
Overhead lines /poles erection-fastening of insulator

Objectives: At the end of this lesson you shall be able to

- **state the power transmission and distribution by O.H lines**
- **list out the main components and explain each of them**
- **explain the line supports used in transmission lines**
- **state the types of power lines with respect to the classification of voltage**
- **state about corona effect, sag and skin effect in O.H lines.**

Overhead lines

Electric power, which is generated from generating plant / station to the consumer end is transmitted and distributed either by means of overhead lines (O.H) or by under ground cables (U.G. cables).

Electrical power transmission is the bulk movement of electrical energy from generated power plant to electrical substation. This inter connected lines are known as **transmission network**. The electrical link from substations to customer is typically referred as electrical power **distribution**. The combined transmission and distribution network is known as the '**Power Grid**'.

Electricity is transmitted at high voltages (11, 33, 66, 230, 400, and 500 Kv) to reduce the energy loss which occurs in long distance transmission. The power is actually transmitted through O.H lines (or) underground cables.

The O.H lines are high voltage three phase alternating current, and also single phase A.C sometimes used in Railway Electrification system. High voltage Direct-Current (HVDC) is used for greater efficiency even for very long distances, used in submarine power cables and to stabilize large power distribution network.

Main components used in O.H lines

An overhead line may be used to transmit or distribute electric power. The successful operation of an overhead line depends to a great extent upon the mechanical design of the line. While constructing an overhead line, it should be ensured that mechanical strength of the line is such so as to provide against the most probable weather conditions. In general, the main components of an overhead line are,

- i Conductors which carry electric power from the sending end station to the receiving end station.
- ii Supports which may be poles or towers and keep the conductors at a suitable level above the ground.
- iii Insulators which are attached to supports and insulate the conductors from the ground.
- iv Cross arms which provide support to the insulators.

- v Miscellaneous items such as phase plates, danger plates, lightning arrestors, anti-climbing wires etc.

Conductor materials

The conductor is one of the important items as most of the capital outlay is invested for it. Therefore, proper choice of material and size of the conductor is of considerable importance. The conductor material used for transmission and distribution of electrical power should have the following properties.

- i High electrical conductivity
- ii High tensile strength in order to withstand mechanical stresses.
- iii Low cost so that it can be used for long distances.
- iv Low specific gravity so that weight per unit volume is small.

Commonly used conductor materials

The most commonly used conductor material for overhead lines are copper, aluminium, steel reinforced aluminium, galvanized steel and cadmium copper. The choice of a particular material will depend upon the cost and the required electrical and mechanical properties and the local conditions.

All conductors used for overhead lines are preferably stranded in order to increase the flexibility. In stranded conductors, there is generally one central wire and round this, successive layers of wires containing 6, 12, 18, 24... wires.

Copper

Copper is an ideal material for overhead lines owing to its high electrical conductivity and greater tensile strength. It is always used in the hard drawn form as stranded conductor. Although hard drawing decreases the electrical conductivity slightly yet it increases the tensile strength considerably.

Aluminium

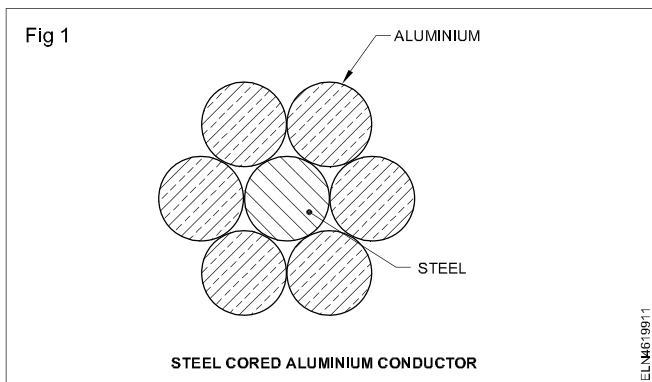
Aluminium is cheap and light as compared to copper but it has much smaller conductivity and tensile strength. The relative comparison of the two materials is briefed below.

The conductivity of aluminium is 60% that of copper. The smaller conductivity of aluminium means that for any particular transmission efficiency, the cross sectional area of conductor must be larger in aluminium than in copper. For the same resistance, the diameter of aluminium conductor is about 1.26 times the diameter of copper conductor.

Steel cored aluminium

In order to increase the tensile strength, the aluminium conductor is reinforced with a core of galvanized steel wires. The composite conductor thus obtained is known as steel cored aluminium and is abbreviated as ACSR (Aluminium Conductor Steel Reinforced).

Steel-cored aluminium conductor consists of central core of galvanized steel wires surrounded by a number of aluminium strands (Fig 1). Usually, diameter of both steel and aluminium wires is the same.



Galvanised steel

Steel has a very high tensile strength. Therefore, galvanized steel conductors can be used for extremely long-spans, or for short line sections exposed to abnormally high stresses due to climatic conditions. They have been found very suitable in rural areas where cheapness is the main consideration. Due to poor conductivity and high resistance of steel, such conductors are not suitable for transmitting large power over a long distance.

Line Supports

The supporting structures for overhead line conductors are various types of poles and towers called line supports. In general, the line supports should have the following properties:

- i High mechanical strength to withstand the weight of conductors and wind loads etc.
- ii Light in weight without the loss of mechanical strength
- iii Cheap in cost and economical to maintain.
- iv Longer life
- v Easy accessibility of conductors for maintenance

The line supports used for transmission and distribution of electric power are of various types including wooden, poles, steel poles, R.C.C poles and lattice steel towers. The choice of supporting structures for a particular case depends upon the line span, cross sectional area, line voltage, cost and local conditions.

Wooden poles

These are made of seasoned wood (sal or ehir) and are suitable for lines of moderate cross sectional area and of, relatively shorter spans, say up to 50 metres. Such supports are cheap, easily available, provide insulating properties and, therefore are widely used for distribution purposes in rural areas as an economical proposition. Double pole structures of the 'A' or 'H' type are often used (see Fig 2) to obtain a higher transverse strength than could be economically provided by means of single poles.

The main objections to wooden supports are: (i) tendency to rot below the ground level (ii) comparatively smaller life (20 – 25 years) (iii) cannot be used for voltage higher than 20 kV (iv) less mechanical strength and (v) require periodical inspection.

Steel poles

The steel poles are often used as a substitute for wooden poles. They possess greater mechanical strength, longer life and permit longer spans to be used. Such poles are generally used for distribution purposes in the cities. This type of supports need to be galvanized or painted in order to prolong its life. The steel poles are of three types viz (i) rail poles (ii) tubular poles and (iii) rolled steel joints.

RCC Poles

The reinforced cement concrete (RCC) poles have become very popular as line supports in recent years. They have greater mechanical strength, longer life and permit longer spans than steel poles. Moreover, they give good outlook, require little maintenance and have good insulating properties. Fig 3 shows R.C.C poles for single and double circuit. The holes in the poles facilitate the climbing of poles and at the same time reduce the weight of line supports.

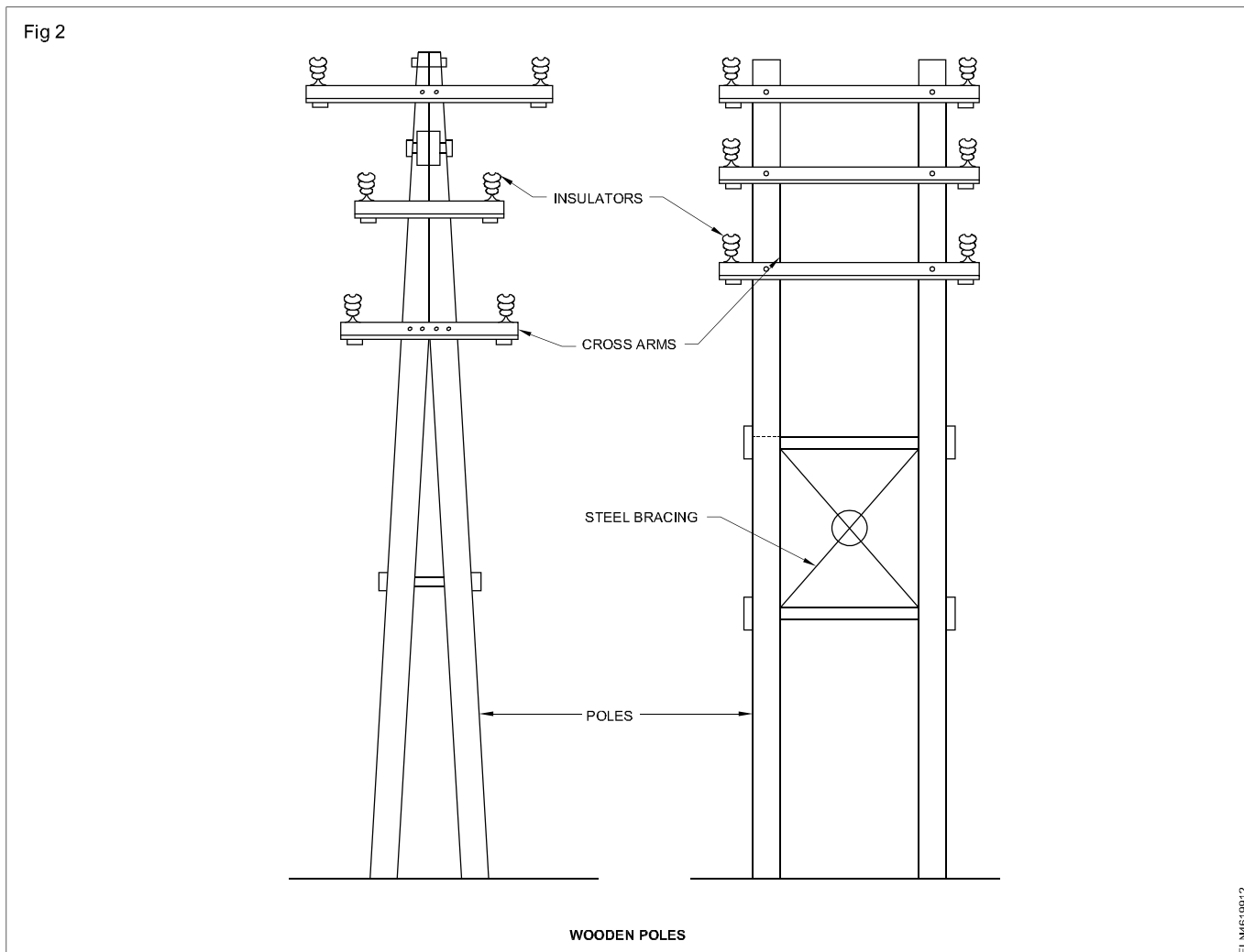
The main difficulty with the use of these poles is the high cost of transport owing to their heavy weight. Therefore, such poles are often manufactured at the site in order to avoid heavy cost of transportation.

Steel towers

In practice, wooden, steel and reinforced concrete poles are used for distribution purpose at low voltages, say upto 11 KV. However for long distance transmission at higher voltage, steel towers are invariably employed. Steel towers have greater mechanical strength, longer life, can withstand more severe climatic conditions and permit the

use of longer spans. The risk of interrupted service due to broken or punctured insulation is considerably reduced owing to longer spans. Tower footings are usually grounded by driving rods into the earth. This minimizes the lightning troubles as each tower acts as a lightning conductor.

Fig 4 (a) shows a single circuit tower. However, at a moderate additional cost, double circuit tower can be provided as shown in Fig 4(b). The double circuit has the advantage that it ensures continuity of supply. In case there is breakdown of one circuit, the continuity of supply can be maintained by the other circuit.



Types of power line

Electrical energy is generated, transmitted and distributed in the form of alternating current as an economical proposition. The electrical energy produced at the power station is transmitted at very high voltages by 3-phase, 3-wire system to step-down sub stations for distribution. The distribution system consists of two parts viz. primary distribution and secondary distribution. The primary distribution circuit is 3-phase, 3-wire and operates at voltages 3.3 or 6.6 or 11 KV which is somewhat higher than general utilisation levels. It delivers power to the secondary distribution circuit through distribution transformers situated near consumers' localities. Each distribution transformer steps down the voltage to 415 V and power is distributed to ultimate consumers by 415/240 V, 3-phase, 4-wire system.

The electric supply is transmitted at different voltages through over head lines and the types of power lines are furnished below:

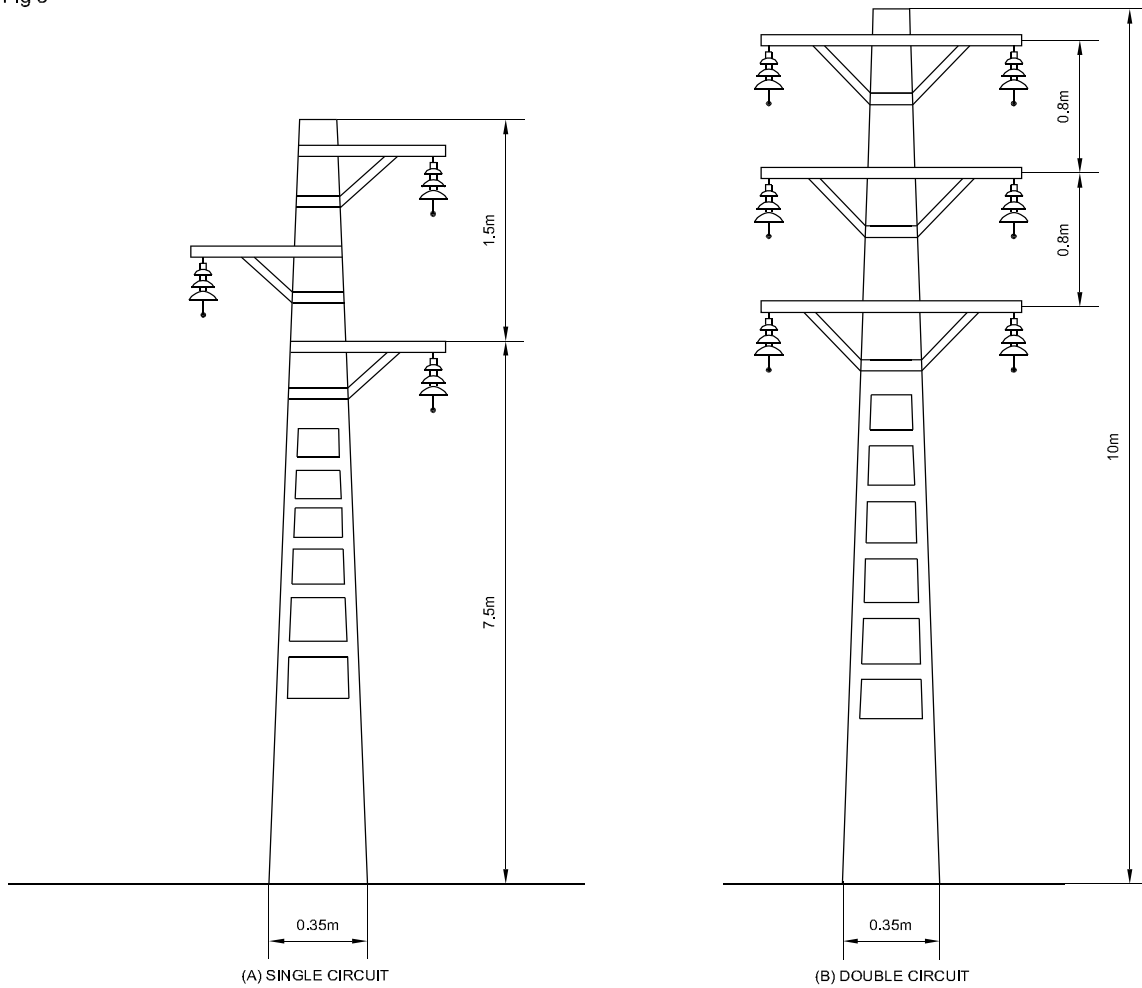
- Low voltage line (should not exceed 250V)
- Medium voltage line (should not exceed 650V)
- High voltage line (should not exceed 33000V (33 KV)
- Extra high voltage line (above 33KV)

Voltage standard

The voltage standard of above types have been defined in I E Rules 2

“Voltage” means the difference of electric potential measured in volts between any two conductors or between any part of either conductor and the earth as measured by a suitable voltmeter and is said to be;

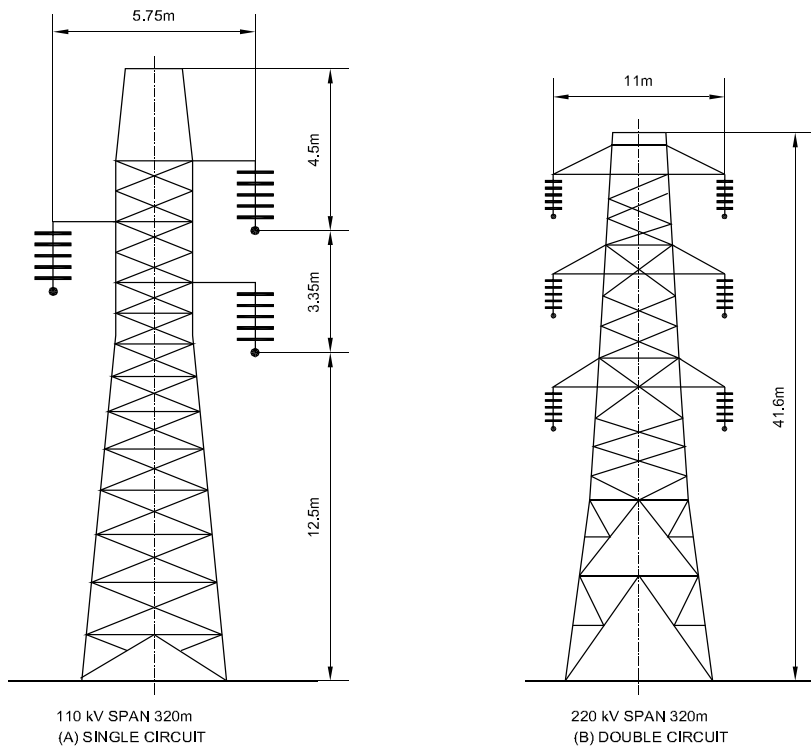
Fig 3



RCC POLES

ELN4619913

Fig 4



STEEL TOWERS

ELN4619914

Low where the voltage does not exceed 250 volts
 Medium where the voltage does not exceed 650 volts
 High where the voltage does not exceed 33,000 volts
 "Extra high" where the voltage exceeds 33,000 volts
 The nominal system voltage generally used is given below:

- a) 240 V
- b) 415 V
- c) 650 V
- d) 11 kV
- e) 33 kV
- f) 66 kV
- g) 110 kV
- h) 132 kV
- i) 220 kV
- j) 400 kV
- k) 800 kV

Corona

The phenomenon of violet glow, hissing noise and production of ozone gas around an overhead transmission line is known as **corona**.

When an alternating potential difference is applied across two conductors whose spacing is large as compared to their diameters, there is no apparent change in the condition of atmospheric air surrounding the wires if the applied voltage is low. However, when the applied voltage exceeds a certain value, called critical disruptive voltage, the conductors are surrounded by a faint violet glow called **corona**.

Factors affecting Corona

The phenomenon of corona is affected by the physical state of the atmosphere as well as by the conditions of the line. The following are the factors upon which corona depends:

- 1 Atmosphere
- 2 Conductor size
- 3 Spacing between conductors
- 4 Line voltage

Advantages and Disadvantages of Corona

Corona has many advantages and disadvantages.

Advantages

- (i) Due to corona formation, the air surrounding the conductor becomes conducting and hence virtual diameter of the conductor is increased. The increased diameter reduces the electrostatic stresses between the conductors.

- (ii) Corona reduces the effects of transients produced by surges.

Disadvantages

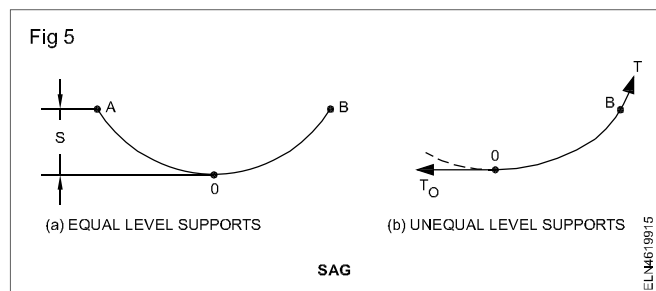
- (i) Corona is accompanied by a loss of energy. This affects the transmission efficiency of the line.
- (ii) Ozone is produced by corona and may cause corrosion of the conductor due to chemical action.
- (iii) The current drawn by the line due to corona is non-sinusoidal. This may cause inductive interference with neighbouring communication lines.

(e.g. bigger cross arms and supports) may increase to a considerable extent.

Sag in Overhead Lines

The difference in level between points of supports and the lowest point on the conductor is called 'Sag'.

Fig 5 (a) shows a conductor suspended between two equal level supports A and B. The conductor is not fully stretched but is allowed to have a dip. The lowest point of the conductor is O and the sag is S. Fig 5(b) shows unequal level supports.



Conductor sag and tension

This is an important consideration in the mechanical design of overhead lines. The conductor sag should be kept to a minimum in order to reduce the conductor material required and to avoid extra pole height for sufficient clearance above ground level.

Classification of Overhead Transmission Lines

The capacitance effect introduces complications in transmission line calculations. Depending upon the manner in which capacitance is taken into account, the overhead transmission lines are classified as:

- (i) **Short transmission lines:** When the length of an overhead transmission line is up to about 50 km and the line voltage is comparatively low (<20 KV), it is usually considered as a short transmission line. Due to smaller length and lower voltage, capacitance effects are small and hence can be neglected.
- (ii) **Medium transmission lines :** When the length of an over-head transmission line is about 50 – 150 km and the line voltage is moderately high (20 KV - 100 KV), it is considered as a medium transmission line. Due

to sufficient length and voltage of the line, the capacitance effects are taken into account.

(iii) Long transmission lines: When the length of an over-head transmission line is more than 150 km and line voltage is very high (>100 KV), it is considered as a long transmission line. For the treatment of such a line, the line constants are considered uniformly distributed over the whole length of the line.

The two important terms for performance of transmission lines are

(i) Voltage Regulation

The difference in voltage at the receiving end and sending end of a transmission line is called Voltage regulation and is expressed as a percentage of the receiving end voltage.

Mathematically, %age Voltage regulation =

$$\frac{V_s - V_R}{V_R} \times 100$$

V_s = Sending end voltage

V_R = Receiving end voltage

Obviously, it is desirable that the voltage regulation of a transmission line should be low i.e. the increase in load current should make very little difference in the receiving end voltage.

(ii) Transmission efficiency: The power obtained at the receiving end of a transmission line is generally less than the sending end power due to losses in the line resistance.

The ratio of receiving end power to the sending end power of a transmission line is known as the transmission efficiency of the line. i.e.

Percentage of Transmission efficiency =

$$\frac{\text{Receiving end power}}{\text{Sending end power}} \times 100$$

$$= \frac{V_R I_R \cos\phi_R}{V_S I_S \cos\phi_S} \times 100$$

Where, $V_R I_R$ and $\cos\phi_R$ are the receiving end voltage, current and power factor while $V_S I_S$ and $\cos\phi_S$ are the corresponding values at the sending end.

Constants of a Transmission Line

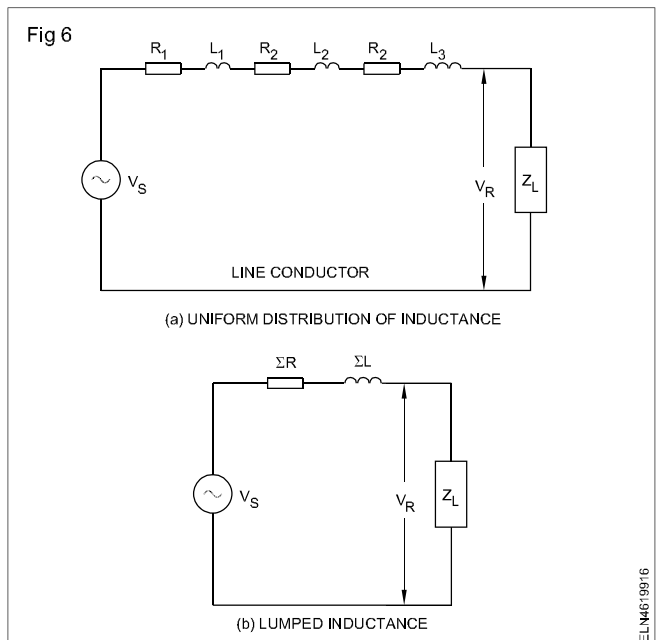
A transmission line has resistance, inductance and capacitance uniformly distributed along the whole length of the line.

- (i) Resistance: It is the opposition of line conductors to the current flow. The resistance is distributed uniformly along the whole length of the line as shown in Fig 6
- (ii) Inductance: When an alternating current flows through a conductor, a changing flux is set up which links the conductor. Due to these flux linkages, the conductor possesses inductance. Mathematically, inductance is defined as the flux linkage per ampere i.e.

$$\text{Inductance, } L = \frac{\phi}{I} \text{ henry}$$

Where ϕ = flux linkages in weber-turns
 I = current in amperes.

The inductance is also uniformly distributed along the length of the line as in Fig 6 (a). Again for the convenience of analysis, it can be taken to be lumped as in Fig 6 (b).



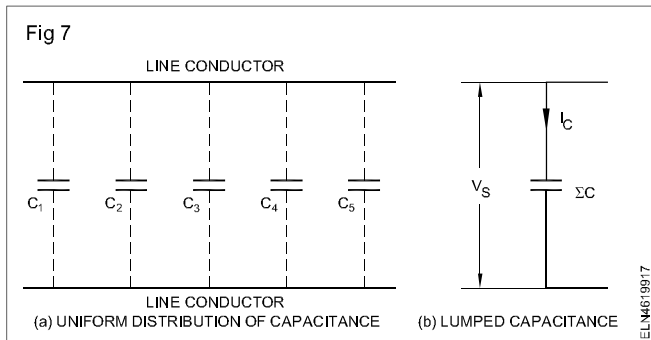
- (iii) Capacitance. If any two conductors of an overhead transmission line are separated by air which acts as an insulation. The capacitance exists between any two overhead line conductors. The capacitance between the conductors is the charge per unit potential difference i.e.

$$\text{Capacitance, } C = \frac{q}{v} \text{ farad}$$

Where q = charge on the line in coulomb
 v = p.d. between the conductors in volts.

The capacitance is uniformly distributed along the whole length of the line and may be regarded as a number of capacitors connected between the conductors as in Fig 7 (a). When an alternating voltage is impressed on a transmission line, the charge on the conductors at any point increases and decreases with the increase and

decrease of the instantaneous value of the voltage between conductors at the point.



The result is that a current (known as charging current) flows between the conductors [see Fig 7 (b)]. This charging current flows in the line even when it is open-circuited i.e. supplying no load. It affects the voltage drop along the line as well as the efficiency and power factor of the line.

Resistive Line

The resistance of transmission line conductors is the most important cause of power loss in a transmission line. The resistance R of a line conductor having resistivity ρ length l , and area of cross section a is given by

$$R = \rho \frac{l}{a}$$

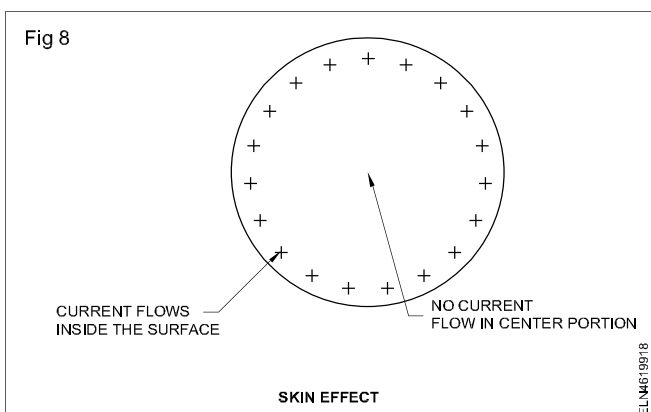
- (i) In a single phase or 2-wire d.c. line, the total resistance (known as loop resistance is equal to double the resistance) of either conductor.
- (ii) In case of a 3-phase transmission line, resistance per phase is the resistance of one conductor.

Skin Effect

The tendency of an alternating current to concentrate only near the surface of a conductor is known as **Skin effect**.

Due to skin effect, the effective area of cross-section of the conductor through which current flows is reduced. Consequently, the resistance of the conductor is slightly increased when carrying an alternating current.

The skin effect depends upon (Fig 8)



- (i) Nature of material
- (ii) Diameter of wire – skin effect increases with the diameter of wire
- (iii) Frequency – increases with the increase in frequency
- (iv) Shape of wire – less for stranded conductor than for solid conductor.

It may be noted that skin effect is negligible when the supply frequency is low (< 50 Hz) and conductor diameter is small (< 1 cm).

Erection of overhead line poles

Length of span

The length of span of line supports will depend upon various factors like the type of pole and conductors used, voltage of transmission, environment, ground clearances for safety etc.

However, following data given in Table 1 may be taken as a rough guide.

Table 1

Type of poles and permissible span

Sl.No	Type of pole	Span length in m.
1	Wooden poles	40 - 50
2	Steel tubular poles	50 - 80
3	RCC poles	60 - 100
4	Steel tower	100 - 300
5	G.I pipe (Medium)	30 - 50

When distribution lines and street lighting fixtures are erected on the same support, the span should not exceed 45 metres.

The recommended span for power lines over 11KV is given in Table 2.

Table 2

Relation between voltage, circuits and span

Nominal system voltage KV (rms)	No. of circuits	Span range in m
33 (over poles)	1	90 - 135
	2	180 - 305
66	1	240 - 305
	2	240 - 320
110	1	305 - 335
	2	305 - 365
132	1	305 - 365
	2	305 - 380
220	1	320 - 380
	2	320 - 380

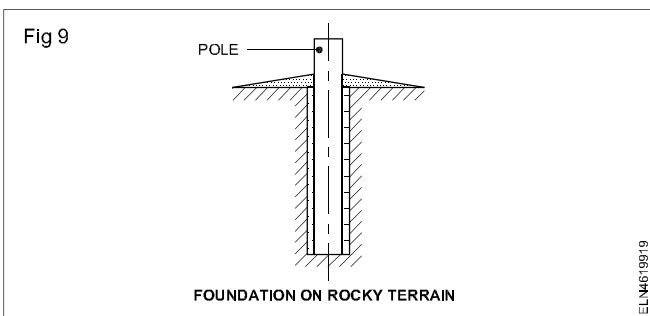
Choice of spans : The following factors influence the choice of spans

- i Ease of construction and the cost of the line
- ii Ease of maintenance and cost of line maintenance
- iii Terrain conditions

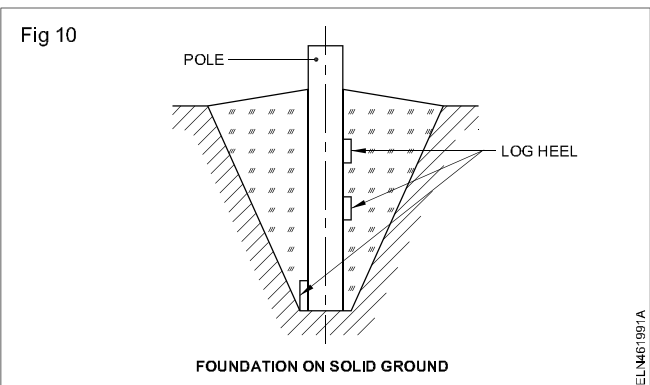
The depth of the pit depends upon the soil and height of the pole: The depth of pit below the ground level should be about 1/6 of the length of the pole. (ie) a 9 metres long pole should go down atleast 1.5 metres below the ground level leaving 7.5 metres above the surface.

The depth of foundation setting is dependent upon the density of the soil and depth of frost penetration. In addition to the above we should take into account disturbances to the structure of the earth as the soil filled up is always less strong than the natural earth.

Wooden and reinforced concrete : Supports for the 33 KV overhead lines with pin insulators are placed directly in the earth with no special foundations. Holes for these supports having a diameter 5 -10 cm greater than that of the pole to be erected as in Fig 9.

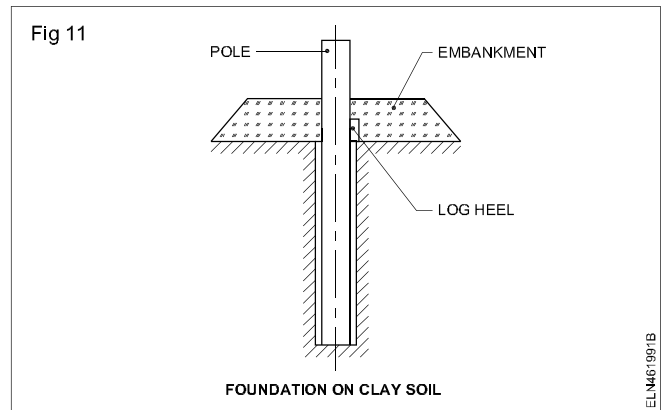


The poles are also reinforced by log heels placed at the pole inside the area of excavation bottom as in Fig 10.

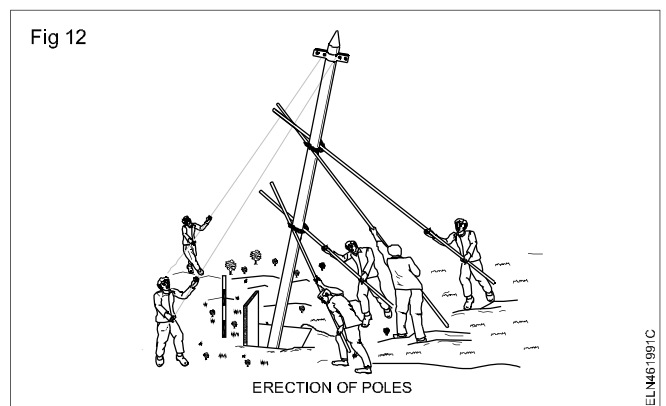


If water is found at a depth of 1.5 to 2 metres, the poles are generally placed above the underground water level and reinforced by embankment or special measures are taken as in Fig 11.

In such locations mass concrete foundations are to be adopted to avoid collapse of foundation in the black cotton soil.



Method of erection of poles : The poles to be erected may be brought to the pit location by manual labour or by improvised carts. Then the pole may be erected in the pit. Wooden support poles may be utilized to facilitate lifting of the pole at the pit locations as in Fig 12.



Before the pole is placed into the pit, RCC padding or alternatively a suitable base plate maybe 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 the weight of the pole on the soil.

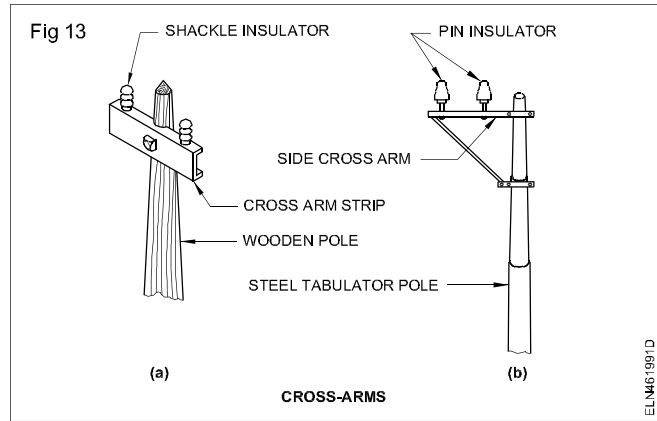
Having lifted the pole, the same should be kept in a vertical position with the help of Manila /sisal ropes of 20/25 mm dia. using the rope as a temporary anchor. As the poles are being erected, say, from an anchor point to the next angle point, the alignment of the poles are to be checked and set right by visual check. The verticality's of the poles are to be checked with a spirit level on both transverse and longitudinal directions.

Having satisfied that the vertical and longitudinal alignment are all right, earth filling is to be done. In some soils the poles are to be concreted up to ground level of the pit. After the poles have been set, the temporary anchors are to be removed.

Use of cross - arms : These are also known as insulator supports and are made of either wood or angle iron. Cross-arms are installed at the top of the pole for holding the insulators on which conductors are fastened. They are also known according to their relative position on the poles. If the cross - arm is fixed in the centre of the poles then it is called a cross - arm (Fig 13a) and if installed on one side of the pole, then it is termed as side cross -arm

(Fig 13b) U-shaped cross - arms are specially used for three phase lines.

Channel iron cross-arms fabricated from channels of size 75 mm x 40 mm x 5.7 kg/m or size 100mm x 50 mm x 7.9 kg/m are used for H.T. lines, and those made from angle irons of size 50 mm x 50 mm x 6 mm are used for L.T lines.



Joining of aluminium conductors

Objectives: At the end of this lesson you shall be able to

- state the type of joints
- explain the type and use of connectors used to joining conductors
- explain the steps to testing of O.H lines
- state the preliminary safety procedure for OH line erection.

Joining accessories in O.H lines: Normally connectors are used for joining the O.H. aluminium conductors. Connectors may be of several types of which few are described below.

- 1 Sleeved joints
- 2 Straight through connectors / taps
- 3 Vice - clamp connectors /taps with parallel grooves
- 4 Nut and bolt connector

Sleeved joints

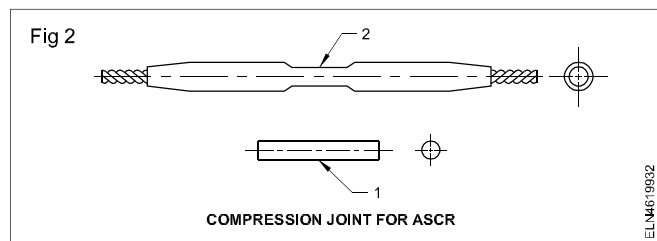
Twisted joints: Oval shaped aluminium sleeves are inserted over the conductors to be joined and then twisted as in Fig 1. Only one sleeve is sufficient for all aluminium conductors whereas two concentric sleeves are used for ACSR conductors. One each for the aluminium and steel portions. Twisting joints are recommended for conductors up to 15 mm diameter. Only special wrenches should be used for twisting the sleeves.



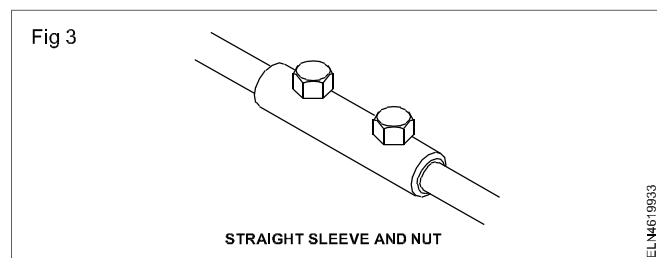
Compression joints : ACSR conductors are joined by compression joints having two sleeves as in Fig 2. The larger sleeve is of aluminium, fitting over the entire conductor, and the smaller one is of steel fitted on the steel portion of the wire eccentrically. Conductors to be joined are inserted into the sleeves one after the other and compressed either by hand or by hydraulic compressors. Compression joints for all aluminium conductors consist of aluminium sleeve only.

Straight through connectors / taps : Two types of connectors are used to join two straight through run of wires in such locations where mass concrete foundations

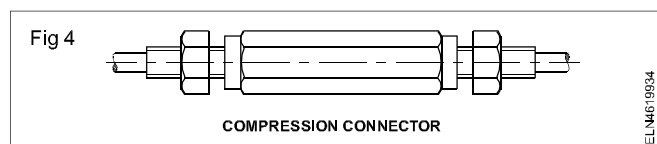
are to be adopted to avoid collapse of foundation in the black cotton soil.



Straight sleeve and nut connector: This is in Fig 3. It has a sleeve (round or oval in section) made of cadmium plated brass or aluminium. The conductors are inserted into the sleeve and tightened by the nuts.



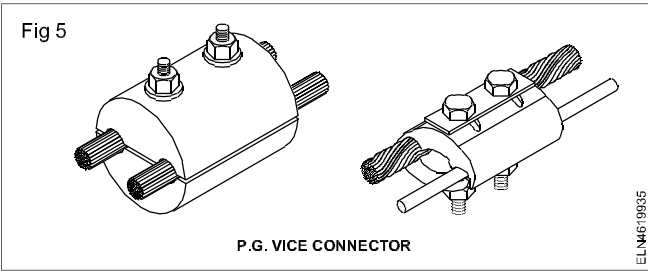
Compression connector: In this, the conductors are wrapped at both ends and then compressed with nuts as in Fig 4.



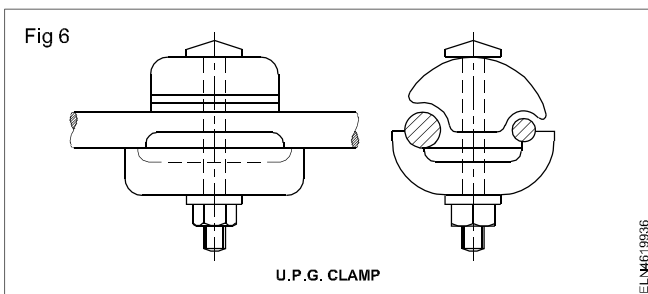
Vice-clamp connectors/taps with parallel grooves (PG): There are several types as explained below.

Standard P.G. clamps: This clamp as in Fig 5 consists of two aluminium halves, having two semi-circular parallel grooves in each half. After inserting the conductors to be joined, the galvanized steel nuts are

tightened. As the grooves are of the same size, it is useful only when the joining conductors are also of the same size.

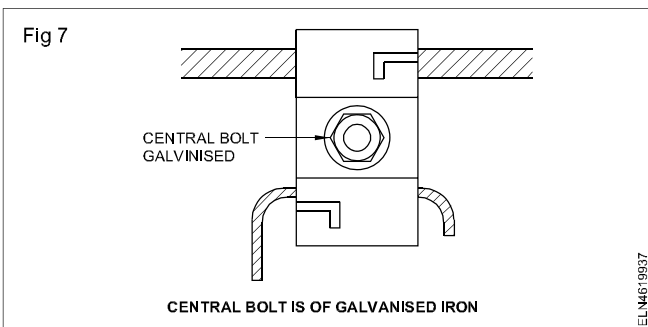


Universal P.G. clamp: This is in Fig 6. It has grooves of slightly different shape to accommodate different sizes of conductors, and has only one bolt. This clamp is not for heavy duty service but can be used for tapping connections from the distribution line to individual consumers through aluminium conductors.

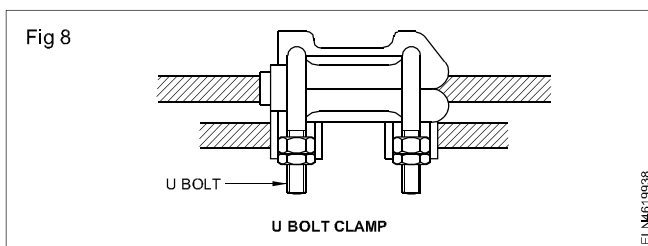


Bimetallic universal parallel groove clamps (B.M.P.G. clamps)

This clamp is in Fig 7. It has a brass body with cadmium plating. The two halves are tightened by a galvanised bolt. This is used for connecting copper wire to aluminium conductors in the case of consumer service connections.



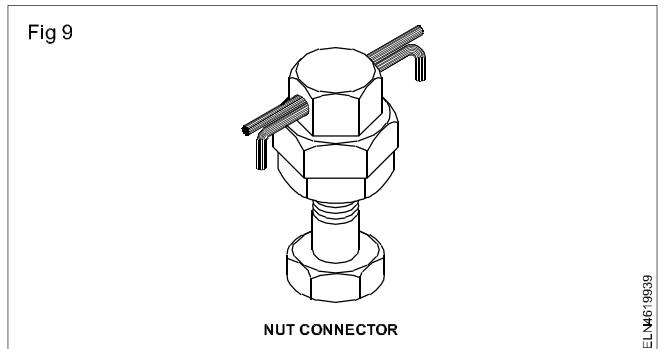
U bolt clamps: This is in Fig 8. It uses 'U' bolts as these bolts exert 4 times more pressure than the conventional straight bolts. Such clamps are suitable for heavy duty conductors.



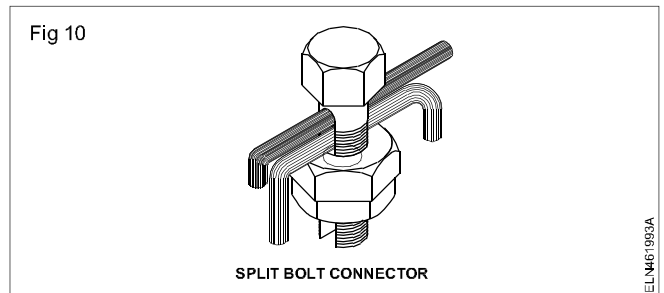
Nut and bolt connectors are of two types

Nut connector

This is in Fig 9. It has a transverse hole through which the conductors to be joined are inserted and then tightened by the bolt.



Split bolt connector: This is in Fig 10. It is split at the stem. The conductors to be joined are to be inserted into the split and then tightened by the external nut.



Precautions to be followed while using aluminium conductors: Technical problems involved in electric connections in connectors for aluminium wire, are quite different from those encountered, with copper conductors. There are several ways to approach these problems, but it is essential that connectors for aluminium must be specially designed for aluminium.

Several problems arise which must be taken into account when aluminium is to be connected to copper. All these technical problems are related to the oxide film on the surface of aluminium, the contact pressures exerted by the connector, and the possibility of galvanic corrosion between dissimilar metals.

Basically, the efficiency of any electrical contact depends on the cleanliness of the contacting surfaces, the area of the contacting surfaces, and the pressure applied. A joining compound applied just after abrading will protect the surface from further oxidation and prevent the formation of an oxide film thick enough to interfere seriously with most connections.

To ensure complete elimination of the oxide film under the most extreme service conditions, apply the joining compound prior to abrading so that the oxide film underneath the compound will be removed. The joining compound prevents or retards re-formation of the oxide film and so it should not be removed before the connection is made.

A satisfactory connector for aluminium will exert about the same overall pressure as on satisfactory for copper, but will provide considerably more contact area and thus hold unit stresses to values the aluminium is capable of withstanding.

If a connector is made of a metal different from that of the conductors, the difference in the rates of expansion and contraction of the two metals, with changes in temperature, will cause contact pressure to vary with the temperature.

Very often, aluminium conductors must be connected to copper conductors and the possibility of galvanic corrosion must be forestalled. When two different metals are in contact with each other in the presence of moisture, (thereinafter called the electrolyte) a small voltage is developed between them which causes a flow of electric current.

This electric current ultimately tends to corrode the conductor. The possibility of galvanic corrosion is completely eliminated if connectors used to connect the aluminium conductors to other aluminium or copper conductors are made of aluminium.

It is recommended that a good joining compound must always be used on electrical connections to aluminium regardless of the metals involved. The joining compound, when liberally applied, will fill all voids in the contacting surface and all voids in the vicinity of the contacting surfaces. By doing so, it excludes the entry of air and moisture and makes oxidation or corrosion impossible.

There are several good joining compounds in the market, all of which are grease-type materials. However, the period of time a joining compound will provide protection cannot be established except by experience, but when liberally applied, they will last for many years under any service condition.

Testing of overhead line: Before connecting the services to the transformer, equipments etc., a pressure voltage test of appropriate standard shall be carried out on the line, as desired by the Engineer in-Charge.

Before charging the M.V. lines, the same shall be tested with a 500V Megger for insulation.

Where pressure test is not done on H.V. lines, it shall be tested with a 2500V/5000V Megger for insulation, before charging.

The distribution lines shall be charged only if the pressure/ Megger test is satisfactory.

The lines shall be commissioned in the presence of the Engineer in-Charge.

Preliminary safety procedures: Before starting any major work on a pole, carry out the following drill.

- Before working on an overhead line which already exists, shut down permission should be taken from competent authorities.
- Before working on overhead lines which are already supplying power, the line should be made dead by opening the concerned switches and the line should be earthed through earth rods.
- Use a safety belt while working on poles.
- Inspect the structure, Eg. pole etc.
- Decide the best way to approach the job.
- Select the best ladder position.
- Erect the ladder. The ladder must be 'footed', that is, the ladder feet should be prevented from slipping and the ladder should be held by other workmates until the ladder head has been secured.

Domestic service line - IE rules

Objectives: At the end of this lesson you shall be able to

- explain the domestic service connection with bare and insulated conductors
- state the method of laying the service cable from the pole to the consumer premises
- state the safety precautions to be followed in domestic service connections
- list out the IE rules pertaining to domestic service connections
- explain the methods of taping service connections.

Service connections

The distribution networks ends at consumer premises either single phase or three phase connections. The category of connections either single phase or three phase depends as the maximum load demand by the consumer and the wiring of the house or the premises. The decision of power allocation by the electricity officials after surveying the wiring and load demand by the consumer.

Once the power requirement finalised and arrived the connection to the consumer the point from where the service line to be connected. It is also decided the drawing of line from the pole cross arm structure to the consumer mains panel either in over head or through UG cable. If the distance from over head pole terminal to consumer panel board is more than 50 Mtrs separate pole should be erected and OH line to be drawn from the distribution pole cross arm structure.

Service connection with bare conductor: Any of the following methods shall be adopted as specified.

The bare conductors shall be strung with shackle insulators fixed to the cross arms on both ends. The feeding end cross-arms shall be fixed to the support and the one at the receiving end shall be mounted on a G.I. pipe of a maximum diameter of 5 cm. The bare conductors shall be kept at a height of atleast 2.5 m from the top of the structure in accordance with Rule 79 of I.E. rules.

The G.I. pipe shall be provided with double bends at the top. The pipe shall be secured by atleast 2 clamps made of 50 mm X 6 mm. with M.S. flats fixed firmly to the wall in the vertical position. It shall in addition be provided with a G.I. stay wire of 7/3. 15 mm size anchored to the building with one eye bolt. Service connection shall be given with weather proof/PVC insulated cable through this G.I. pipe. Wooden/PVC pushings shall be provided at both ends of this G.I. pipe.

The bare conductors shall be strung with shackle insulators as above except at the receiving end where the insulators shall be fixed to a bracket made of an angle iron, of a size not less than 50 mm x 50 mm x 6 mm. The ends of the bracket shall be cut and split and embedded in the wall with cement mortar. The bare conductor shall be kept

atleast 1.2 m away from the edge of the structure, in accordance with Rule 79 of I.E. Rules.

The service connection shall be given with weather proof/PVC insulated cable through GI pipe of a minimum diameter of 4 cm. fixed to the wall. The GI pipe shall be bent downwards near the service entry. Wall fitting wooden/PVC bushes shall be provided at both ends of the G.I. pipe.

Service connection with insulated conductors: Service connection may be given by weather-proof/PVC insulated cable on a GI bearer wire. The cables shall be supported by the bearer wire by means of suitable link clips spaced 30 cm apart or by wooden/porcelain cleats 50 cm. apart. The GI bearer wire shall be of a minimum 10 SWG size.

One end of the GI bearer wire shall be attached to a clamp which is fastened to the nearest pole carrying distribution lines from where the service connection is intended to be given. The other end of the GI bearer wire shall be fastened to a 5 cm. dia. GI pipe for a span up to 4.5m which is fixed to the wall with guy etc.

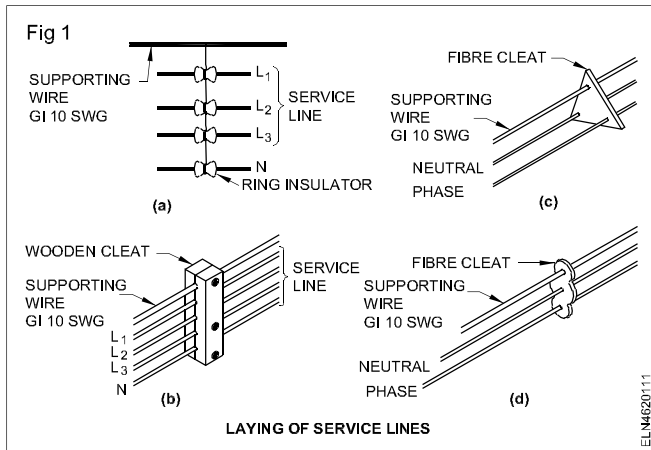
The GI pipe shall be fixed to an angle iron of size 40 mm x 40 mm x 6 mm with a suitable guy for high supports and for a span exceeding 4.5 m. Alternatively when the height of the structure permits minimum ground clearance, the other end of this GI bearer wire may be fixed to a hook, eye bolt or bracket embedded with cement mortar in the wall.

The weather proof/PVC insulated cable shall pass through a GI pipe of minimum diameter 5 cm, which is bent downwards. Wall fittings wooden/PVC bushes shall be provided at both ends of the GI pipe.

Method of laying the service cable from the pole to the consumer main: In practice either a glass or porcelain ring insulator or wooden fibre cleats are used to lay the overhead service line from the pole to the consumer mains as in Fig 1.

Safety Precautions to follow while connecting pole to consumer premises

- 1 The cable conductor size must be as per the IE rule standard either single phase or three phase.
- 2 If the service line crosses public road the clearance must be as per IE rule.



- The conductor slag should not exceed as per the IE rules.
- If UG cables are providing the depth of cable in ground should be as per IE rules.
- Do not keep much more cable unused and buried in soil in the coil form in case of UG cable laying.
- The excess cable should not be kept by making coil and kept on the pole cross arm. Use only required cable for connection.
- If the cable passing through excess heat producing areas in near to chimney, kitchen etc; adequate protection from heat to be provided.
- Service cable run along with stay wire tightly tied with stay wire to avoid tension on service cable.
- No rain water flows along with service cable and reach to consumer main panel. Necessary looping of cable to be provided either side.
- The connection to main line is to be made so tight and clean surface, so that loose contact, sparking and formation of oxide coating can be avoided.

I.E. Rules pertaining to domestic service connection

Rule 10. Construction, installation, protection, operation and maintenance of electric supply lines and apparatus

All electric supply lines and apparatus shall be sufficient in power and size and of sufficient mechanical strength for the work they may be required to do, and so far as practicable, shall be constructed, installed, protected, worked and maintained in accordance with standards of the Indian Standards Institution so as to prevent danger.

Rule 30. Service lines and apparatus on consumer's premises.

- The supplier shall ensure that all electric supply lines, wires, fittings and apparatus belonging to him or under his control which are on a consumer's premises are in a safe condition and in all respects fit for supplying energy, and the supplier shall take due precautions to avoid danger arising in the premises from such supply lines, wires, fittings and apparatus.

- The consumer shall also ensure that the installation under his control is maintained in a safe condition.

Rule 31. Cut-out on consumer's premises.

The supplier shall provide a suitable cut-out in each conductor of every line other than an earthed or earthed neutral conductor, or the earthed external conductor of concentric cables within a consumer's premises, in an accessible position. Such cut-out shall be contained within adequately enclosed fire-proof receptacle.

Where more than one consumer is supplied through a common service line, each such consumer shall be provided with an independent cut-out at the point of junction to the common service.

Rule 33. Earthed terminal on consumer's premises.

The supplier shall provide and maintain on the consumer's premises, for the consumer's use, a suitable earthed terminal in an accessible position at or near the point of commencement of supply as defined under Rule 58.

Provided that in the case of medium, high or extra high voltage installation the consumer shall, in addition to the afore-mentioned arrangement provide his own earthing system with an independent electrode.

Rule 48. Precautions against leakage before connecting.

- The supplier shall not connect with his works the installation or apparatus on the premises of any applicant for supply unless he is reasonably satisfied that the connection will not at the time cause a leakage from the installation or the apparatus exceeding five thousandth part of the maximum current supplied to the premises.
- If the supplier declines to make connection under the provisions of sub-rule(1) he shall serve upon the applicant a notice in writing stating his reason for so declining.

Rule 54. Declared voltage of supply to consumer.

Except with the written consent of the consumer or the previous sanction of the State Government, a supplier shall not permit the voltage at the point of commencement of supply as defined under Rule 58, to vary from the declared voltage by more than 5 percent in the case of low or medium voltage or by more than 12½ percent in the case of high or extra high voltage.

Rule 77. Clearances above ground of the lowest conductor.

- No conductor of an overhead line, including service lines erected across a street shall at any part thereof be at a height less than :-

- a) for low and medium voltage lines 5.791 m
 - b) for high voltage lines 6.096 m.
- 2 No conductor of an overhead line including service lines erected along any street shall at any part thereof be at a height less than:
- a) for low and medium voltage lines 5.486 m
 - b) for high voltage lines 5.791 m.
- 3 No conductor of an overhead line including service lines, erected elsewhere than along or across any street shall be at a height less than:
- a) for low, medium and high voltage lines upto and including 11,000 V if bare 4.572 m
 - b) for low, medium and high voltage lines upto and including 11,000 V if insulated 3.963 m.

Rule 79. Clearances from building of low and medium voltage lines and service lines.

- 1 Where a low or medium voltage overhead line passes above or adjacent to or terminates on any building, the following minimum clearances from any accessible point, on the basis of maximum sag, shall be observed.
- a) for any flat roof, open balcony, verandah, roof and lean-to-roof.

- i) when the line passes above the building, a vertical clearance of 2.439 m from the highest point.
 - ii) when the line passes adjacent to the building, a horizontal clearance of 1.219 m from the nearest point.
- b) For pitched roof
- i) when the line passes above the building, a vertical clearance of 1.219 m immediately under these lines.
 - ii) when the line passes adjacent to the building, a horizontal clearance of 1.219 m.
- 2 Any conductor so situated as to have a clearance less than that specified in sub-rule (i) shall be adequately insulated and shall be attached by means of metal clips at suitable intervals to a bare earthed bearer wire having a breaking strength of not less than 517.51 kg.
- 3 The horizontal clearance shall be measured when the line is at maximum deflection from the vertical due to wind pressure.

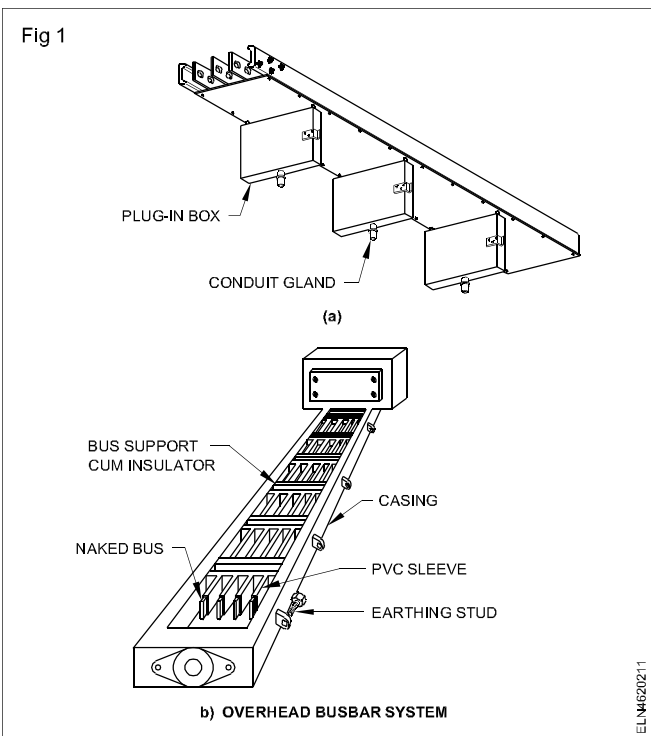
Tapping service connections: No service connection line should be tapped from an OH line from any point mid span, except at the point of support. When a service connection is taken overhead with a bare conductor, it should be provided with guard wires.

Bus-bar system - power tariff terms and definitions

Objectives: At the end of this lesson you shall be able to

- explain the bus-bar system and the method of installation
- state the advantages of the bus-bar system
- determine the rating of the bus-bar
- state the use of plug-in boxes and their construction
- state the method of cable or conduit termination in plug-in boxes.

In industrial workshops and factories, a number of machines are installed in the shop floor closely but apart from each other. connecting these machines to electrical supply through underground cables or overhead wires or cables may involve cumbersome methods resulting in shock hazards. For such places, an overhead enclosed bus-bar system as in Fig 1a and 1b is recommended.



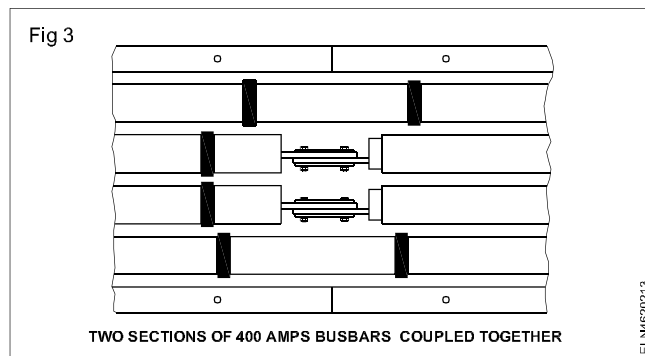
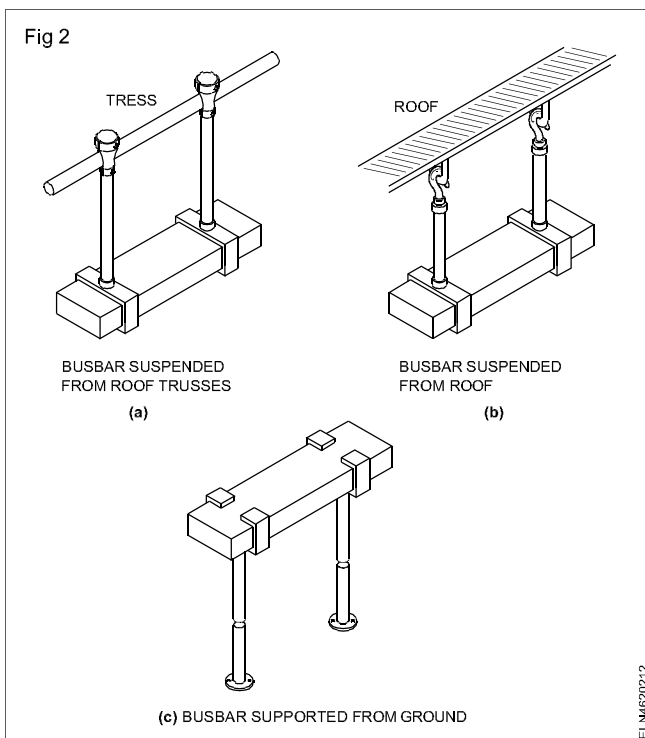
This bus-bar system is sometimes referred to as bus way or bus duct.

Bus-bar assembly should be installed at a height of 2.75metre from ground, suspended by M.S. angles or flats from ceiling/roof or supported by framed structure from ground as in Fig 2.

Bus coupler

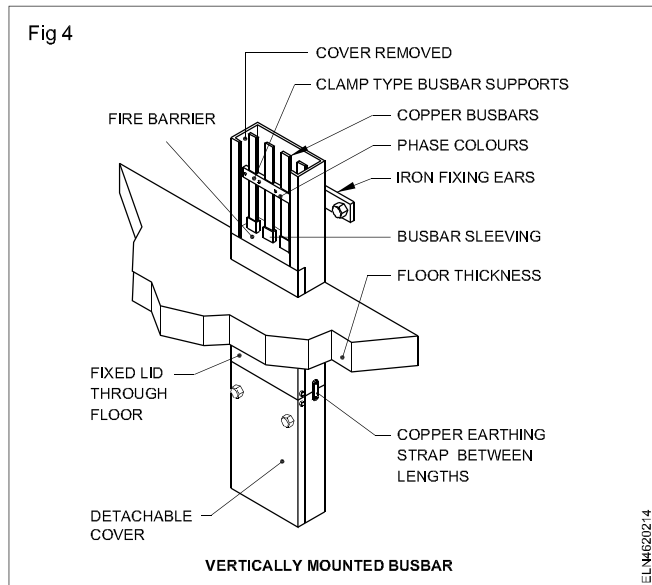
The bus-bars are either of high conductivity, high purity copper or alloy aluminium having rectangular sections mounted on insulating supports enclosed in standard length of metal trunking. The bus-bar sections are available in standard lengths (3.65metre for 200 ampere and 2.44metre for 400 ampere) which can be connected to another bus-bar by blowing the respective bus-bar ends

thus forming a continuous bus-bar along the entire length of the workshop. Method of coupling two bus-bars is in Fig 3.



The standard rating of bus-bar are 100, 200, 400, 600, 800, 1200, 1600, 2000, 2400 and 3600 ampere with rated voltage of 500V. These bus-bars also available for indoor or outdoor use as point to point feeders or as plug-in take off points for power. These bus-bars are used in generating stations, sub stations, in metal industry and textile industry. These bus-bars are also used in multi storied flats to facilitate connection to various stories from the mains by

using vertically mounted bus-bars as in Fig 4. These vertical bus-bars are provided with a fire barrier made up of high grade fire-resisting material positioned at the top of each fixed section of the trucking passing through the floors. This barrier is the collecting points for dirt, dust and moisture which could be removed at intervals.



Recommended current density for a copper bus-bar which is not enclosed should not exceed 165A/sqcm and for aluminium 118A/sqcm.

Recommended section of aluminium and copper bus-bars and their respective ratings are in Table.

Earthing continuity is provided by two strips of aluminium or copper running throughout the bus-bar assembly. When extending the bus-bar lengths, these earthing strips also to be connected to have earth continuity.

Note:

- 1 Above rating is for rectangular cross-section of E-91 E-WP grade as per IS : 5082-1969 in still unconfined air without enclosure, presuming longer section vertical.**
- 2 Denting factor of 0.88 may be applied for ambient of 30°C and temperature rise of 35°C. Similarly in outdoor application denting may be done for 0.85 to 0.9. Indoor well ventilated areas 0.6 to 0.8 and partly ventilated areas 0.5 to 0.6.**

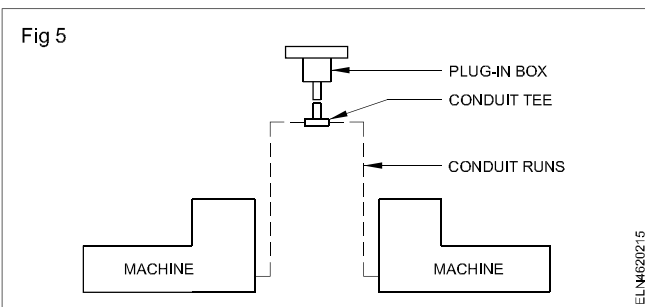
Bus-bar size in mm	Rating at 50Hz AC current at average ambient of 35°C and 40°C maximum and temperature rise of 50°C.				
	Aluminium				Copper
	Single bar	Two bars	Three bars	Four bars	Single bar
12.5 x 3	—	—	—	—	160
25 x 3	—	—	—	—	290
50 x 3	335	650	850	950	525
75 x 3	475	875	1150	1300	750
100 x 3	600	1075	1400	1600	970
12.5 x 4.5	125	260	315	370	205
25 x 4.5	225	525	635	750	365
32 x 4.5	320	660	800	940	510
50 x 4.5	500	970	1270	1425	650
25 x 6	350	700	950	1000	430
50 x 6	675	1300	1700	1925	760
75 x 6	950	1750	2300	2600	1080
100 x 6	1225	2150	2800	3200	1380
125 x 6	1500	2500	3200	3700	1680
25 x 10	—	—	—	—	540
50 x 10	85	1500	1950	2250	960
75 x 10	1180	2050	2650	3000	1350

Bus-bar size in mm	Rating at 50Hz AC current at average ambient of 35°C and 40°C maximum and temperature rise of 50°C.				
	Aluminium				Copper
	Single bar	Two bars	Three bars	Four bars	Single bar
100 x 10	1500	2475	3150	3550	1710
125 x 10	1850	2925	3600	4200	2070
150 x 10	2100	3325	4000	4606	2430
250 x 10	2750	4100	4900	5700	—
25 x 12.5	—	—	—	—	650
50 x 12.5	—	—	—	—	1120
75 x 12.5	1350	2250	800	3200	1570
100 x 12.5	1750	2700	3350	3900	2050
125 x 12.5	2100	3100	390	4500	2420
150 x 12.5	2400	3500	4450	5100	2820
200 x 12.5	3050	4500	5300	6100	—

Advantages of Bus-bar system

Following are the advantages of bus-bar system

- 1 Reduced cost:** Simple rapid installation with complete elimination of expensive floor chasing (cutting) reduces cost at the initial period of installation and needs no expenditure for maintaining the bus-bar system while in regular use.
- 2 Maximum flexibility:** As plug-in-points are provided at intervals of 60.96cm (2 feet) along every length of bus-bar the connections can be taken for machines installed on either side. Refer Fig 5.



- 3 Complete safety:** As the plug-in-point are completely insulated, safety is ensured for operating and maintenance personnel.
- 4 'Live' connection:** As the plug-in-boxes could be connected to 'live' bus-bars quickly and safely without shut down and the time is saved without disturbing the normal work of the factory.
- 5 Guaranteed protection:** As the fuse in the plug-in boxes of HRC type the circuit is protected positively and reliably against short circuit.

- 6 Easily extended for layout modification in the factory:** As the bus-bars can be extended in straight lengths or at an angle to suit the layout with the help of standard accessories, the bus-bars can be remounted or rearranged within a short time.
- 7 Saving of time while initial erection:** The advantages of this system are that the trucking and bus-bars can be erected before the installation of the machinery, and the latter can be connected up and set to work as soon as they are installed.
- 8 Reduction of voltage drop in feeders:** By bringing the heavy main feeders near to the actual loads, the circuit wiring is reduced to a minimum and voltage drop is lower than would otherwise be the case.
- 9 Addition and alterations:** Subsequent additions and alterations to plant layout can be easily accomplished, and where bus-bar sections have to be removed they can be used again in other positions.
- 10 Internal grid for welders:** The overhead bus-bar system is especially advantageous where a large number of electric welders have to be fed with heavy currents from a step down transformer.
- 11 Branching from plug-in-boxes for small loads:** If a large number of small machines are to be fed it is usual to fix a distribution box near the trucking system and to protect this with a tap-off fitted with HRC fuses of suitable capacity.
- 12 Durable and trouble free service:** Normally bus-bars give much durable service than U.G. Cables and give many years of trouble free service.

Method of determining the ratings of the bus-bars

In a small factory, ten motors having each of 5 HP ratings to be installed. The total load is approximately 10×5 i.e. 50 HP. Assuming 5 HP motor takes approximately full load current at 7.5A. The total current in the factory load will be 75A and has to be supplied through a single bus-bar. Normally the ratings of bus-bar is 200A or 400A. Hence a 200A rating bus-bar is selected for this case as the same bus-bar also could be used when there is expansion of load in the factory in future. Considering the overload, bus-bars are manufactured in standard sections of 3.65m (200A) and 2.44m (400A). We can decide the number of bus-bars to meet the entire length of machine layout.

Technical Data

Rating	Overall dimensions in mm	No.of plug
200A	3658 x 248 x 76	6
400A	2440 x 248 x 108	4

Bus-bar length can be increased by providing mechanical coupling and any length at run in multiples of the standard length may be thus achieved.

Plug-in-Boxes

Plug-in-boxes (Fig 6) are compact sheet steel boxes with hinged doors housing the HRC fuse holders, which are solidly connected to high conductivity copper clip on contacts reinforced by spring steel strips. These clip on contacts plug directly to the bus-bars at the plug-in-points.

Power tariff - terms and definitions

Objectives: At the end of this lesson you shall be able to

- state the term maximum demand
- explain the concept of average demand
- explain load factor
- state the term of diversity factor and its application
- explain the importance of plant utility factor.

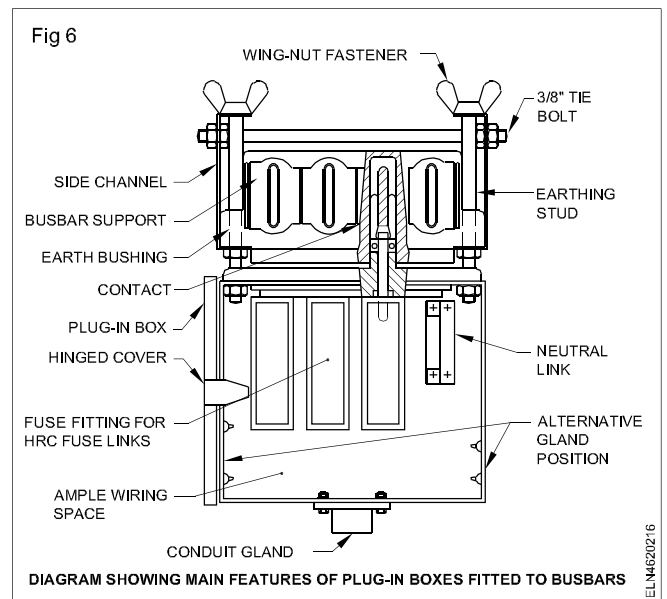
Introduction

The alternators in the power station should run at their rated capacity for maximum efficiency and on the other hand, the demands of the consumers have wide variations from time to time due to uncertain demands of the consumers. This makes the design of a power station highly complex. We shall focus our attention on the problems of variable load on power stations.

Maximum Demand

It is the highest level or greatest electrical demand monitored in a particular period or a month.

Two earth pins are located at the two ends of these boxes which also serves to mount the plug-in-boxes on bus-bars.



Rating of plug in boxes

Plug in Boxes must be able to withstand faults current capability of bus-bars. There are rated in 16, 32, 63 and 100Amp at 415/500V (TPN).

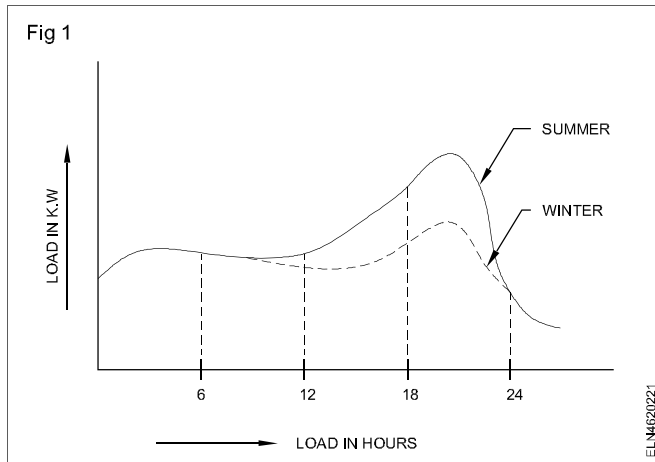
Cables (or) conductors with termination connection to plug-in-boxes for outgoing supply by using conduit pipe to conduit glands supplied with plug in boxes either vertically down or on to either side.

However remember to use oxide inhibiting grease at all aluminium joint to maintain conductivity.

The maximum demand is in between 18 hours and 24 hours in the night during summer as well as in winter seasons as in Fig 1. All other times the maximum demand falls very low to the connected load. However the maximum load demand less than the connected load because all the consumers do not switch 'ON' their connected load of the system at a time.

The importance of the maximum demand knowledge is very important as it helps in determining the installed capacity of the stations, and the station must be capable of meeting the maximum demand.

The ratio of maximum demand as the power station to its connected load is known as demand factor; Mathematically



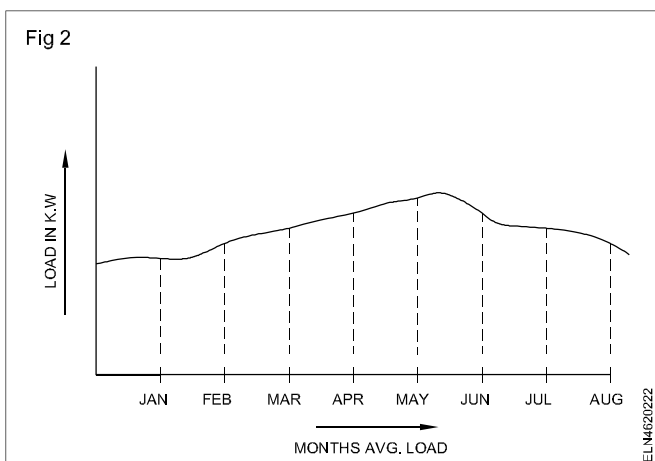
$$\text{Demand factor} = \frac{\text{Max. Demand}}{\text{Connected load}}$$

Usually it always less than one. The knowledge of demand factor is vital in determining the capacity of the plant equipment.

Average demand

It is the total demand in a month divided by number of days in that time period.

The average demand in a month taken to find the load requirement for a certain period is in Fig 2. It is evident that average load requirement is not uniform among all the months consumption as it depend on the environmental conditions; such as Winter, Summer, Monsoon seasons.



Load factor

In electrical engineering the load factor is defined as the total load divided by the peak load in specified time period. It is a measure of the utilization rate, or efficiency of electrical energy usage; a low load factor indicates that load is not putting a strain on the electric system, whereas consumers or generators that put more of a strain on the electric distribution will have a high load factor.

$$f_{\text{Load}} = \frac{\text{Total load}}{\text{Maximum load in given time period}} \text{ or } \frac{\text{Total load}}{\text{Peak load.}}$$

An example, using a large commercial electrical bill:

- peak demand = 436 KW
- use = 57 200 kWh
- number of days in billing cycle = 30

Hence:

- load factor = { 57 200 kWh/ (30 d x 24 hours per day x 436 kW) } x 100% = 18.22%

It can be derived from the load profile of the specific device or system. Its value is always less than one because maximum demand is always higher than average demand, since facilities likely never operate at full capacity for the duration of an entire 24 hours day. A high load factor means power usage is relatively constant. Low load factor shows that occasionally a high demand is set. To service that peak, capacity while remaining idle for long periods, thereby imposing higher costs on the system. Electrical rates are designed so that customers with high load factor are charged less over all per kWh.

The load factor is closely related to and often confused with demand factor.

$$f_{\text{Demand}} = \frac{\text{Maximum load in given time period}}{\text{Maximum possible load}}$$

The major difference to note is that the denominator in the demand factor is fixed depending on the system. Because of this the demand factor cannot be derived from the load profile but needs the addition of the full load of the system in question.

Diversity factor

Diversity factor (Or simultaneity factor K_s) is a measure of the probability that a particular piece of equipment will turn on coincidentally to another piece of equipment. For aggregate system it is defined as the ratio of the sum of the individual non - coincident maximum loads of various sub divisions of the system to the maximum demand of the complete system.

$$\text{Diversity factor} = \frac{\text{Sum of individual max Demands}}{\text{Maximum Demand}}$$

The diversity factor is almost always larger than 1 since all components would have be on simultaneously at full load for it to be one. The aggregate load is time dependent as well being dependent upon equipment characteristics. The diversity factor recognizes that the whole loads does not equal the sum of its parts due to this time interdependence (i.e. diverseness). For example, we might have ten air conditioning units that are 20 tons each at a

facility. We typically assume that the average full load equivalent operating hours for the units are 2000 hours per year. However, since the units are each thermostatically controlled, we do not know exactly when each unit turns on. If the ten units are substantially bigger than the facility's actual peak A/C load, then fewer than all ten units will likely come on at once. Thus, even though each unit runs a total of 2000 hours a year, they do not all come on at the same time to affect the facility's peak load. The diversity factor gives us a correction factor to use, which results in a lower total kW load for the ten A/C units. If energy balance we do for this facility comes out within reasons, but the demand balance shows far too many kW for the peak load, then we can use the diversity factor to bring the kW into line with the facility's true peak load. The diversity factor does not affect the kWh; it only affects the kW.

Plant utility factor

The utility factor or use factor is the ratio of the time that a piece of equipment is in use to total time that it could be in use. It is often averaged over time in the definition such that the ratio becomes the amount of energy used divided by the maximum possible to be used. These definitions are equivalent.

The utility factor, K_u , is the ratio of the maximum load which could be drawn to rated capacity of the system. This is closely related to the concept of load factor. The factor is the ratio of the load that piece of equipment actually draws (time averaged) when it is in operation to the load it could draw (which we call full load).

$$\text{Utility Factor} = \frac{\text{Ratio of maximum power}}{\text{Plant capacity}} \times 100$$

For example, an oversized motor - 15 kW - drives a constant 12 kW load whenever it is on. The motor load factor is then $12/15 = 80\%$. The motor above may only be used for eight hours a day, 50 weeks a year. The hours of operation would then be 2800 hours, and the motor use factor for a base of 8760 hours per year would be $2800/8760 = 31.96\%$. With a base of 2800 hours per year, the motor use factor would be 100%.

In power plant utility factor varies according to the demand on the plant from the electricity market.