

## Over Voltage Protection & Insulation Co-ordination. (1)

### Volt-Time Curve:

The breakdown voltage for a particular insulation or flashover voltage for a gap is a function of both the magnitude of voltage and the time of application of the voltage. The Volt-time curve is a graph showing the relation between the crest flashover voltage and the time to flashover for a series of impulse voltages and the time to flashover for a series of impulse applications of a given wave shape. For the construction of Volt-time curves a series of impulse applications of a given wave shape. For the construction of Volt-time curve the following procedure is adopted. Waves of the same shape but of different peak values are applied to the insulation whose Volt-time curve is required. If flashover occurs on the front of the wave, the flashover point gives one point on the Volt-time curve. The other possibility is that the flashover occurs just at the peak value of wave; this gives another point on the V-T curve. The possibility is that the flashover occurs on the tail side of the wave. In this case to find the point on the V-T curve, draw a horizontal line from the peak value of this wave and also draw a vertical line passing through the point where the flashover takes place. The intersection of the horizontal and vertical lines gives the point on the V-T curve. This procedure is nicely shown in fig 1.

The overvoltages against which coordination is required could be caused on the system due to system faults, switching operation or lightning surges. For lower voltages, normally up to 345 kV, overvoltages caused by system faults or switching operation do not cause damage to equipment insulation although they may be detrimental to protective devices.

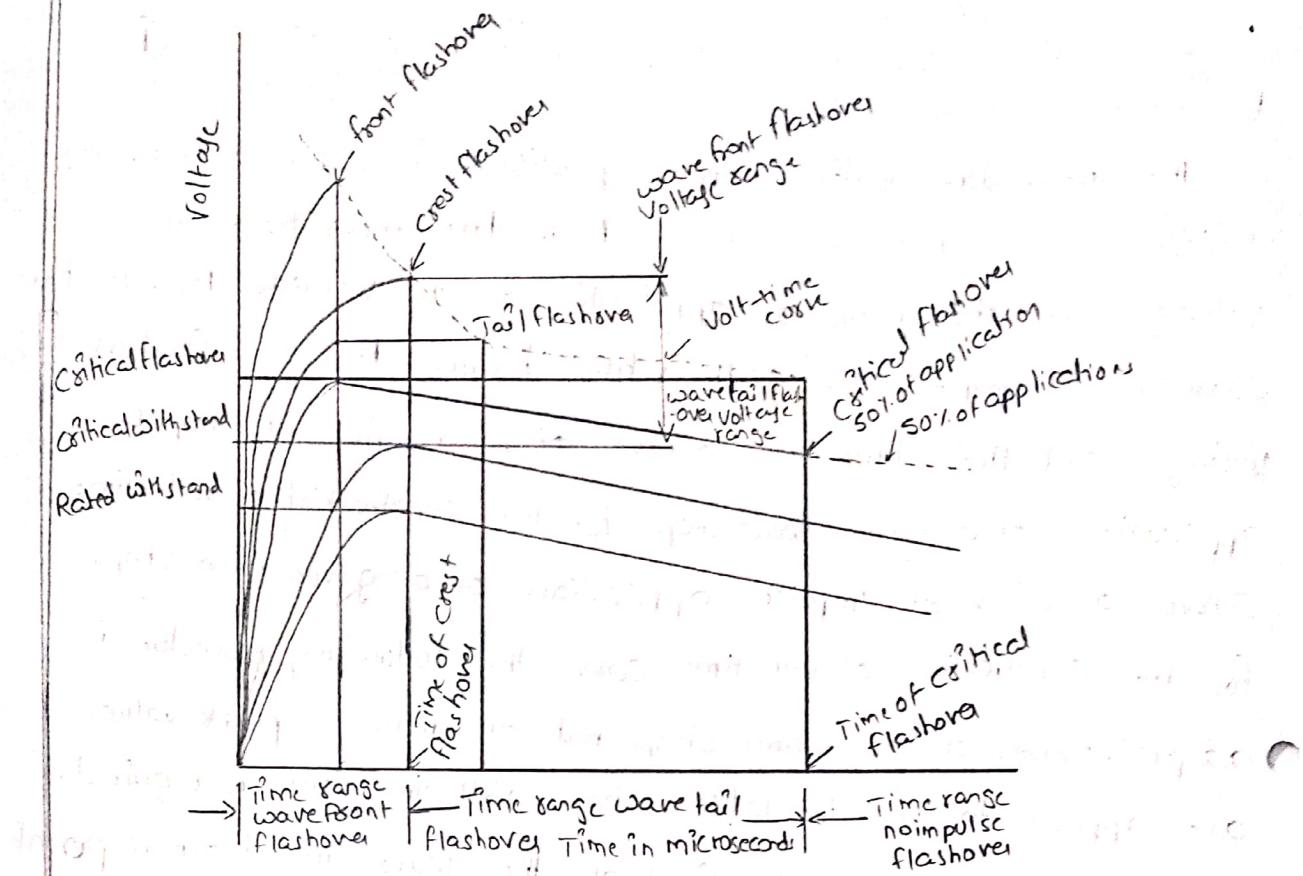


fig:1-10 Volt-time Curve (Construction)

whereas for voltages above 345 kV it is these switching surges which are more dangerous for the equipments than the lightning surges.

### Over Voltage Protection:

The causes of Overvoltage in the system have been studied extensively in Chapter 12. Basically there are two sources of i) external overvoltages due to mainly lightning, and ii) internal overvoltages mainly due to switching operation. The system can be protected against external overvoltages using what are known as shielding methods which do not allow an arc path to form between the line conductor and grounds, thereby giving inherent protection in the line design. For protection against internal voltages normally non-shielding methods are used which allow an arc path between the ground structure and the line.

Conductor but means are provided to quench the arc. (2)  
 The use of ground wire is a shielding method whereas the  
 use of spark gaps, and lightning arresters are the non-shielding  
 methods. We will study first the non-shielding methods and  
 then the shielding methods. However, the non-shielding methods  
 can also be used for external overvoltages.

The non-shielding methods are based upon the principle  
 of insulation breakdown as the overvoltage is incident on  
 the protective device; thereby a part of the energy content in the  
 overvoltage is discharged to the ground through the protective  
 device.

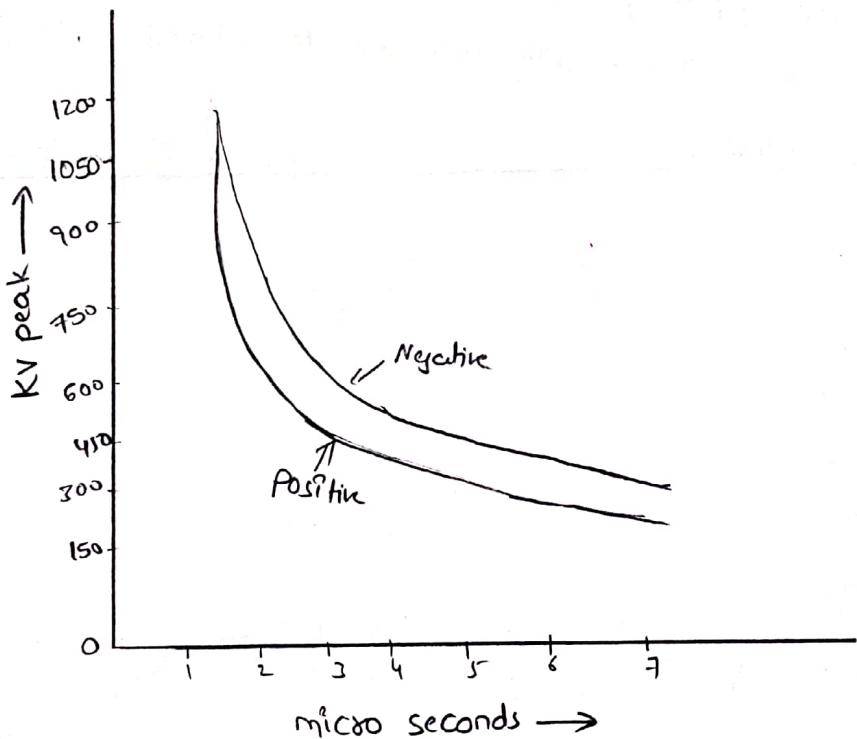


Fig: Volt-time curves of gaps for positive and negative polarity.

The Volt-time characteristics of gaps having one electrode grounded depend upon the polarity of the voltage wave. From fig. it is seen that the Volt-time characteristic for positive polarity is lower than the negative polarity, i.e., the breakdown voltage for a negative impulse is greater than for a positive because of the nearness of earthed metal or of current carrying conductors. For post insulators the negative polarity

Wave has a high breakdown value whereas for suspension insulators, the reverse is true.

### Horn Gap:

The Horn Gap consists of two horn shaped rods separated by a small distance. One end of this is connected to the line and the other to the earth as shown in fig, with or without a series resistance. The choke connected between the equipment to be protected and the horn gap serves two purposes i) The steepness of the wave incident on the equipment to be protected is reduced. ii) It reflects the voltage surge back on to the horn.

There are two major drawbacks of the horn gap i) The time of operation of the gap is quite large as compared to the modern protective gear. ii) (the time of operation of the) If used on isolated neutral the horn gap may constitute a vicious kind of arcing. For these reasons, the horn gap has almost vanished from ground.

Important power lines.

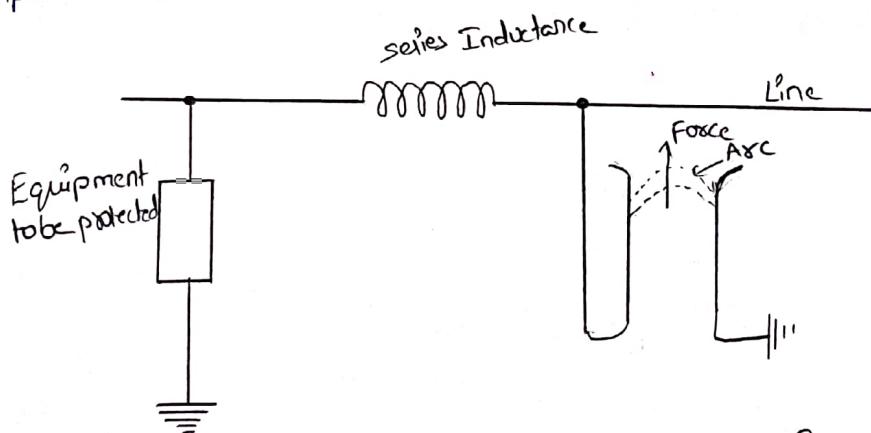


Fig: Horn gap Connected in the system for protection.

### Surge Diverters:

The following are the basic requirement of a surge diverter.

- i) It should not pass any current at normal or abnormal (normally 5% more than the normal voltage) power frequency Voltage.
- ii) It should breakdown as quickly as possible after the abnormal high frequency voltage arrives.
- iii) It should not only protect the equipment for which it is used.

but should discharge the surge current without damaging itself. ③

iv) It should interrupt the power frequency follow current after the surge is discharged to ground.

There are mainly three types of surge diverters i) Rod gap, ii) protector tube or expulsion type of lightning arrester, iii) Valve type of lightning arrestor.

Rod Gap:

This type of surge diverter is perhaps the simplest, cheapest and most rugged one. Fig: shows one such gap for a breaker bushing. This may take the form of arcing ring. Fig: shows the breakdown characteristics (Volt-time) of a rod gap. For a given gap and wave shape of the voltage, the time for breakdown varies approximately inversely with the applied voltage.

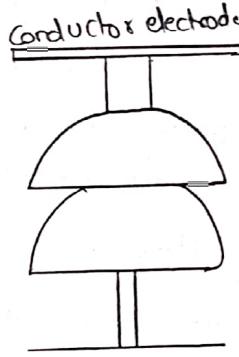


Fig: A rod gap.

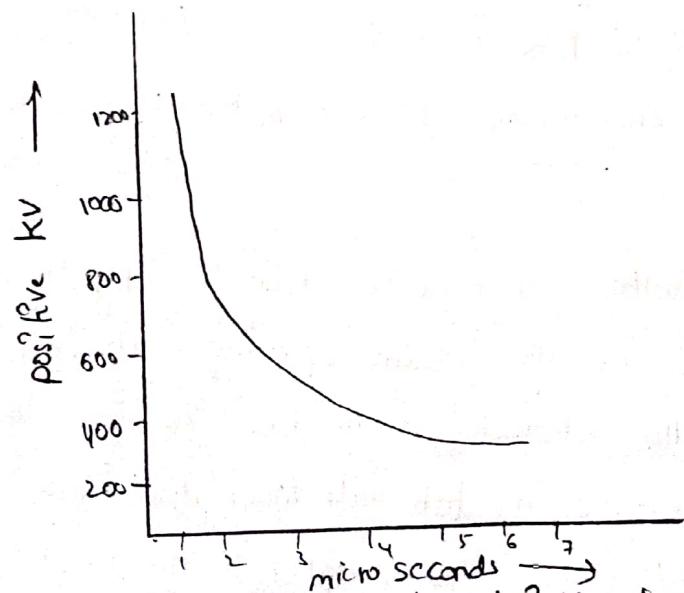


Fig: Volt-time characteristics of rod gap. UNIT-IV, PG NO: 5/13

The times to flashover for positive polarity are lower than for negative polarities. Also it is found that the flashover voltage depends to some extent on the length of the lower (grounded) rod. usually a length of 1.5 to 2.0 times the gap spacing is good enough to reduce this difference to a reasonable amount.

Even though rod gap is the cheapest form of protection, it suffers from the major disadvantage that it does not satisfy one of the basic requirement of a lightning arrester listed at no. iv) i.e., it does not interrupt the power frequency follow current. This means that every operation of the rod gap results in a L-G fault and the breakers must operate to de-energize the circuit to clear the flashover. The rod gap, therefore is generally used as back up protection.

**Expulsion Type of Lightning Arrester.** An improvement of the rod gap is the expulsion type which consists of i) a series gap (ii) external to the tube which is good enough to withstand normal system voltage, thereby there is no possibility of corona or leakage current across the tube; iii) a tube which has a fibre lining on the inner side which is a highly gas evolving material; iv) a spark gap (2) in the tube; and iv) an open vent at the lower end for the gases to be expelled.

The breakdown voltage of expulsion tubes is slightly lower than for plain rod gaps for the same spacing. with each operation of the tube the diameter of the tube increases; thereby the insulation characteristics of the tube will lower down even though not materially. The Volt-time characteristics of the expulsion tube

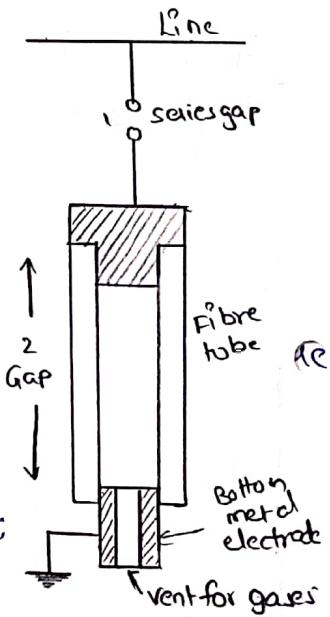


Fig: Expulsion type Lightning arrester.

are somewhat better than the rod gap and have the ability to interrupt power voltage after flashover. (4)

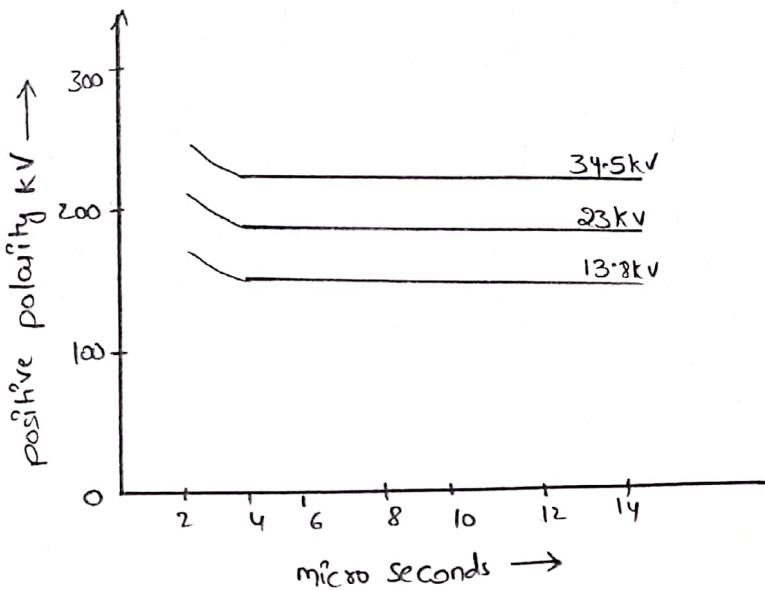


Fig: Volt-time characteristic of expulsion gaps.

**Valve Type Lightning Arresters:** An improved but more expensive surge diverter is the valve type of lightning arrestor or anode. A porcelain bushing contains a number of linear surge dividers. A porcelain bushing contains a number of series gaps, coil units and the valve elements of the non-linear resistance material usually made of silicon carbide disc, the latter possessing low resistance to high currents and high resistance to low currents. The characteristic is usually expressed as  $I = KV^n$ , where  $n$  lies between 2 and 6 and  $K$  is constant, a function of the geometry and dimension of the resistor. The high resistance keeps the inner assembly dry due to some heat generated.

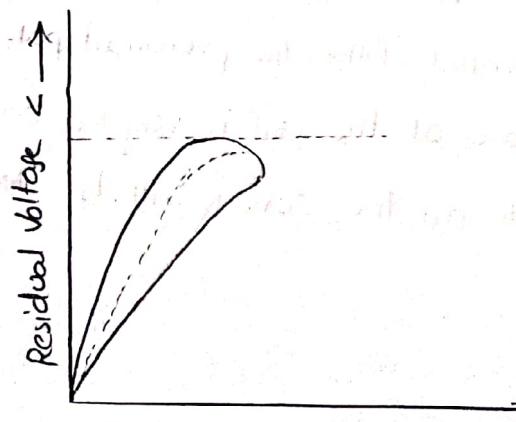


Fig: Volt-ampere characteristic of valve-type LA.

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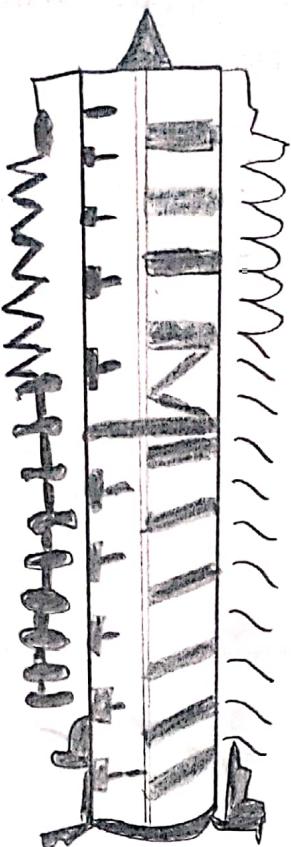


Fig: Valve-type lightning arrester.

The operation of the arrester can be easily understood with the help of figs. and when a surge voltage is incident at the terminal of the arrester it causes the two gap units to flashover, thereby a path is provided to the surge to the ground through the coil element and the non-linear resistor element. Because of the high frequency of the surge, the coil develops sufficient voltage across its terminals to cause the by-pass gap to flashover. With this the coil is removed from the circuit and the voltage across the LA is the IR drop due to the non-linear element. This condition continues till power frequency currents follow the preionized path. At power frequency the impedance of the coil is very low and, therefore, the arc will become unstable and the current will be transferred to the coil.

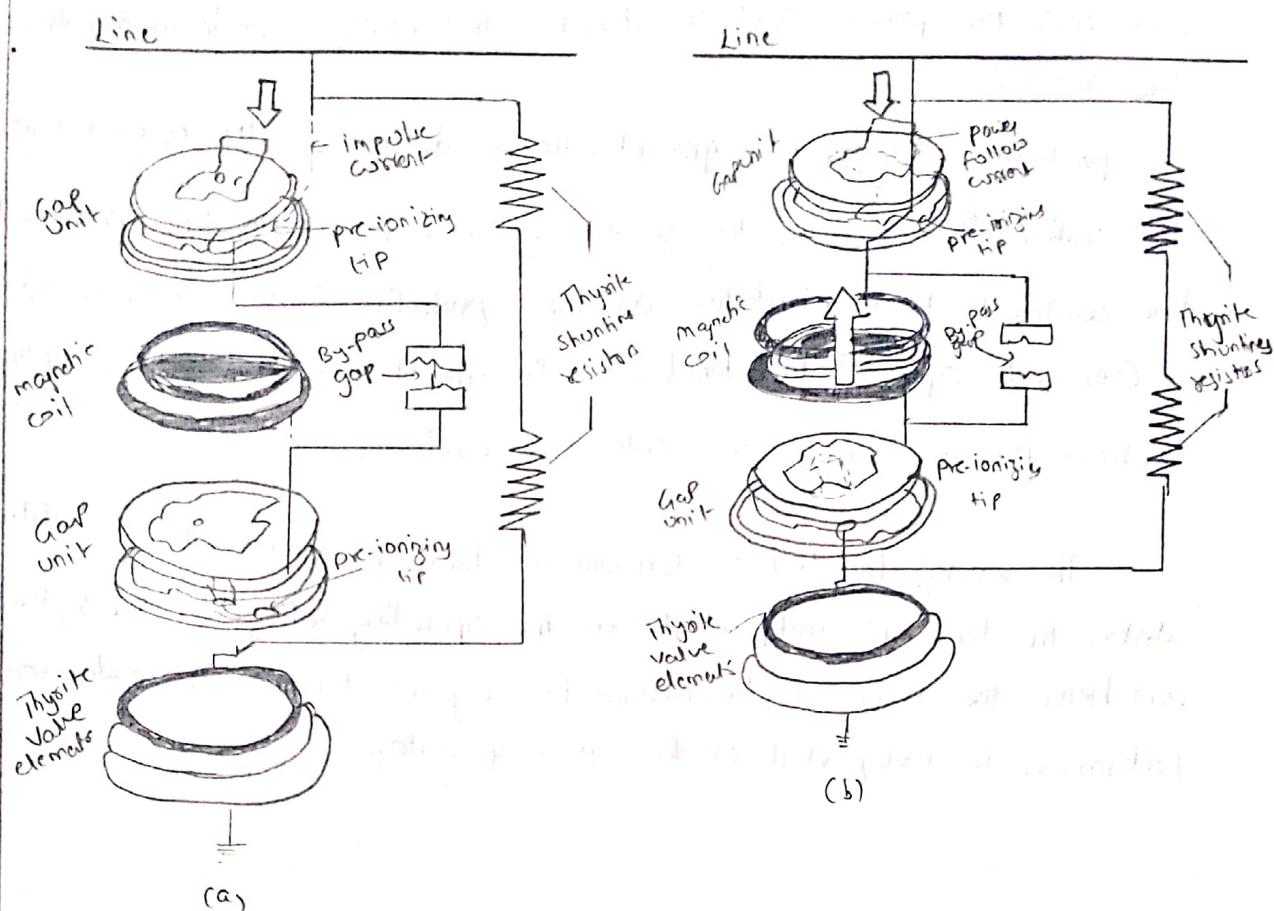


fig: schematic diagram of valve-type arrester indicating path of  
a) surge current b) follow current.

### Ground wires:

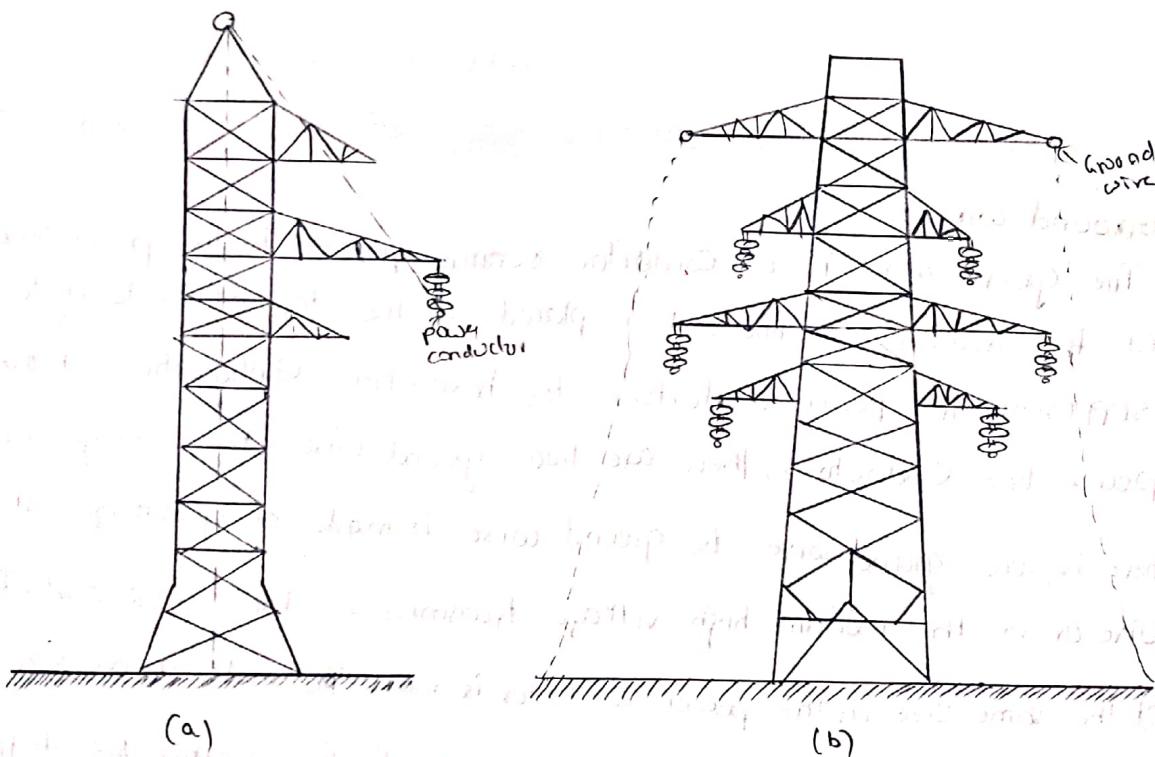
The ground wire is a conductor running parallel to the power conductors of the transmission line and is placed at the top of the tower structure supporting the power conductors. For horizontal configuration of the power line conductors, there are two ground wires to configuration. There is one ground wire. The ground wire is made of galvanized steel wire or in the modern high voltage transmission lines ACSR conductor of the same size as the power conductor is used. The material and size of the conductor are more from mechanical consideration rather than electrical. A reduction in the effective ground resistance can be achieved by other relatively simpler and cheaper means. The ground wire serves the following purposes:

- It shields the power conductors from direct lightning strokes.
- Whenever a lightning stroke falls on the tower, the ground wires on both sides of the tower provide parallel paths for the stroke, thereby the effective impedance (Surge impedance) is reduced and the tower top potential is relatively low.

less. iii) There is electric and magnetic coupling between the ground wire and the power conductors, thereby the chances of insulation failure are reduced.

protective angle of the ground wire is defined as the angle between the vertical line passing through the ground wire and the line passing through the outermost power conductor and the protective zone is the zone which is a cone with apex at the location of the ground wire and surface generated by lines passing through the outermost conductor.

The voltage to which a transmission tower is raised when a lightning strikes the tower, is independent of the operating voltage of the system and hence the design of transmission line against lightning for a desired performance is independent of the operating voltage.



(a) protective angle; (b) protection afforded by two ground wires.

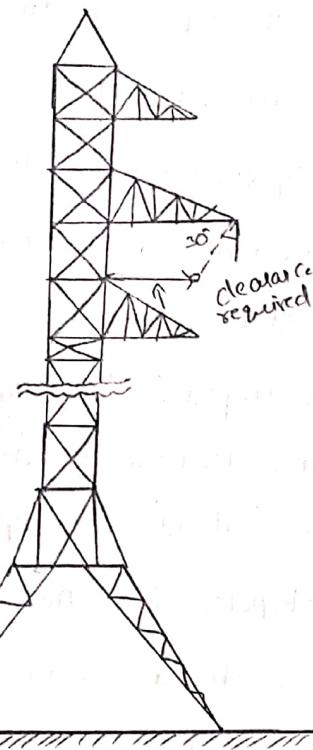


Fig: clearance determination or cross arm length determination.

### Ground rods:

Ground rods are used to reduce the tower footing resistance. These are put into the ground surrounding the tower structure. shows the variation of ground resistance with the length and thickness of the ground rods used. It is seen that the size (thickness) of the rod does not play a major role in reducing the ground resistance as does the length of the rod. Therefore, it is better to use thin but long rods over small rods.

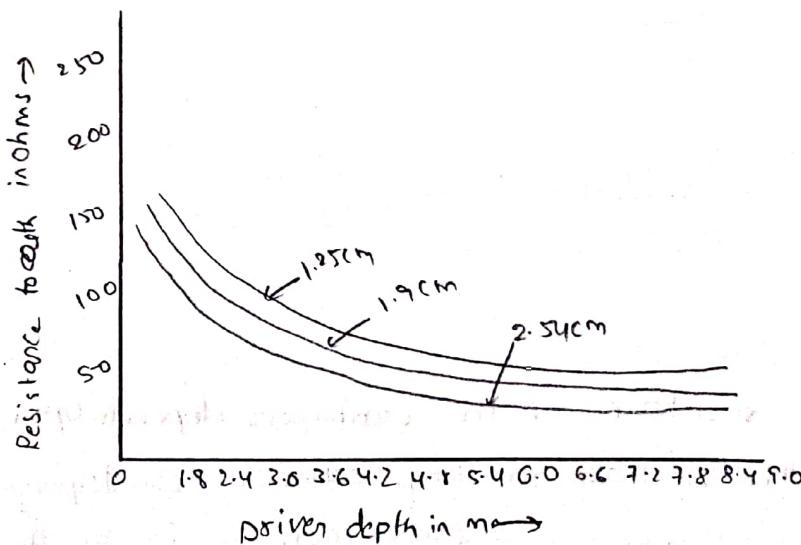


Fig: Ground rod resistance as a function of rod length.

## Counter poise:

A Counter poise is galvanised steel wire run in parallel or radial or a combination of the two, with respect to the overhead line. The various configurations used are shown in fig.

The corners of the squares indicate the location of the tower legs.

The lightning stroke as incident on the tower, discharges to the ground through the power and then through the counterpoises. It is the surge impedance of

the counterpoises which is important initially and once the surge has travelled over the counterpoise it is the leakage resistance of the counterpoise that is effective. While selecting a suitable counterpoise that is effective, while

Selecting a suitable counterpoise it is necessary to see that the leakage

resistance of the counterpoise should always be smaller than the surge impedance otherwise, positive reflections of the surge will take place and hence instead of lowering the potential of the tower it will be raised.

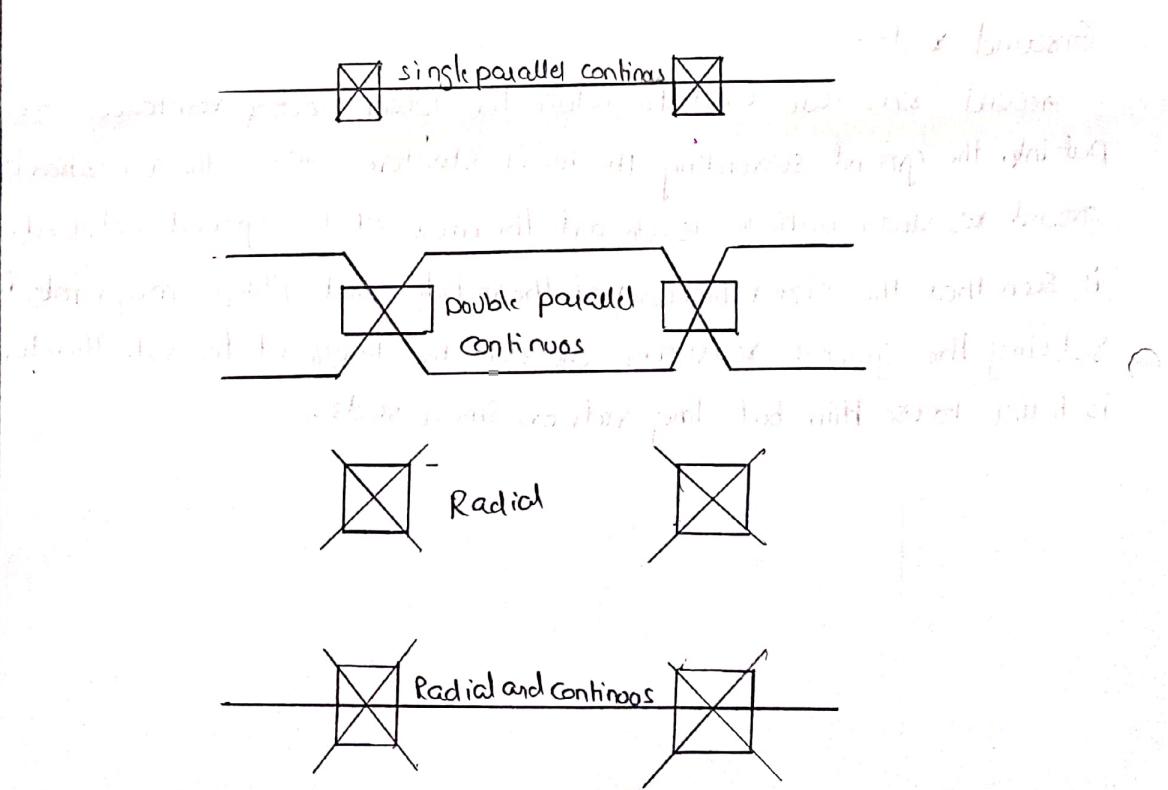


Fig: Arrangement of Counterpoise.

The leakage resistance of the counterpoise depends upon the surface area. i.e., whether we have one long continuous counterpoise say 1000m or four smaller counterpoise of 250m each, as far as the leakage resistance is concerned it is same, whereas the surge impedance of each as these four wires will now be concerned in parallel.

But we should not have too many short counterpoises, otherwise (7) the surge impedance will become smaller than the leakage resistance and positive reflections will occur.

**Surge absorbers:** A surge absorber is a device which absorbs energy contained in a travelling wave. Corona is a means of absorbing energy in the form of corona loss. Another method of absorbing energy is the use of Ferranti surge absorber which consists of an air core inductor connected in series with the line and surrounded by the earthed metallic sheet called a dissipator. The dissipator is insulated from the inductor by the air.

The surge absorber acts like an air

Coupled transformer whose primary is

the low inductance inductor and the dissipator

acts as the single turn short circuit secondary. Because of the series inductance, the steepness of the wave also is reduced.

It is claimed that the stress in the end turns is reduced by 15% with the help of surge absorber.

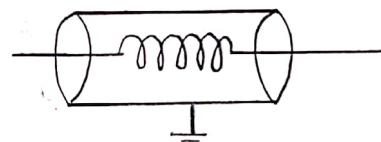


Fig: Ferranti surge absorber.