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

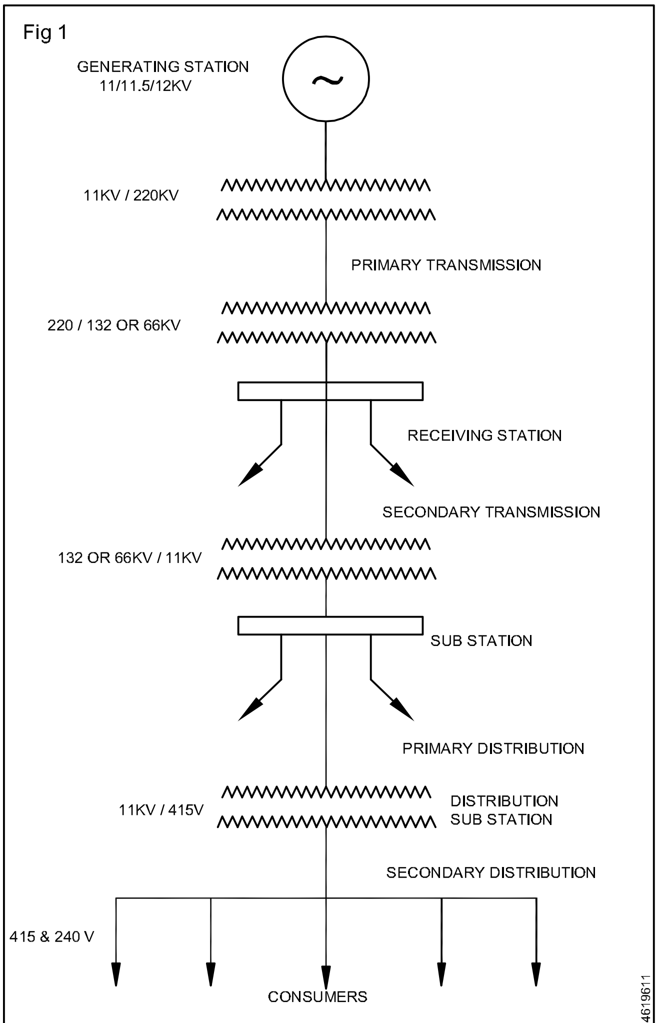
3 Secondary transmission

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).



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

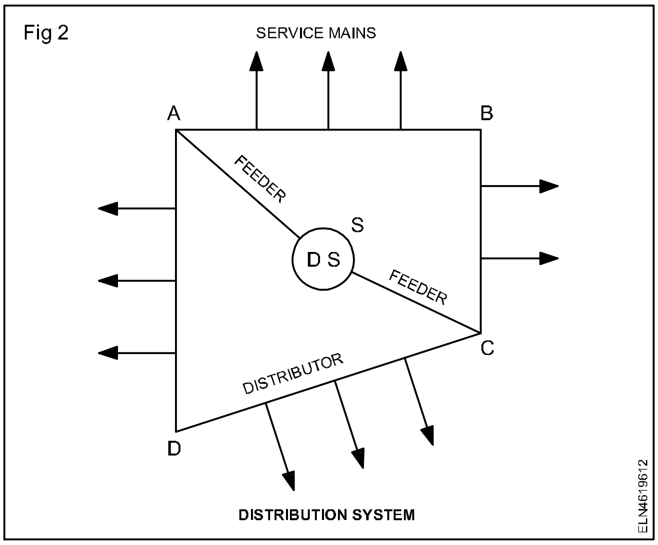
2 Distributors

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.

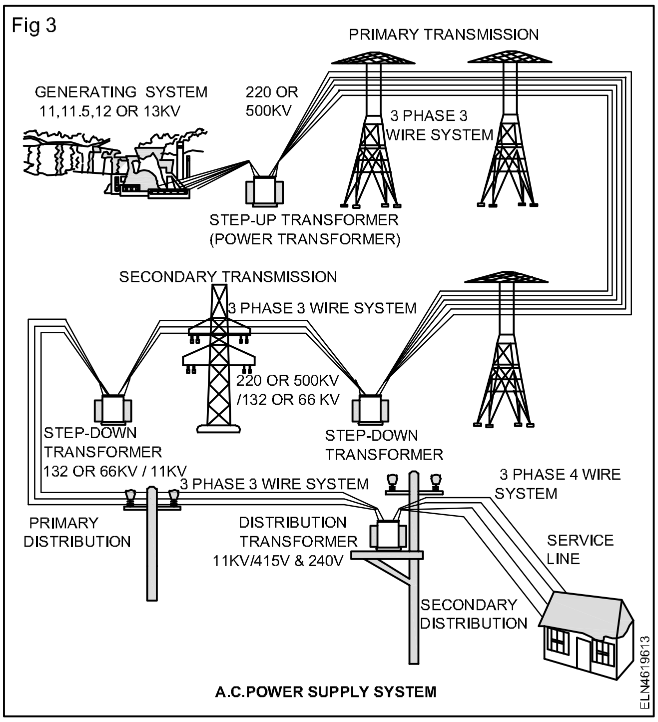
Distributors

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.



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

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.

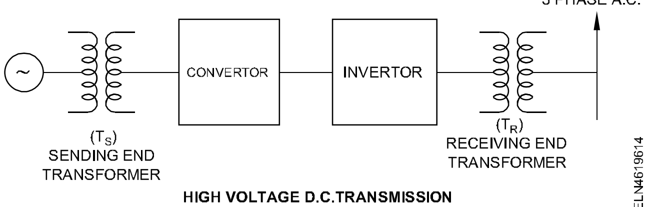
4 Effective resistance of AC transmission lines is increased due to skin effect.

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

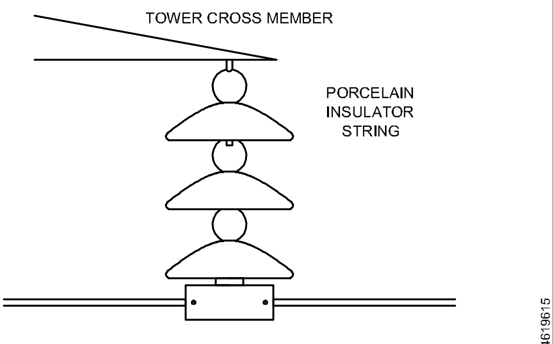
Very high voltages are used for transmission systems because, as a general principle, the bigger the voltage the cheaper is the supply.

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

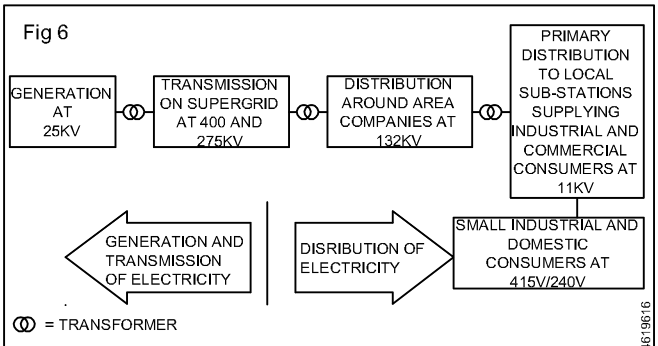


CROSS MEMBER OF THE TOWER

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

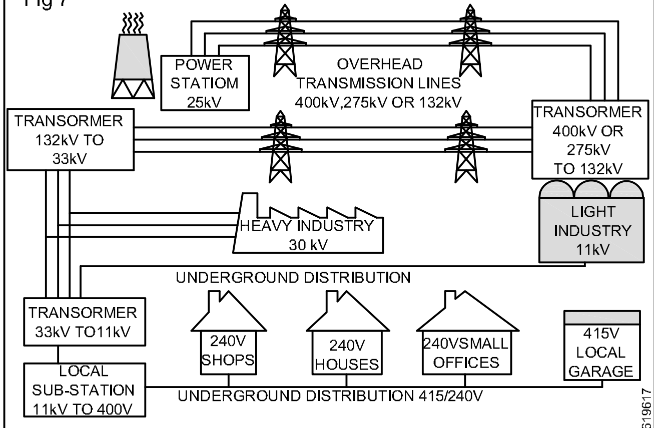
Distribution system at 11KV may be radial system offers continuous supply.

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

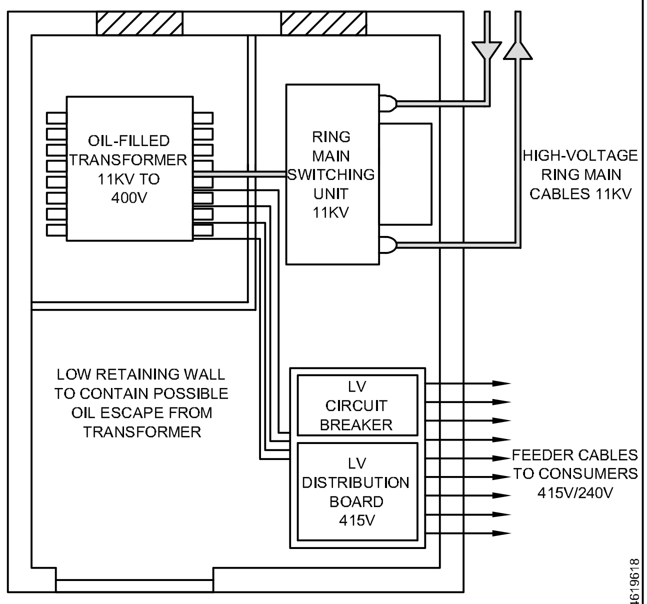
High voltage distribution

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

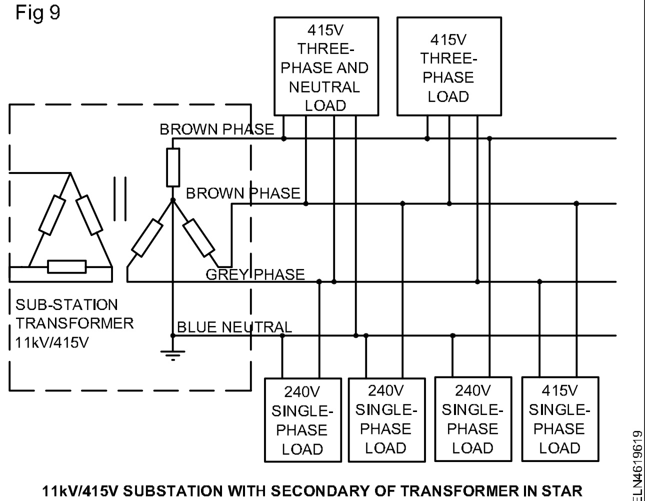


LOAD CENTRES AROUND THE FACTORY

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.

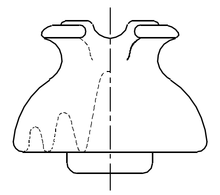
The following are the common types of insulators in use.

- 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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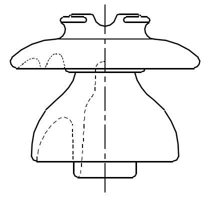
Fig 2



DOUBLE SHED TYPE OF PIN INSULATOR

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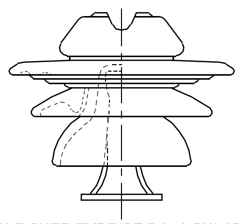
Fig 3



TRIPLE SHED TYPE OF PIN INSULATOR

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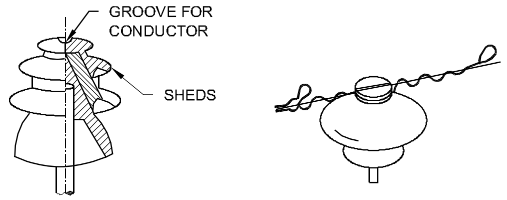
Fig 4



SECTION VIEW OF A PIN INSULATOR

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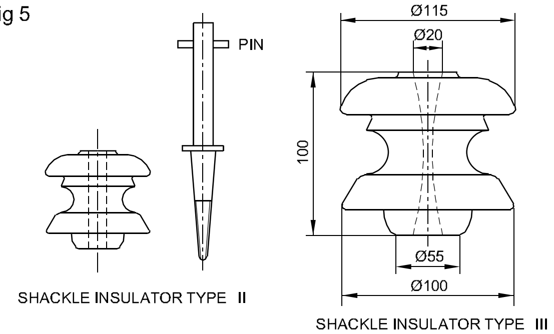
Shackle insulators : Shackle insulators are generally used for terminating on corner poles. These insulators are used for medium voltage line only. (Fig 5a & 5b)

Fig 5



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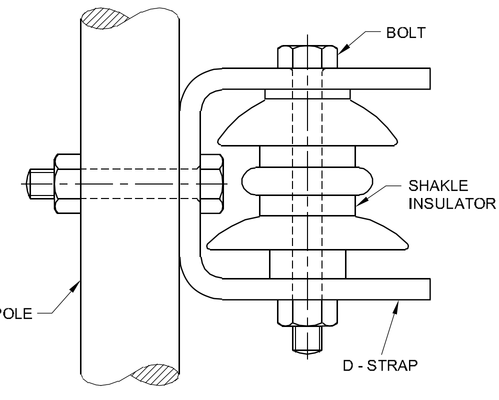
But now a days, they are frequency used for low voltage distribution lines. Such insulators can be used either in horizontal position or in a vertical position. They can be directly fix to the pole with a bolt or to the cross arm. Fig 6 shows a shackle insulator fixed to the pole. The conductor in the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

Fig 6



SHACKLE TYPE INSULATOR

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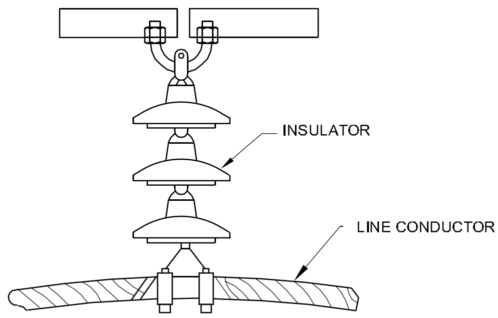
Suspension type insulators

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.

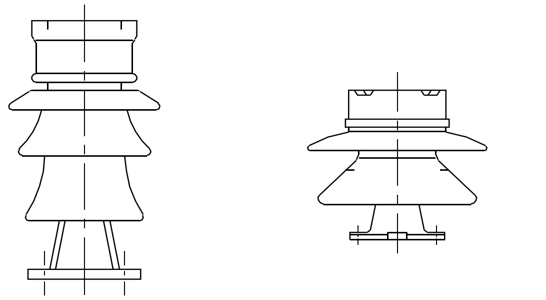
Strain insulators

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

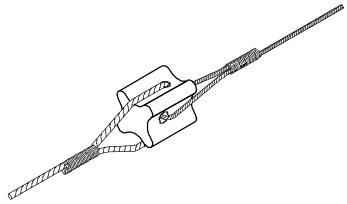


a) CAP AND PIN INSULATOR FOR GOAB SWITCH

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.

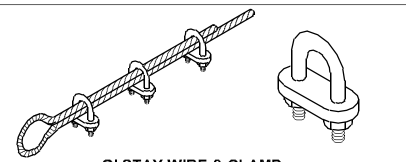
Fig 9



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.

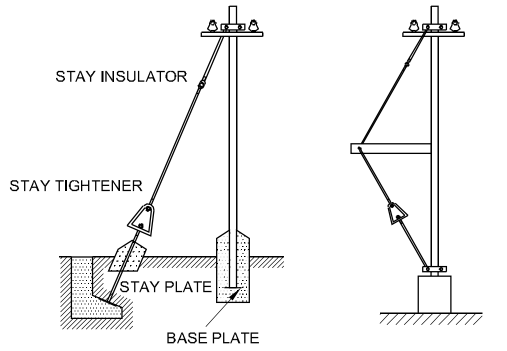
Fig 10



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

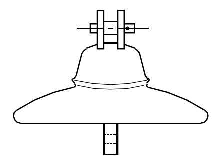
One end of the stay is fixed at the top of the pole and its other end is grouted in the concrete foundation.

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.

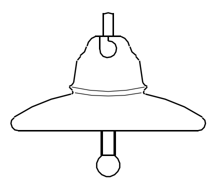
Fig 12



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.

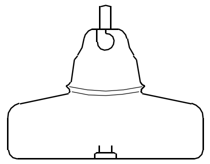
Fig 13



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

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)