Electrical supply system - transmission - 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**
- **state the advantages of high voltage transmission**
- **state single phase and 3 phase - 3 wire system in 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.

Possible systems are :-

1 DC system

i DC two wire

ii DC two - wire with mid point earthed

iii DC three wire

2 AC single phase system

i Single-phase two wire

ii Single - phase two wire with mid point earthed

iii Single phase three wire

3 AC Two - phase system

i Two- phase three wire

ii Two - phase - four wire

4 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.

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

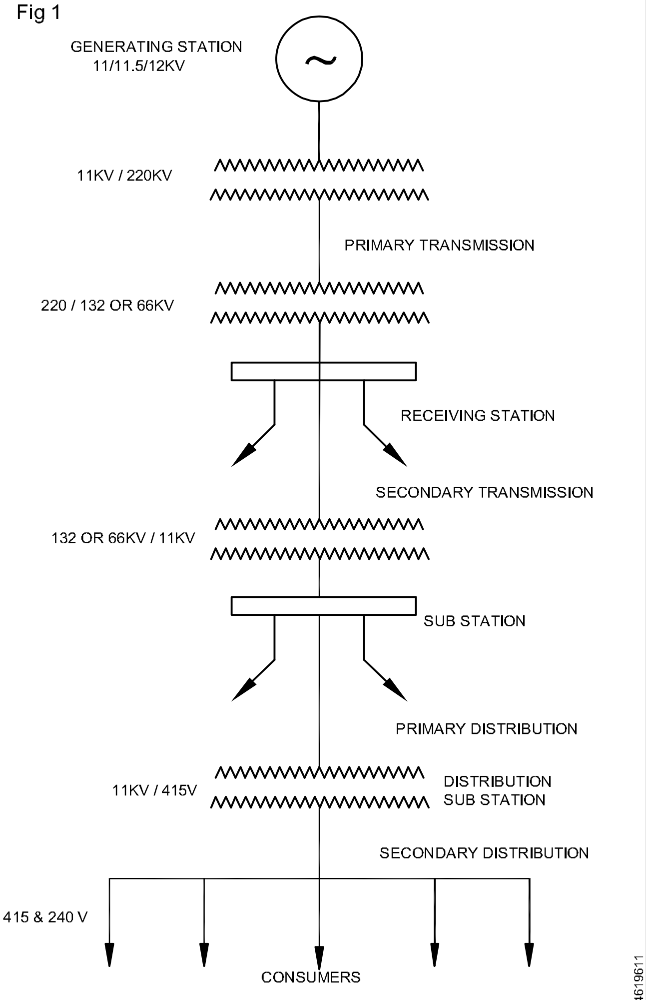
4 Primary distribution

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).

Fig 1



TYPICAL AC POWER SUPPLY SCHEME

The 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

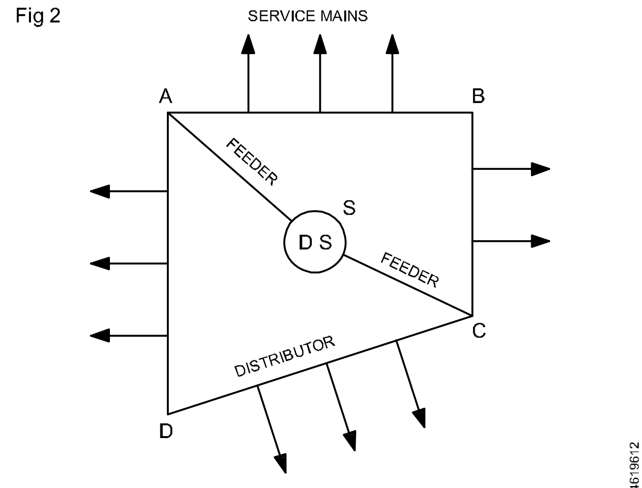
3 Service lines or service mains

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

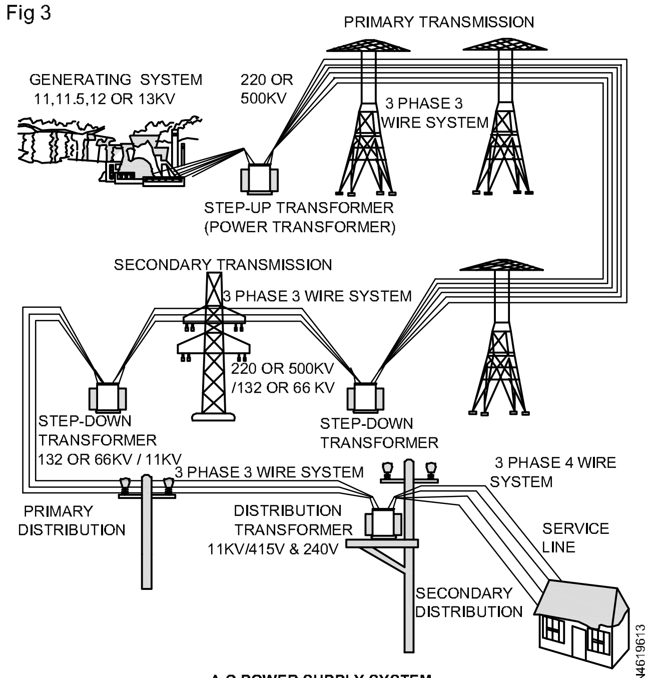


DISTRIBUTION SYSTEM

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.

Fig 3



A.C.POWER SUPPLY SYSTEM

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

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.

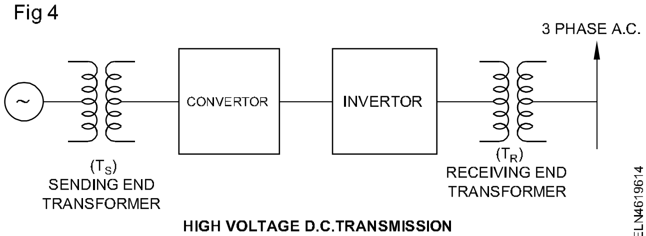
4 Effective resistance of AC transmission lines is increased due to skin effect.

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 single line diagram of high voltage DC transmission is in Fig 4. The power is generated as AC and stepped up to high voltage by the transformer at sending end (T_s) .

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.

Fig 4



HIGH VOLTAGE D.C.TRANSMISSION

Advantages of high voltage transmission

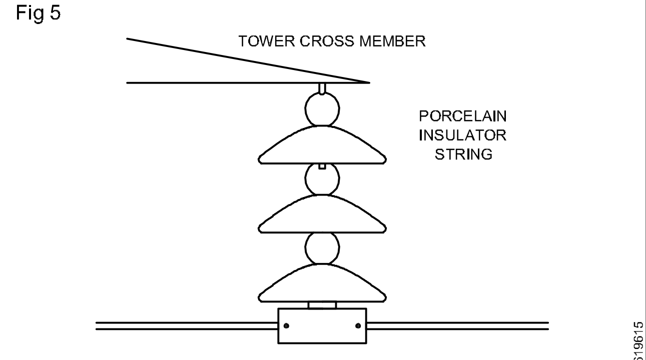
Very high voltages are used for transmission systems because, as a general principle, the bigger the voltage the cheaper is the supply.

Since power in an AC system is expressed as **P=VI cosθ,** that means increase in voltage will reduce the current for a given amount of power. A lower current will result in reduced cable switch gear size and the line power losses, given by the equation $P = I^2R$ will also be reduced.

The 132KV grid and 400KV **supergrid transmission lines** are for the most part, steel - cored aluminimum conductors suspended on steel lattice towers, since this is about 16 times cheaper than the equivalent underground cable.

The conductors are attached to porcelain insulator strings which are fixed to the cross - members of the tower is in Fig 5. Three conductors comprise a single circuit of a three phase system so that towers with six arms carry two separate circuits.

Fig 5

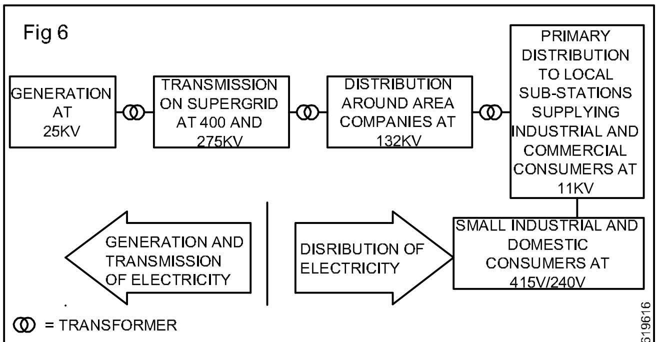


CROSS MEMBER OF THE TOWER

Primary distribution to consumers is from 11KV substations, which for the most part are fed from 33 KV substations, but direct transformation between 132 and 11KV is becoming common policy in city areas where over 100 MW can be economically distributed at 11KV from one site.

Fig 6 shows a block diagram indicating the voltage at the various stages of the transmission and distribution system.

Fig 6



VOLTAGE STAGES OF TRANSMISSION AND DISTRIBUTION SYSTEM

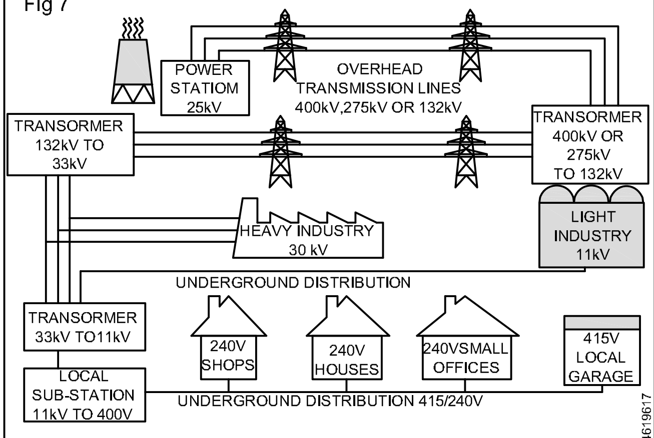
Distribution system at 11KV may be radial system offers continuous supply.

The maintenance of a secured supply is an important consideration for any electrical engineer or supply authority because in industrial society, a loss of supply may cause inconvenience, financial loss and danger to the consumer or the public.

The principle employed with a ring system is that any consumer's substation is fed from two directions, and by carefully grading the overload and cable protection equipment a fault can be disconnected without loss of supply to the consumers.

Fig 7 is a simplified diagram of distribution of electricity from power station to consumer.

Fig 7



DISTRIBUTION OF ELECTRICITY FROM POWER STATION TO CONSUMER

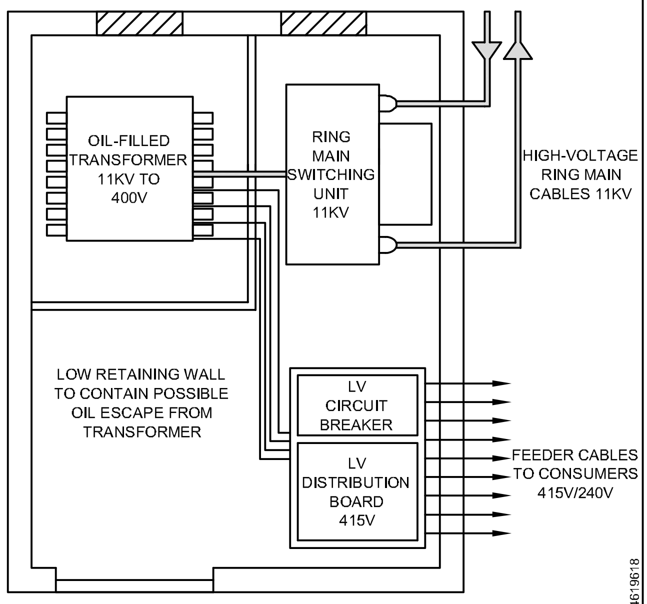
High voltage distribution

High voltage distribution to primary substation is used by the electricity boards to supply small industrial, commercial and domestic consumers.

This distribution method is also suitable for large industrial consumers where 11KV substations as in Fig 8 may be strategically placed at load centres around the factory site.

The final connections to plant, distribution boards, commercial or domestic loads are usually by simple underground radial feeders 415V/240V.

Fig 8

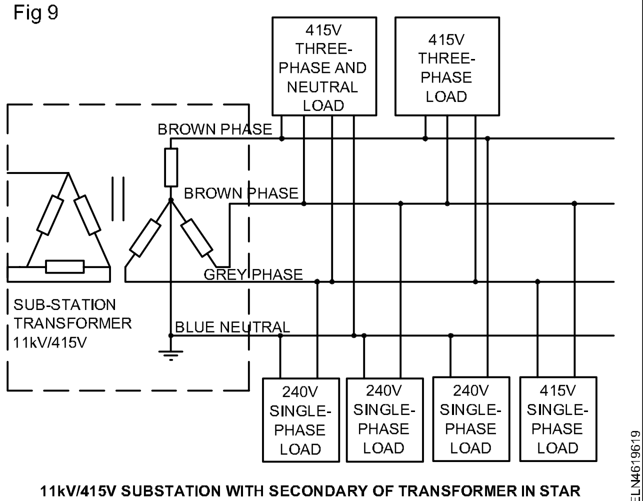


LOAD CENTRES AROUND THE FACTORY

These outgoing circuits are usually protected by circuit breakers in a distribution board.

The 415 V/240V is derived from the 11KV/415V sub-station transformer by connecting the secondary winding in star is in Fig 9.

Fig 9



11kV/415V SUBSTATION WITH SECONDARY OF TRANSFORMER IN STAR

The star point is earthed to an earth electrode sunk into the ground below the substation, and from this point is taken the fourth conductor, the neutral. Loads connected between phases are fed at 415V, and those fed between one phase and neutral at 240V.

A three - phase 415V, supply is used for supplying small industrial and commercial loads such as garages, schools and blocks of flats. A single - phase 240V supply is usually provided for individual domestic consumers.

Line insulators

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

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.

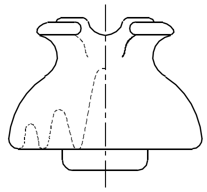
The following are the common types of insulators in use.

- 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.

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 1



SINGLE SHED TYPE OF PIN INSULATOR

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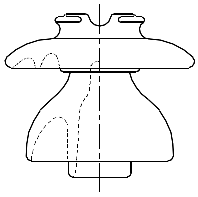
Fig 2



DOUBLE SHED TYPE OF PIN INSULATOR

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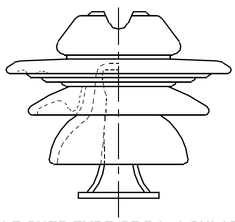
Fig 3



TRIPLE SHED TYPE OF PIN INSULATOR

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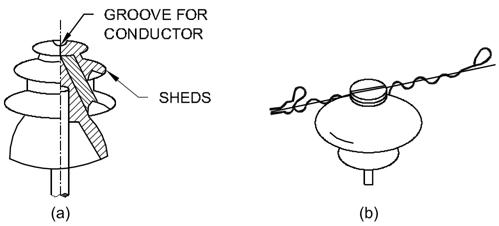
Fig 4



SECTION VIEW OF A PIN INSULATOR

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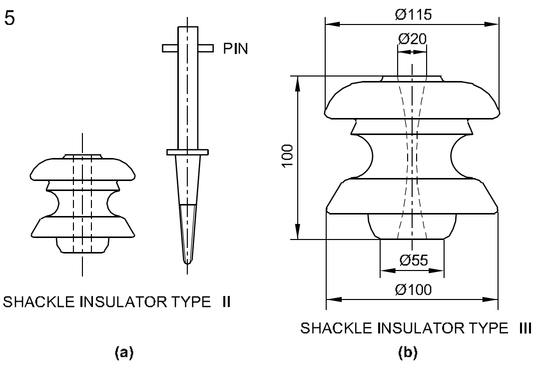
Shackle insulators : Shackle insulators are generally used for terminating on corner poles. These insulators are used for medium voltage line only. (Fig 5a & 5b)

Fig 5



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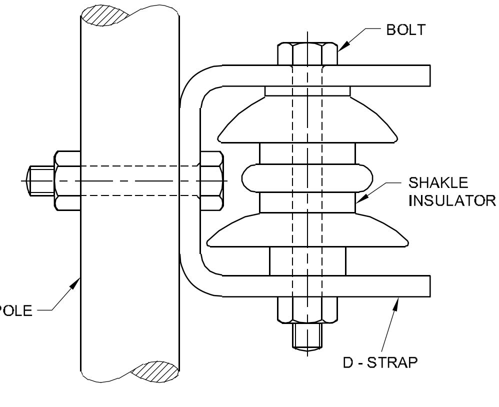
But now a days, they are frequency used for low voltage distribution lines. Such insulators can be used either in horizontal position or in a vertical position. They can be directly fix to the pole with a bolt or to the cross arm. Fig 6 shows a shackle insulator fixed to the pole. The conductor in the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

Fig 6



SHACKLE TYPE INSULATOR

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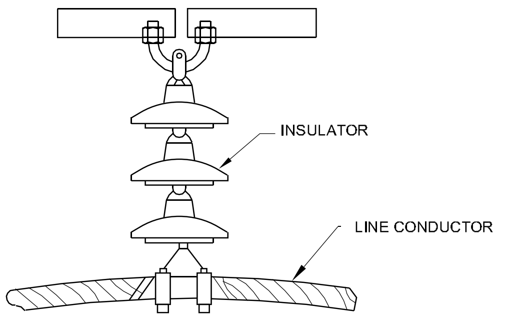
Suspension type insulators

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.

Fig 7



SUSPENSION INSULATOR

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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.

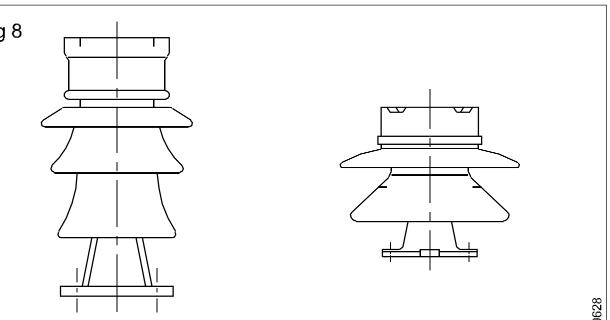
Strain insulators

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.

Fig 8

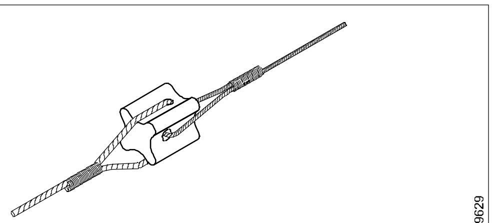


a) CAP AND PIN INSULATOR FOR GOAB SWITCH

b) ANOTHER DESIGN OF CAP AND PIN INSULATOR FOR GOAB SWITCH

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.

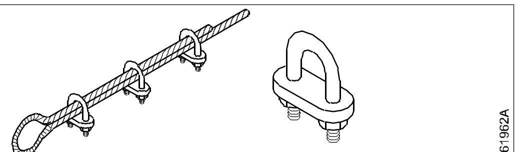
Fig 9



STAY INSULATOR

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.

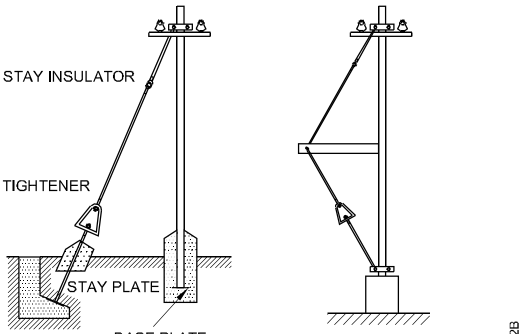
Fig 10



GI STAY WIRE & CLAMP

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.

Fig 11



STAY TYPE SUPPORT

STRUT TYPE SUPPORT

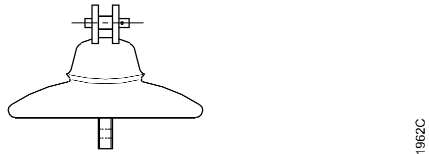
One end of the stay is fixed at the top of the pole and its other end is grouted in the concrete foundation.

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.

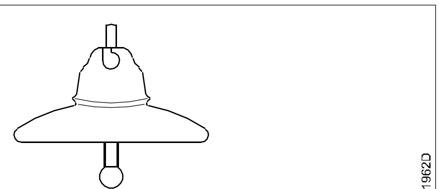
Fig 12



DISC INSULATOR TONGUE AND CLEVIS TYPE

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.

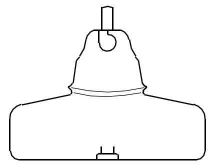
Fig 13



DISC INSULATOR BALL AND SOCKET TYPE

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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Guard wires

These are a set of wires erected as a preventive guard to falling conductors so that the live conductor after breaking does not come in touch with the public or moving vehicles. These are erected in places where the line crosses a street, road or railway line, OH power or communication lines and others.

Minimum clearance required between conductors on the same support :-

a) L.T. lines

i) Vertical configuration of conductors :-

Minimum clearance between earth and live conductors is 30 cm.

Minimum clearance between live conductors is 20 cm.

ii) Horizontal configuration of conductors :-

Minimum clearance between live wires on either side of a support is 45 cm.

Minimum clearance between live wires on the same side of support is 30 cm.

Minimum distance between the centre of insulator pin hole and end of cross-arm is 8cm.

b) H.T. lines

Triangular configuration :-

Minimum distance between the centre of insulator pin hole and end of cross arm is 10 cm.

The conductors are erected in such a way that they form an equilateral pattern of side of 1 metre minimum.

Necessity of binding: In overhead transmission lines, the line conductors have to be tied to the post type and shackle type insulators to hold the wire in the correct position, without allowing for any further change in position after stretching the wires by wire stretchers with allowable 'sag' as required.

Method of binding insulator in overhead lines: The insulators should be bound with the line conductor with the help of copper binding wire in case of copper conductors, galvanised iron binding wire for galvanised iron conductors and aluminium binding wire tape for aluminium and aluminium steel reinforced conductors (ACSR). The size of the binding wire should not be less than 2 sq mm.

After binding of the aluminium cored conductors, the binding joint is provided with protective grease. The binding turns must be very close (without any gap) and must be very tight enough so that more sparking is avoided.

While binding, only a mallet has to be used for making the conductor straight and hammer should never be used.

Current carrying capacity of a conductor

Introduction

The current carrying capacity of a insulated conductor or cable is the maximum current that it can continuously carry without exceeding its temperature rating it is also known as ampacity.

While the cables are in operation they suffer electrical losses which is manifest on heat in the conductor, insulation and any others metallic components in the construction.

The current rating will depend on hand this heat in dissipated through the cable surface and into the surrounding areas. The temperature rating of the cable is a determining factor in the current carrying capacity of the cable. The maximum temperature rating for the cable is essentially determined by the insulation material.

By choosing an ambient temperature as a base for the surroundings, a permissible temperature rise is available from which a maximum cable rating can be calculated for a particular environment. If the thermal resistivity values are known for the layers of materials in the cable construction then the current rating scan be calculated.

The formula for calculating current carrying capacity in given an

$$I = \left(\frac{\Delta\theta - W_d\left[\frac{1}{2}T_1 + \eta(T_2 + T_3 + T_4)\right]}{RT_1 + \eta R(1+\lambda_1) + T_2 + \eta R(1+\lambda_1+\lambda_2)(T_3+T_4)} + \right)^{\frac{1}{2}}$$

where

I = Permissible current rating

$\Delta\theta$ = Conductor temperature rise in (K)

R = AC resistance per unit length of the conductor at maximum operating temperature (Ω/m)

T_1 = Dielectric loss per unit length between one conductor and the sheath (K_m/W)

T_2 = Thermal resistance per unit length of the bedding between sheath and the armour (K_m/W)

T_3 = Thermal resistance per unit length of the external sheath of the cable (K_m/W)

T_4 = Thermal resistance per unit length between the cable surface and the surrounding medium (K_m/W)

W_d = Dielectric loss per unit length for the insulation surrounding the conductor. (W/m)

η=Number load carrying conductors in the cable (conductors of equal size and carrying the same load)

λ_1 = Ratio of loses in the metal sheath to total losses in all conductors in that cable.

λ_2 = Ratio of losses in the armouring to total losses in all conductors in that cable.

NEC (National Electrical Code)

When selecting a cable it must know its wire ampacity rating. This rating has been determined by the NEC (National Electrical Code)

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 it 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.

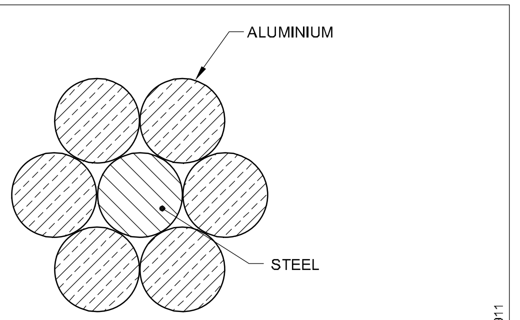
The conductivity of aluminium is 60% that of copper. The smaller conductivity of aluminium means that for any particular transmission efficiency, the cross sectional area of conductor must be larger in aluminium than in copper. For the same resistance, the diameter of aluminium conductor is about 1.26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

Fig 1



STEEL CORED ALUMINIUM CONDUCTOR

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.

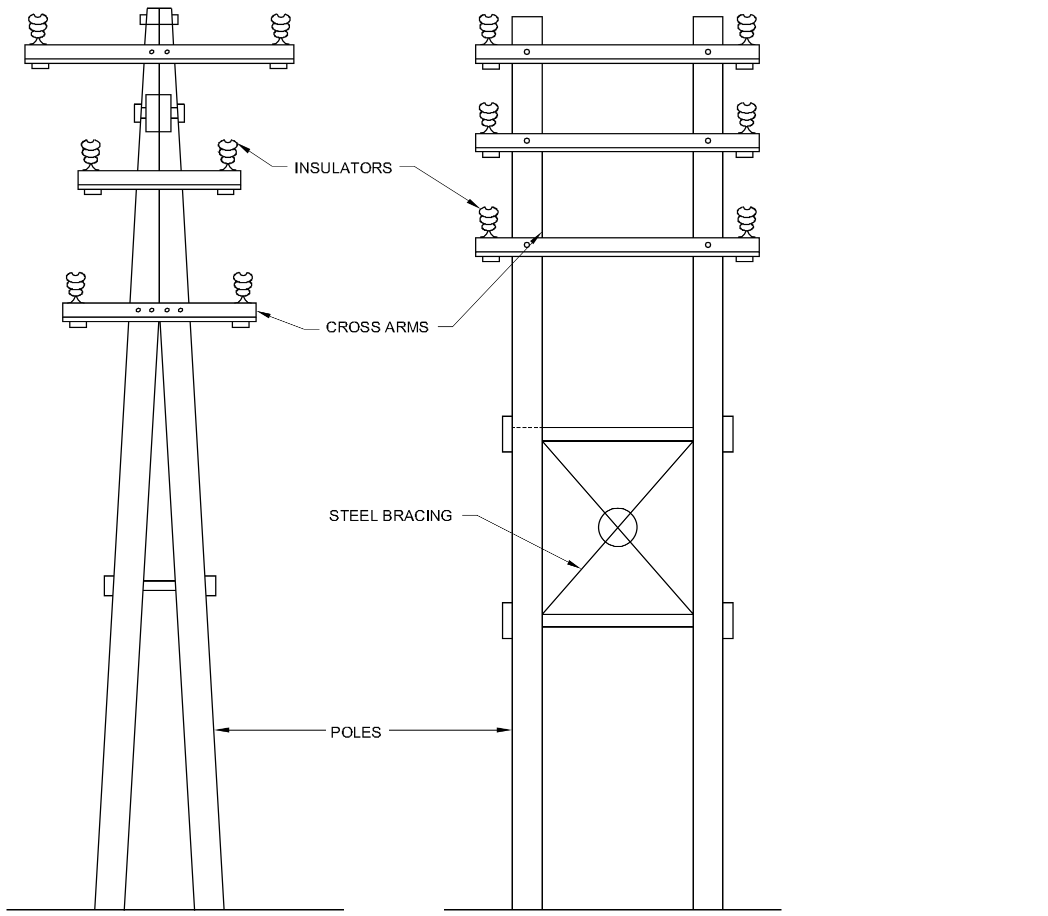
The main difficulty with the use of these poles is the high cost of transport owing to their heavy weight. Therefore, such poles are often manufactured at the site in order to avoid heavy cost of transportation.

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.

Fig 2



WOODEN POLES

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:

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)

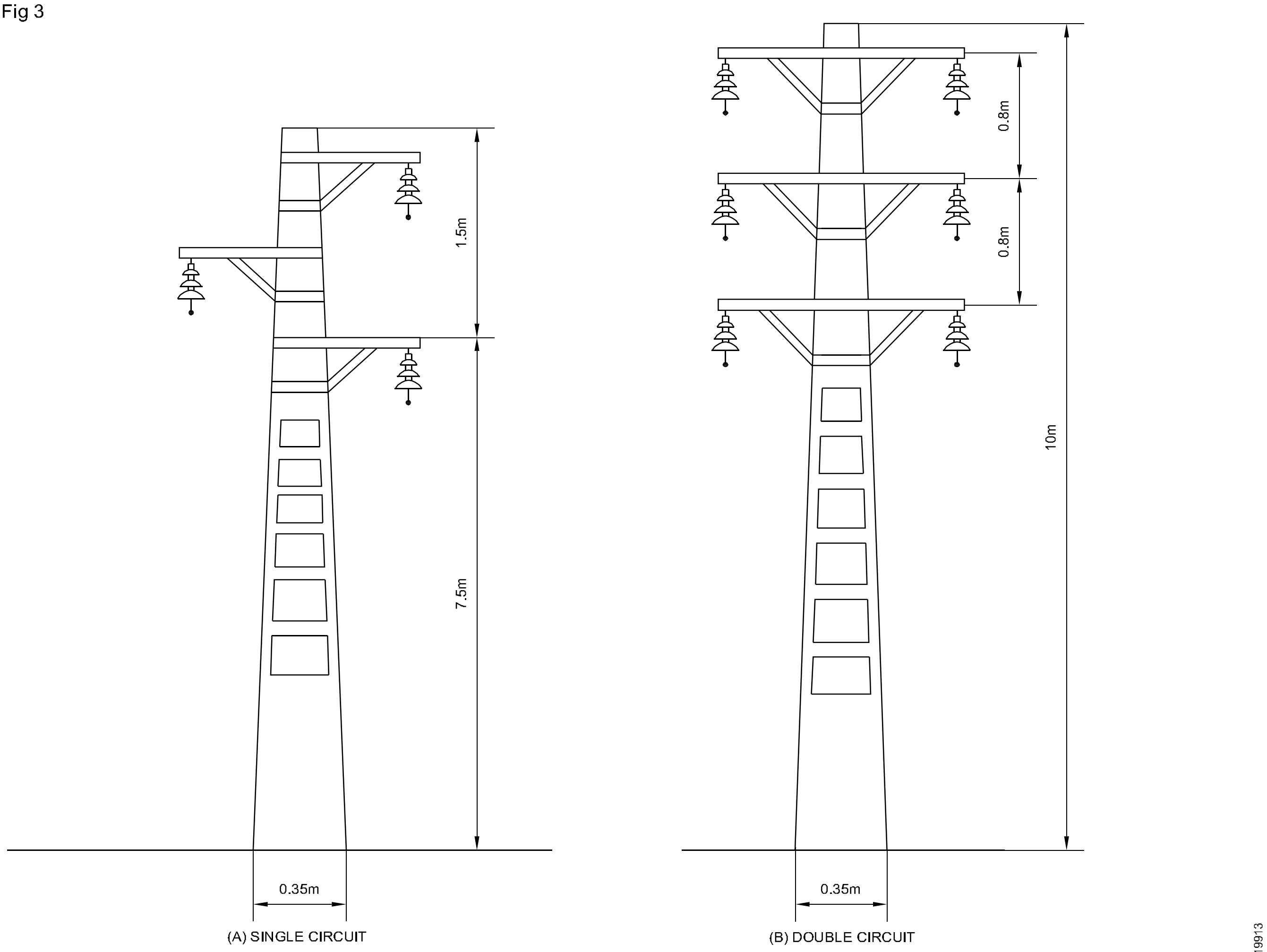
d. Extra high voltage line (above 33KV)

Voltage standard

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

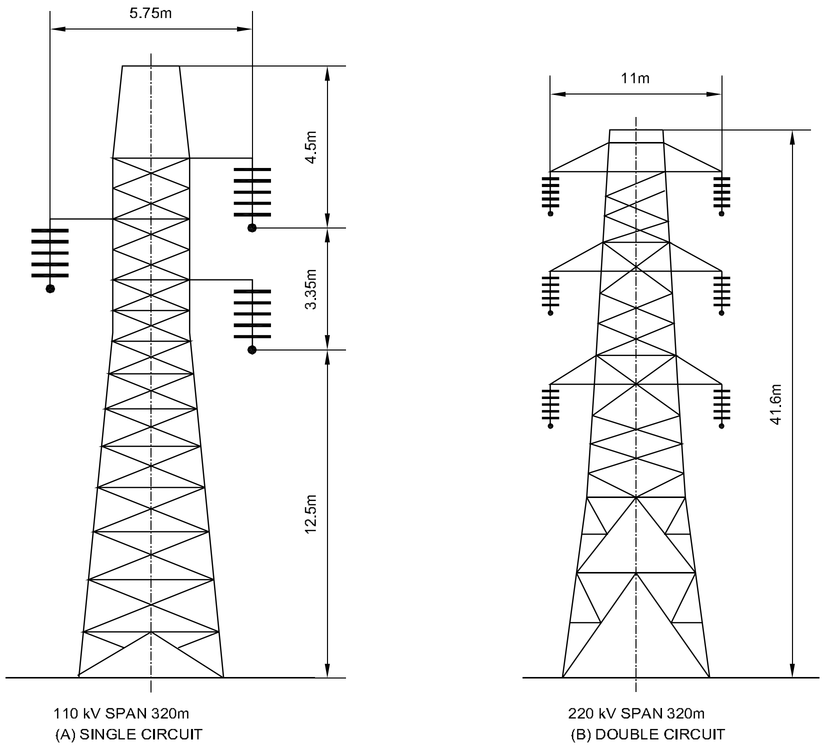
"Voltage" means the difference of electric potential measured in volts between any two conductors or between any part of either conductor and the earth as measured by a suitable voltmeter and is said to be;

Fig 3



RCC POLES

Fig 4



STEEL TOWERS

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.

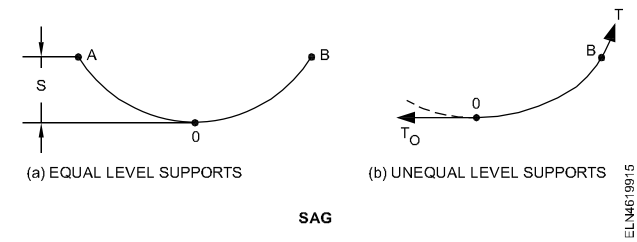
(e.g. bigger cross arms and supports) may increase to a considerable extent.

Sag in Overhead Lines

The difference in level between points of supports and the lowers 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.

Fig 5



(a) EQUAL LEVEL SUPPORTS (b) UNEQUAL LEVEL SUPPORTS

SAG

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.

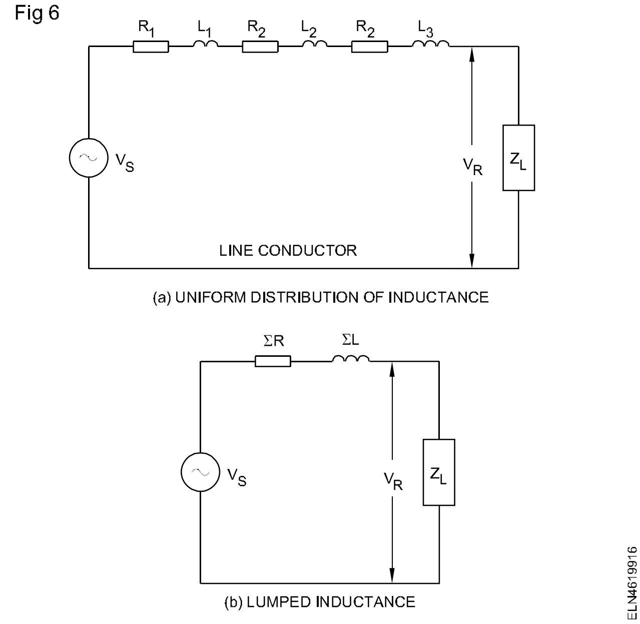
Inductance, $L = \frac{\varphi}{I}$ henry

Where ϕ = flux linkages in weber-turns

I = current in amperes.

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

Fig 6



(a) UNIFORM DISTRIBUTION OF INDUCTANCE

(b) LUMPED INDUCTANCE

(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.

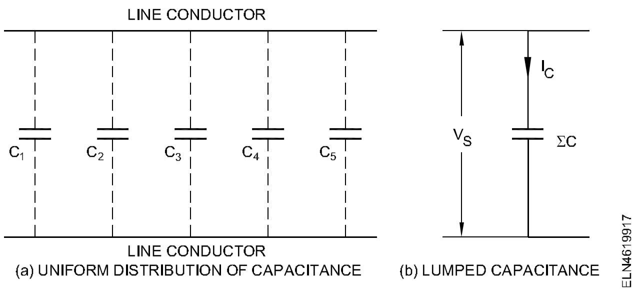
Capacitance, $C = \frac{q}{v}$ farad

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.

Fig 7



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.

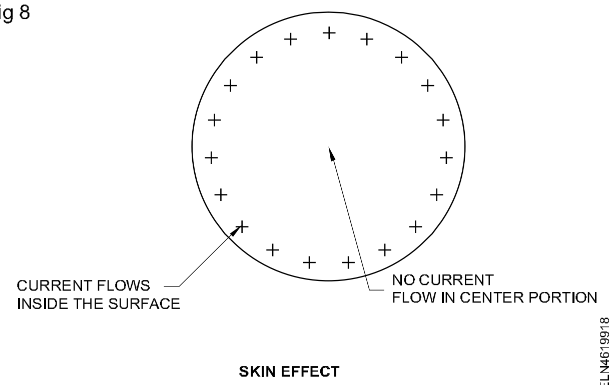
Skin Effect

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)

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

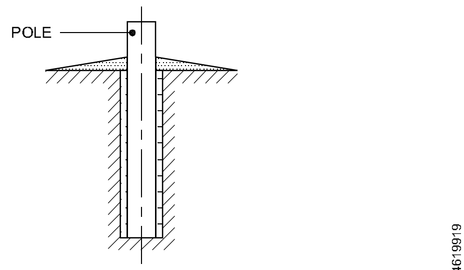
iii Terrain conditions

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.

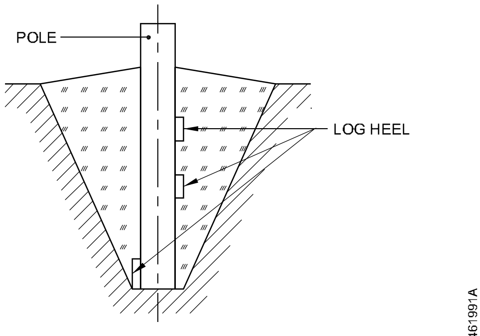
Fig 9



FOUNDATION ON ROCKY TERRAIN

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

Fig 10

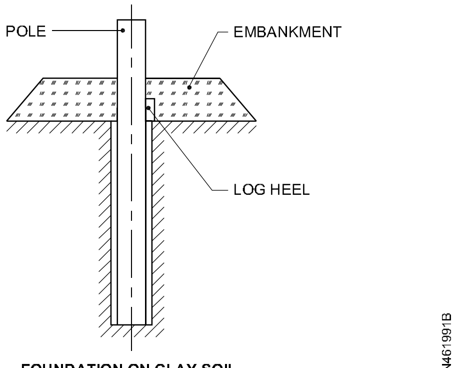


FOUNDATION ON SOLID GROUND

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.

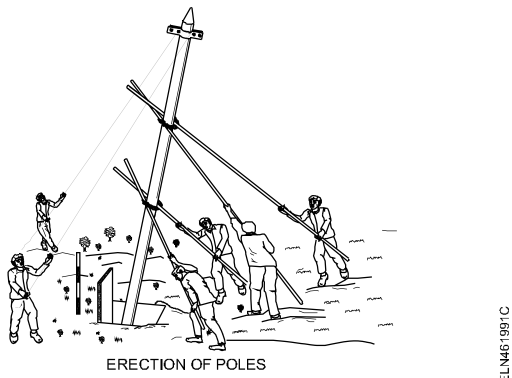
Fig 11



FOUNDATION ON CLAY 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.

Fig 12



ERECTION OF POLES

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.

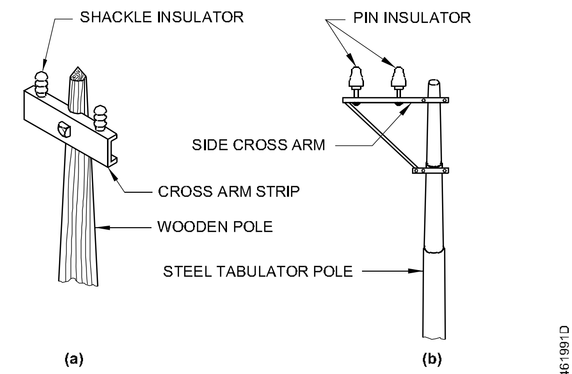
Having satisfied that the vertical and longitudinal alignment are all right, earth filling is to be done. In some soils the poles are to be concreted up to ground level of the pit. After the poles have been set, the temporary anchors are to be removed.

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.

Fig 13



CROSS-ARMS

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.

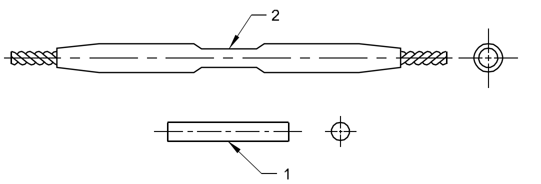
Fig 1

TWISTED JOINTS

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.

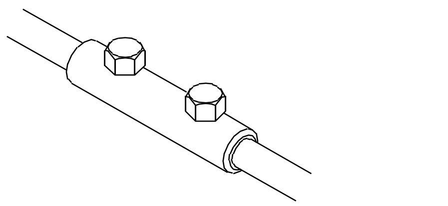
Fig 2



COMPRESSION JOINT FOR ASCR

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.

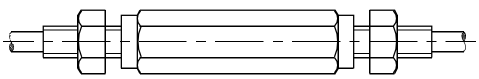
Fig 3



STRAIGHT SLEEVE AND NUT

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

Fig 4

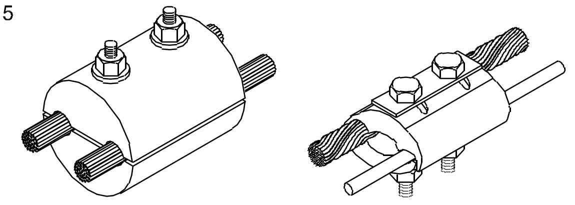


COMPRESSION CONNECTOR

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

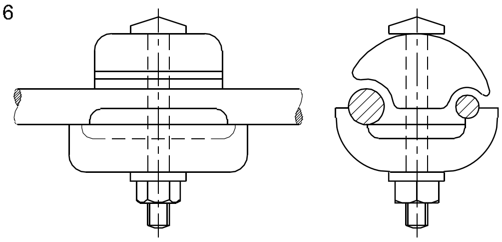


P.G. VICE CONNECTOR

ELN4619935

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



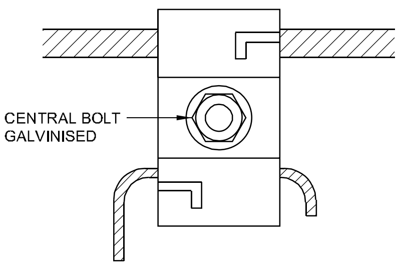
U.P.G. CLAMP

ELN4619936

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

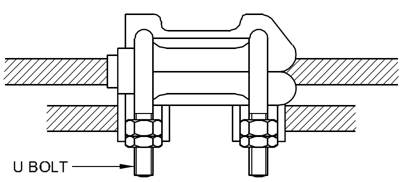


CENTRAL BOLT IS OF GALVANISED IRON

ELN4619937

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

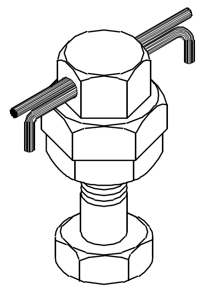
ELN4619938

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

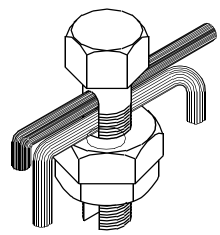


NUT CONNECTOR

ELN4619939

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

ELN461993A

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.