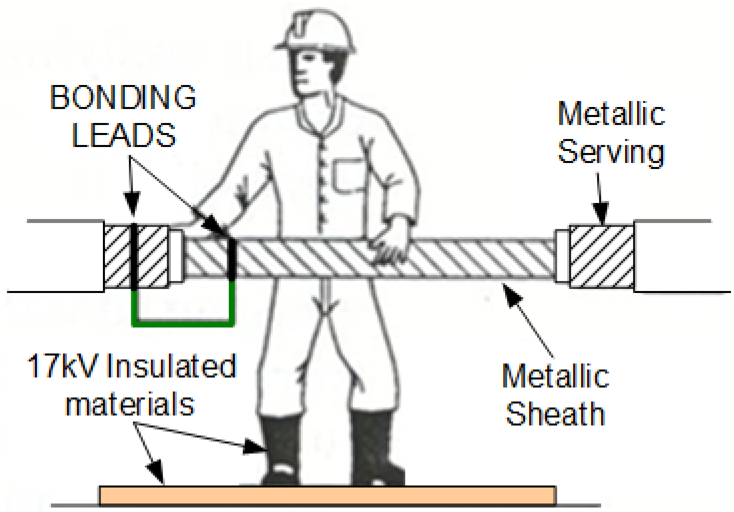


Typical Arrangement of Insulated Work Conditions for a Joint Bay

Figure 2: Insulated Working Conditions Arrangement

6.3 Safe Work Methods

The following figures illustrate the safe working methods to be used when effecting repairs on a cable.



Working Method for effecting Repairs on Reinforcing tapes

Figure 3: Insulated Working

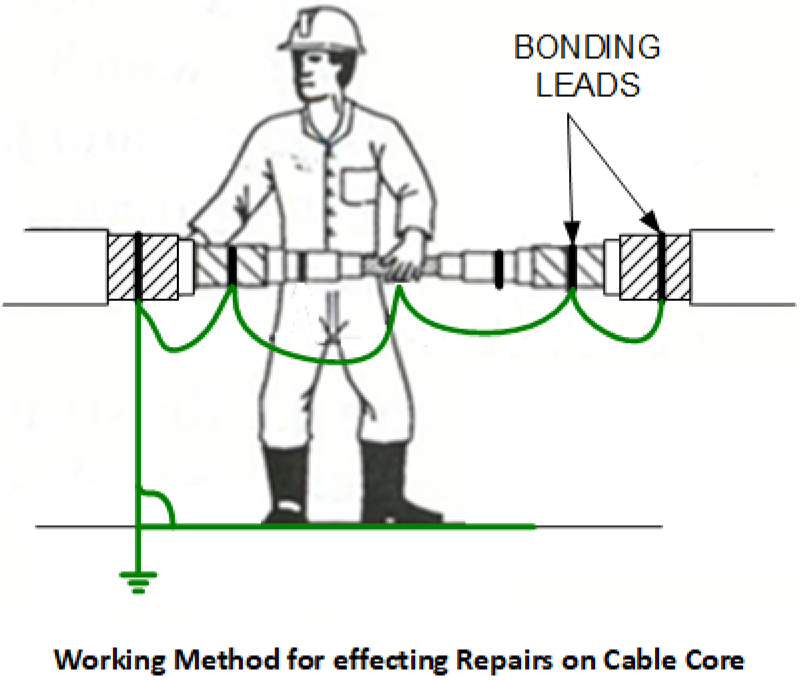


Figure 4: Fully Bonded (Preferred)

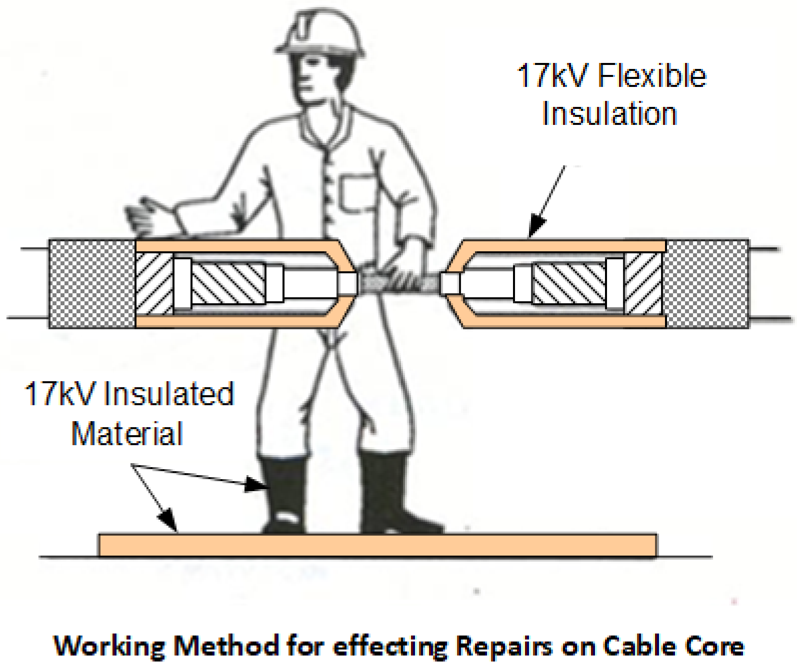


Figure 5: Insulated working

7. Identification of HV Cables and Pilot Cables

7.1 General

The location of TransGrid's HV cables shall be identified using TransGrid's cable routing records. The location of other utilities services is available through Dial Before You Dig 1100 or www.1100.com.au.

Where the location of previously installed cables is discovered to be inaccurately recorded, the records shall be updated. Where existing cables are de-commissioned, but left in situ, the records, including Dial Before You Dig and spatial information shall be maintained until the cables are removed.

Cable identification involving injection of a signal into the cable sheath shall be via induction coupling.

Tests shall be carried out to correctly identify a cable prior to any work, except in the following cases:

7.1.1 HV Transmission Cables

(a) Work permitted by the PSSR 7.1.3 with the cable in service.

(b) Work on cable terminations in high voltage switchyards where the terminations have been isolated, proved de-energised and earthed in accordance with the PSSR.

7.1.2 Pilot Cables

(a) Where pilot cores are not exposed or will not become exposed as a result of the repairs.

(b) Movement of the cable which does not involve excessive bending or mechanical stress.

7.2 High Voltage Cable Identification

The issuer and receiver of the Access Authority carrying out the identification shall employ at least two of the following methods, or alternatively, repeat method (a) or (b) from a different location or, using different personnel, from the same location.

(a) Identification by Plans
By identification from cable route plans, provided route plans are considered a true record.

(b) Local labelling of ancillary equipment directly connected to the cable.

(c) Low voltage audio frequency current injection at the end of the cable
Injection of an audio frequency current into the core and detection of the current at the worksite by an electro-magnetically coupled search coil and amplifier.

(d) Low voltage 50Hz current injection at the end of the cable or bond system from a known/labelled sheath link box.
Injection of an interrupted 50Hz current into the core and measurement of the current at the worksite with a tong ammeter or similar device and trigger/interruption pulses identified.

(e) D.C. Simulated Sheath Fault Location Test
Detection of an interrupted sheath earth fault connected at the point of work.

(f) Visual Identification
By visually tracing the cable back to its source or bonding leads to link pits which have been correctly identified as in (a) or (b).

(g) GPS coordinates and where true and accurate survey data exists and no other similar services are in the vicinity.

7.3 Pilot Cable Identification

The issuer and receiver of the Access Authority carrying out the identification shall employ one or more of the following methods.

(a) Identification by Plans
By identification from cable route plans, provided route plans are considered a true record.

(b) Visual Identification
By visually tracing the cable back to its source.

(c) Identification by Labels
By identification from labels at pilot cable marshalling kiosks.

(d) Low voltage audio frequency current injection at the end of the cables
Injection of an audio frequency current into a core or into the insulated metallic screen and detection of the current at the work site by an electromagnetically coupled search coil and amplifier.

(e) Low voltage 50Hz current injection at the end of the cable
Injection of an interrupted 50Hz current into a core or into the insulated metallic screen and measurement of the current at the work site with tong ammeter or similar device.

(f) D.C. simulated screen fault location test
Detection of an interrupted insulated metallic screen earth fault connected at the point of work.

(g) Core continuity
By establishing continuity of an exposed core end at a break in the pilot cable to an identified termination position by injection of a continuous a.c. or d.c. current by megger or similar device, provided such method does not affect system security.

7.4 Precautions

Whatever method is used, the authorised person carrying out the identification shall affect self-protection, and protection for others from possible dangerous voltages that can occur during a system surge, by the following means:

(a) At cable terminations in high voltage switchyards no connection or disconnection is to be made to any metallic part of a cable unless a local earth is first applied to the metallic part or unless the work is to be carried out under insulated working conditions.

(b) In the field, insulated working conditions must be used to make connections to any metallic part of any HV cable or pilot cable.

(c) Whilst operating the testing equipment, the qualified person shall employ insulated working conditions.

(d) Where possible, all metallic parts of a HV cable not being used in the identification procedures shall be left continuous and earthed at both ends.

8. Routine Maintenance

A work method statement shall be produced and approved prior to conducting cable routine maintenance. The work method statement shall utilise the safe working practices in the following sections.

8.1 Sheath Repairs

Insulated working conditions shall be established and maintained until at least 3mm radial thickness of insulation has been applied over exposed metallic parts.

8.2 Work on Link Boxes

All work on link boxes must be carried out either:

(a) With all links and terminals bonded and earthed in accordance with bonded earth conditions; or

(b) Under insulated working conditions; or

(c) Where it is necessary to remove links for identification or testing purposes, an approved type of insulated working must be used.

8.3 Work on Oil System Equipment

(a) Where work is required between the insulating section in the metallic pipes and associated joint or sealing end the work shall be treated as a metallic part repair.

(b) Any temporary feed pipe must be insulated from the metallic parts.

(c) Any work on cable oil systems requiring the cable out of service for safety of equipment shall not be commenced until clearance has been received from the Controller and the requirements of section 4.2.2 have been met.

8.4 Work on Cable Pressure Monitoring Equipment

Cable "low oil" alarm equipment in the field is usually shrouded to prevent accidental contact with metallic parts that can be livened up due to induction or transferred earth potential.

When it is necessary to work on such metallic parts (for example on the contact assembly of a pressure gauge) insulated working conditions should be established.

Bonded earth conditions may be used provided the user ensures that the earthing of pilot cores is not harmful to the alarm system.

Caution is also required to ensure that personal contact is not made with more than one core at a time with the exception of where cores are commoned.

8.5 Use of Instruments and Testing Equipment

Instruments and Testing Equipment must conform to the requirements specified in Appendix C.

9. Non-Routine Maintenance

A work method statement shall be produced and approved prior to conducting cable non-routine maintenance. This work method shall take into account any cable type and manufacturer specific requirements for the equipment to be worked on. The work method statement shall, where possible, relevant and practical, utilise the safe working practices in the following sections.

9.1 Cutting a Cable

9.1.1 Cutting a HV Cable or Pilot Cable

The following steps are to be followed if a HV cable needs to be cut.

(a) Identify the cable

(b) Set up an exclusion zone around the cable to be cut

(c) If necessary, use a remote detonation earth spike

(d) Setup a remote operated cutter/guillotine and bond cutting head with a 16mm^2 cable to local earth/stake.

(e) Bond all metallic parts of each end locally with 16mm^2 cable. If this is not practical, bridge all metallic parts across the cut with 16mm^2 cable. Alternatively (or in conjunction) apply 17kV insulated capping.

(f) Contain any oil loss

9.2 Making a Joint in a Cable

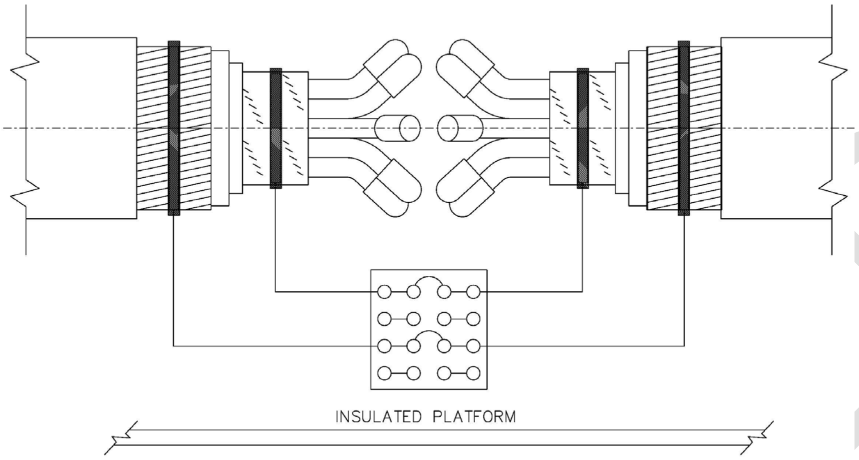
Cable jointing is a highly specialised activity and the safe work methods and controls will vary depending on the cable type and manufacturer. Type and manufacturer specific techniques, hazards and controls must be considered when the safe work method for the work is being developed.

An example of jointing techniques and safety controls is provided in Appendix G.

9.2.1 Making a Joint in a Pilot Cable

(a) Initial Preparation

i) Prepare the cable ends as outlined in Section 6.1.2 (a) to (g). Great care must be taken to ensure that bonding is completed, as shown in the following figure, by connection to the earthing board i.e., not by direct connections.



PILOT CABLE WITH METALLIC PARTS BONDED TO EARTH

Figure 6: Pilot Cable Bonding

ii) Continue with insulated working conditions.

iii) Select the first pair to be joined and remove the temporary insulation. Slip on a core insulating sleeve and/or an insulated sleeve of material which will withstand 17kV ac.

iv) Handling one core end by the insulated sleeve and the other core end with its own insulation, lay down the core ends and mark the core joint positions.

(b) Ferruled Core Joints

i) Cut and strip the core end and crimp a ferrule on the core end, avoiding contact with the other core end.

ii) Handling one core end with insulated sleeve and the other core end with its own insulation, bring the two core ends together in the ferrule and complete crimping or sweating of the ferrule.

iii) Bring the core insulation sleeve over the core joint before proceeding with the next core joint.

(c) Twisted Core Joints

i) Bare the sections of cores only where the twist is to be made and complete at least one metal-to-metal turn without bridging the conductors by hand. The bare conductors are then safe to handle to complete the joint.

ii) Bring the core insulation sleeve over the core joint before proceeding with the next core joint.

(d) Completion of Joints

i) Remove the temporary insulating material from the innermost metallic part.

ii) Complete the continuity of this metallic part.

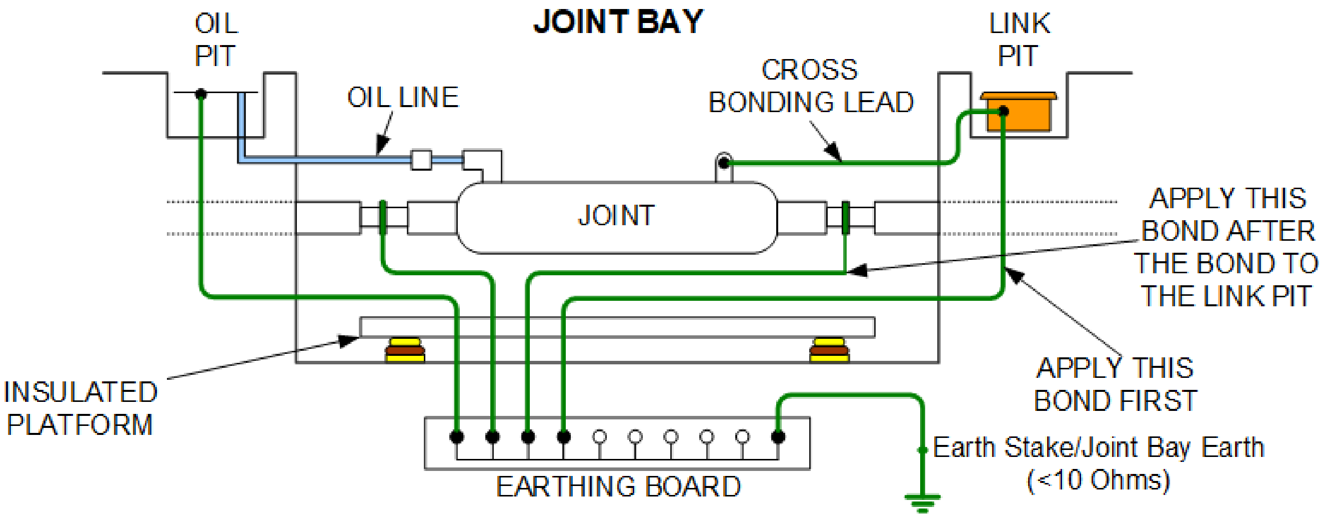
iii) Remove the bond on the innermost metallic part and apply insulation.

iv) Repeat steps (a) to (c) above for other metallic parts.

9.3 Breaking Down a Joint in a HV Cable

(a) Utilising insulated working conditions expose a section of the outermost metallic part on either side of the joint.

(b) Using bonding leads and an earthing board make a connection between the exposed metallic parts and an earth stake. Refer to figure below.



Bonding Leads applied to either side of a Cable Joint

Figure 7: Joint Bay Earthing

(c) If oil lines and/or bonding leads are connected to the joint in question, then these lines and/or leads must also be connected to the earth stake. If these connections cannot easily be made near the joint, then they may be made in the adjacent oil, gas or link pits.

(d) Establish bonded earth conditions.

(e) Expose the joint sleeve (this usually involves de-compounding).

(f) Disconnect oil pipes and bonding leads if required.

(g) Remove joint sleeve.

(h) Remove screen and stress wire if required.

(i) Re-establish insulated working conditions.

(j) Remove insulation.

(k) If cutting of the conductor is contemplated the provisions of Section 9.1 apply.

Note: Items (g) – (k) may vary depending on the cable type and manufacturer. Specific requirements shall be detailed in the work method developed for the work.

9.4 Constructing a Sealing End on a HV Cable

(a) The sealing end supporting structure and working platform scaffolding shall be effectively earthed to the local earth mat or earth stake as shown below.

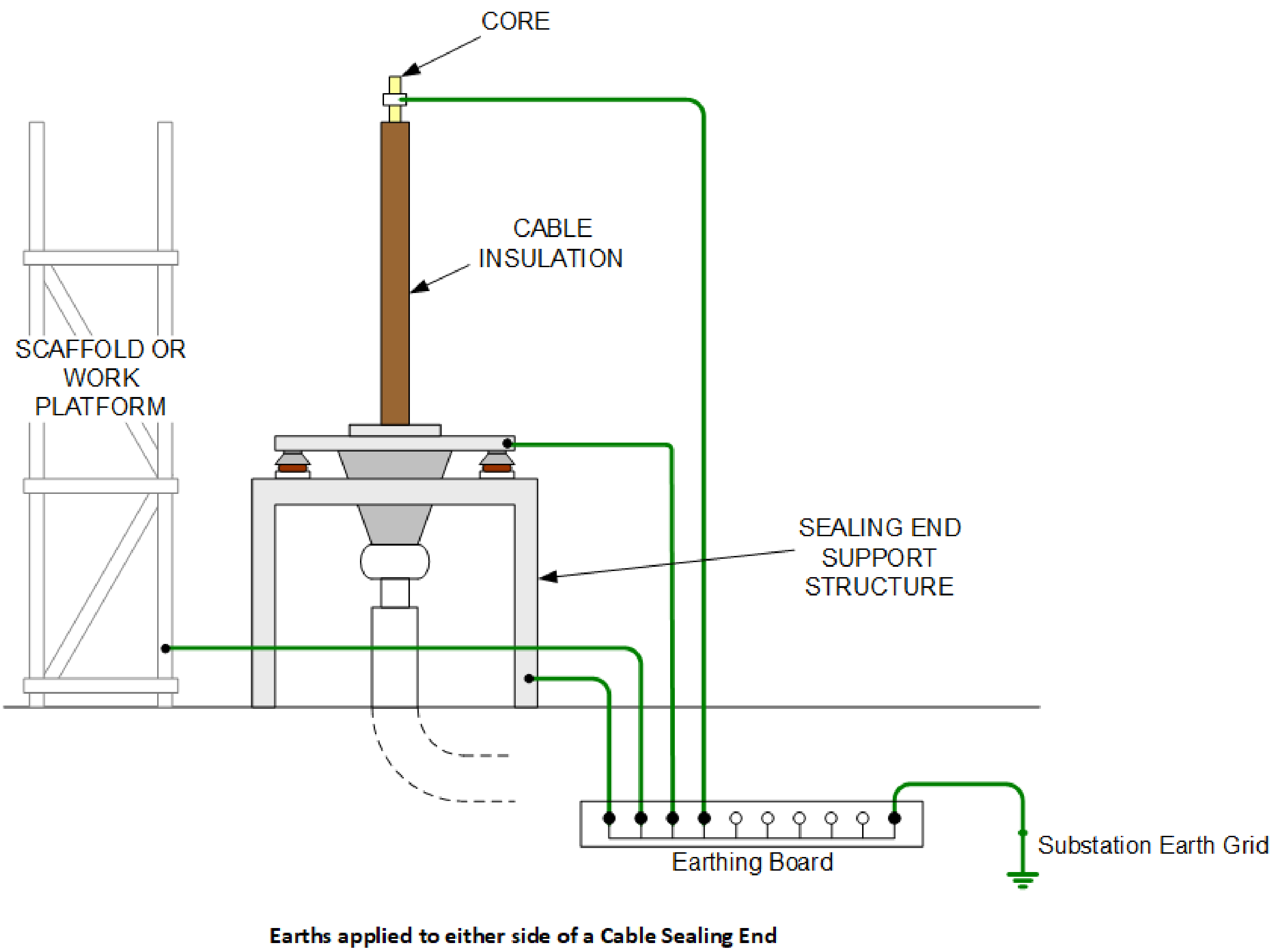


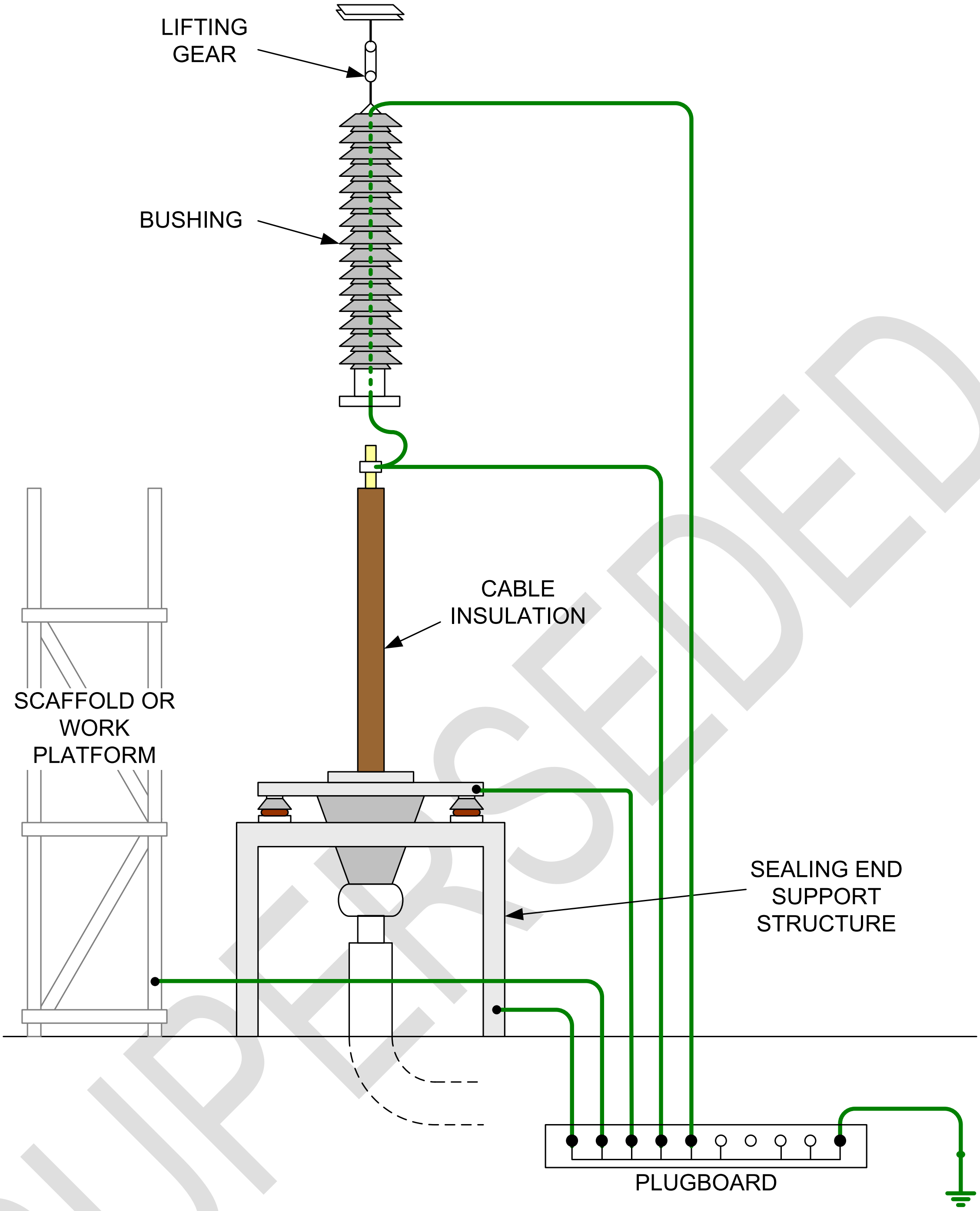
Figure 8: Cable sealing end earthing

(b) Prepare the cable

(c) Continue with bonded earth conditions.

(d) The earth bonds to all metallic parts must be maintained throughout all trimming, taping and screening operations until the bushing is in position ready to be lowered over the cable head.

(e) Before removing the original core earths a bonding lead connection shall be made to the core passing up through the bushing as shown in the following figure.



Bonding Lead applied to either side of a Cable Sealing End

Figure 9: Cable Sealing End Bushing Installation

The bonding lead is to be maintained until electrical contact is made with the top bushing fitting and this fitting is solidly earthed.

The core earth must not be disconnected until standard earthing equipment has been applied.

(f) If it is impossible to comply with step (e) because of the design of the sealing end, the sealing end earth may be removed and the bushing lowered into position using insulated working conditions. The earth must be replaced as soon as possible and the remainder of the work carried out under bonded earth mat conditions.

9.5 Breaking down a Sealing End in a HV Cable

(a) If the sealing end has not already been earthed by operating workers, make a connection between the primary conductor of the sealing end and the earth. Insulated working conditions must be used during this operation.

(b) Continue with insulated working conditions and ensure that there is a connection between the metallic cable sheath and earth.

(c) If oil lines and/or bonding leads are connected to the sealing end, then these lines and/or leads must also be connected to earth.

(d) The sealing end supporting structure and working platform scaffolding shall be effectively bonded to the earth mat.

(e) Establish bonded earth mat conditions.

(f) Without removing the earth connection on top of the sealing end, expose the conductor within the top of the sealing end and connect a bonding lead between the conductor and the earth. The bonding lead shall be long enough to pass through the bushing as it is being withdrawn.

(g) Remove the external oil pipes.

(h) Without disturbing the bonding lead remove the main earth connection from the top of the sealing end and remove the bushing.

(i) If it is impossible to comply with step (f) because of the design of the sealing end, the sealing end earth and the bushing may be removed using insulated working conditions. The earth must be replaced as soon as possible and the remainder of the work carried out under bonded earth conditions.

9.6 Terminating a Pilot Cable

9.6.1 Terminating in Pilot Isolation Kiosks

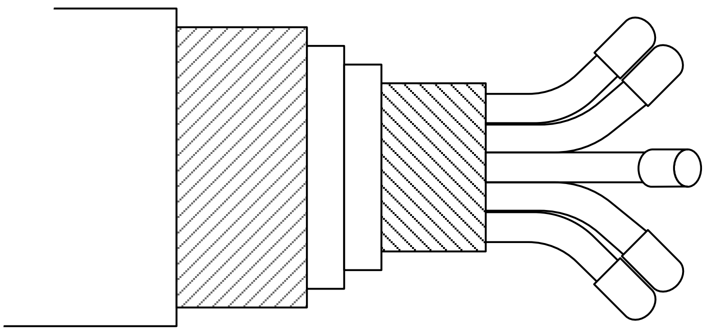
(a) Check that the insulating rubber floor matting is present and in good condition. Temporary additional matting may be required in order to establish insulated working conditions.

(b) At all remote terminating points, all conductors shall be isolated from their terminal equipment and all other metallic parts shall be isolated from earth wherever possible.

(c) A section of the outermost metallic part shall be exposed and then be shrouded with temporary insulating material which will withstand 17kV ac.

(d) Any other metallic part shall, in turn, be exposed and treated in the same manner until the insulated cores are exposed.

(e) The exposed core ends shall be insulated from each other as shown below. Where this is not possible an alternative technique can be used provided it ensures the safety of the work party.



Pilot Cable – Cores Insulated from each other

(f) Ensure that the plugs on the terminal strips are removed. Treating one core at a time, remove the core insulation and join the core to its terminal strip. Permanently insulate each termination before proceeding to the next.

(g) On completion of all terminations remove the temporary insulation over the innermost metallic part.

Note: Some metallic parts such as armouring or metallic sheaths are permanently earthed, whereas other metallic parts (such as metallic screens) are deliberately not earthed. Steps (h) to (j) indicate how these permanent earths should be applied.

(h) Using bonding leads, bond the exposed metallic part to the earth busbar provided in the isolation kiosk. Great care must be taken to ensure that this bonding is carried out by connecting to the earthing board, i.e. not by direct connection.

(i) The innermost metallic part may now be permanently earthed to the earth busbar.

(j) The bonding leads applied in (h) may now be removed.

(k) If permanent earthing of the innermost conductor is not required, then full insulation shall be applied over it.

(l) Repeat steps (g) to (k), as appropriate, for all other metallic parts in turn.

9.6.2 Terminating at Locations other than in Isolation Kiosk (including Cable Road Pits)

(a) Establish insulated working conditions.

(b) At all remote terminating points, all conductors shall be isolated from their terminal equipment and all other metallic parts shall be isolated from earth wherever possible.

(c) Prepare the cable as detailed in Section 9.6.1 (c) to (e).

(d) Establish bonded earth mat conditions.

(e) Earth all terminal strips to which connections are to be made and where removable links are provided, ensure that the links are removed.

(f) Handling the core by its permanent insulation, remove the temporary insulation and terminate the core on its terminal strip.

(g) Terminate all other cores in turn as outlined in (f).

Caution: Whereas the terminals in an isolation kiosk are fully shrouded, the terminals at other locations are usually fully exposed. Care must therefore be taken that once a core is terminated, no further personal contact be made with it and another core. A form of temporary shrouding may be necessary.

(h) Complete the termination of the cable as detailed in Section 9.6.1 (g) to (l).

9.7 Metallic Part Repairs of HV Cables or Pilot Cables

All work must be carried out utilising either bonded earth conditions or insulated working conditions.

The bonded earth conditions method of working shall be the preferred method. The insulated working conditions method would normally only be used for metallic part repairs where the extent of the repairs and the time take to effect the repairs is small.

9.7.1 Metallic Part Repairs Utilising Insulated Working Conditions

(a) Establish insulated working conditions.

(b) Expose the outermost metallic part.

(c) If continuity of the outermost metallic part is already broken because of damage or if continuity has to be broken to effect repairs, a "through bond" shall be established using bonding leads and a earthing board in a similar way to that shown for cutting a pilot cable.

(d) If the repairs require that more than one metallic part be exposed then the metallic parts must be insulated from each other using material which will withstand 17kV ac.

(e) Repair the innermost faulty metallic part and apply permanent insulation over it.

(f) If more than one metallic part was exposed, remove the temporary insulation applied in step (d), effect repairs on the next outermost metallic part and so on.

9.7.2 Metallic Part Repairs Utilising Bonded Earth Mat Conditions

(a) Prepare the work but in this case use an earthing board with the earth not connected.

(b) Establish bonded earth mat conditions by connecting an earth to the earthing board and repair the innermost metallic part.

(c) Change to insulated working conditions by removing the earth connection to the earthing board.

(d) Using insulated working conditions the bond wire(s) may be removed from the innermost metallic part and full insulation applied.

(e) If repairs to more than one metallic part are involved, then the remaining metallic parts may be repaired by again reverting to bonded earth mat conditions or by continuing with insulated working conditions.

10. Installation of HV Cables and Pilot Cables

A work method statement shall be produced and approved prior to the installation of HV cables and pilot cables. The work method statement shall utilise the safe working practices in the following sections.

10.1 General

When laying cables into high voltage areas or jointing to cables coming from these areas under disconnected apparatus conditions, attention is drawn to the dangers of electric shock which may arise during a system fault or system switching unless adequate precautions are taken.

During system fault or system switching the potential of the high voltage area earth grid may rise and be transferred via the cable pulling equipment and/or cable conductors or metallic parts of the cable to working parties remote from the high voltage area. Similarly, persons working in high voltage areas connected via pulling equipment and/or cable conductors or metallic parts to remote earth may be in danger.

10.2 Advice to Controller

The controller shall be advised prior to and on completion of pulling operations into HV areas.

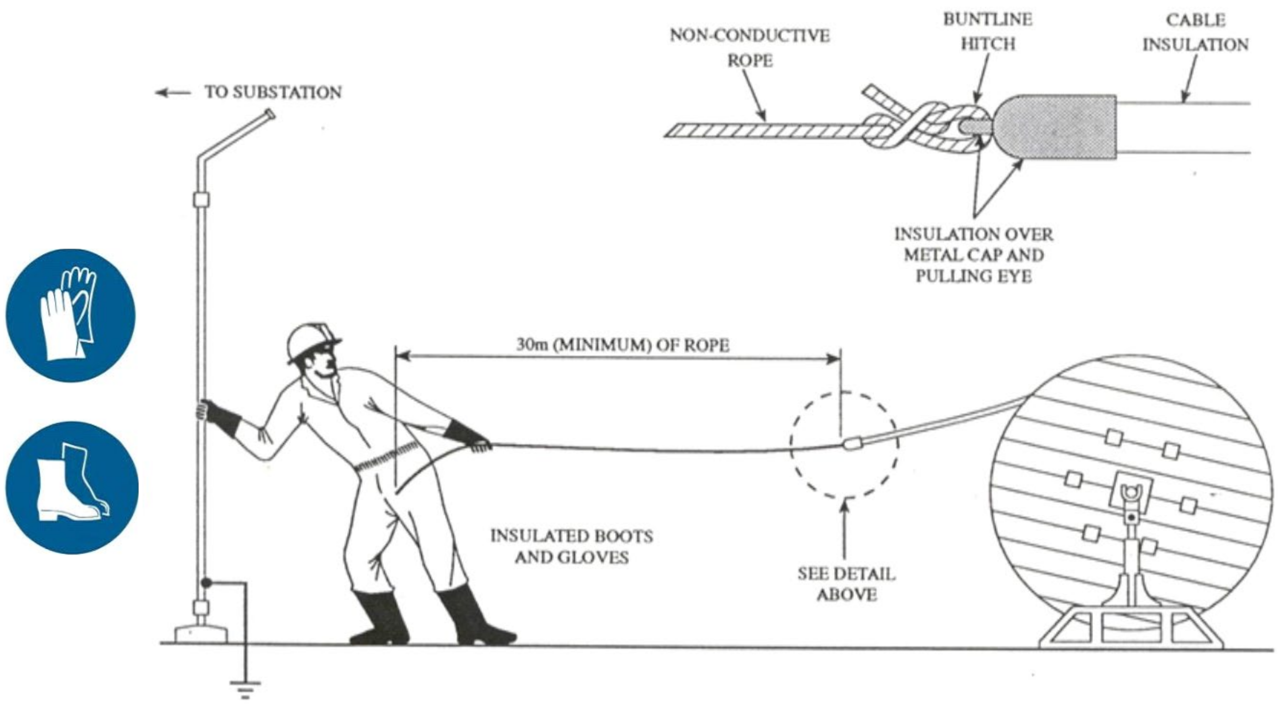
10.3 Positioning of Oil Plants and Other Equipment

Where oil plants (or similar items of equipment) are connected to sealing ends or other parts of a cable in a switchyard, then such plants should preferably be located on the switchyard earth mat or, if this is impractical, the oil lines (or other components reaching into the earth mat area) must be provided with an insulating piece, capable of withstanding 17kV ac separating the equipment outside the earth mat area from that within.

10.4 Pulling of HV Cables and Pilot Cables

10.4.1 Cable Pulling Requirements

When pulling a cable between a live high voltage area and an external joint bay it is essential that precautions, such as those listed below, are taken to prevent transfer of potential as described in section 7.1.



Pulling Cable into Substation

(a) Bare conductive equipment such as steel wire ropes shall not be used within 30 meters of the substation earth mat.

(b) Due to the presence of a conducting graphite coating on power and pilot cables, workers must work under insulated conditions, i.e. suitably approved insulated footwear and gloves must be worn and care must be taken to ensure that the cables does not come into contact with exposed parts of the body.

Pulling shall be carried out by one of the following methods or alternatively a specific work method developed for the work which addresses the transfer potential risk. :

Method 1:

The cable drum shall be set up in a position not less than 30 metres from the high voltage boundary fence and the cable pulled in a direction away from the fence using conventional equipment and methods. When just sufficient cable is left on the drum to reach the station sealing end pulling shall cease.

OR

Method 2:

The cable can be pulled towards and into the high voltage area providing a suitably sized non-conductive rope is used in the area extending 30 metres from the boundary fence and provided all exposed metallic parts are insulated to withstand 17kV ac.

OR

Method 3:

The cable drum shall be set up inside the substation area and the cable pulled to a distance not less than 30 metres beyond the high voltage boundary fence using a suitable sized non-conductive minimum stretch rope. Any exposed metallic parts on the nose of the cable must be fully insulated to withstand 17kV ac.

Note: it is essential for control of the pulling operation and for safety of workers and equipment that minimum stretch rope is used.

At the 30-metre point a steel wire rope may be used to complete the pull provided that at least 2 metres of non-conductive rope is used between the cable pulling eye and the steel wire rope and the metallic parts on the nose of the cable are fully insulated to withstand 17kV ac.

10.4.2 First Joint Bay-Insulation of Cable Metallic Parts

The cable metallic parts and all oil supplies to the cable shall be fully insulated in the first joint bay external to the high voltage area as soon as practicable after the cable pulling and before the insulation is removed from the end of the cable within the high voltage area.

To ensure the adequacy of the applied insulation and the absence of damage to the cable sheath, a serving test of 17kV ac shall be applied between the cable sheaths.

10.4.3 Cable Sealing Ends – Working Methods

The cable shall be terminated in the cable sealing ends working under either insulated working conditions or bonded earth mat conditions as determined by an engineering assessment.

10.4.4 Cable Sealing Ends – Isolation from Substation Earth

On completion of terminating the sealing ends and where further work is to be performed in remote joint bays, the following conditions shall be established at the sealing ends.

(a) The sealing end cap and the cable metallic sheath shall be bonded together and insulated from the high voltage area earth grid by sufficient insulation to withstand 17kV ac.

(b) Warning signs shall be fixed to the sealing end support structures warning of the possible existence of capacitive voltages and directing that the sealing ends must not be connected to earth or the high voltage system.

Note: The sealing end can still be considered as disconnected apparatus, provided sufficient insulation, delineation and labelling is provided.

10.4.5 Field Jointing

Working methods will depend on field conditions and will be determined by the engineer in charge. When a section of the cable has been connected to a terminal station all further work on that section shall be carried out in accordance with Section 9.2.

10.5 Pilot Cable Terminations and Jointing

All field jointing shall preferably be carried out before the ends are terminated within the high voltage area. During this operation, the ends within the high voltage areas shall have all metallic parts insulated to withstand 17kV ac and field jointing shall be carried out under insulated working conditions.

Terminating within the high voltage areas shall be carried out in accordance with Section 9.6. If termination of the pilot is required in advance of jointing along the route, then termination shall be made in accordance with Section 9.6 and all subsequent jointing shall be carried out as detailed in Section 9.2.1.

11. Accountability

Responsible person	Responsibility
Head of HSE	Maintenance and ownership of this work instruction
Manager – Training	Implementation of the training impacts of this work instruction
Authorised persons	Comply with this work instruction

12. Implementation

This procedure is to be implemented in conjunction with the implementation of TransGrid's Power System Safety Rules. It will be available as a resource, published on the Wire.

13. Monitoring and Review

The Head of HSE is responsible for the ongoing monitoring and review of the documents associated with the Power System Safety Rules. This can include but is not limited to:

- Requesting regular feedback on the effectiveness of procedures and work instructions. Appropriate feedback tools include focus groups and online assessments;
- Where a change has occurred in our processes; and
- Recommendations arising from incidents.

14. Change from previous version

Revision no	Approved by	Amendment
0	Lionel Smyth, EGM/Network Services & Operations	> Replaces GD SR G2 006 R2 "Safe Working Practices on High Voltage Transmission Cables"
1	K McCall, Manager Health, Safety & Environment	> Revised accountability for this work instruction; > Reference to Access Authority updated to Cable AA or Cable Testing AA where relevant; > Hazardous Situations table summarised
2	M Gatt, EM, Works Delivery	> Work Instruction updated to new template > References to Gas cables and systems removed > HV Transmission Cable definition changed to start at 22kV rather than 132kV to more accurately represent TransGrid's installed cables. > Minor clarifications throughout > Greater allowance and reference made to the fact that work methods and controls will vary depending on manufacturer and cable type. > Insulating rating requirements changed from 15kV to 17kV ac > Defined terms reduced to remove obvious inclusions > 4.2.2 Wording updated to better align with access procedures > 6.1 – Overall earth resistance to be 10 Ohms > Figures updated to include more relevant terminology > 7.1 updated to required identification through signal injection to be via inductive coupling > 7.2 (b) existing content removed, replaced by new alternative, (d) updated and (g) added. > Existing section 9.1 removed and replaced by a more high level guidance > Existing 9.2 moved to Appendix G. 9.2 now refers workers to manufacturer and cable type specific requirements > Plug board replaced by earthing board throughout

		> Appendix A dated content removed, new content added. > Appendix B dated content removed, new content added. > Appendix D dated content removed, new content added.

15. Reference Documents

Document
Power System Safety Rules
Access for Work on High Voltage Transmission Cables
Work on Disconnected Apparatus
Access for work on LV/MECH Apparatus

16. Attachments

- Appendix A – Insulating Materials and Equipment
- Appendix B – Earthing & Bonding Clamps and Leads
- Appendix C – Isolating Transformers, Instrument Transformers and Testing Equipment
- Appendix D – Earth Stake and Cable Spike
- Appendix E – Earthing board
- Appendix F – Induced Voltages
- Appendix G – Making a Joint in a HV Cable - Example

Appendix A – Insulating Materials and Equipment

A.1 Insulated Platforms, Sheets or Mats

Insulating sheets shall be either Neoprene or EPMD rubber to Class 2 (17kV) from IEC 61111

SWMS involving use of these items should consider:

- Cleanliness requirements;
- Installation location for step potential;
- Installation/Environment requirements;
- Checks for potential damage due to wear and tear and heat;
- Potential for reduced effectiveness due to movement;
- Risk of moisture contamination;
- Prior use inspection for cuts and tears; and
- Testing requirements (6 monthly)

A.2 Insulated Gloves and Footwear

Insulated gloves and Footwear shall be:

- Manufactured, tested and stored in accordance with recognised standards.
- They shall be appropriately rated, both mechanically and electrically for the task to be performed.
- They shall be inspected immediately prior to use to ensure they are in suitable condition to perform the work.

IEC 60903 is currently used as the standard for insulating gloves

Appendix B – Earthing & Bonding Clamps and Leads

For the attachment of an earth lead or bond lead to a sheath, core, etc., a bonding cable shall be used which has clamps which:

(a) Are of adequate mechanical strength to support the attached earth lead or bonding lead; and

(b) Can be tightened to produce a stable and effective contact between the clamp and the core or sheath surface.

The earthing leads or bonding leads shall be made of a conductor of minimum size $16mm^2$ copper equivalent.

Appendix C – Isolating Transformers, Instrument Transformers and Testing Equipment

Isolating Transformers
To ensure that remote earth potentials are not transferred to the worksite, all electrically operated portable tools, lead lamps, etc., shall be supplied from an isolating transformer which electrically separates the incoming power supply and its earth system from the power supply to the worksite. The isolating transformer shall:

(a) Provide an insulating barrier between its input and output windings and between output windings and case and core which will withstand 17kV ac.

(b) Have its core and case earthed to the "supply side" earth.

(c) The secondary winding of the isolating transformer shall supply only the load that is within the confines of the bonded earth mat working area. Secondary terminals, and cabling (up to at least the edge of the bonded earthmat) shall be insulated to withstand 17kV ac or delineated to ensure it cannot be touched.

Note: any electrical plant or equipment used on the bonded earth mat which requires earthing must have its earth lead connected to the local earth stake. In all other cases earth leads of electrical plant and/or equipment shall be earthed in accordance with the SAA Wiring Rules. Where possible, RCD/earth leakage protection devices shall be used.

Instrument Transformers and Testing Equipment
All instrument and testing equipment shall conform to and be used in accordance with one of the following conditions:

(a) All internal circuit components shall be completely covered by a rigid case from which they are insulated. The insulation between the circuit components and the case shall be capable of withstanding 17kV ac.

All terminals for connection of external test leads and control adjustments, range switches and the like, shall be covered by an insulation which will withstand 17kV ac.

Such equipment may be operated under bonded earth mat conditions or insulated working conditions.

Under bonded earth mat conditions no connection or disconnection of this equipment shall be made to the cores or sheaths unless these cores or sheaths are earthed.

(b) For mains power test equipment, all internal circuits shall be enclosed in a metallic case which is fitted with an earth terminal. The earth connection between the earth terminal and the earth stake shall be a stranded conductor not less than 4mm^2 or equivalent.

All terminals for connection of external test leads and the external sections of control adjustments, range switches, movement adjusting screws and the like shall be covered by insulation which will withstand 17kV ac.

Such equipment may be operated under bonded earth mat conditions provided that:

i. If it has a metallic case, of the instrument is bonded to the local earth stake prior to making any connections from the instrument to any cable sheath or core.

ii. The connection bonding the metallic case to the local earth stake is not removed whilst the instrument is connected to a cable sheath or core.

If no special case or high voltage insulation is provided, the equipment shall only be used whilst working under insulated working conditions.

The operator of the equipment must ensure that personal contact is made with only one conducting part of the instrument at any time. This will enable operation of instrument controls, such as range switches, but will not permit making or breaking of connections.

High voltage insulating links or jacks must be used in test leads. Such links or jacks shall be capable of withstanding 17kV ac both across the opened link and from conductive parts (including operating handle or plug) to earth.

Earthing of a high voltage cable section or sheath shall be via a discharge resistor and shall be applied under insulated working conditions, usually incorporated into the handle and insulated to 17kV.

Appendix D – Earth Stake and Cable Spike

Earth Stake

The standard earth stake shall at a minimum be a copper clad steel earthing rod (1.4m x 13mm) with a clamp arrangement suitable for $16mm^2$ conductor.

Cable Spike

TransGrid does not have standard cable spiking equipment. Appropriate equipment is to be risk assessed, have work methods prepared and approved for use if required.

Appendix E – Earthing board

The standard earthing board used in TransGrid is a 6mm fixed earth strap with brazed studs with wing nuts (size 12mm). It has a clamp plate for attachment to steelwork and mesh earth mat.

A person installing or working on the metallic parts of a HV cable (cores, sheath, armour wires, bonding leads, oil lines, etc.) may be subject to dangerous voltages and electric shock if appropriate working procedures are not followed.

Dangerous voltages due to induced and\or transferred voltage rises may occur even though the cable is isolated from the electrical system and solidly connected to earth.

It is important to understand that whilst it may be perfectly safe to work on an out of service HV cable under normal system conditions, dangerous voltages can occur expectantly at any time as a result of:

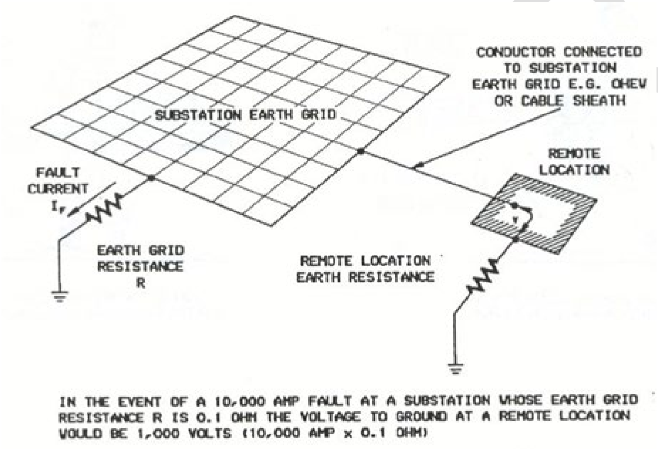
- Faults on the main electrical system
- System switching or other voltage surges
- Lightning strikes, etc.

It is important to carefully consider the voltages that may appear on an HV cable and determine the correct safe working methods to be employed before any work is undertaken.

Transferred Voltage Rise Conditions

Under system earth fault or system switching conditions, large currents can flow via the earthing system to the supply transformer. As the earthing system has a definite resistance to true (or remote) earth, the passage of current through this resistance will cause the earthing system and all conductors connected to it, to rise in voltage relative to true earth. Where the conductors connected to the earthing system are insulated too, rise will be transferred along the insulated conductor.

The figure below illustrates the path formed when a conductor is connected between a remote earth and a substation earth mat.



TRANSFERRED EARTH GRID POTENTIAL

Also the sharing of earth return fault current by the metallic sheath or armour wires, where applicable, of a HV cable will result in a voltage rise on the sheath or armour wires relative to true earth.

Transferred voltage rises can also occur on insulated conductors as a result of direct contact between overhead power circuits or lightning strikes.

If a cable is connected to a section of overhead line it is advisable not to work on insulated conductors if lightning activity is anticipated or present.

Induced Voltage Conditions

Current flowing in fully insulated power cable systems, overhead or underground, may give rise to induced voltages in nearby parallel fully insulated power or supervisory cables. For example, an overhead power line one or two streets away from a parallel fully HV cable system may give rise to unacceptably high induced voltages in the cable.

There are two main types of induced voltages:-

- Electrostatic (Capacitive), and
- Electromagnetic

Electrostatic (Capacitive) Induction

Where a conductor is located within the electric field of an energised conductor, an electrostatic voltage will be induced in the conductor.

The voltage due to electrostatic induction is constant along the conductor and the application of an earth to an otherwise insulated conductor will effectively drain the charge from the conductor and reduce it to earth potential. The application of multiple earths will not result in circulating currents.

Electromagnetic Induction

Where a conductor is located within the varying magnetic field of an energised conductor carrying alternating current, an electromagnetic voltage will be induced tin the conductor.

These electromagnetically induced voltages are commonly referred to as low frequency induction.

The voltage due to electromagnetic induction appears as a difference in potential between the ends of the conductor and the application of an earth to one end of an otherwise insulated conductor will result in a potential above earth at the remote end. The application of a further earth at the remote end will result in a circulating current in the conductor.

If a conductor subject to electromagnetic induction and earthed at both ends is cut, a voltage will appear across the cut ends of the conductor. This can be avoided by placing a bonding conductor across the proposed cut position prior to cutting the cable.

Under power system fault conditions heavy fault current will flow for the period taken for the protection equipment to open the faulty circuit. These heavy currents can give rise to very high electromagnetic induced voltages in adjacent parallel conductors (and metallic cable sheaths and armouring).

Unacceptably high electromagnetically induced voltages can occur from adjacent circuits carrying normal load current. The magnitude of the induced voltage is dependent upon separation of the circuits, lengths for which the circuits are parallel and magnitude of the local current

Shielding Effects

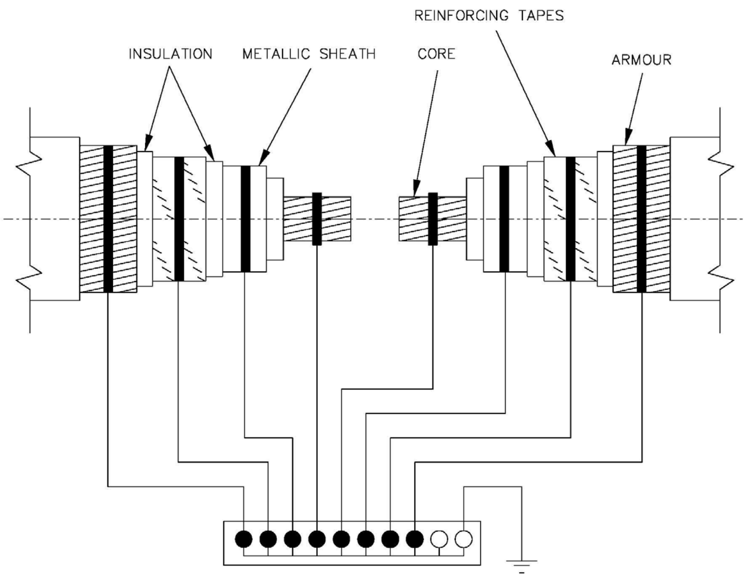
Electromagnetically induced voltages can be reduced if there is another conductor in the vicinity that is connected to earth in at least two locations that would allow an opposing current can circulate. The amount of shielding provided depends on the number and spacing of these conductors.

The conductors of a metal sheathed cable with porous textile servings are effectively shielded as the cable is continuously earthed through saturated/non-insulating servings. However, metallic sheathed cables with a plastic serving are not effectively shielded unless the metal sheath is earthed at both ends.

Appendix G – Making a Joint in a HV Cable - Example

The following steps provide an example of how a joint may be performed. Techniques and necessary safety controls will vary depending on the manufacturer and cable type and those specific considerations must be considered when the safe work method for the work is being developed.

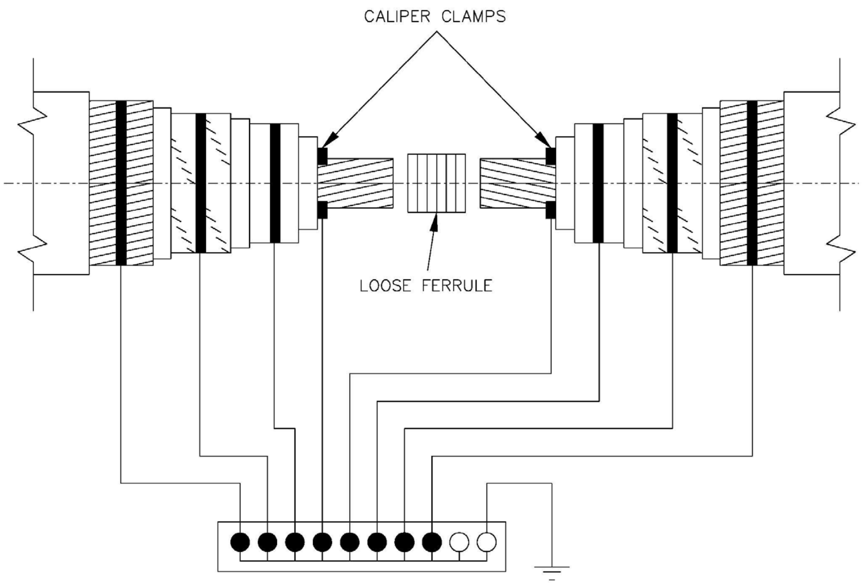
(a) Prepare each cable end in turn as outlined in Section 6.1.1, the ends being bonded as shown in the following figure.



HV CABLE WITH METALLIC PARTS AND CORE BONDED TO EARTH

(b) Continue with bonded earth mat conditions.

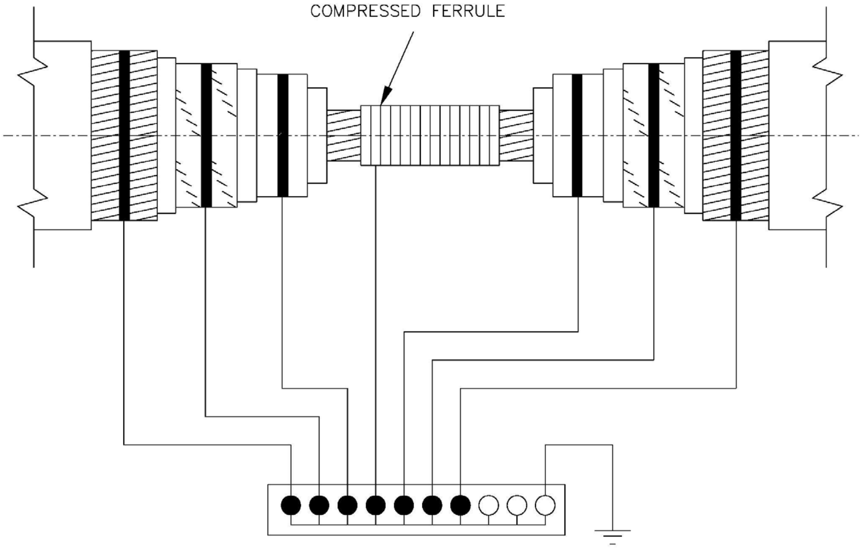
(c) Apply a conductor calliper clamp to the core as close as possible to the insulation on either side of the loose ferrule. The conductor earth clamps applied previously can now be removed as shown in below.



HV CABLE WITH CALIPER CLAMPS APPLIED TO CORE

(d) Join the cores of the cable ends together by compressing the ferrule.

(e) Using bonding leads apply an earth to the ferrule via the earthing board. The calliper clamps applied in step (c) can now be removed as shown in below.



HV CABLE WITH COMPRESSED FERRULE APPLIED TO CORE

(f) Establish insulated working conditions at the worksite.

(g) Temporary insulating material, which will withstand 17kV ac, shall be applied over the exposed metallic parts but not over the core.

(h) Break continuity of the earth connection to the ferrule by removing the appropriate connection on the earthing board. The earth clamp on the ferrule may now be removed.

(i) Apply insulation to the core until at least 3mm radial thickness of insulation has been applied to the joint.

(j) Re-establish bonded earth mat conditions. The temporary insulation applied in step (g) may now be removed.

(k) Proceed as follows:

   i) For uninsulated and poorly insulated metallic sheath systems continue jointing under bonded earth mat conditions until contact with metallic parts is no longer necessary. This will usually last until the final attachment of the permanent earth connection or to the start of the bitumen filling of the coffin.

   ii) For fully insulated and/or cross-bonded systems where joints have no cross-bonding or earth connection facilities continue under bonded earth mat conditions until the temporary earth connection must be removed to complete joint insulation. At this stage insulated working conditions must be set up and employed until sheath insulation is completed.

   iii) For fully insulated and/or cross-bonded systems where joints have cross-bonding or earth connection facilities, permanent bond leads are attached to the sleeve. The temporary sheath earth can then be removed and the sheath insulation completed after the permanent bond leads are earthed. Where the permanent bond leads are connection to an earth stake rather than the permanent link box, insulated working conditions must be set up to remove the bond leads from the earth stake. The exposed ends of the bond leads must be insulated to 17kV. Subsequent work on these leads must be carried out under insulated working conditions. Alternatively, the bond leads may be spiked and work carried out under bonded earth mat conditions.