

Lecture 11: Underground cables

11.1 Introduction.

Electric power can be transmitted or distributed either by overhead system or by underground cables. The underground cables have several advantages such as less liable to damage through storms or lightning, low maintenance cost, less chances of faults, smaller voltage drop and better general appearance.

However, their major drawback is that they have greater installation cost and introduce insulation problems at high voltages compared with the equivalent overhead system. For this reason, underground cables are employed where it is impracticable to use overhead lines. Such locations may be thickly populated areas where municipal authorities prohibit overhead lines for reasons of safety, or around plants and substations or where maintenance conditions do not permit the use of overhead construction.

The chief use of underground cables for many years has been for distribution of electric power in congested urban areas at comparatively low or moderate voltages.

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

Although several types of cables are available, the type of cable to be used will depend upon the working voltage and service requirements. In general, a cable must fulfil the following necessary requirements :

- (i) The conductor used in cables should be tinned stranded copper or aluminium of high conductivity. Stranding is done so that conductor may become flexible and carry more current.
- (ii) The conductor size should be such that the cable carries the desired load current without overheating and causes voltage drop within permissible limits.
- (iii) The cable must have proper thickness of insulation in order to give high degree of safety and reliability at the voltage for which it is designed.
- (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 the manufacture of cables should be such that there is complete chemical and physical stability throughout.

11.2 Construction of Cables

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. 11.1 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.

(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.

(iii) Metallic sheath. In order to protect the cable from moisture, gases or other damaging liquids (acids or alkalis) in the soil and atmosphere, a metallic sheath of lead or aluminium is provided over the insulation as shown in Fig. 11.1

(iv) 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.

(v) 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.

(vi) 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*.

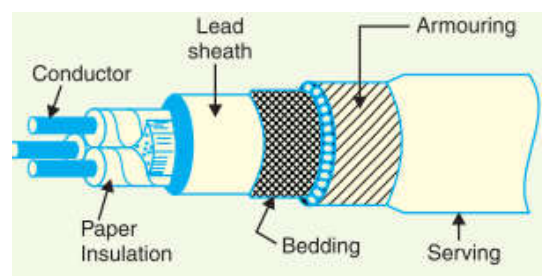


Figure 11.1 Construction of a cable

Armouring and serving are only applied to the cables for the protection of conductor insulation and to protect the metallic sheath from mechanical injury

11.3 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 materials 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 so as to make the underground system a viable proposition.
- (vii)** Unaffected by acids and alkalis to avoid any chemical action.

No one insulating material possesses all the above mentioned properties. Therefore, 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 rubber, impregnated paper, varnished cambric and polyvinyl chloride (PVC).

11.4 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 latter method of classification is generally preferred, according to which cables can be divided into the following groups :

- (i)** Low-tension (L.T.) cables — up to 1000 V
- (ii)** High-tension (H.T.) cables — up to 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 kV 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.

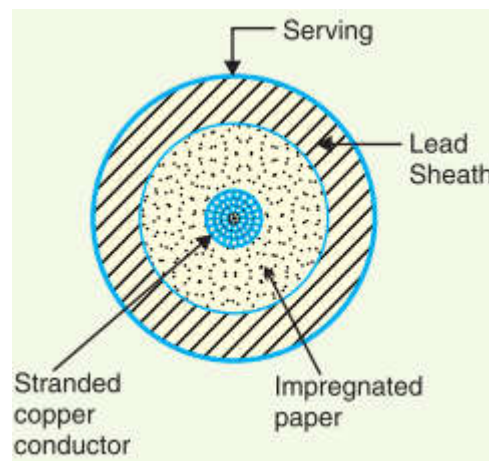


Figure 11.2

Fig. 11.2 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 surrounded by a lead sheath which prevents the entry of moisture into the 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 larger copper section.

11.5 Cables for 3-Phase Service

In practice, underground cables are generally required to deliver 3-phase power. For the purpose, either three-core cable 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. However, for voltages beyond 66 kV, 3-core-cables become too large and unwieldy and, therefore, single-core cables are used. 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. These cables are used for voltages upto 11kV but in extraordinary cases, their use may be extended upto 22kV. Fig. 11.3 shows the constructional details of a 3-core belted cable. 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.) so as to give circular cross-section to the cable. The cores are generally stranded and may be of noncircular shape to make better use of available space. The belt is covered with lead sheath to protect the cable against ingress of moisture and mechanical injury.

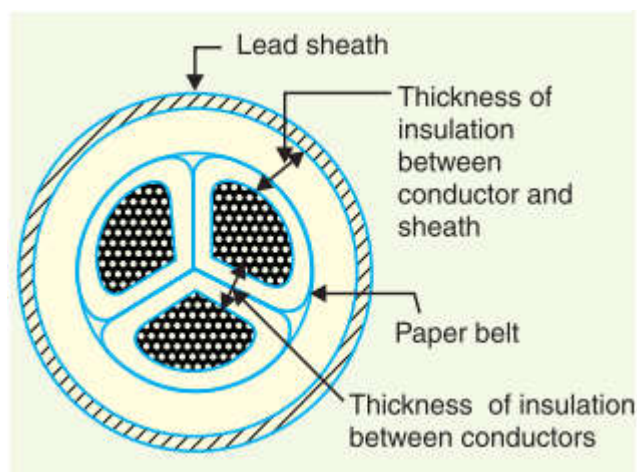


Figure 11.3 Belted cables

2. Screened cables. These cables are meant for use upto 33 kV, but in particular cases their use may be extended to operating voltages upto 66 kV.

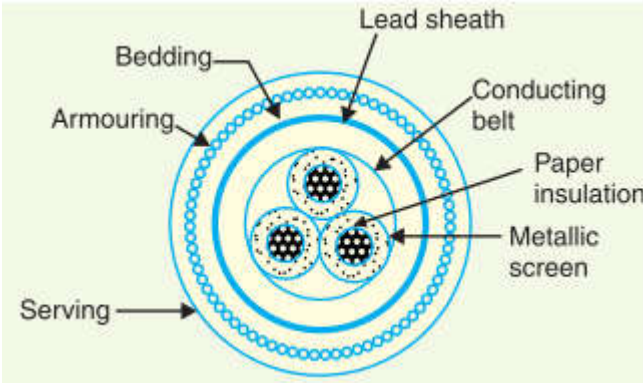


Figure 11.4 Screened cables

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.

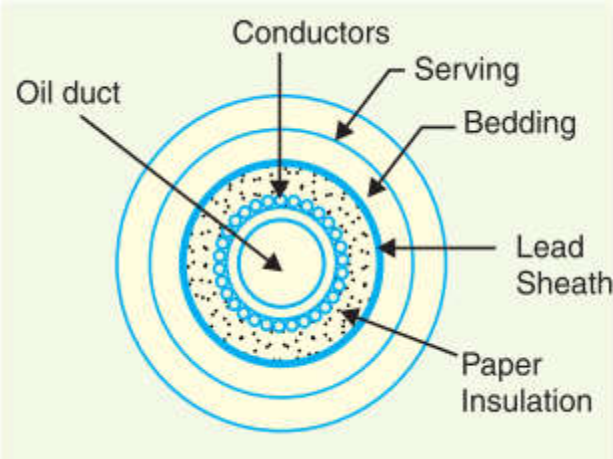


Figure 11.5 Single-core conductor channel, oil filled cable.

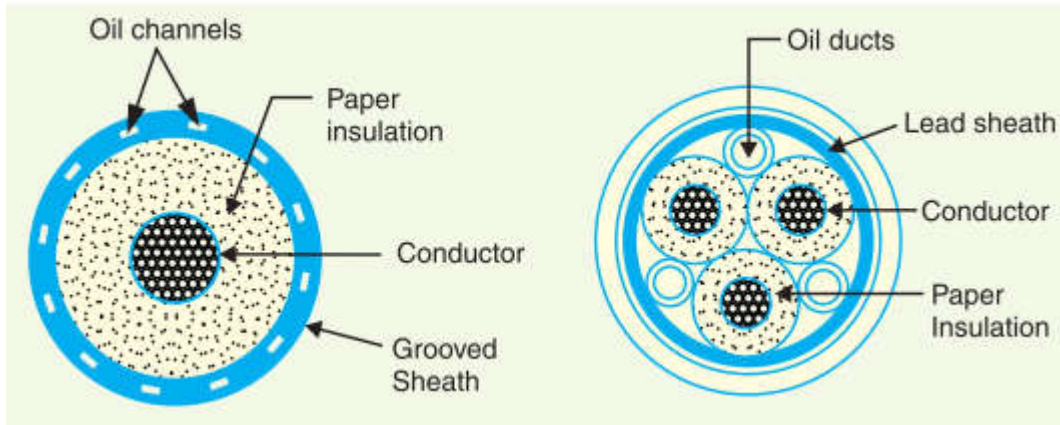


Figure 11.6 Oil filled cables.

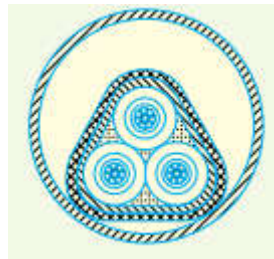


Figure 11.6 Gas filled cables.

11.6 Types of Cable Faults

Cables are generally laid directly in the ground or in ducts in the underground distribution system.

For this reason, there are little chances of faults in underground cables. However, if a fault does occur, it is difficult to locate and repair the fault because conductors are not visible.

Nevertheless, the following are the faults most likely to occur in underground cables:

(i) Open-circuit fault.

(ii) Short-circuit fault.

(iii) Earth fault.

(i) Open-circuit fault. When there is a break in the conductor of a cable, it is called open circuit fault. The open-circuit fault can be checked by a megger. For this purpose, the three conductors of the 3-core cable at the far end are shorted and earthed. Then resistance between each conductor and earth is measured by a megger. The megger will indicate zero resistance in the

circuit of the conductor that is not broken. However, if the conductor is broken, the megger will indicate infinite resistance in its circuit.

(ii) Short-circuit fault. When two conductors of a multi-core cable come in electrical contact with each other due to insulation failure, it is called a short-circuit fault. Again, we can seek the help of a megger to check this fault. For this purpose, the two terminals of the megger are connected to any two conductors. If the megger gives zero reading, it indicates short-circuit fault between these conductors. The same step is repeated for other conductors taking two at a time.

(iii) Earth fault. When the conductor of a cable comes in contact with earth, it is called earth fault or ground fault. To identify this fault, one terminal of the megger is connected to the conductor and the other terminal connected to earth. If the megger indicates zero reading, it means the conductor is earthed. The same procedure is repeated for other conductors of the cable.