Under ground (UG) cables - construction - materials - types - joints - testing

Objectives: At the end of this lesson you shall be able to
- **define UG cable**
- **explain the construction of UG cables**
- **list and state the insulating materials used in cables**
- **list out and state the types of UG cables used for 3 phase service**
- **state the types of cable joints and laying methods**
- **expalin the faults and testing procedures of cables.**

Under Ground (UG) cables

"A cable so prepared that it can withstand pressure and can be installed below the ground level and normally two or more conductors are placed in an UG cablewith separate insulation on each conductor"

Electric power can be transmitted (or) distributed either by over-head lines system or by underground cable system. The underground cable system have several advantage, such

Advantages

- Less chance to damage through storms or lightning.
- Low maintenance cost.
- Less chances of fault.
- Not affected by man- made problems like sabotage, strike etc.
- Voltage regulation in UG cables system is much better, because they have less inductive losses.
- Better general appearance of area compared to O.H lines.

Disadvantages

However, their major draw back / disadvantages are

- Initial cost of UG cable system is heavy.
- The cost of joints are more.
- Introduce insulation problems at high voltages compared with O.H lines.

For these reasons UG cables are employed where it is impracticable to use O.H lines like (i) thickly populated areas, where municipal authorities prohibit O.H lines for the reason of safety.

ii Around plants

iii In Substations,

iv Where maintenance conditions do not permit the use of O.H construction.

The UG cable were used many years for distribution of electric power in congested urban areas to low and medium voltages. Then with improvement and development of design, the manufactures have made it possible to use at high voltage transmission of electric power for same moderate distances.

General construction of UG cables

An underground cable essentially consists of one or more conductors covered with suitable insulation and surrounded by a protecting cover.

Necessity requirements for cables

In general, a cable must fulfill the following necessary requirements.

i The conductor used in cables should be tinned stranded copper or aluminum of high conductivity. (Strands of cable gives flexibility and carry more current).

ii The size of the conductor should be selected, so that the cable carries the desired load current without overheating and limits the voltage drop to a permissible value.

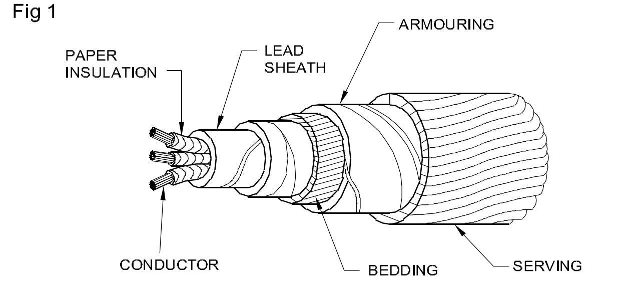
iii The cable must have proper thickness of insulation to ensure the safety and reliability for the designed voltage.

General construction of UG cables

iv The cable must be provided with suitable mechanical protection so that it may withstand the rough use in laying it.

v The materials used in cables should be with complete chemical and physical stability throughout.

Fig 1



CONSTRUCTION OF CORE CABLE

Construction of Cables

Fig 1 shows the general construction of a 3-core cable. The various parts are:

i) Cores or conductors: A cable may have one or more than one core (conductor) depending upon the type of service for which it is intended. For instance, the 3-

conductor cable shown in Fig 1 is used for 3-phase service. The conductors are made of tinned copper or aluminium and are usually stranded in order to provide flexibility to the cable and having high conductivity.

ii Insulation: Each core or conductor is provided with a suitable thickness of insulation, the thickness of layer depending upon the voltage to be withstood by the cable. The commonly used materials for insulation are impregnated paper, varnished cambric or rubber mineral compound. Petrolium jelly is applied to the layers of the cambric to prevent damage.

iii Metallic sheath: In order to protect the cable from moisture, gases or other damaging liquids (acids or alkalies) in the soil and atmosphere, a metallic sheath of lead or aluminium is provided over the insulation as shown in Fig 1. The metallic sheath is usually a lead or lead alloy.

iv Paper Belt: Layer of imprignated paper tape is wound round the grouped insulated cores. The gap in the cores is filled with fibrous insulating material (jute etc.)

v Bedding: Over the metallic sheath is applied a layer of bedding which consists of a fibrous material like jute or hessian tape. The purpose of bedding is to protect the metallic sheath against corrosion and from mechanical injury due to armouring.

vi Armouring: Over the bedding, armouring is provided which consists of one or two layers of galvanized steel wire or steel tape. Its purpose is to protect the cable from mechanical injury while laying it and during the course of handling. Armouring may not be done in the case of some cables.

vii Serving: In order to protect armouring from atmospheric conditions, a layer of fibrous material (like jute) similar to bedding is provided over the armouring. This is known as serving.

It may not be out of place to mention here that bedding, armouring and serving are only applied to the cables for the protection of conductor insulation and to protect the metallic sheath from mechanical injury.

Insulating materials for cables

The satisfactory operation of a cable depends to a great extent upon the characteristics of insulation used. Therefore, the proper choice of insulating material for cables is of considerable importance. In general, the insulating material used in cables should have the following properties:

i) High insulation resistance to avoid leakage current.

ii) High dielectric strength to avoid electrical breakdown of the cable.

iii) High mechanical strength to withstand the mechanical handling of cables.

iv) Non-hygroscopic i.e. it should not absorb moisture from air or soil The moisture tends to decrease the insulation resistance and hastens the breakdown of the cable. In case the insulating material is hygroscopic, it must be enclosed in a waterproof covering like lead sheath.

v) Non-inflammable

vi) Low cost compared to O.H. system.

vii) Unaffected by acids and alkalies to avoid any chemical action.

The type of insulating material to be used depends upon the purpose for which the cable is required and the quality of insulation to be aimed at.

The principal insulating materials used in cables are

(i) Rubber

(ii) Vulcanized India rubber

(iii) Impregnated paper

(iv) Varnished cambric and

(v) Polyvinyl chloride.

1 Rubber: Rubber may be obtained from milky sap of tropical trees or it may be produced from oil products. It has relative permittivity varying between 2 and 3, dielectric strength is about 30 KV/mm and resistivity of insulation is $10^{17}\,\Omega$ cm.

It suffers from some major drawbacks viz readily

(i) absorbs moisture

(ii) maximum safe temperature is low (about 38^0 C)

(iii) soft and liable to damage due to rough handling and ages when exposed to light.

Therefore, pure rubber cannot be used as an insulating material.

2 Vulcanised Indian Rubber (V.I.R.) : It is prepared by mixing pure rubber with mineral matter such as zinc oxide, red lead etc. and 3 to 5% of sulphur. The compound so formed is rolled into thin sheets and cut into strips. The rubber compound is then applied to the conductor and is heated to a temperature of about 150°C. The whole, process is called **vulcanization** and the product obtained is known as **V**ulcanized **I**ndian **R**ubber.

Advantages: Vulcanised India rubber has greater mechanical strength, durability and water resistant property than pure rubber.

Disadvantages: Its main drawback is that sulphur reacts quickly with copper. So, cables using VIR insulation must have tinned copper conductor. The VIR insulation is generally used for low and moderate voltage cables.

3 Impregnated paper: It consists of chemically pulped paper made from wood chippings and impregnated with some compound such as paraffinie or naphthenic material.
Aadvantages:

(i) Low cost

(ii) Low capacitance

(iii) High dielectric strength and

(iv) High insulation resistance.

Disadvantages:

(i) The paper is hygroscopic and even if it is impregnated with suitable compound

(ii) It absorbs moisture and thus lowers the insulation resistance of the cable.

For this reason, paper insulated cables are always provided with some protective covering and are never left unsealed. If it is required to be left unused on the site during laying, its ends are temporarily covered with wax or tar.

Since the paper-insulated cables have the tendency to absorb moisture, they are used where the cable route has a few joints. For instance, they can be profitably used for distribution at low voltages in congested areas where the joints are generally provided only at the terminal apparatus. However, for smaller installations, where the lengths are small and joints are required at a number of places, VIR Cables will be cheaper and durable than paper insulated cables.

4 Varnished cambric: It is a cotton cloth impregnated and coated with varnish. This type of insulation is also known as empire type. The cambric is lapped on to the conductor in the form of tape and its surface is coated with petroleum jelly compound to allow for the sliding of one turn over another as the cable is bent. As the varnished cambric is hygroscopic, therefore, such cables are always provided with metallic sheath. Its dielectric strength is about 4 KV/mm and permittivity is 2.5 to 3.8.

5 Polyvinyl chloride (PVC): This insulating material is a synthetic compound. It is obtained from the polymerization of acetylene and is in the form of white powder. For obtaining this material as a cable insulation, it is compounded with certain materials known as plasticiser which are liquids with high boiling point.

Advantages:

(i) It has high insulation resistance

(ii) Good dielectric strength

(iii) Mechanical toughness over a wide range of temperature.

This type of insulation is preferred over VIR in extreme environmental conditions such as in cement factory or chemical factory.

Classification of cables

Cables for underground service may be classified in two ways according to (i) the type of insulating material used in their manufacture (ii) the voltage for which they are manufactured. However, the later method of classification is generally preferred as

(i) Low-tension (L.T) cables – upto 1100 V

(ii) High-tension (H.T) cables – upto 11,000 V

(iii) Super-tension (S.T cables – from 22 KV to 33 KV

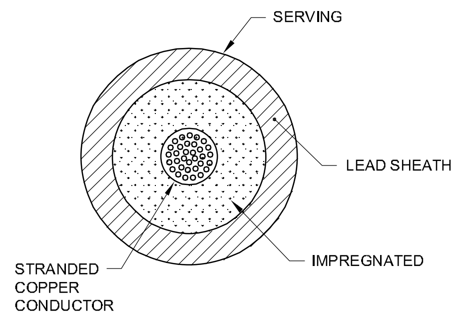
(iv) Extra high-tension (E.H.T) cables – from 33 to 66 KV

(v) Extra super voltage cables – beyond 132 KV

A cable may have one or more than one core depending upon the type of service for which it is intended. It may be (i) single-core (ii) two-core (iii) three-core (iv) four-core etc. For a 3-phase service, either 3-single core cables or three-core cable can be used depending upon the operating voltage and load demand.

Fig 2 shows the constructional details of a single-core low tension cable. The cable has ordinary construction because the stresses developed in the cable for low voltages (upto 6600 V) are generally small. It consists of one circular core of tinned stranded copper (or aluminium) insulated by layers of impregnated paper. The insulation is

Fig 2



SINGLE CORE L.T. CABLE

surrounded by a lead sheath which prevents the entry of moisture into inner parts. In order to protect the lead sheath from corrosion, an overall serving of compounded fibrous material (jute etc.) is provided. Single-core cables are not usually armoured in order to avoid excessive sheath losses. The principal advantages of single-core cables are simple construction and availability of large copper section.

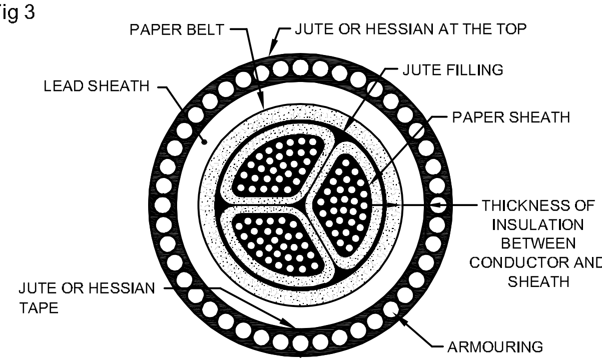
Cables for 3-Phase Service

In practice, underground cables are generally required to deliver 3-phase power. For the purpose, either three-core cables or three single core cables may be used. For voltages upto 66 KV, 3-core cable (i.e. multi-core construction) is preferred due to economic reasons. The following types of cables are generally used for 3-phase service.

1. Belted cables – upto 11 KV
2. Screened cables – from 22 KV to 66 KV
3. Pressure cables – beyond 66 KV

1. Belted cables

Fig 3



BELTED TYPE CABLE

These cables are used for voltages upto 11 KV but in extraordinary cases, their use may be extended upto 22 KV. Fig 3 shows the constructional details of a 3-core belted cables. The cores are insulated from each other by layers of impregnated paper.

Another layer of impregnated paper tape called paper belt is wound round the grouped insulated cores. The gap between the insulated cores is filled with fibrous insulating material (jute etc.) The belt is covered with lead sheath to protect the cable against ingress of moisture and mechanical injury.

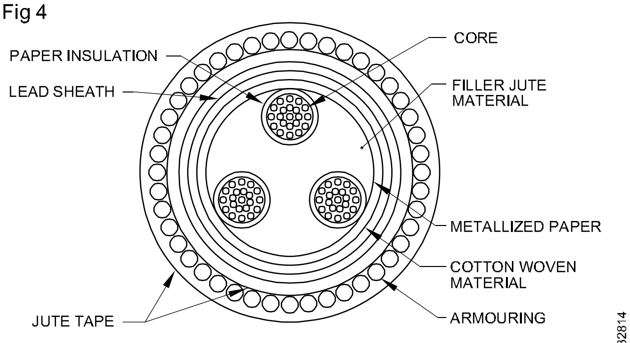
The belted type construction is suitable only for low and medium voltages as the electrostatic stresses developed in the cables for these voltages are more or less radial i.e. across the insulation. However, for high voltages (beyond 22 KV), the tangential stresses also become important.

2. Screened cable

These cables are meant for use upto 33 KV but in particular cases their use may be extended to operating voltages upto 66 KV. Two principal types of screened cables are H-type cable and S.L. type cables.

(i) **H-type cables**. This type of cable was first designed by H. Horchstadter and hence the name. Fig 4 shows the constructional details of a typical 3-core, H-type cable. Each core is insulated by layers of impregnated paper. The insulation on each core is covered with a metallic screen which usually consists of a perforated aluminium foil.

Fig 4



H TYPE CABLE

The cable has no insulating belt but lead sheath, bedding, armouring and serving follow as usual. As all the four screens (3 core screens and one conducting belt) and the lead sheath are at earth potential.

Advantages:

- The posibility of air pockets or volds in the dielectric is eleminated

- The metalic screen increase the heat dissipating power of the cable

(ii) **S.L. type cables** Fig 5 shows the constructional details of 3-core S.L **(separate lead)** type cable. It is basically H-type cable but the screen round each core insulation is covered by its own lead sheath. There is no overall lead sheath but only armouring and serving are provided.

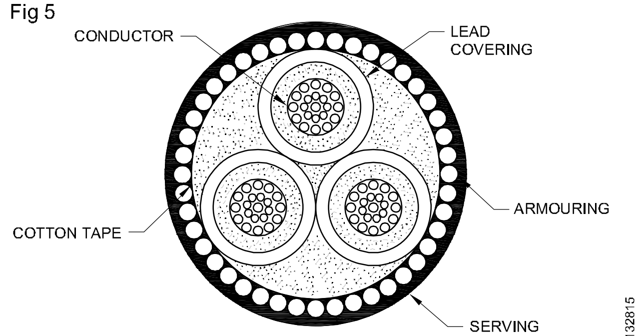
The S.L type cables have two main advantages over H-type cables.

a) The separate sheaths minimize the possibility of core-to-core breakdown.

b) Bending of cables become easy due to the elimination of overall lead sheath.

The disadvantage is that the three lead sheaths of S.L. cable are much thinner than the single sheath of H-cable

Fig 5



SL TYPE CABLE

Limitations of solid type cables

All the cables of above constructions are referred to as solid type cables because solid insulation is used and no gas or oil circulates in the cable sheath. The voltage limit for solid type cables is 66 KV due to the following reasons:

a. As a solid cable carries the load, its conductor temperature increases and the cable compound (i.e. insulating compound over paper) expands. This action stretches the lead sheath which may be damaged.

b. When the load on the cable decreases, the conductor cools and a partial vacuum is formed within the cable sheath. If the pinholes are present in the lead sheath, moist air may be drawn into the cable. The moisture reduces the dielectric strength of insulation and may eventually cause the breakdown of the cable.

c. In practice, voids are always present in the insulation of a cable. Modern techniques of manufacturing have resulted in void free cables. However, under operating conditions, the voids are formed as a result of the differential expansion and contraction of the sheath and impregnated compound.

3. Pressure cables

For voltages beyond 66 KV, solid type cables are unreliable because there is a danger of breakdown of insulation due to the presence of voids. When the operating voltages are greater than 66 KV, pressure cables are used. In such cables, voids are eliminated by increasing the pressure of compound and for this reason they are called pressure cables. Two types of pressure cables viz oil filled cables and gas pressure cables are commonly used.

(i) **Oil filled cables.** In such type of cables, channels of ducts are provided in the cable for oil circulation. The oil under pressure (it is the same oil used for impregnation) is kept constantly supplied to the channel by means of external reservoirs placed at suitable distances (say 500 m) along the route of the cable.

Oil under pressure compresses the layers of paper insulation and is forced into any voids that may have formed between the layers. Due to the elimination of voids, oil-filled cables can be used for higher voltages, the range being from 66 KV upto 230 KV.

Oil-filled cables are of three types viz.

(i) Single-core conductor channel

(ii) Single-core sheath channel and

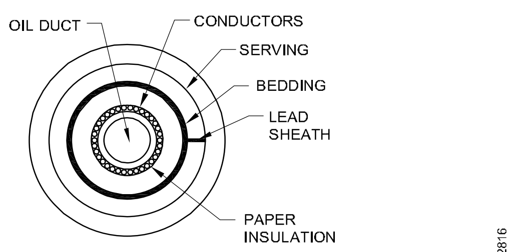
(iii) Three-core filler-space channels.

(i) Single-core Conductor channel

Fig 6 shows the constructional details of a single-core conductor channel, oil-filled cable. The oil channel is formed at the centre by stranding the conductor wire around a hallow cylindrical steel spiral tape. The oil under pressure is supplied to the channel by means of external reservoir. As the channel is made of spiral steel tape, it allows the oil to percolate between copper strands to the wrapped insulation.

The oil pressure compresses the layers of paper insulation and prevents the possibility of void formation. The disadvantage of this type of cable is that the channel is at the middle of the cable which is at full voltage w.r.t earth, so that a very complicated system of joints is necessary.

Fig 6

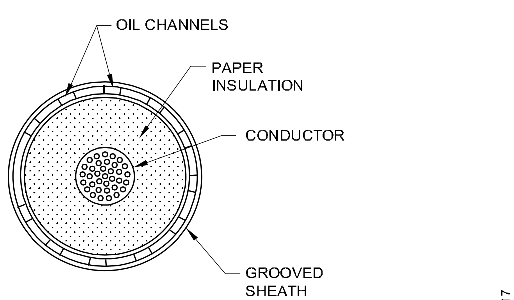


SINGLE - CORE CONDUCTOR CHANNEL OIL - FILLED CABLE

(ii) Single-core sheath channel (Fig 7)

In this type of cable, the conductor is solid similar to that of solid cable and is paper insulated. However, oil ducts are provided in the metallic sheath.

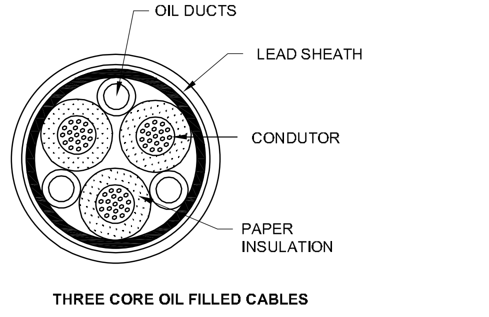
Fig 7



OIL - FILLED CABLES

In the 3-core oil-filled cable shown in Fig 8, the oil ducts are located in the filler space. These channels are composed of perforated metal-ribbon tubing and are at earth potential.

Fig 8



THREE CORE OIL FILLED CABLES

Advantages

(a) Formation of voids and ionization are avoided.

(b) Allowable temperature range and dielectric strength are increased.

(c) If there is leakage, the defect in the lead sheath is at once indicated and the possibility of earth faults is decreased.

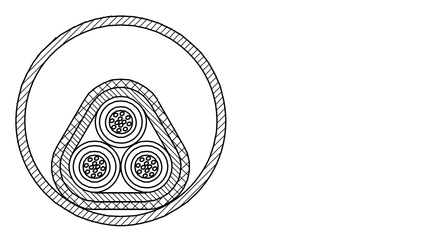
Disadvantages

(a) High initial cost and complicated system of laying

(ii) **Gas pressure cables**. The voltage required to set up ionization inside a void increases as the pressure is increased. Therefore, if ordinary cable is subjected to a sufficiently high pressure, the ionization can be altogether eliminated. At the same time, the increased pressure produces radial compression which tends to close any voids. This is the underlying principle of gas pressure cables.

Fig 9 shows the section of external pressure cable designed by Hockstadter, Vogal and Bowden. The construction of the cable is similar to that an ordinary solid type except that it is of triangular shape and thickness of lead sheath is 75% that of solid cable. The triangular section reduces the weight and gives low thermal resistance but the main reason for triangular shape is that the lead sheath acts as a pressure membrane. The sheath is protected by a thin metal tape. The cable is laid is a gas-tight steel pipe.

Fig 9



EXTERNAL PRESSURE CABLE

The pipe is filled with dry nitrogen gas at a pressure of 12 to 15 atmospheres. The gas pressure produces radial compression and closes the voids that may have formed between the layers of paper insulation.

Advantages:

a) Cables can carry more load current

b) Operate at higher voltages than a normal cable.

c) Maintenance cost is small and the nitrogen gas helps in quenching any flame.

Disadvantages:

The overall cost is very high.

Further the cables are also classified according to their insulation system as under:

PVC insulated cables (Poly vinyl chloride)

MI cables (Mineral insulation)

PILC cables (Paper insulated lead covered)

XLPE cables (Cross linked poly ethylene)

PILCDTA cables (Paper insulated lead covered double tape armoured)

The specification of underground cables

The cables shall carry the following information either labelled or stenciled on the reel or drum or container.

1 Reference to the Indian Standard; for example Ref. IS 694-1977.

2 Manufacturer's name, brand name or trademark.

3 Type of cable and voltage grade.

4 Number of cores.

5 Nominal cross-sectional area of conductor.

6 Cable code.

7 Colour of cores (in case of single core cables)

8 Length of cable on the reel, drum or coil

9 Number of lengths on the reel, drum or coil (if more than one).

10 Direction of rotation of drum (by means of arrow).

11 Approximate gross weight.

12 Country of manufacturing.

13 Year of manufacture.

Fig 10 shows the paper insulated 3 phase 3 ½ core cable.

UG cables laying method

The reliability of the underground cable (UG) installation depends upon the proper laying and attachment of fittings (i.e) cable and boxes, joints, branch connectors etc.

Methods of laying of UG cables

The following are the methods of laying underground cables

1 Laying direct in ground

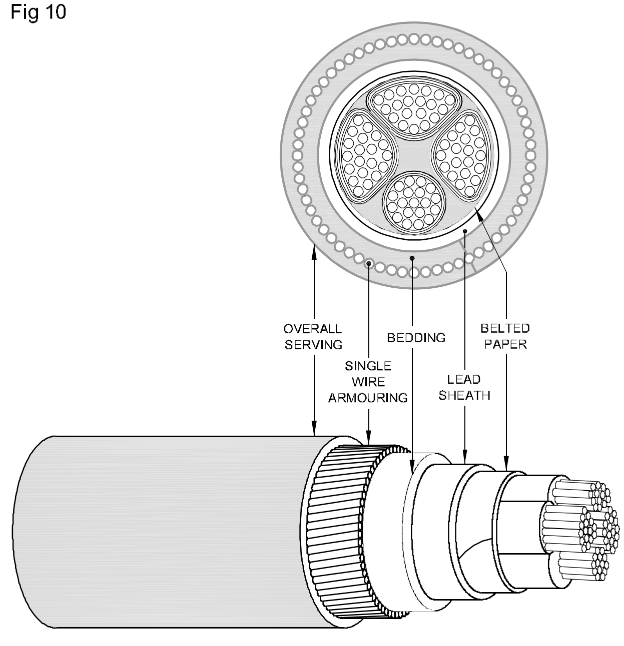
2 Laying in ducts

3 Laying on racks in air.

4 Laying on racks inside a cable tunnel.

5 Laying along buildings or structures.

Fig 10



PAPER INSULATED 3 PHASE 3 ½ CORE CABLE

The choice of any of the systems given above depends on

(i) The actual installation conditions

(ii) Inital cost of laying

(iii) Maintenance and repair charges

(iv) Deisred care in replacement of any cable or adding new cables for the future.

As far as the possible cable should be laid along the roads and streets. Power and communication cables should cross at right angles.

During the preliminary stages of laying the cable, consideration should be given to a proper location of the joints position so that when the cable is actually laid, the joints are made in the most suitable places.

As far as possible water logged locations, carriage ways, pavements, proximity to telephone cables, gas or water mains in accessible places, ducts pipes, racks etc shall be avoided for joint position.

Laying direct in ground:

This method involves digging a trench in the ground and laying cable(s) on a bedding of minimum 75 mm riddled soil or sand at the bottom of the trench, and covering it with additional riddled soil or sand of minimum 75 mm and protecting it by means of tiles, bricks or slabs.

Depth: The desired minimum depth from ground surface to the top of cable is as follows:

a) High voltage cables, 3.3 KV to 11 KV rating : 0.9 m.

b) High voltage cables, 22 KV, 33 KV rating : 1.05 m.

c) Low and medium voltage and control cables : 0.75 m.

d) Cables at road crossings : 1.00 m.

e) Cables at railway level crossings (measured from bottom of sleepers to the top of pipe) : 1.00 m.

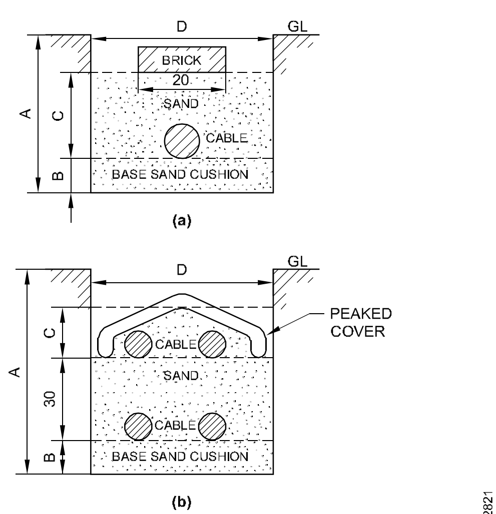
Width: The width of a trench for laying a single cable should be minimum 35 cm. When more than one cable is laid in the same trench in horizontal formation, the width of the trench shall be so increased that the inter-axial spacing between two cables is 20 cm.

Clearance from the terminal cable to the sides of a trench should be 15 cm.

Cable is protected by sand or layer of brick as shown in Fig 1a. Bricks should be second class bricks of a size not less than 20 cm x 10 cm x 10 cm and laid for full length for one cable (bricks to be laid breadthwise).

When more than one cable is to be laid in the same trench, this protective covering shall extend atleast 5 cm. over the sides of the end cables. An alternative to this covering can be earth ware or R.C.C. or fire-bricks of peaked covers section as shown in Fig 1b.

Fig 1



LAYING DIRECT IN GROUND METHOD

It is good practice to leave about 3 metres of cable spare in a loop formation near poles and joints, so that in case joint fails, this additional cable comes to rescue. Cable should be laid 0.4 metre away from water and power mains.

For cable of rating

Ref.	Upto 1.1 kV	Exceeding 1.1 kV
A	75	120
A1	(75+n1x30)	(120+n1x30)
B	8	8
C	17	17
D	35	35
D1	(30+n2x20)	(30+n2x20)
E	15	15

n1 = Number of additional cables in vertical formation.

n2 = Number of additional cables in horizontal formation.

For road crossings cast iron, or 2nd class RCC pipes or M.S/G.I. Pipe of medium class having an appropriate diameter should be laid during construction of the road to avoid damage to the road later on. The top surface of the pipe should be at a minimum depth of 1m. Pipes provided for entry to a building shall slope upward to prevent entry of water into the building. After laying of the cable they should be sealed.

Advantages

1 It is a simple and less costly method.

2 It gives the best conditions for dissipating the heat generated in the cables.

3 It is a clean and safe method as the cable is invisible and free from external disturbances.

Disadvantages

1 The extension of load is possible only by a complete new excavation which may cost as much as the original work.

2 The alterations in the cable network cannot be made easily.

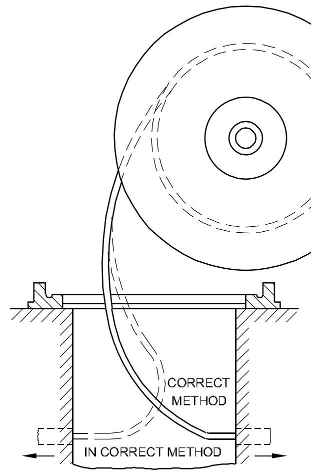
3 The maintenance cost is very high.

4 Localisation of fault is difficult.

5 It cannot be used in congested areas where excavation is difficult.

Drawing the cables into duct pipes: When drawing the cables through ducts, lack of space in the drawing pits usually restricts the distance from the cable drum to the duct mouth. It is essential that the direction of curvature of the cables is not reversed as it enters the duct. If the cable drum is on the same side of the drawing pit, as shown in Fig 2, this condition is fulfilled.

Fig 2



METHOD OF PULLING CABLES INTO DUCTS

Advantages

1 Reparis, alterations or additions to the cable network can be made without opening the ground.

2 As the cables are not armoured, therefore, joints become simpler and maintenance cost is reduced considerably.

3 There are very less chances of fault occurrence due to strong mechanical protection provided by the system.

Disadvantages

1 The initial cost is very high.

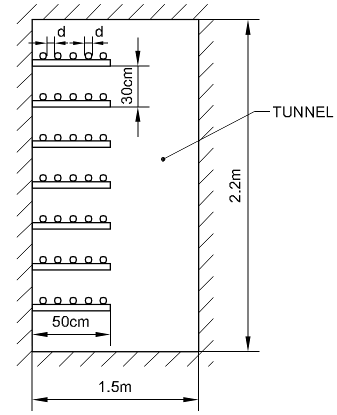
2 The current carrying capacity of the cables is reduced due to the close grouping of cables and unfavourable conditions for dissipation of heat.

This method of cable laying is suitable for congested areas where excavation is expensive and inconvenient, for once the conduits have been laid, repairs or alterations can be made without opening the ground. This method is generally used for short length cable routes such as in workshops, road crossing where frequent digging is costlier or impossible.

Laying cables on racks in air: Inside buildings, industrial plants, generating stations, substations and tunnels, cables are generally installed on racks fixed to the walls or supported from the ceiling. Racks may be ladder or perforated type and may be either fabricated at the site or pre-fabricated. Considerable economy can be achieved by using standard factory made racks. The necessary size of the racks and associated structure has to be worked out taking into consideration the cable grouping and permissible bending radii. Fig 3 shows the method of laying cables inside a tunnel on racks.

Laying cables along buildings or structures: Cables can be routed inside the building along with structural elements or with trenches under floor ducts or tunnels. The route of the proposed cable should be such that intersection with other cables will be minimum. The route should not subject these cables to any vibrations, damage due to heat or other mechanical causes. All adequate precautions should be taken to protect the cables.

Fig 3



LAYING OF CABLE INSIDE TUNNEL

Precautions while handling cables

1 Prevent the cable from dragging on the floor.

2 Prevent kinking of the cable.

3 After laying the cable in the ducts it should be immediately covered or suspended.

Cable jointing methods: This process consists of the following steps.

a) Exact measurement of the cable for insulation removal.

b) Removal of insulation.

c) Replacing of the original insulation with high grade tapes and sleeves.

d) Dressing the cable ends and conductor joints through sleeves/split sleeves.

e) Providing separators between cables.

f) Fixing a cast iron or any other protective shell around the joint and filling the joint boxes with molten bitumen compound.

g) Plumbing metallic sleeves or brass glands to the lead sheath of the cable to prevent moisture from entering the joint in case of cast iron joint boxes or tape insulation in case of cast resin kit joint boxes.

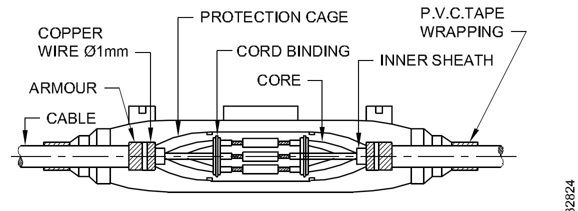
Straight through joints

The emphasis should be laid on quality and selection of proper cable, cable accessories, proper jointing techniques. The quality of joint in cable should be such that, it does not add any resistance to the circuit. The material and techniques employed in joining the cables should give adequate mechanical and electrical protection to the joint under all service conditions. The joints should further be resistant to corrosion and other chemical effects.

For PILC cable: For paper insulated lead sheathed cables, straight joints are made either by using sleeve joints or crimping joints up to voltage grade 11 KV. Above 11 KV, compound filled copper or brass sleeves, along with cast iron, fibre glass protection boxes are used.

Fig 4 shows such a joint.

Fig 4



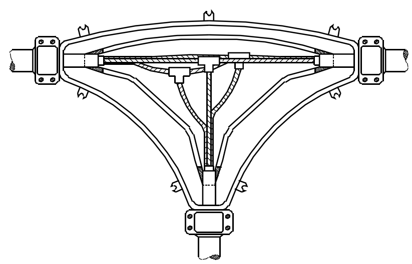
STRAIGHT THROUGH JOINTS FOR CABLES 3.3 KV GRADE

The cast iron protection boxes used up to 11 KV or moulds used for 1.1 KV joints in cast resin joints should conform to the relevant Indian Standard. Above 11 KV cast resin system is not yet standardized.

Tee joint: These joints are to be restricted up to 11 KV.

These joints are made either using cast resin kits or C.I. boxes with or without sleeves for PILC cables and cast resin kits for PVC and XLPE cables. (Fig 5)

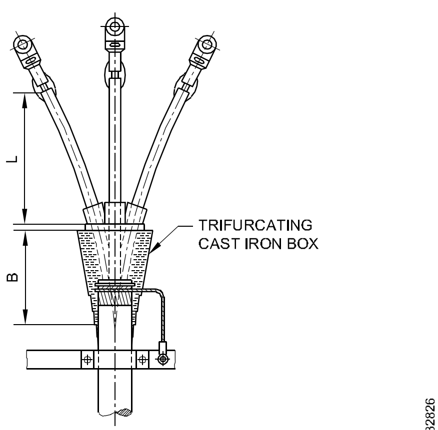
Fig 5



TEE JOINT OF 11 kV PAPER INSULATED CABLE

Tri-furcating end connections: In order to connect UG cables to the air break switches etc. tri-furcating boxes are used. They can be either cast resin type up to 1.1 KV or cast iron type for 11 KV and above. This type of box is shown in Fig 6.

Fig 6



TERMINATION FOR PVC CABLE

Method of preparing and filling compounds

– Hot pouring

– Cold pouring

Hot pouring compounds: A bituminous compound of melting temperature 90°C and pouring temperature 180°C - 190°C is used for hot pouring.

Properties: The bituminous compound has the following properties.

a) High electrical strength

b) High resistance to moisture

Compounding process: Heat the compound in a special bucket on firewood or charcoal fire, stir with a clean metal rod to have even melting of the compound. Check the temperature with a thermometer and heat the compound up to 180° to 190°C.

Heat the sealing box to 70°C with a blow torch. Open all air escape plugs. Fit a heated funnel to the pouring hole. Pour the compound carefully and evenly in 2 or 3 stages with an interval between them to allow the compound to solidify. Take care that no air bubble is trapped inside.

Cold pouring compound: Cold pouring is used by using cast resin system for PVC cable jointing. This has been developed for application up to 11 KV grade cables. The compound consists of a resin base and a polyamino hardener. The two component liquids are mixed at the site in accordance with the recommendation of the manufacturer.

Typical epoxy straight joint for PVC cable: In this system of jointing the insulation is removed and conductors are joined. The core joints in the case of LV/MV cables should be kept apart to avoid any flash over between them. Spacers are provided between the cores for H.V. cables.

No insulation is applied over the core joints. A cover earth ring is placed tight over the two cut ends of the armour and soldered to the armour wires. The two rings are then jointed by a copper wire and the cut ends of the armouring are bent over the rings to have continuity of armour as earth conductor.

Sandpaper is applied to the inner sheath surface and is cleaned by using methyl chloride. The joint is enclosed by plastic mould, which is in two parts, whose ends are duly cut to match the size of cable. PVC tape is wrapped at the two places where the mould will touch the cables. The two halves are pasted together and kept clamped to avoid any air gap. The mould ends are enclosed with putty which is supplied in the joint kit.

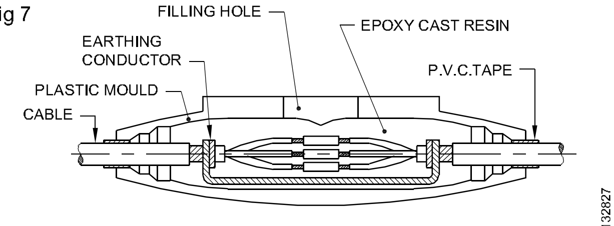
The expiry date of resin is checked and the hardener added to resin. The mixture is churned thoroughly for about 15 to 20 minutes till the colour of the mixed compound becomes grey. The mix is poured slowly into the mould taking care to avoid formation of air bubbles till the mould is filled and it comes out at the risers.

Allow the joint to set for a minimum of three hours till it becomes a solid mass before charging the cable. The mould may be removed, if desired.

Normally all the components required for joints are supplied as kits for various sizes of cables.

Fig 7 illustrates a typical straight through and outdoor termination of PVC cable with epoxy resin respectively.

Fig 7



TYPICAL EPOXY STRAIGHT JOINT FOR PVC CABLE

Types of cable faults and testing procedure

The common faults which are likely to occur in cables are:

1. **Ground fault.** The insulation of the cable may breakdown causing a flow of current from the core of the cable to the lead sheath or to the earth. This is called "Ground Fault".
2. **Short circuit fault.** If the insulation between two conductors is faulty, a current flows between them. This is called a "short circuit fault".

Methods for locating ground and short circuit faults.

The methods used localizing the ground and short circuit faults differ from those used for localizing open circuit faults.

In the case of multi core cables it is advisable, first of all, to measure the insulation resistance of each core to earth and also between cores. This enables us to sort out the core that is earthed in-case of ground fault; and to sort out the cores that are shorted in case of a short circuit fault. Loop tests are used for location of ground short circuit faults. These tests can only be used if a sound cable runs along with the faulty cable or cables.

The loop tests work on the principle of a Wheatstone bridge. The advantage of these tests is that their setup is such that the resistance of fault is connected in the battery circuit and therefore does not effect the result. However, if the fault resistance is high, the sensitivity is adversely affected. In this section only two types of tests viz., Murray and Varley loop tests are being described.

Murray Loop Test. The connection for this test are shown in Fig 8a relates to the ground fault and Fig 8b relates to the short circuit fault.

In both cases, the loop circuit formed by the cable conductors is essentially a wheatstone bridge consisting of resistances P, Q, R and X. G is a galvanometer for indication of balance,

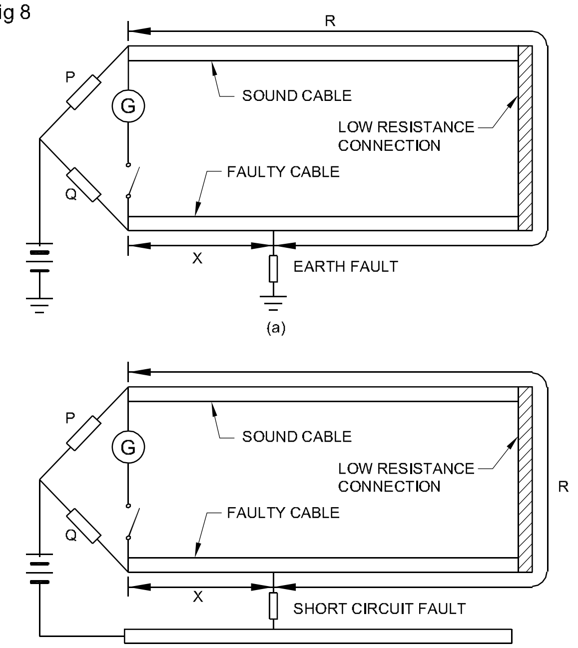
The resistors P, Q forming the ratio arms may be decade resistance boxes or slide wires.

Under balance conditions :

$$\frac{X}{R} = \frac{Q}{P} \text{ or } \frac{X}{R+X} = \frac{Q}{P+Q}$$

$$\therefore X = \frac{Q}{P+Q}(R+X)$$

Fig 8



MURRAY LOOP TEST
(b)

Where (R+X) is total loop resistance formed by the sound cable and the faulty cable. When the conductors have the same cross-sectional area and the same resistivity, the resistance are proportional to lengths. If l_1 represents the length of the fault from the test end and 'l' is the length of each cable. Then

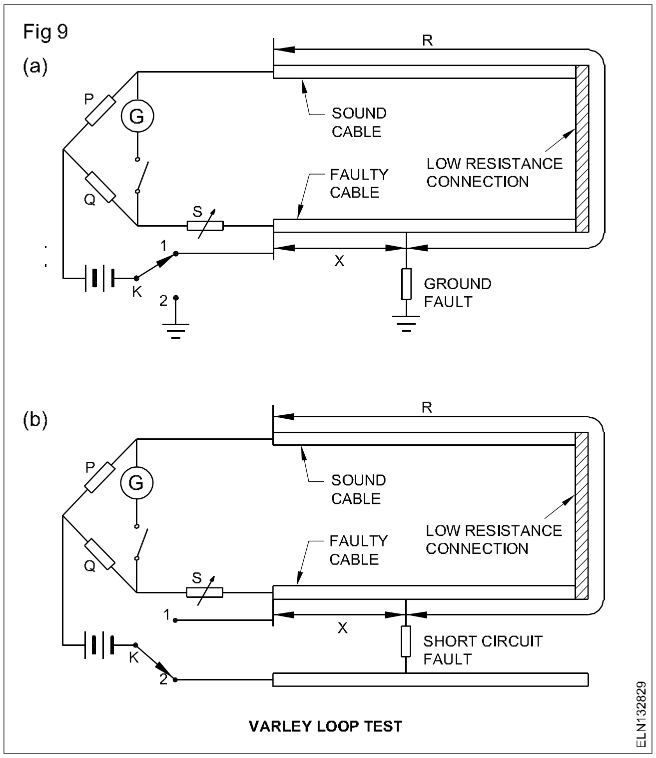
$$l_1 = \frac{Q}{P+Q} \cdot 2l$$

The above relation shows that the position of the fault may be located when the length of the cable is known. Also, the fault resistance does not alter the balance condition because its resistance enter the battery circuit hence effects only the sensitivity of the bridge circuit. However, if the magnitude of the fault resistance is high, difficulty may be experienced in obtaining the balance condition on account of decrease in sensitivity and hence accurate determination of the position of the fault may not be possible.

In such a case, the resistance of the fault may be reduced by applying a high direct or alternating voltage, in consistence with the insulation rating of the cable, on the line so as to carbonize the insulation at the point of the fault.

Varley loop test. In this test we can determine experimentally the total loop resistance instead of calculating it from the known lengths of the cable and its resistance per unit length. The necessary connections for the ground fault are shown in Fig 9a and for the short circuit fault in Fig 9b. The treatment of the problem, in both cases, is identical.

A single pole double throw switch A is used in this circuit. Switch K is first thrown to position 'I' and the resistance 'S' is varied and balance obtained.



Measurement of resistance

Let the value of S for balance be S. The four arms of the Wheatstone bridge are P, Q, R + X, S_1 at balance:

$$\frac{R+X}{S_1}=\frac{P}{Q}$$

This determines R + X i.e. the total loop resistance as P, Q and S_1 are known.

The switch K is then thrown to position '2' and the bridge is rebalanced. Let the new value of S for balance be S_2. The four arms of the bridge now are P, Q, R, X + S_2.

At balance

$$\frac{R}{X+S_2}=\frac{P}{Q}$$

$$\frac{R+X+S_2}{X+S_2}=\frac{P+Q}{Q} \text{ or } X=\frac{(R+X)Q-S_2P}{P+Q}$$

Hence, X is known from the known value of P, Q, S_2 from this equation and R+X (the total resistance of 2 cables) as determined from Eqn. knowing the value of X, the position of the fault is determined.

Now

$$\frac{X}{R+X}=\frac{l_1}{2l} \text{ or } l_1=\frac{X}{R+X}2l$$

Where

l_1= length of fault from the test end and

l = total length of conductor.

Equations for murrary loop test and varley loop test are valid only when the cable sections are uniform throughout the loop. Corrections must be applied in case the cross-sections of faulty and sound cables are different or when the cross-section of the faulty cable is not uniform over its entire length.

Since temperature affects the value of resistance, corrections must be applied on this account if the temperatures of the two cables are different. Corrections may also have to be applied in case the cables have a large number of joints.