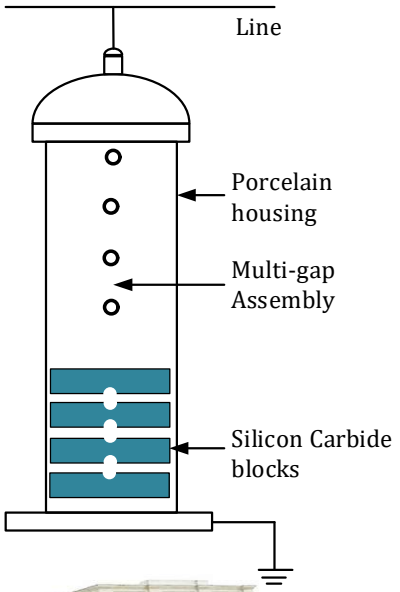
EEN-206: Power Transmission and Distribution

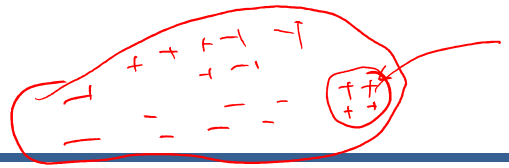
Lecture - 38



Chapter 6: Transients in Power System

- Protection from Over-voltages

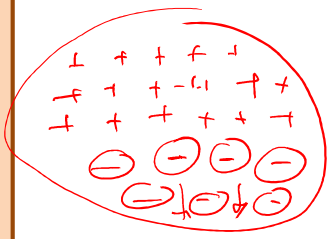
Wilson's Theory of Charge Accumulation



Polarization of large drops:
upper side –ve
Lower side +ve

Large drops comes down due to its weight than smaller droplets which fill air drag.

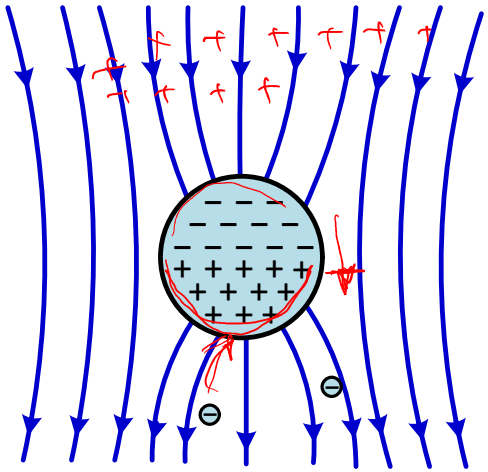
Selective a attraction of negative ions at undersurface of the water drop. No such attraction of positive ions at top surface.



So large drops carries negative charge and accumulate at lower portion of the cloud

Loss of negative ions from the atmosphere remaining small ions are predominantly positive

The smaller drops moving relatively slow acquires positive charges by impact



Simpson's and Scarse's Theory of Charge Accumulation

Region A: air velocity > 800 cm/sec. No rain drops can fall through this region. Only large drops may penetrate.

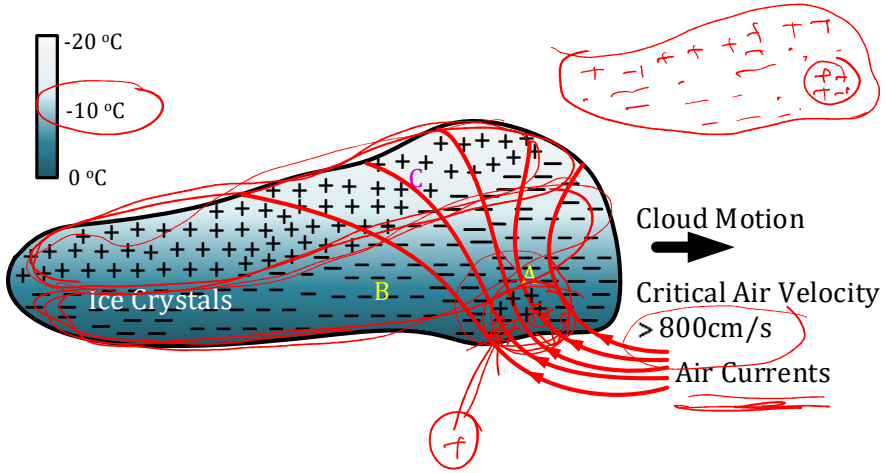
The larger drops will be broken into smaller droplets. Droplets becomes +ve charged and air becomes negatively charged.

Blown of particles recombine and again fall into region A and process of charging will continue.

Thus, region A will acquire intense +ve charge and region B above it will become negatively charged.

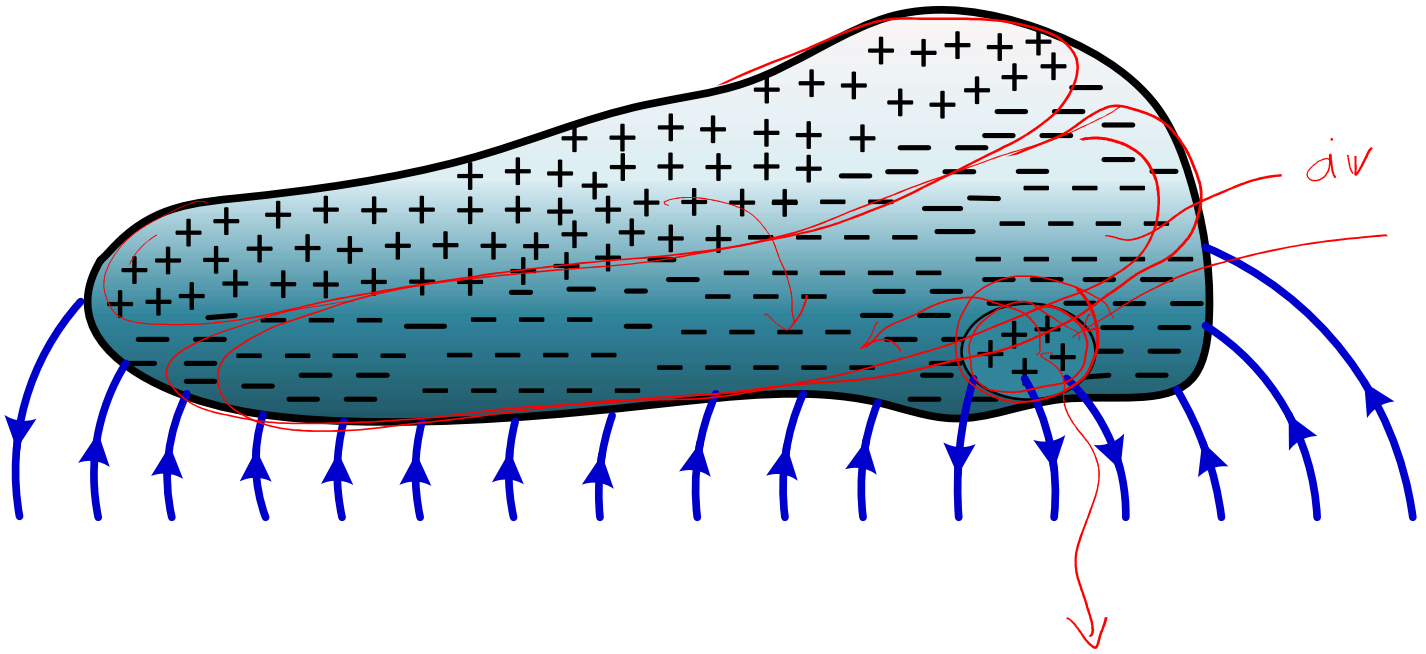
Upper region is at temperature below freezing and only ice crystals can exist.

The impact of air causes them to become negatively charged and air becomes positively charged (Region C).

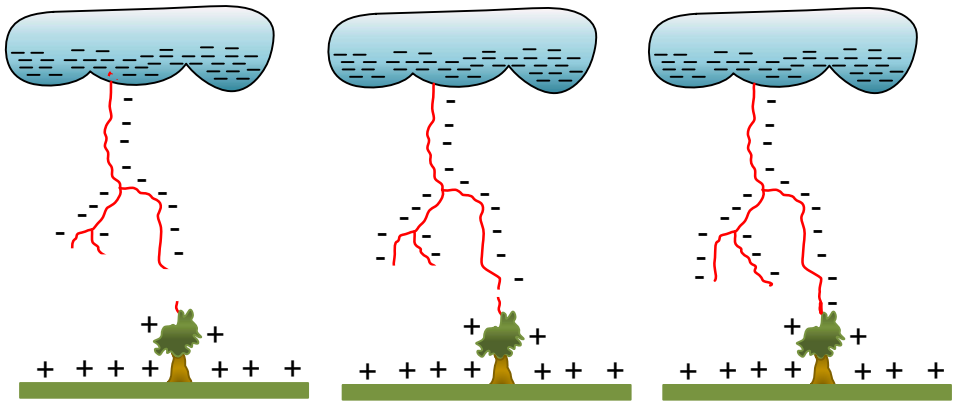


Ref: Subir Ray, *An introduction to High Voltage Engineering, PHI*, New Delhi, 2011.

Charge Distribution Inside the Cloud

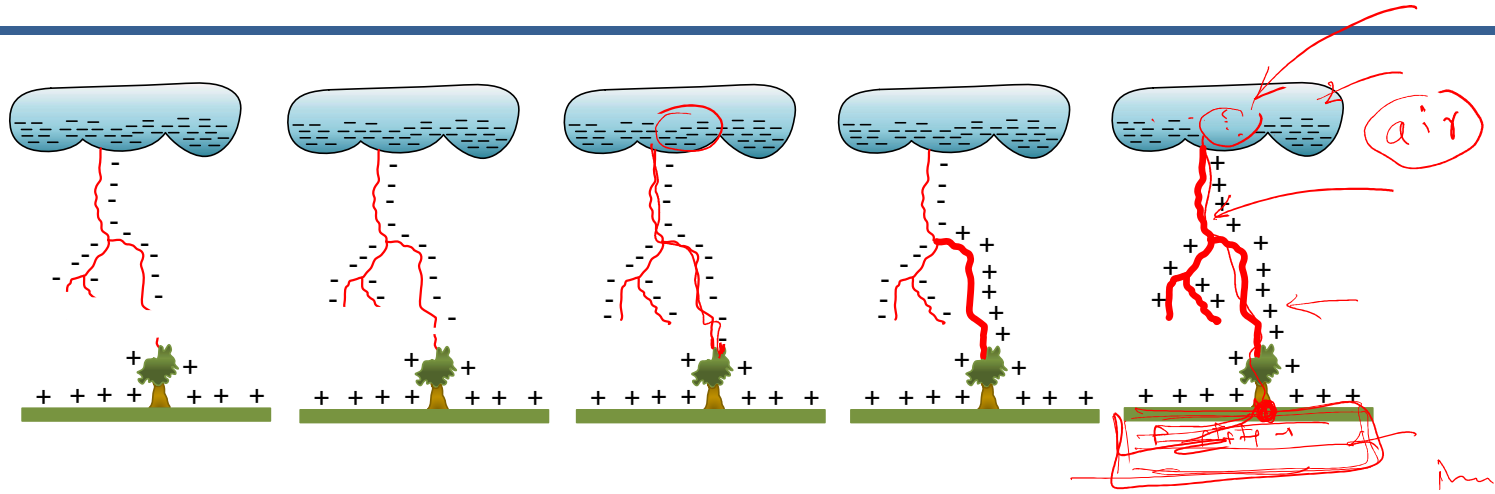


Mechanism of Lightning Stroke



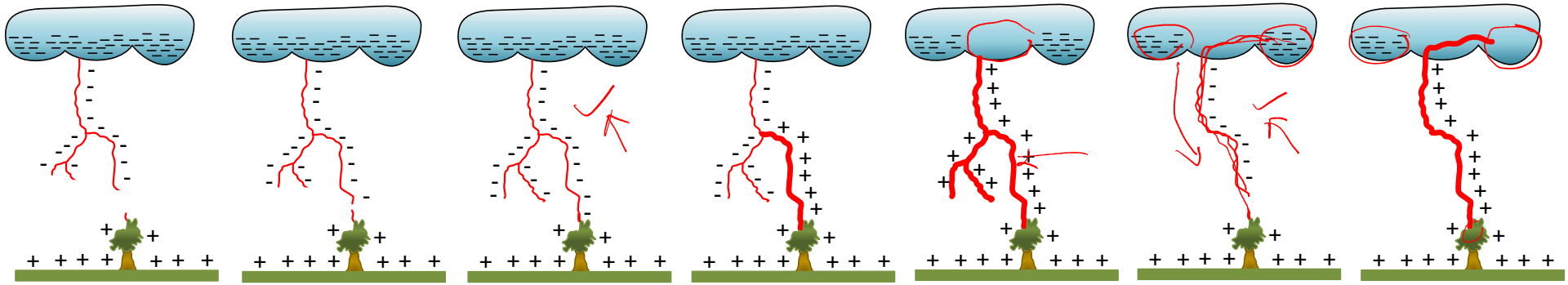
- **Propagation of stepped leader:** (10-20 ms)
  - Critical break down voltage 10 kV/cm for region occupied by the droplets.
  - Intense ionization starts taking place producing large number of electrons.
  - The ionized path offers a conducting channel. Streamer proceeds towards earth through quite torturous way depending upon the local conditions.
  - Streamer may contain many branches pointing towards the earth.
  - Since, it progresses with series of jumps it is known as stepped leader.

Mechanism of Lightning Stroke



- **Return Stroke: (50-100 μs)**
  - As leader travels down, the channel formed by it becomes equivalent to a good conductor carries considerable charge to the earth.
  - Lowering of channel intensifies the electric field on the earth.
  - When channel reaches to the ground , a positive streamer springs out of the ground (or other tall object) and rush upward. It is very fast and violent.
  - Heavy current (1 kA to > 20 kA) flows up the path blazed by stepped leader.
  - It neutralizes charge center in the cloud.

Dart Leader and Subsequent Return Stroke

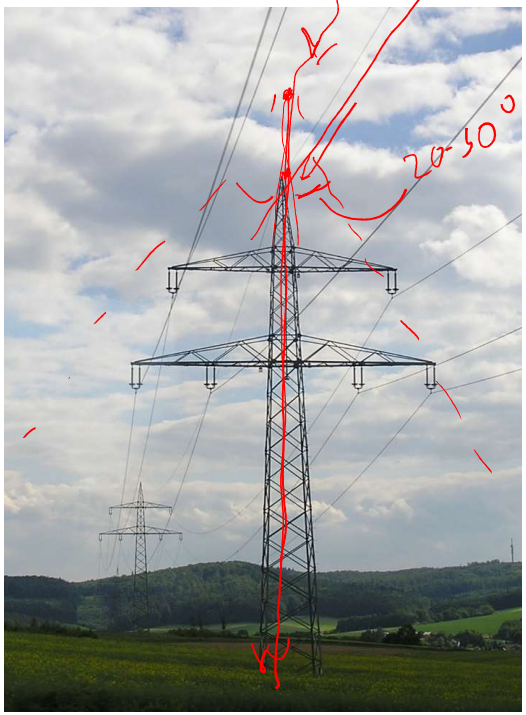


Stepped leader comes down in steps.
The light of return stroke flashes upward.

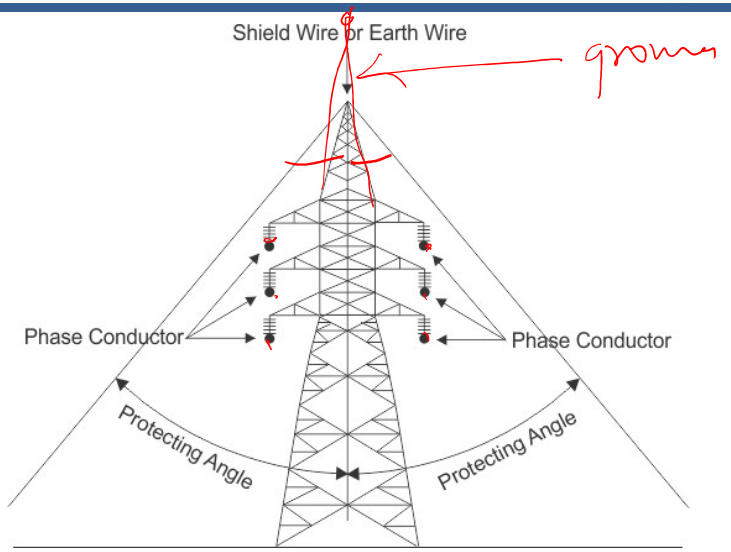
Dart leader comes down through the channel

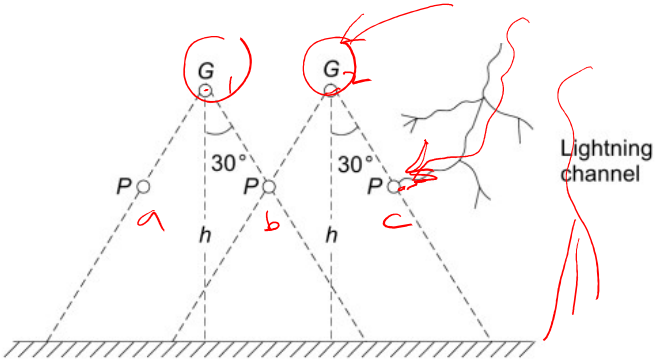
A second return stroke flashes upward

Protection of Transmission Line



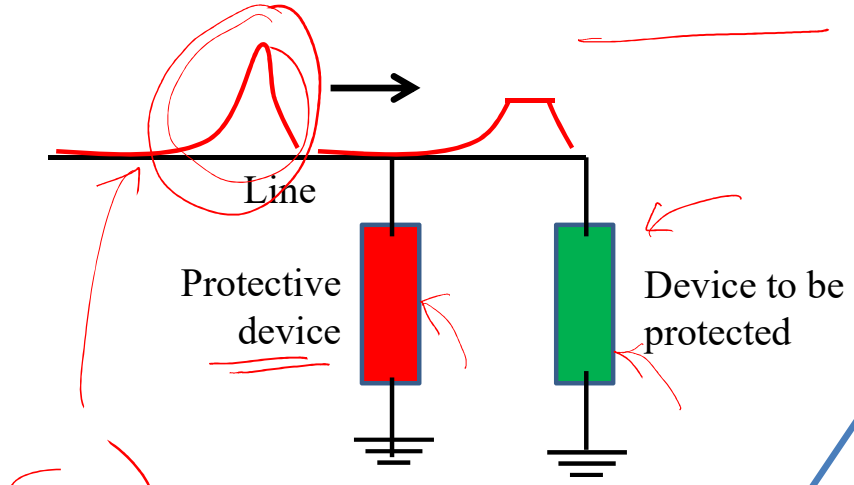
- It is attached from support to support above the transmission line and well grounded at regular interval.
- The protective angle is the angle between the vertical earth wire and the phase conductor which is to be protected.
- The angle between 20° and 30° is quite safe

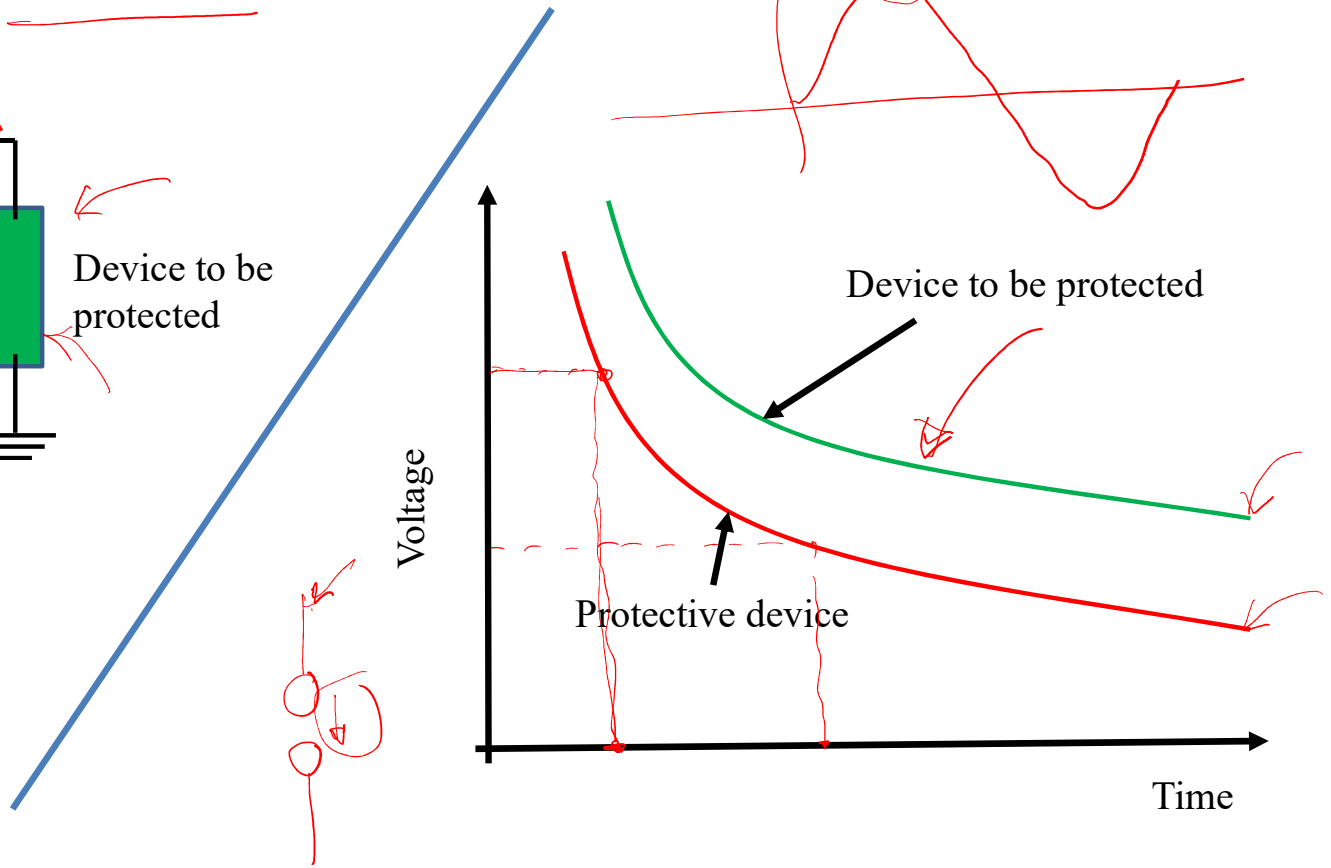




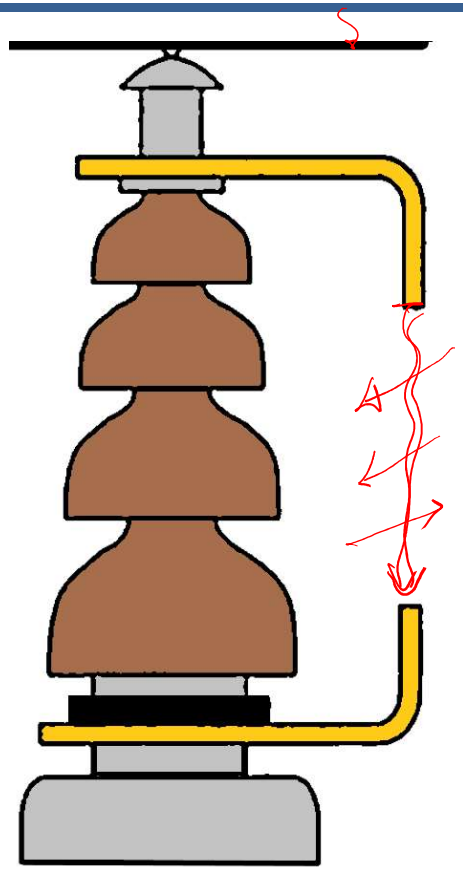
Ref. M. S. Naidu and V. Kamraju, *High Voltage Engineering, 2nd Edi., McGraw Hill, 1995.*

Characteristics of Surge Arresters or Diverters

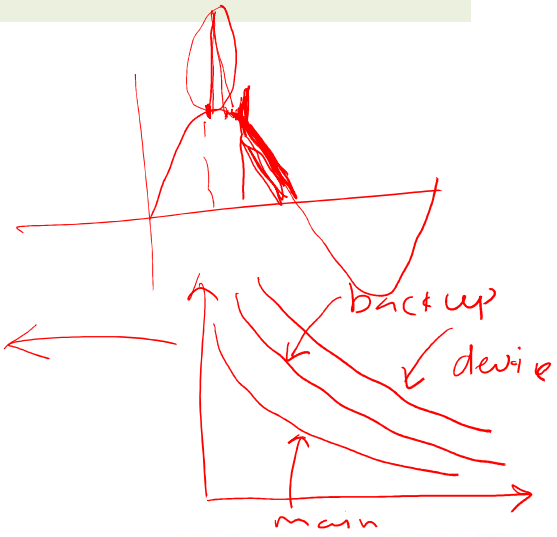




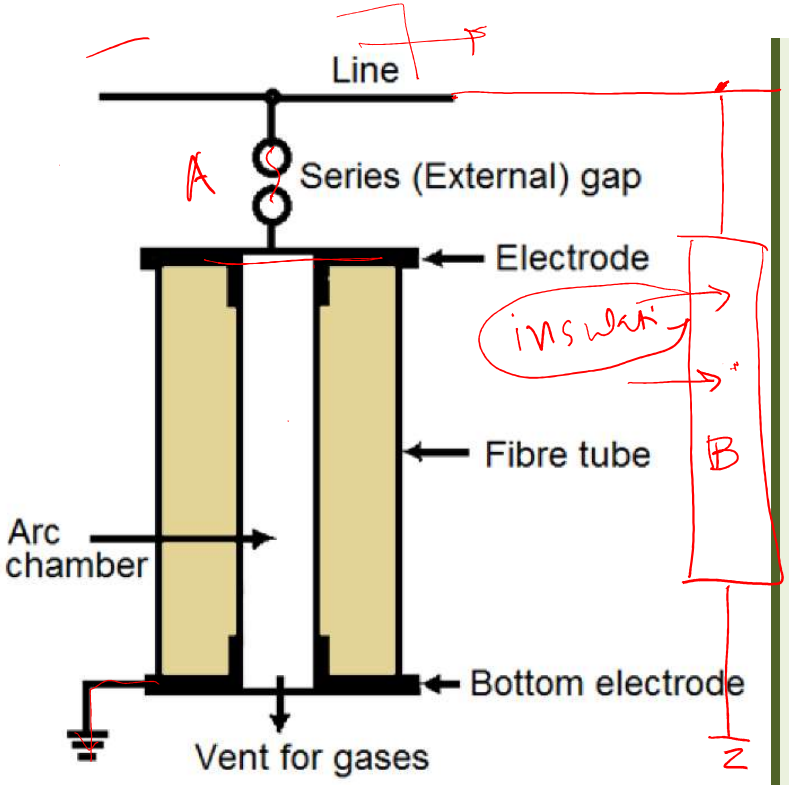
Rod Gap



- When surge voltage reaches the design value of the gap, arc appears in the gap providing ionized path to the ground.
- The power frequency current that flows after breakdown which can be only controlled by circuit breaker operation.
- Generally used as a backup protection. Normally, the setting of rod gap is kept 30% below the voltage withstand level of the equipment to be protected



Expulsion Type Arrester (Protector Tube)



- The tube has a fibre lining on the inner side which is a highly gas evolving material.
- It also has a spark gap in the tube and an open vent at the lower end for the gases to be expelled.
- It is desired that the breakdown voltage of a tube must be lower than that of the insulation for which it is used.
- When a surge voltage is incident on the expulsion tube the series gaps break down and an arc forms between the electrodes within the tube.
- The heat of the arc vaporizes some of the organic material of the tube wall causing a high gas pressure to build up in the tube.
- The resulting gas creates lot of turbulence within the tube and is expelled out from the open bottom vent.
- It extinguishes the arc at the first current zero.

Valve Type Arresters

- The valve elements of nonlinear resistance material usually made of silicon carbide discs.
- Spark gap consists of a number of similar gaps in series. Each gap consists of two electrodes with gap spacing.
- The voltage distribution across the gaps linearized by using additional resistors called grading resistors.
- The gap between two electrodes does not spark during normal voltage.
- But on the occurrence of the high surge, the air between the gaps breaks down forming an arc between electrodes.
- Nonlinear resistors offer high resistance to current at the normal operating voltage and very low resistance to surge current.

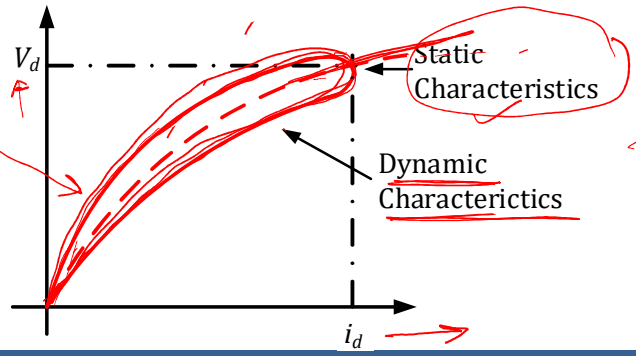
$$I = KV^{\alpha}$$

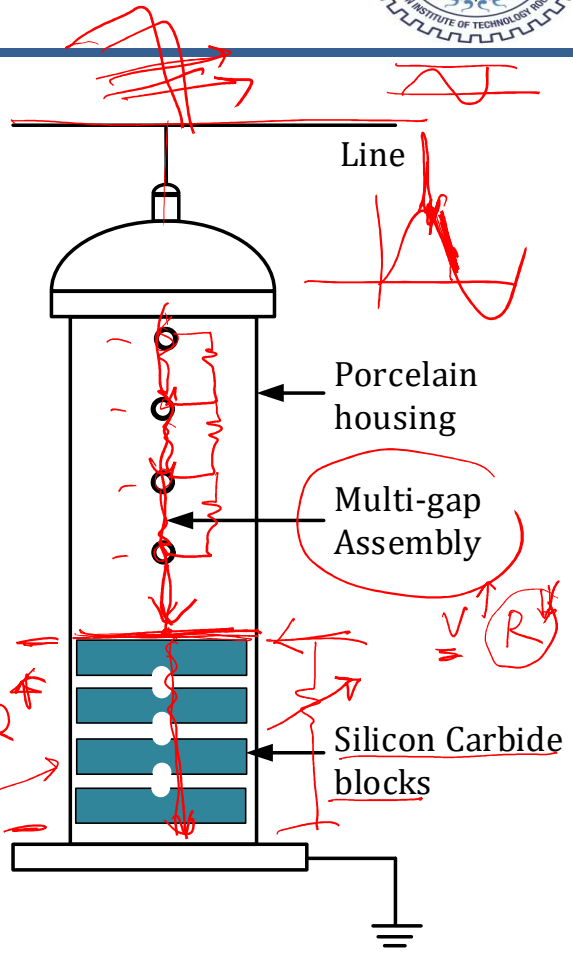
where I = discharge current

V = Voltage acorss element

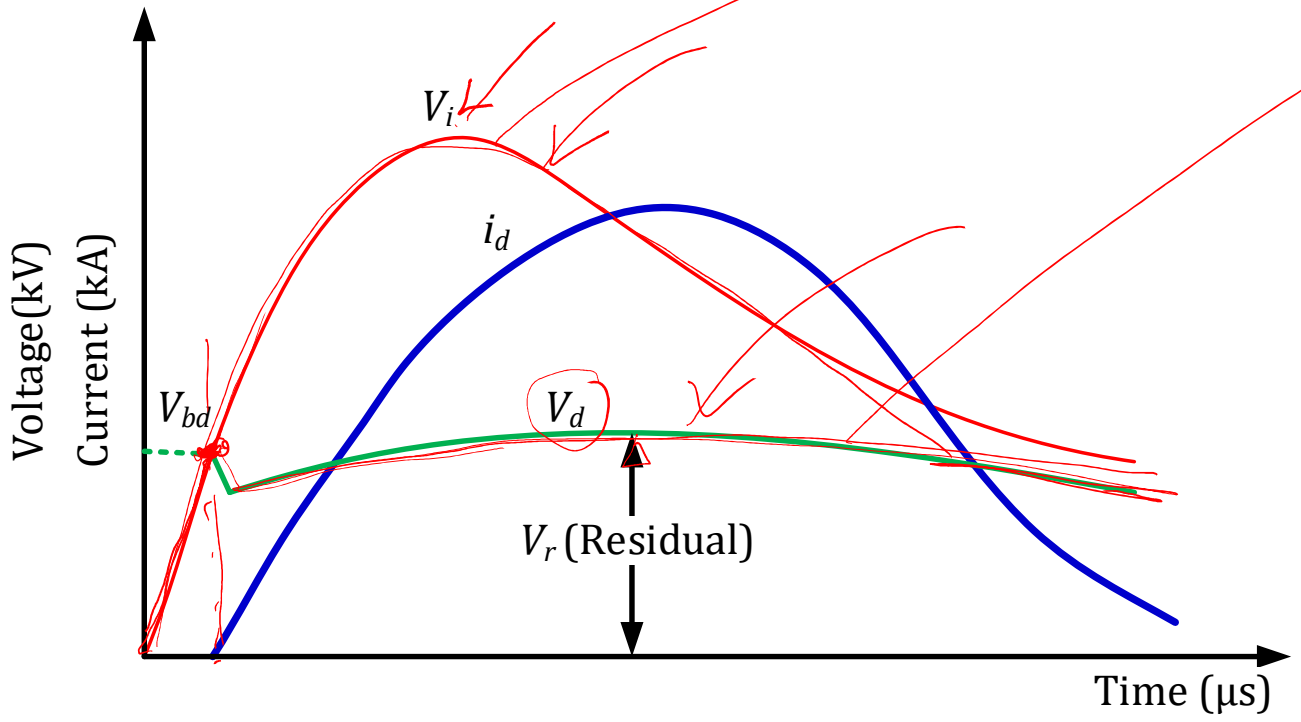
α = An exponent more than unity

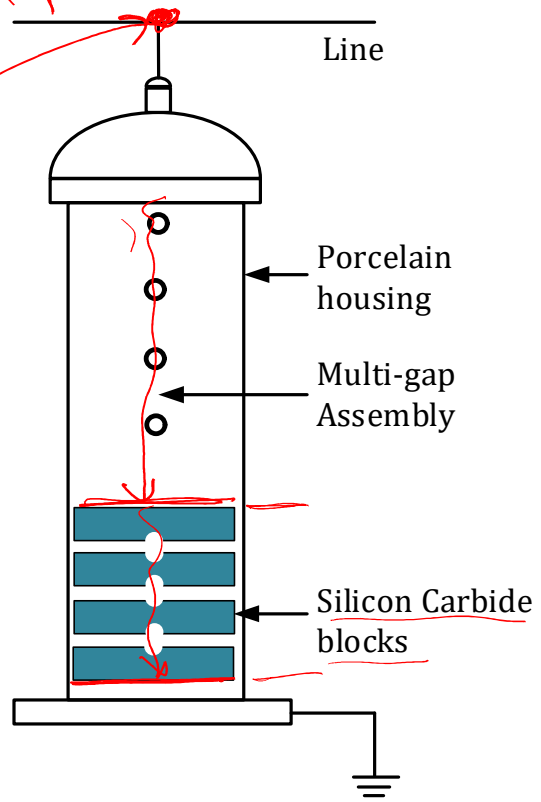
K = Constant





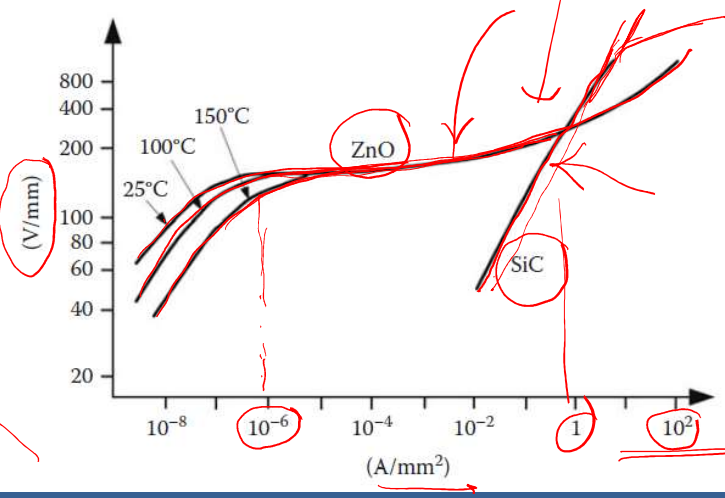
Surge Diverter Operation

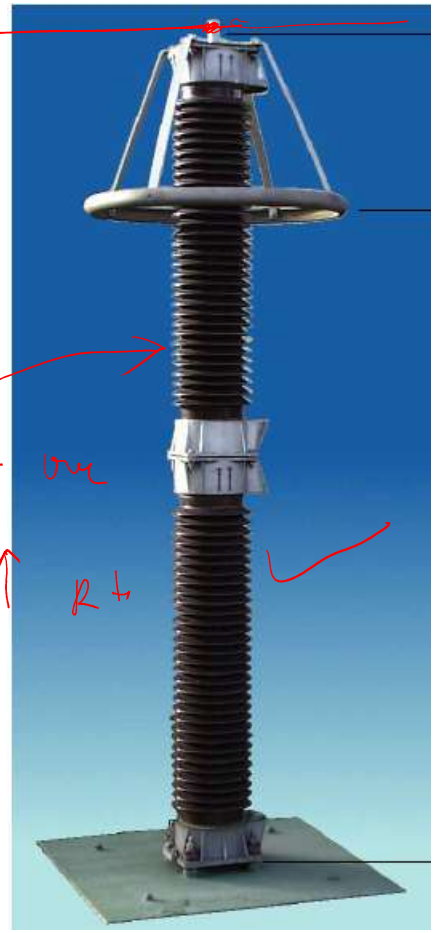




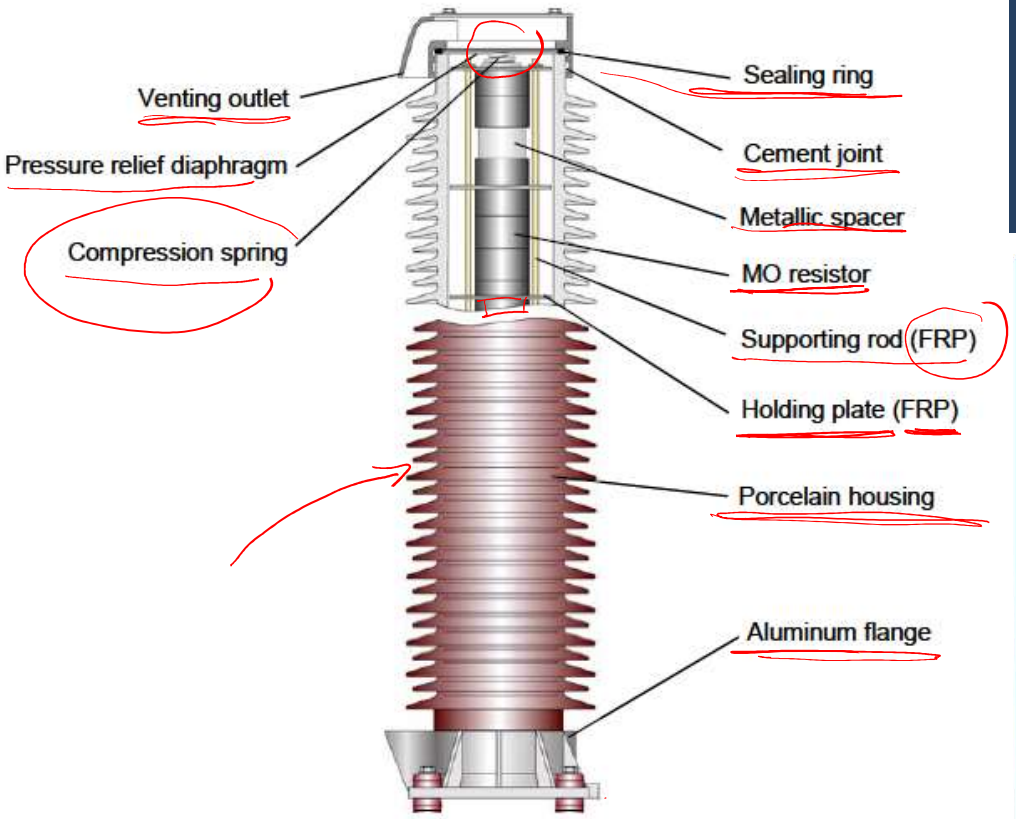
Metal-Oxide Surge Arresters (ZnO)

- This type of arrester comprises of numbers of solid zinc oxide disc.
- This discs are arranged one by one to form a cylindrical stack.
- The normal operation is defined as condition when no surge is presented and the surge arrester is subjected to normal system voltage only.
- The zinc oxide has highly non-uniform current voltage (I-V) characteristics.
- This typical I-V characteristic makes zinc oxide very suitable for designing gap less zinc oxide lightning arrester for surge protection.
- This stack is kept inside a cylindrical housing of polymer or porcelain.

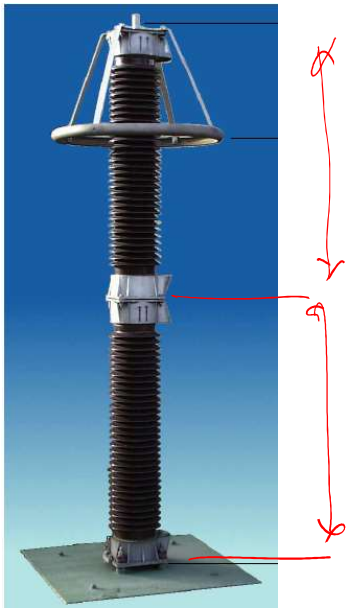


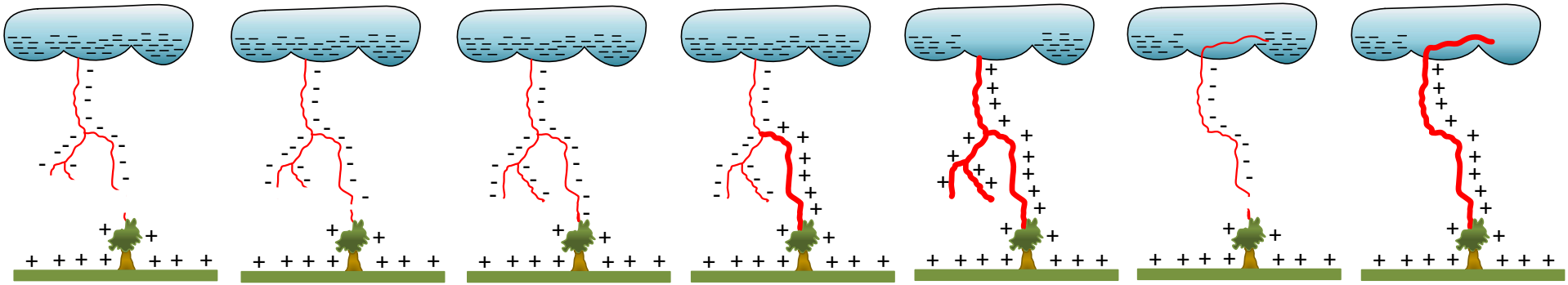


Gapless Metal Oxide Arresters



- The number of zinc oxide discs used per lightning arrester depends upon the voltage rating of the system.
- Then the stack is placed inside the housing and highly pressed by heavy spring load attached to end cap at top.





Thank You