Electrical supply system - transmission and distribution network - line insulators

Objectives: At the end of this lesson you shall be able to
- **explain the electrical supply system and layout of AC power supply scheme**
- **list out the various power transmission**
- **compare AC and DC transmission.**

Electrical supply system

The electrical energy generated from the power plants has to be supplied to the consumers. This is large network, which can be broadly divided into two stages, (ie.) Transmission and distribution.

The conveyance of electric power from a power station to the consumers / premises is called is Electrical supply system.

The Electrical power supply system consists of 3 main components viz (i) The power station / plant (ii) The transmission lines and (iii) The distribution systems. The power is produced at power plant which is away from the consumers, It has to be transmitted over long distances to load centres by transmission and to consumers through distribution network.

This supply system can be classified into

- DC or AC system
- Over head lines (or) underground system

Now a days, 3 phase, 3 -wire AC system is universally adopted as an economical proposition. In some places 3 phase - 4 wire AC system is adopted.

The underground system is more expensive than the over-head system, therefore in our country O.H system is almost adopted.

Types of power transmission system

Universally, 3 - phase - 3 wire AC system is adopted in most of the places. However other systems can also be used for transmission under special circumstances.

1 **AC single phase system**

 i Single-phase two wire

 ii Single - phase two wire with mid point earthed

 iii Single phase three wire

2 **AC three phase system**

 i Three - phase - three wire

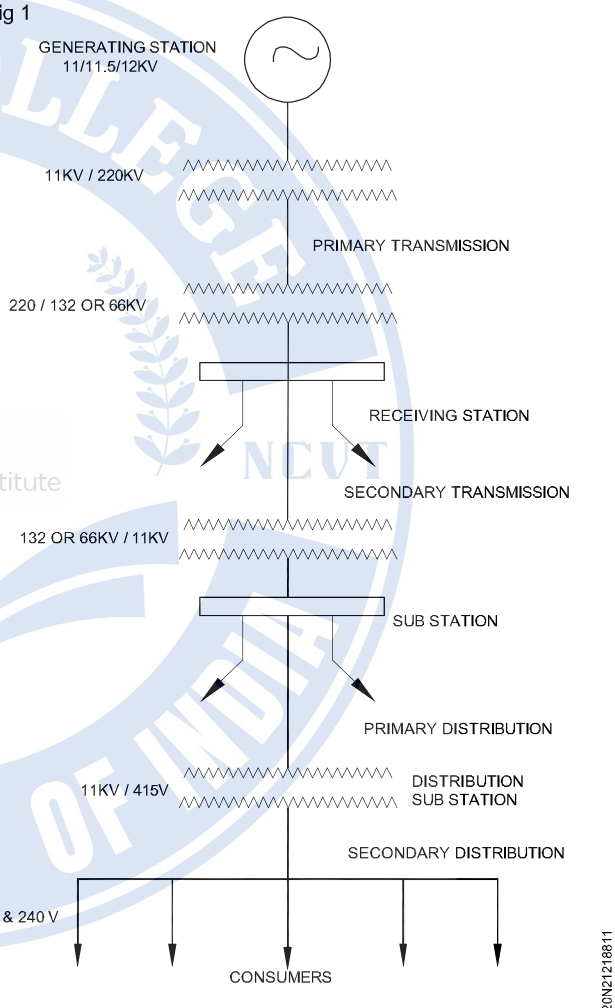
 ii Three - phase - four wire

The line network between generating station (Power station) and consumer of electric power can be divided into two parts.

- Transmission system
- Distribution system

This system can be categorized as primary transmission and secondary transmission. Similarly primary distribution and secondary distribution. This is in Fig 1.

Fig 1



TYPICAL AC POWER SUPPLY SCHEME

It is not necessary that the entire steps which are shown in the diagram must be included in the other power schemes. There may be difference, there is no secondary transmission in many, schemes, in some (small) schemes there is no transmission, but only distribution.

Various stages of a typical electrical power supply system, are as follows

1 Generating station

2 Primary transmission

3 Secondary transmission

4 Primary distribution

5 Secondary distribution

Generating station

The place where electric power produced by the parallel connected three phase alternators / generators is called generating station (i.e power plant).

he ordinary power plant capacity and generating voltage may be 11KV, 11.5 KV, 12KV or 13KV. But economically. It is good to step up the produced voltage from (11KV, 11.5KV or 12KV) to 132KV, 220KV, 400KV or 500KV or greater (in some countries, up to 1500KV) by step up transformer (power transformer).

Primary transmission

The electric supply (132KV, 220 KV, 500KV or greater) is transmitted to load center by three phase three wire (3 phase - 3 wires) overhead transmission system.

Secondary transmission

Area far from city (outskirt) which have connected with receiving station by line is called secondary transmission. At receiving station, the level of voltage reduced by step-down transformers up to 132KV, 66 or 33KV and electric power is transmitted by three phase three wire (3 phase - 3 wires) overhead system to different sub stations. So this is a secondary transmission.

Primary distribution

At a sub station, the level of secondary transmission voltage (132KV, 66 or 33KV) is reduced to 11KV by step down transformers.

Generally, electric supply is given to heavy consumer whose demands is 11KV, from these lines which carries 11KV (in three phase three wire overhead system) and they make a separate sub station to control and utilize this power.

In other cases, for heavier consumer (at large scale) their demand is about 132 KV or 33KV they take electric supply from secondary transmission or primary distribution (in 132KV, 66KV or 33KV) and then step down to the level of voltage by step -down transformers in their own sub station for utilization (i.e for electric traction etc).

Secondary distribution

Electric power is given to (from primary distribution line (i.e.) 11KV) distribution sub station. This sub station is located near by consumers area where the level of voltage reduced by step down transformers is 415V. These transformers are called distribution transformers, in 3 phase four wire system (3 phase - 4 wires), there is 415 volts (Three phase supply system) between any two phases and 240 volts (single phase supply) between neutral and any one of the phase (lives) wire.

Residential load (i.e. Fans, light, and TV etc) may be connected between any one phase and neutral wires, while three phase load may be connected directly to the three phase lines.

Elements of distribution system

Secondary distribution may be divided into three parts.

1 Feeders

2 Distributors

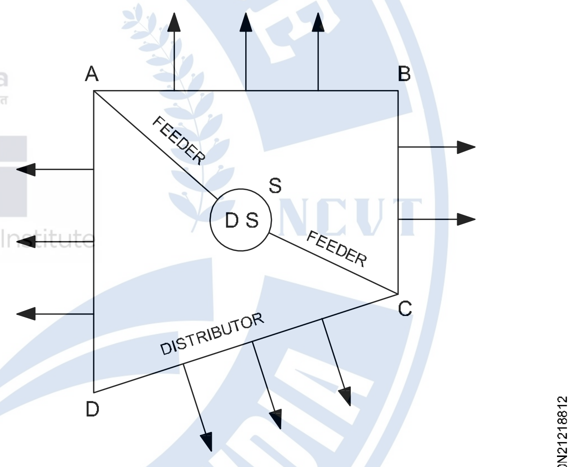
3 Service lines or service mains

Those electric lines which connect generating station (power station) or sub station to distributors are called **feeders.** Remember that current in feeders (in each point) is constant while the level of voltage may be different, the current flowing in the feeders depends on the size of conductor.

Distributors

Those tapings which extracted for supply of electric power to the consumers or those lines, from where consumers get electric supply is called **distributors** (Fig 2). Current is different in each section of the distributors while voltage may be same. The selection of distributors depends on voltage drop and may be designed according to voltage drop. It is because consumers get the rated voltage according to the rules.

Fig 2



DISTRIBUTION SYSTEM

Service lines or service mains

The normal cable which is connected between distributors and consumer load terminal are called **service line or service mains.** A complete typical AC power supply system scheme is in Fig 3.

Comparison of DC and AC transmission

The electric power can be transmitted either by means of DC (or) AC. Each system has it's own merits and demerits. Some technical advantages and disadvantages of two systems are stated below.

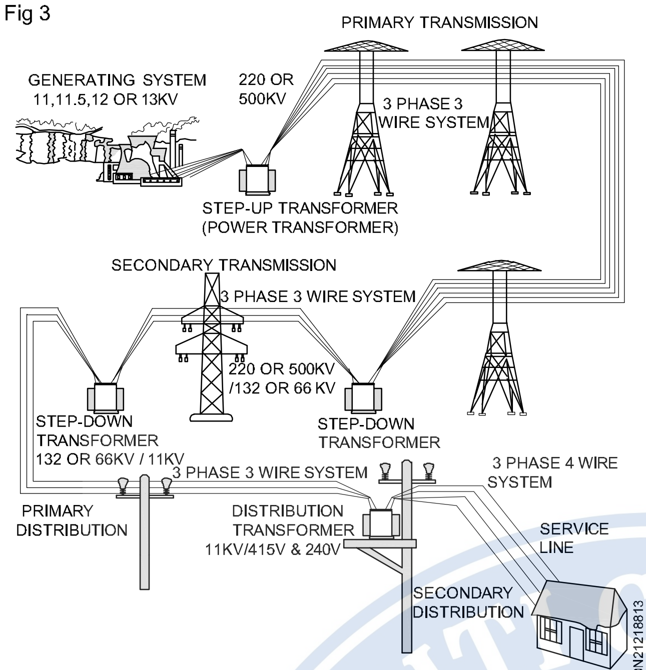
AC transmission

Some years ago, the transmission of electric power by DC has been receiving of the active consideration of engineers due to it's appreciable advantages.

Advantages of DC electric power transmission

1 It requires only two conductors

Fig 3



A.C.POWER SUPPLY SYSTEM

2 There is no problem of inductance, capacitance and phase displacement which is common in AC transmission.

3 For the same load and sending end voltage, the voltage drop in DC transmission lines is less than that in AC transmission.

4 As there is no skin effect on conductors, therefore entire cross - section of conductor is usefully utilized thereby affecting saving in material.

5 For the same value of voltage insulating material on DC lines experience less stress as compared to those on AC transmission lines.

6 A DC line has less corona loss and reduced interference with communication circuits.

7 There is no problem of system instability which is so common in AC transmission.

Disadvantages of DC transmission

1 Generation of power at high DC voltages is difficult due to commutation problems and cannot be usefully utilized at consumer ends.

2 Step up or step -down transformation of DC voltages is not possible in equipment like transformer.

Advantages of AC electric power transmission

1 Power can be generated at high voltages as there is no commutation problems.

2 AC voltages can be conveniently stepped up or stepped down by using transformers.

3 High voltage transmission of AC power reduces losses.

Disadvantages of AC electric power transmission

1 Problems of inductances and capacitances exist in transmission lines.

2 Due to skin effect, more copper is required.

3 Construction of AC transmission lines is more complicated as well as costly.

4 Effective resistance of AC transmission lines is increased due to skin effect.

From the above comparison, it is clear that high voltage DC transmission is superior to high voltage AC transmission. At present, transmission of electric power is carried by AC and effort is making towards DC transmission also. The convertor and inverter have made it possible to convert AC into DC and vice versa easily. Such devices can operate upto 30MW at 400KV in single units. The present day trend is towards AC for generation and distribution at high voltage DC for transmission.

The AC power at high voltage is fed to the convertor which convert AC to DC. The transmission of electric power is carried at high DC voltage. At the receiving emf DC is converted into AC with the help of invertors. The AC supply is stepped down to low voltage by receiving end transformer (T_R) for distribution.

Line insulators

Objectives: At the end of this lesson you shall be able to
- **explain the types of insulators and their uses.**

Line insulators

The aim of using a line insulator in an overhead line is to hold the live conductor to prevent leakage of current from the conductor to the pole. These are made of porcelain clay and are thoroughly glazed to avoid the absorption of moisture from the atmosphere.

Properties of insulators

i High mechanical strength in order to withstand conductor load, wind load etc.

ii High electrical resistance of insulator material in order to avoid leakage currents to earth.

iii High relative permittivity of insulator material in order that dielectric strength is high.

iv The insulator material should be non - porous, free from impurities and cracks otherwise the permittivity will be lowered.

v High ratio of puncture strength to flash over.

The most commonly used material for insulators of overhead line is porcelain but glass, steatite and special composition materials are also used to a limited extent.

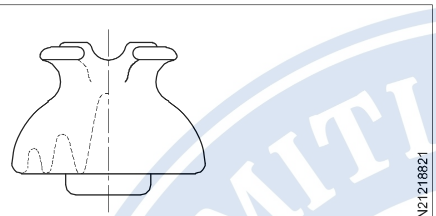
The following are the common types of insulators in use.

- Pin type insulator

- Shackle insulator
- Suspension insulator
- Strain insulator
- Post insulator
- Stay insulator
- Disc insulator

Pin Insulators : Pin insulators are used for holding the line conductors on straight running of poles. Pin insulators are three types. i.e single shed (Fig 1) double shed (Fig 2) and triple shed (Fig 3) The single -shed pin insulators are used for low and medium voltage lines. The double and triple shed pin insulators are used for over 3000V. These sheds are used to drip off the rain water.

Fig 1

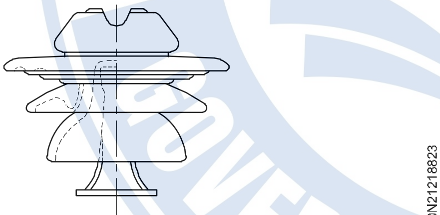


SINGLE SHED TYPE OF PIN INSULATOR

Fig 2

DOUBLE SHED TYPE OF PIN INSULATOR

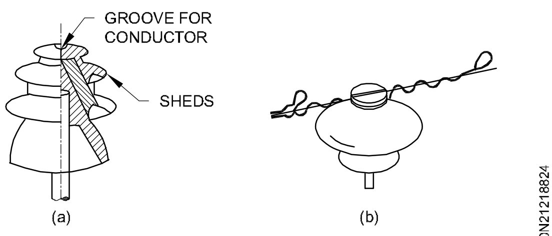
Fig 3



TRIPLE SHED TYPE OF PIN INSULATOR

The part section of a pin type insulator is in Fig 4a & 4b As the name suggest, the pin type insulator is secured to the cross - arm on the pole. There is a groove on the top of the insulator for housing the conductor. The conductor passes through this groove and is bound by the annealed wire of the same material as the conductor.

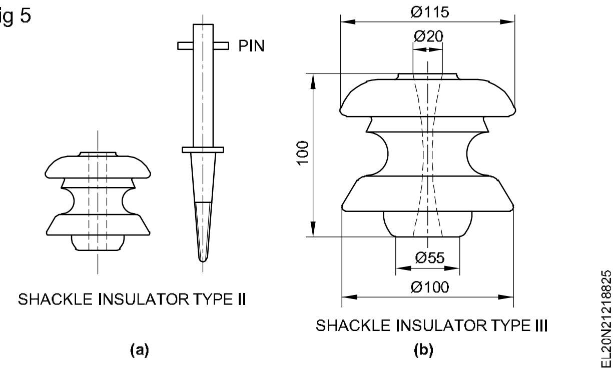
Fig 4



SECTION VIEW OF A PIN INSULATOR

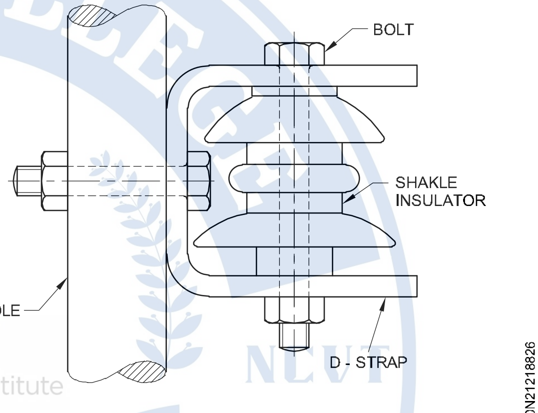
Shackle insulators : Shackle insulators are generally used for terminating on corner poles. These insulators are used for medium voltage line only. (Fig 5a & 5b)

Fig 5



But now a days, they are frequency used for low voltage distribution lines. Such insulators can be used either in horizontal position or in a vertical position. They can be directly fix to the pole with a bolt or to the cross arm. Fig 6 shows a shackle insulator fixed to the pole. The conductor in the groove is fixed with a soft binding wire.

Fig 6



SHACKLE TYPE INSULATOR

Suspension type insulators

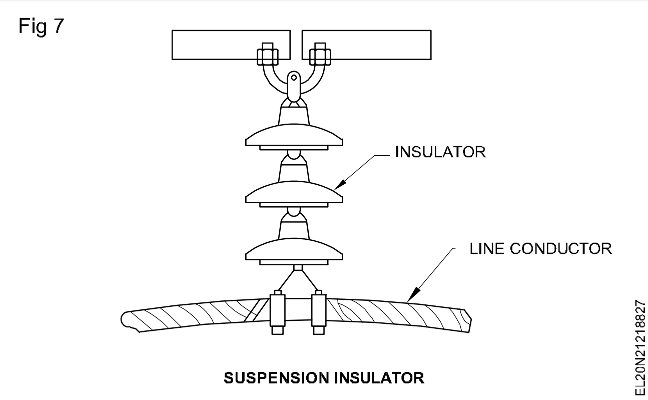
The cost of pin type insulator increases rapidly as the working voltage is increased. Therefore, this type of insulator is not economical beyond 33 KV. For high voltage (>33KV), it is a usual practice to use suspension type insulators as in Fig 7. They consist of a number of porcelain discs connected in series by metal links in the form of a string. The conductor is suspended at the bottom end of this string while the other end of the string is secured to the cross- arm of the tower. Each unit or disc is designed for low voltage, say 11KV. The number of discs in series would obviously depend upon the working voltage. For instance, if the working voltage is 66KV, then six discs in series will be provided on the string.

Advantages

1 Suspension type insulators are cheaper than pin type insulators for voltage beyond 33 KV.

2 Each unit or disc of suspension type insulator is designed for low voltage, usually 11KV. Depending upon the working voltage, the desired number of discs can be connected in series.

3 If any one disc is damaged, the whole string does not become useless because the damaged disc can be replaced by the sound one.



4 The suspension arrangement provides greater flexibility to the line. The connection at the cross arm is such that insulator string is free to swing in any direction and can take up the position where mechanical stresses are minimum.

5 In case of increased demand on the transmission line it is found more satisfactory to supply the greater demand by raising the line voltage than to provide another set of conductors. The additional insulation required for the raised voltage can be easily obtained in the suspension arrangement by adding the desired number of discs.

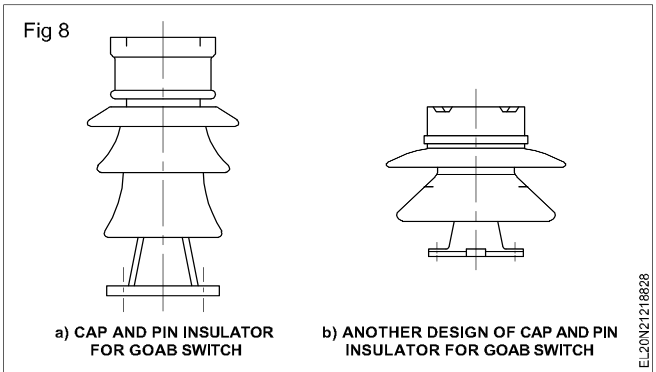
6 The suspension type insulators are generally used with steel towers. As the conductors run below the earthed cross arm of the tower, therefore, this arrangement provides partial protection from lighting.

Strain insulators

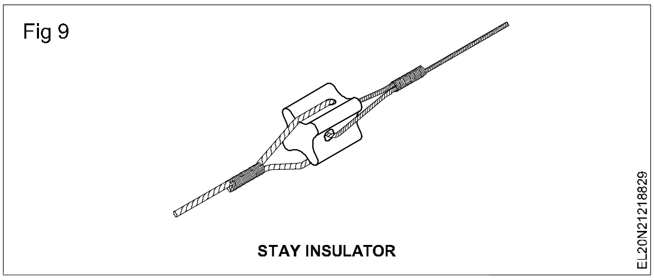
When there is a dead end of the line or there is corner or sharp curve, the line is subjected to greater tension. In order to relieve the line of excessive tension, the strain insulators are used. For low voltage lines (<11KV) shackle insulators are used as strain insulators. However for high voltage transmission lines, strain insulator consists of an assembly of suspension insulators. The discs of strain insulators are used in the vertical plane. When the tension in the lines is excessively high, as at long river spans, two or more strings are used in parallel.

Post insulators

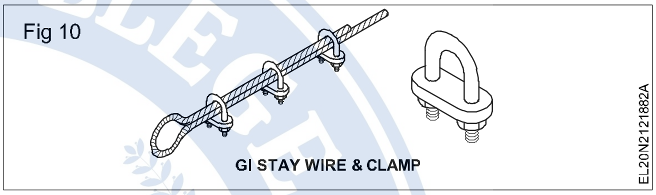
Cap and pin type (Fig 8a & 8b) : Such insulators can be used for mounting of buses, dropout fuses, line conductors, G.O.A.B (Gang Operated Air Break) switches. These are of outdoor type and are available in 11, 22 and 33KV ranges.



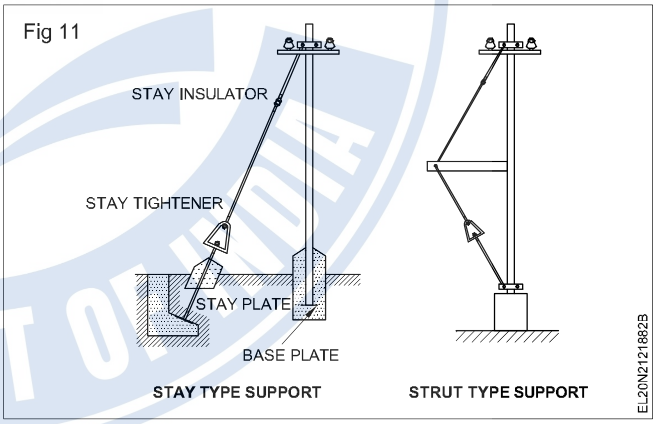
Stay insulators (Fig 9) : Stay insulators are also known as strain insulators and are generally used up to 33 KV line. These insulators should not be fixed below three metres from the ground level. These insulators are also used where the lines are strained.



The supporting wire which is used in the opposite direction of tension on the pole due to overhead conductors is known as 'stay wire'. It prevents the bending of the pole due to tension of the conductor. These stay wires consist of 4 to 7 strands of GI wire is in Fig 10. The correct size to be used depends upon the tension on the pole.



Stays and struts: Stays and struts are the different types of supporting wires for the pole. Stays are generally used for angle and terminating poles to prevent the bending of the pole whereas struts are used where space for stay is very limited. Fig 11 shows both the stay and the strut.



One end of the stay is fixed at the top of the pole and its other end is grouted in the concrete foundation.

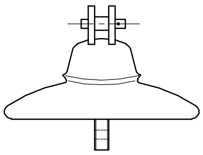
Disc insulators : Disc insulators are made of glazed porcelain or tough glass and are used as insulators at dead ends, or on straight lines as suspension type for voltages 3.3 kV and above. (Figs 12, 13 and 14)

These are available in four designs:

Tongue and clevis type (Fig 12): A round pin with a cotter pin is used to hold the tongue of one unit in the clevis of the other.

Ball and socket type (Fig 13): In this case insulators are assembled by sliding the ball of one insulator from the side. A cotter pin is slipped in from the back of the socket so that the ball cannot slide out. These are used at dead ends.

Fig 12



DISC INSULATOR TONGUE AND CLEVIS TYPE

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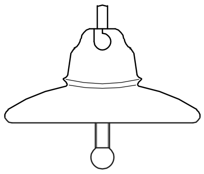
Fig 13



DISC INSULATOR BALL AND SOCKET TYPE

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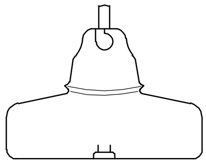
Insulators for cold climate (Fig 14): For cold climate the depth of the lower cap is increased to get creepage distance which becomes necessary in cold climates. Two designs known as fog type and anti-fog types are available.

Fig 14



DISC INSULATOR COLD AND CLIMATE TYPE

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Overhead poles and method of joining aluminium conductors

Objectives: At the end of this lesson you shall be able to
- **state transmission and distribution by O.H lines**
- **list out the main components and explain each of them**
- **state the types of power lines with respect to the classification of voltage**
- **state sag 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).

Main components used in O.H lines

An overhead line may be used to transmit or distribute electric power.

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.

Commonly used conductor materials

The most commonly used conductor material for overhead lines are copper, aluminium, steel reinforced aluminium, galvanized steel and cadmium copper.

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...

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

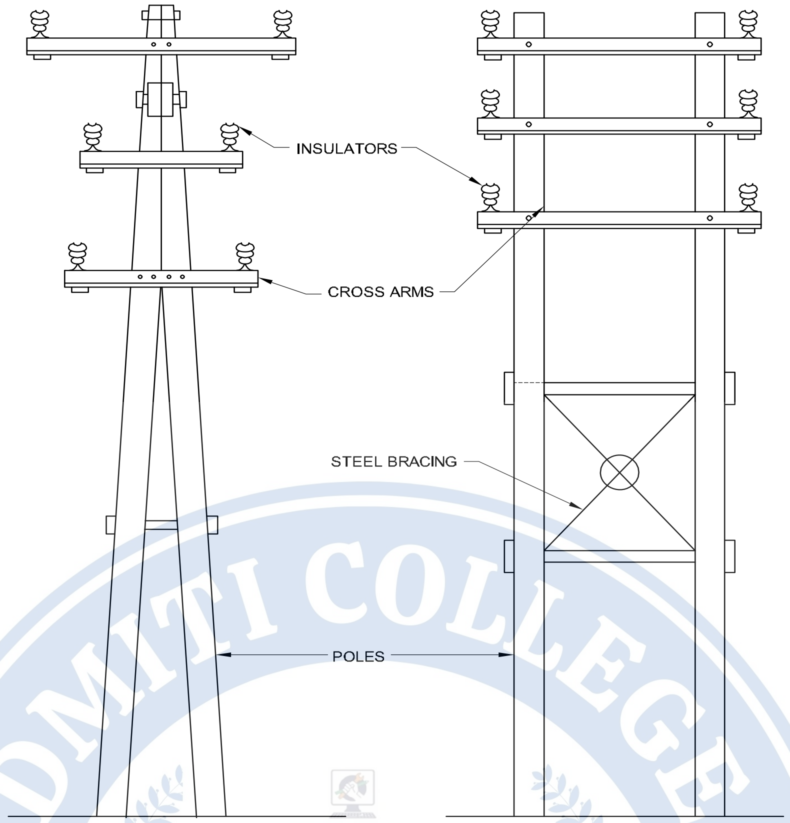
The line supports used for transmission and distribution of electric power are of various types including wooden, poles, steel poles, R.C.C poles and lattice steel towers.

Wooden poles (Fig 1) : 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.

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.

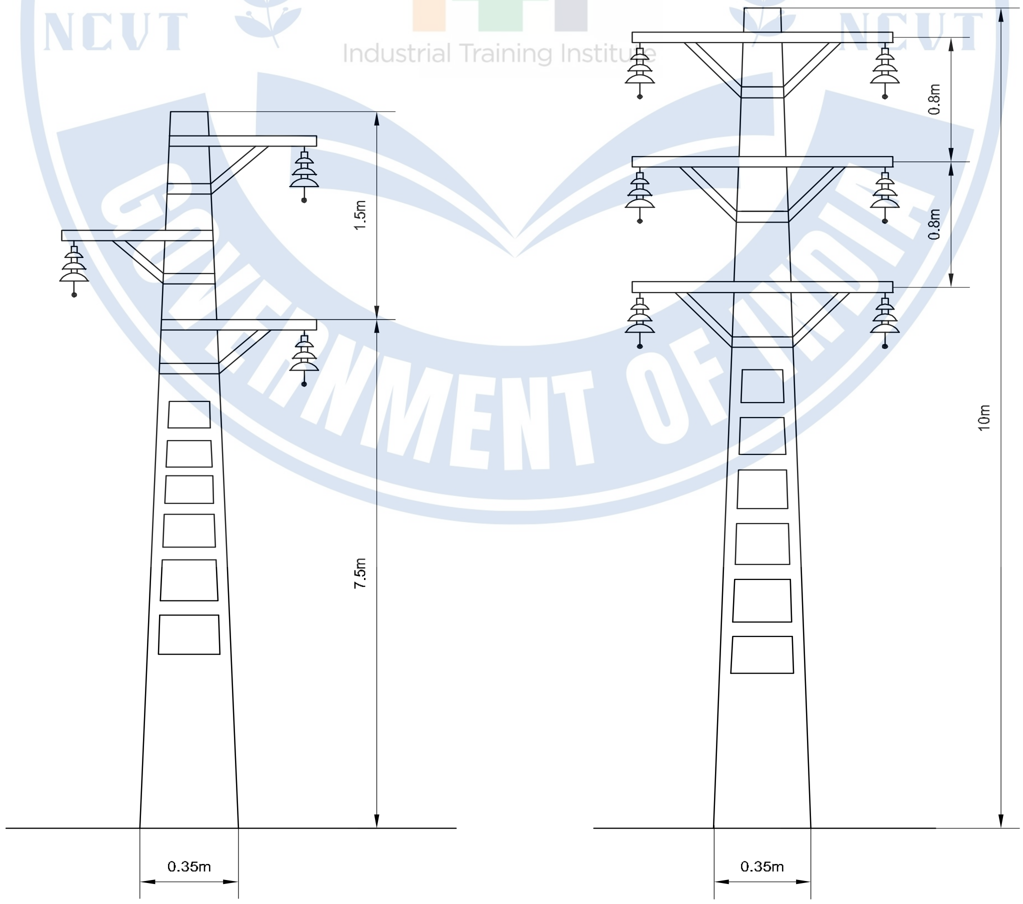
RCC Poles : The reinforced cement concrete (RCC) poles have become very popular as line supports in recent years. They have greater mechanical strength, longer life and permit longer spans than steel poles. Moreover, they give good outlook, require little maintenance and have good insulating properties. Fig 2 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.

Fig 1



WOODEN POLES

Fig 2



(A) SINGLE CIRCUIT

(B) DOUBLE CIRCUIT

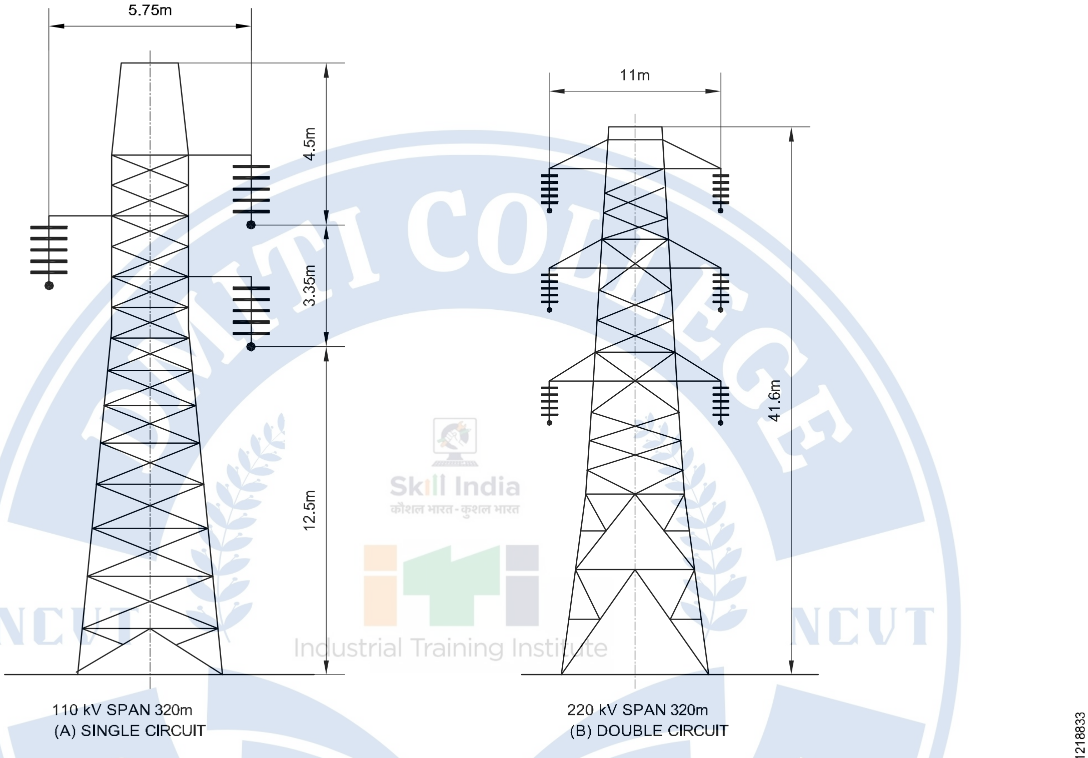
RCC POLES

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 3(a) shows a single circuit tower. However, at a moderate additional cost, double circuit tower can be provided as shown in Fig 3(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.

Fig 3



STEEL TOWERS

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

a Low voltage line (should not exceed 250V)

b Medium voltage line (should not exceed 650V)

c High voltage line (should not exceed 33000V (33 KV)

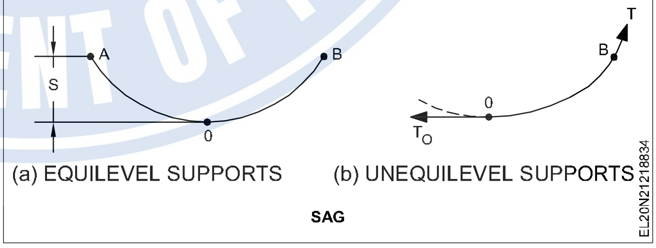
d Extra high voltage line (above 33KV)

Sag in Overhead Lines : The difference in level between points of supports and the lowers point on the conductor is called **'Sag'.**

Fig 4 (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 4(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.

Fig 4

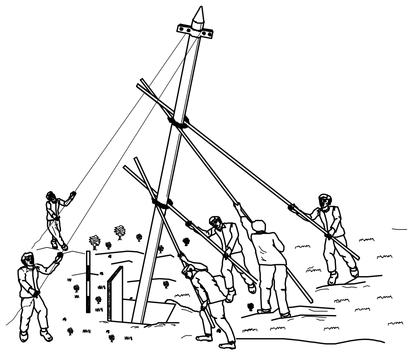


SAG

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 5.

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.

Fig 5



ERECTION OF POLES

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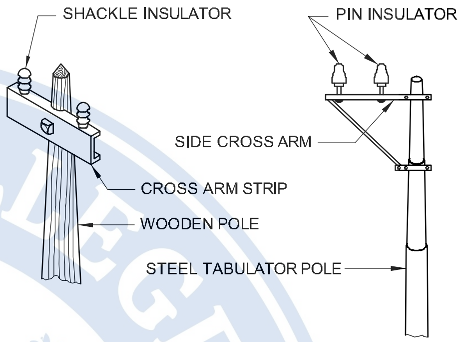
Having lifted the pole, the same should be kept in a vertical position with the help of Manila /sisal ropes of 20/25 mm dia. using the rope as a temporary anchor. As the poles are being erected, say, from an anchor point to the next angle point, the alignment of the poles are to be checked and set right 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 6a) and if installed on one side of the pole, then it is termed as side cross -arm (Fig 6b) 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.

Fig 6



CROSS-ARMS

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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 maybe 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

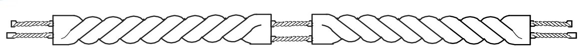
4 Nut and bolt connector

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 .

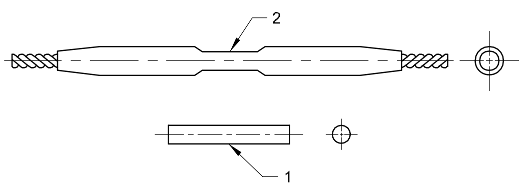
Fig 1



TWISTED JOINT

EL20N21218841

Fig 2



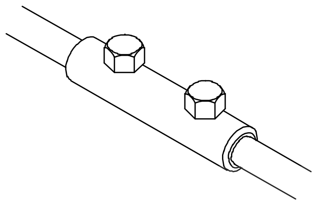
COMPRESSION JOINT FOR ASCR

EL20N21218842

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.

Fig 3

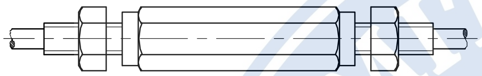


STRAIGHT SLEEVE AND NUT

EL20N21218843

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

Fig 4



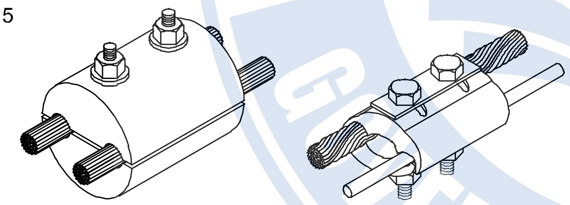
COMPRESSION CONNECTOR

EL20N21218844

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.

Fig 5

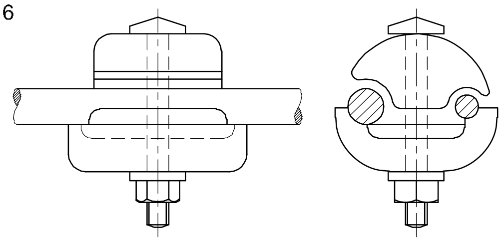


P.G. VICE CONNECTOR

EL20N21218845

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.

Fig 6

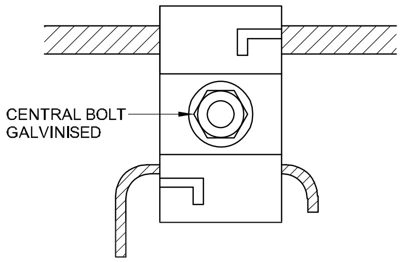


U.P.G. CLAMP

EL20N21218846

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.

Fig 7

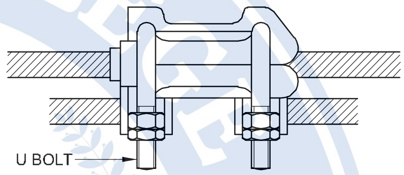


CENTRAL BOLT IS OF GALVANISED IRON

EL20N21218847

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.

Fig 8



U BOLT CLAMP

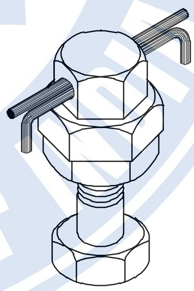
EL20N21218848

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.

Fig 9

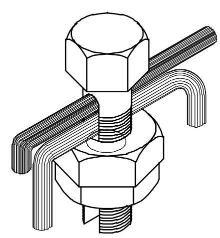


NUT CONNECTOR

EL20N21218849

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.

Fig 10



SPLIT BOLT CONNECTOR

EL20N2121912A

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 alteast 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.

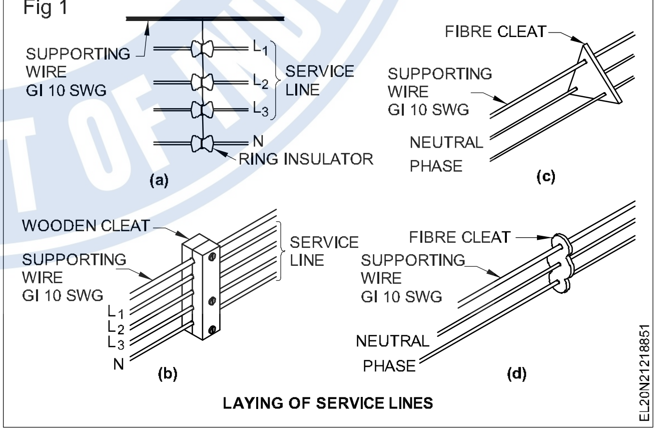
One end of the GI bearer wire shall be attached to a clamp which is fastened to the nearest pole carrying distribution lines from where the service connection is intended to be given. The other end of the GI bearer wire shall be fastened to a 5 cm. dia. GI pipe for a span up to 4.5m which is fixed to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

Fig 1



LAYING OF SERVICE LINES

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.

3 The conductor slag should not exceed as per the IE rules.

4 If UG cables are providing the depth of cable in ground should be as per IE rules.

5 Do not keep much more cable unused and buried in soil in the coil form in case of UG cable laying.

6 The excess cable should not be kept by making coil and kept on the pole cross arm. Use only required cable for connection.

7 If the cable passing through excess heat producing areas in near to chimney, kitchen etc; adequate protection from heat to be provided.

8 Service cable run along with stay wire tightly tied with stay wire to avoid tension on service cable.

9 No rain water flows along with service cable and reach to consumer main panel. Necessary looping of cable to be provided either side.

10 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.

1 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.

2 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.

1 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.

2 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.

1 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.

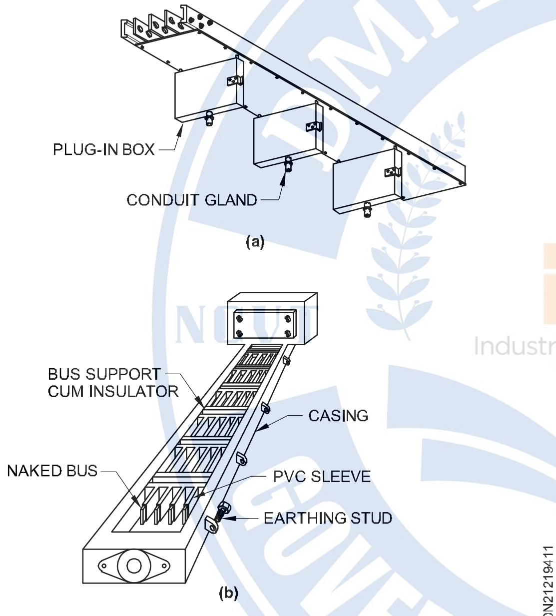
Tapping service connections: No service connection line should be tapped from an OH line from any point mid span, except at the point of support. When a service connection is taken overhead with a bare conductor, it should be provided with guard wires.

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**
- **state various terms like max demand etc.**

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.

Fig 1

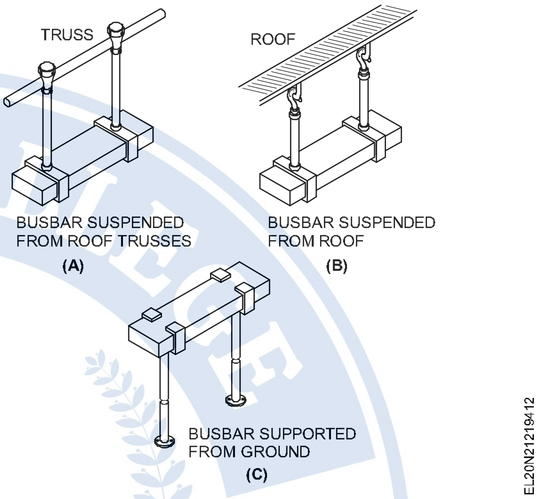


OVERHEAD BUSBAR SYSTEM

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.

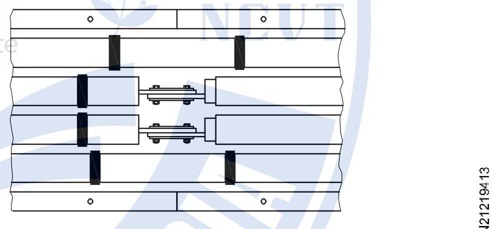
Fig 2



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.

Fig 3



TWO SECTIONS OF 400 AMPS BUSBARS COUPLED TOGETHER

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 fine 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.

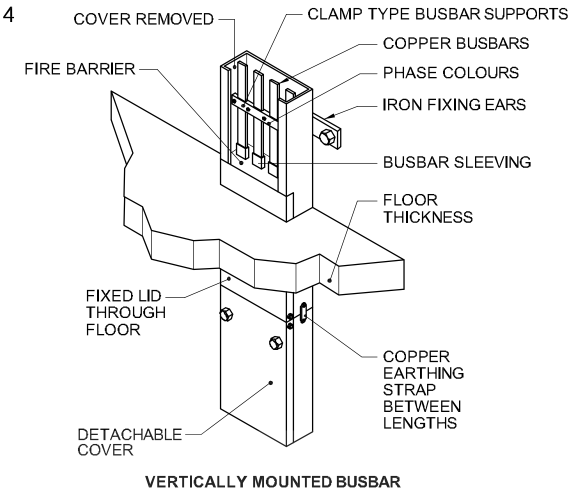
Earthing continuity is provided by two strips of aluminium or copper running throughout the bus-bar assembly. When extending the bus-bar lengths, these earthing strips also to be connected to have earth continuity.

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 0.6 to 0.8 and partly ventilated areas 0.5 to 0.6.**

Fig 4



VERTICALLY MOUNTED BUSBAR

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
Sl.No	**size in mm**	**Single bar**	**Two bars**	**Three bars**	**Four bars**	**Single bar**
1	50 x 6	675	1300	1700	1925	760
2	75 x 6	950	1750	2300	2600	1080
3	100 x 6	1225	2150	2800	3200	1380
4	125 x 6	1500	2500	3200	3700	1680
5	25 x 10	—	—	—	—	540
6	50 x 10	85	1500	1950	2250	960
7	75 x 10	1180	2050	2650	3000	1350
8	100 x 10	1500	2475	3150	3550	1710
9	125 x 10	1850	2925	3600	4200	2070
10	150 x 10	2100	3325	4000	4606	2430

Advantages of Bus-bar system

Following are the advantages of bus-bar system

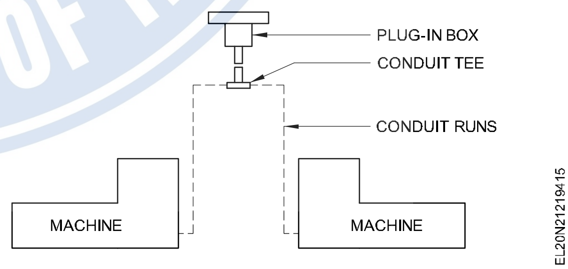
1 **Reduced cost:** Simple rapid installation with complete elimination of expensive floor chasing (cutting) reduces cost at the initial period of installation and needs no expenditure for maintaining the bus-bar system while in regular use.

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.

Fig 5



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

Fig 6

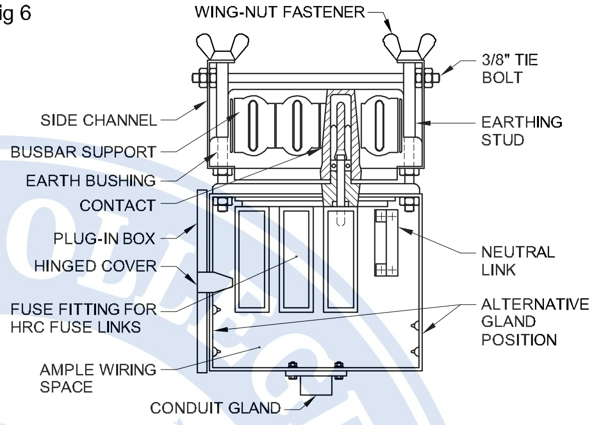


DIAGRAM SHOWING MAIN FEATURES OF PLUG-IN BOXES FITTED TO BUSBARS

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.

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.**

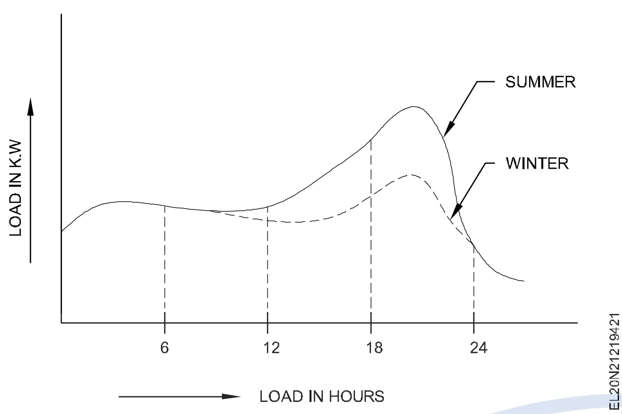
Introduction : The alternators in the power station should run at their rated capacity for maximum efficiency and on the other hand, the demands of the consumers have wide variations from time to time due to uncertain demands of the consumers. This makes the design of a power station highly complex. 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.

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.

Fig 1



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

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

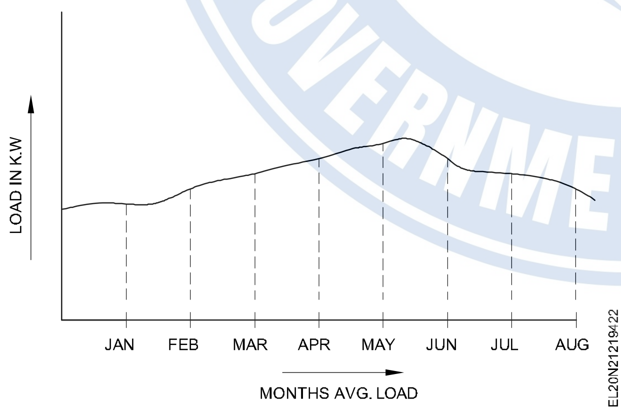
Usually it always less than one. The knowledge of demand factor is vital in determining the capacity of the plant equipment.

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.

Fig 2



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.

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

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%

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.

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. If 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 various according to the demand on the plant from the electricity market.