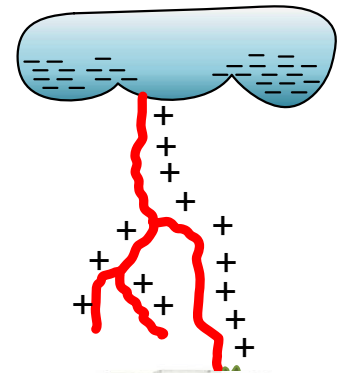


EEN-206: Power Transmission and Distribution

Lecture - 37

Chapter 6: Transients in Power System

- Lightning phenomena
- Protection from Over-voltages



Lightning

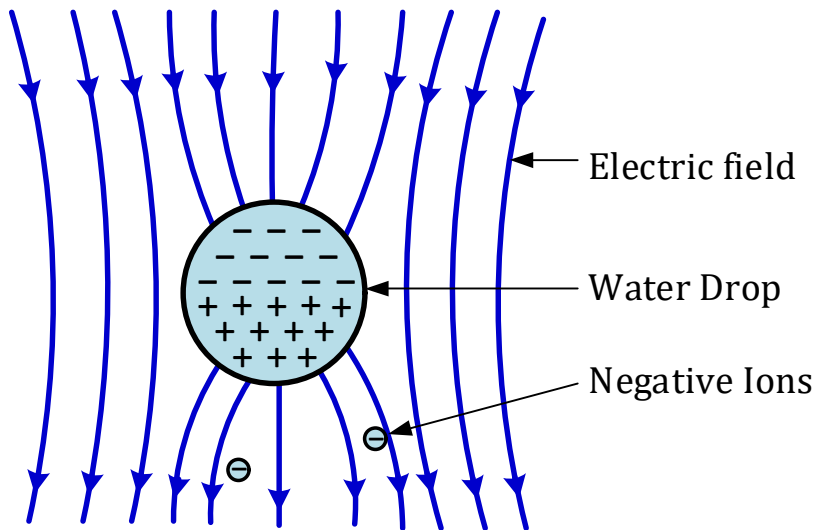


- Lightning has been source of wonder to mankind for thousands of years.
- Lightning is nothing but breakdown of very long air gap under highly uniform field conditions.
- An electric discharge between cloud to earth, between clouds or between charge centers of same cloud is known as lightning.
- The mechanism by which charge accumulation takes place in cloud is not yet fully known.
- This is short time discharge which neutralizes the charge accumulated in the atmosphere.
- Lightning is one of the source of over-voltages in power system.
- If it terminates on power lines or near power line create problems for power engineers.
- Lightning is single greatest cause of outages on transmission sector.



- Height of cloud: 500 to 30000 ft
- Charge centers for lightning: 1000 to 5000 ft
- Charge in cloud: About 10 C and builds seconds to minutes
- Cloud potential: 10 MV to 100 MV
- Energy: 250 kWhr

Charge Accumulation in Clouds

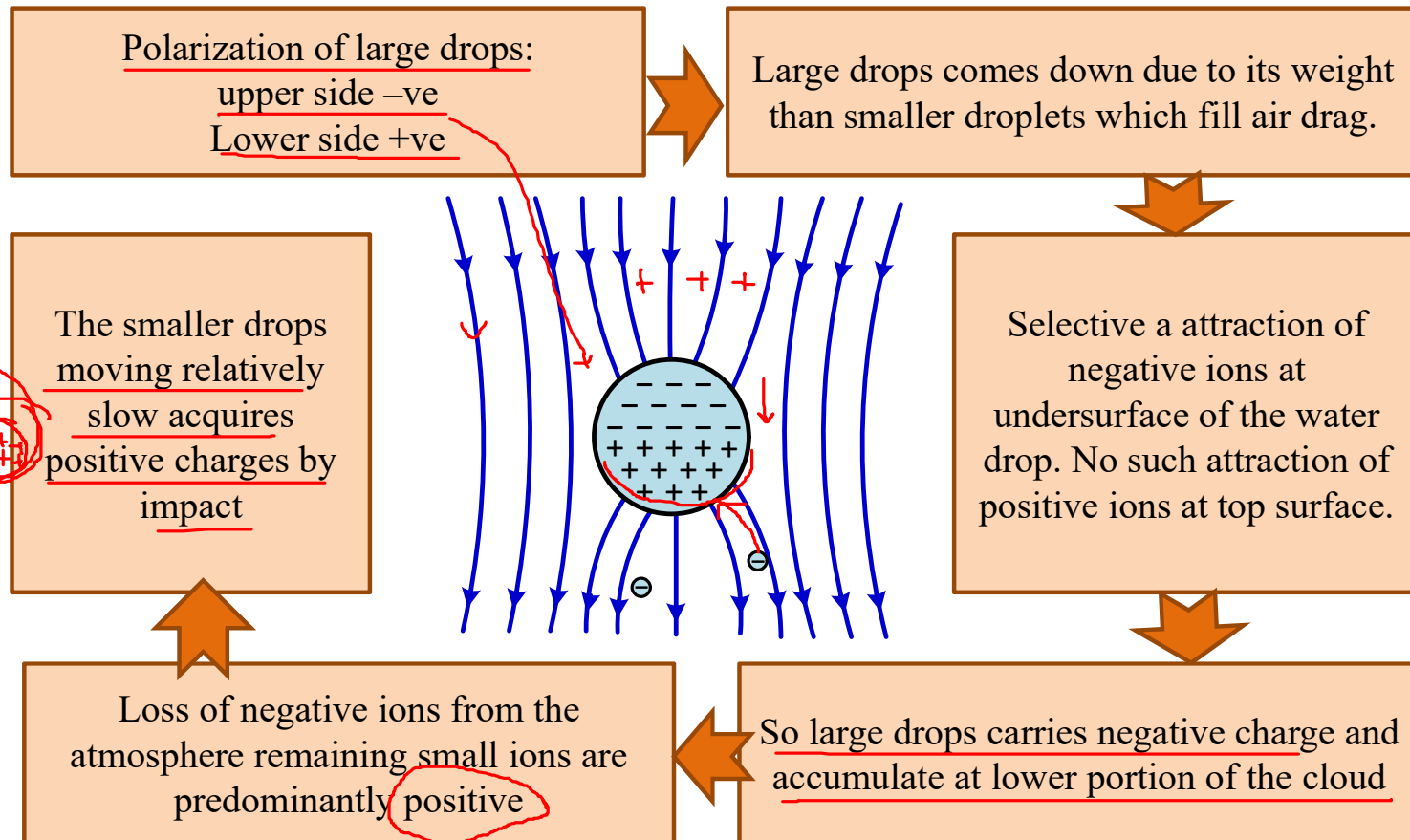


• Wilson's Theory

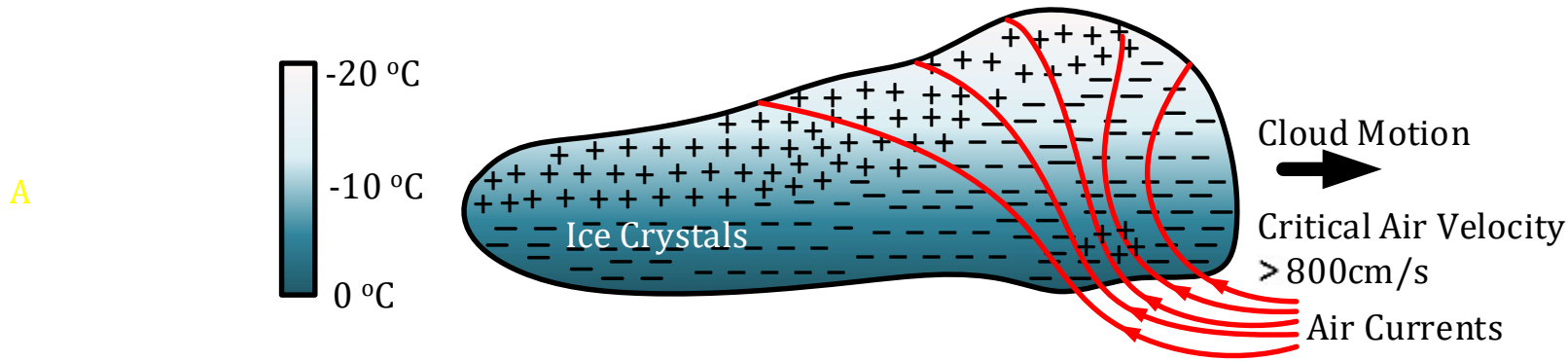
- Droplet Size: There is limitation on water drop size in presence of electric field. No droplet of more than 0.3 cm can exist in the field of 10 kV/cm
- Presence of Electric field on earth: there exists electric field in the atmosphere directed downward in fair weather conditions (1-0.02 V/cm from earth surface to 10000m)

- Large number of ions (+ve and -ve) are present (due to cosmic radiation) in atmosphere having neutral space charge. These ions attach themselves to dust particles and water drops to form large ions. Large ions has mobility 4-10 cm/sec under 1V/cm field.

Wilson's Theory of Charge Accumulation

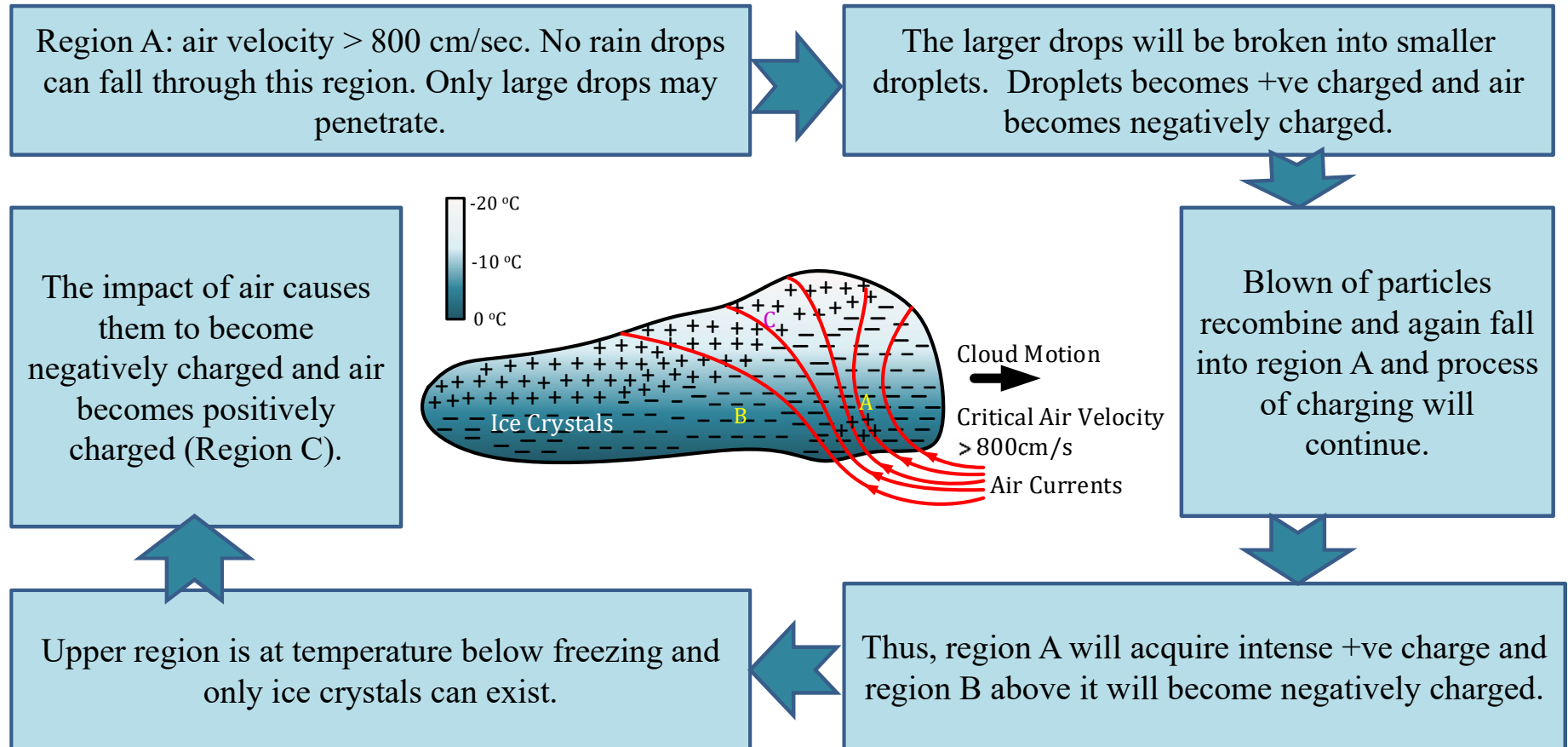


Simpson's and Scarse's Theory of Charge Accumulation

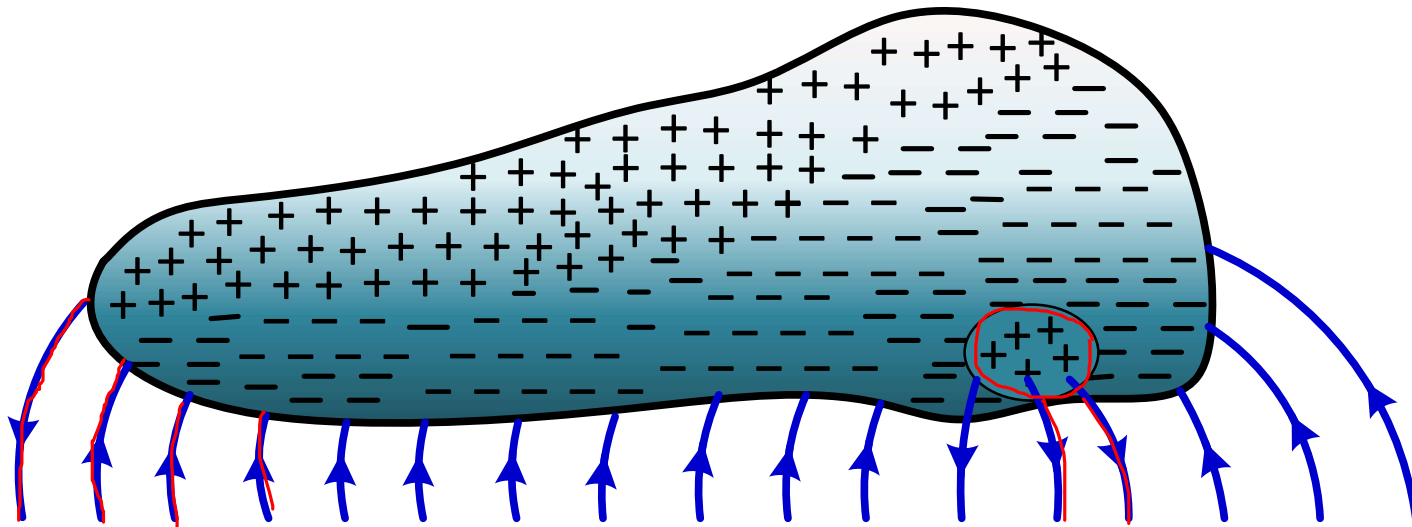


- Large droplets ($> 0.5 \text{ cm}$) will be broken forming smaller droplets.
- No rain drop (0.5 cm) will fall on earth if air velocity is more than 800 cm/s . It is blown up and broken into small droplets.
- In this process, water drop becomes positively charged and air becomes negatively charged.
- Cloud temperature is well below freezing point in upper region. The rain drops freeze into ice crystals. Action of wind causes the ice to become negatively charged and air to be positively charged.

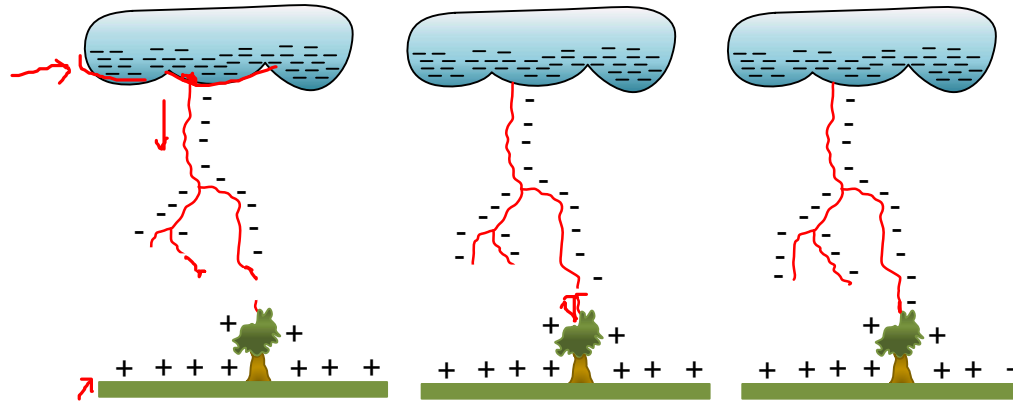
Simpson's and Scarse's Theory of Charge Accumulation



Charge Distribution Inside the Cloud



Mechanism of Lightning Stroke

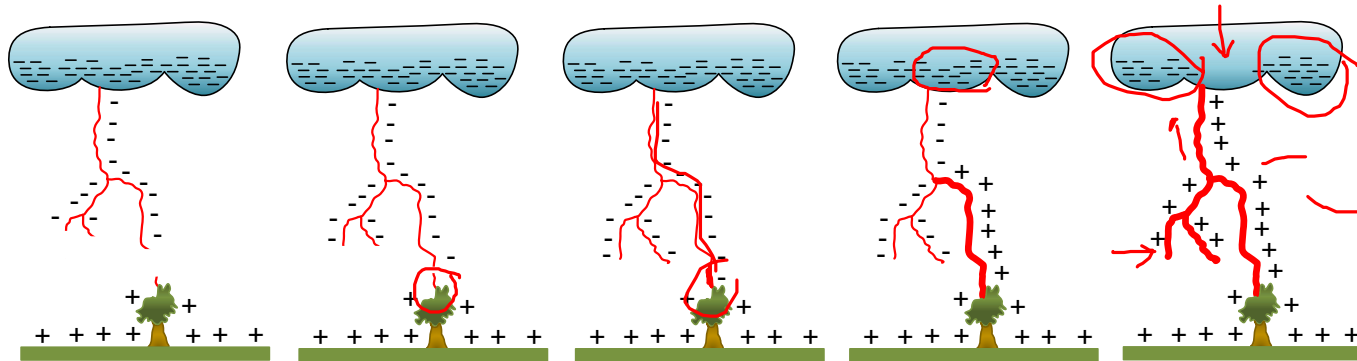


30kV
2ms

▪ 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.

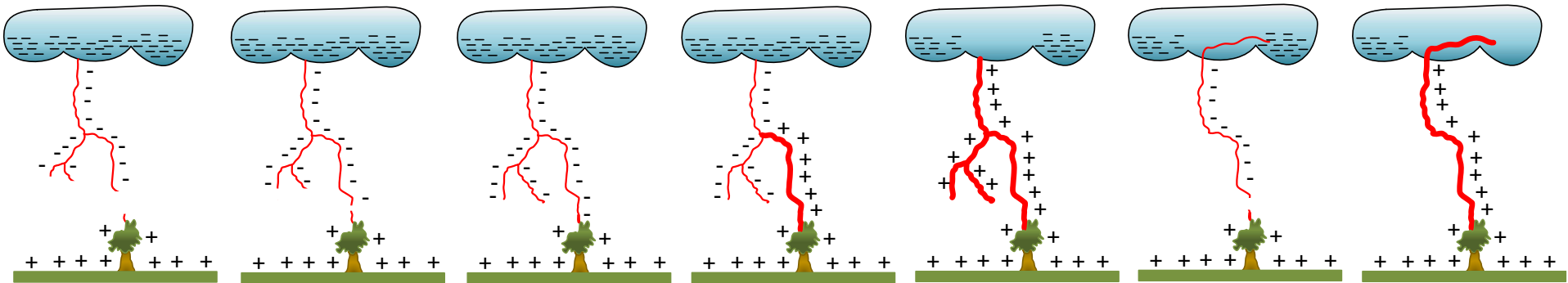
Mechanism of Lightning Stroke



- **Return Stroke: (50-100 μ s)**

- 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

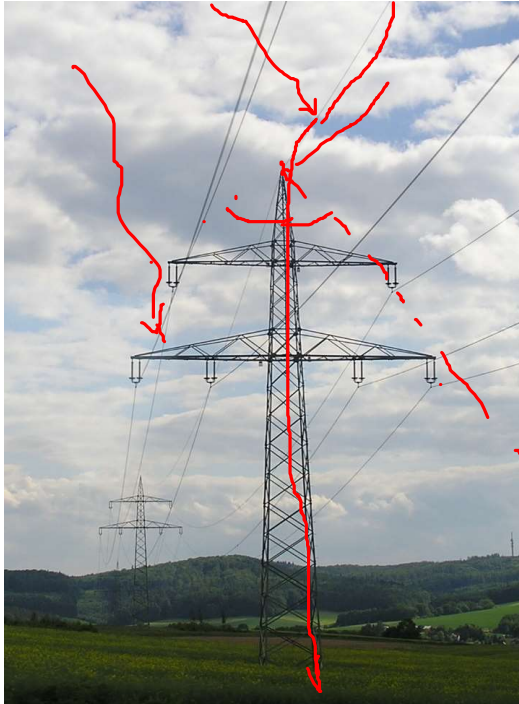


Stepped leader comes down in steps.
The light of return stroke flashes upward.

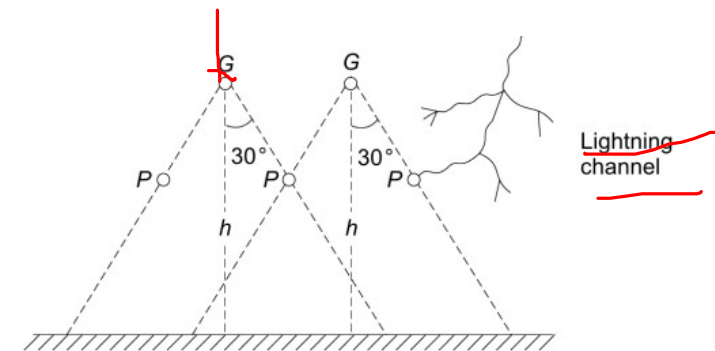
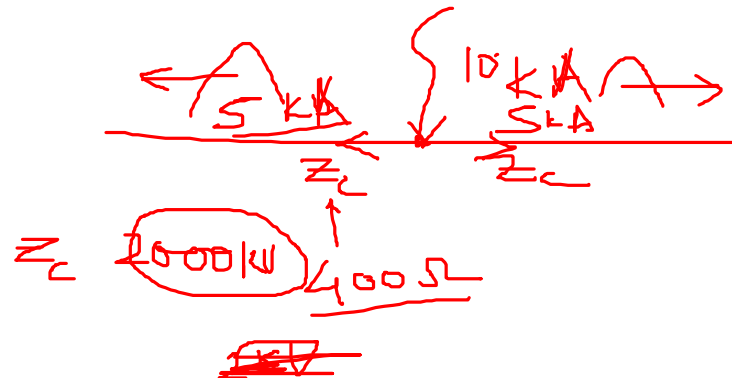
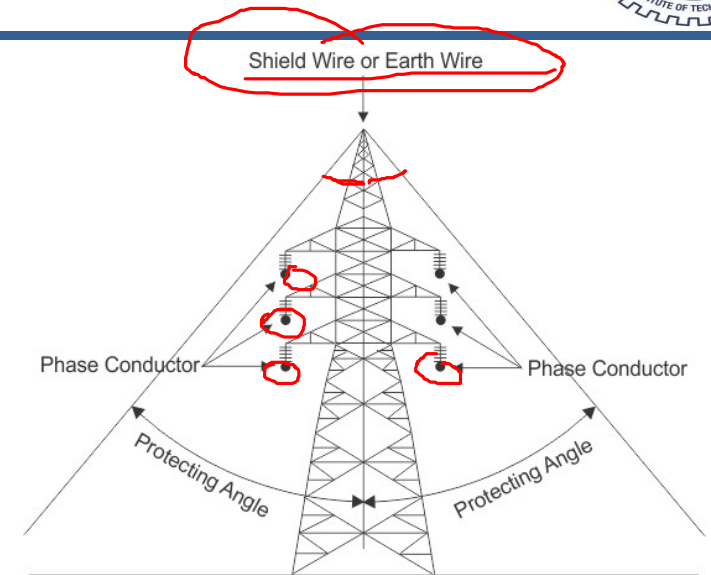
Dart leader
comes down
through the
channel

A second
return stroke
flashes
upward

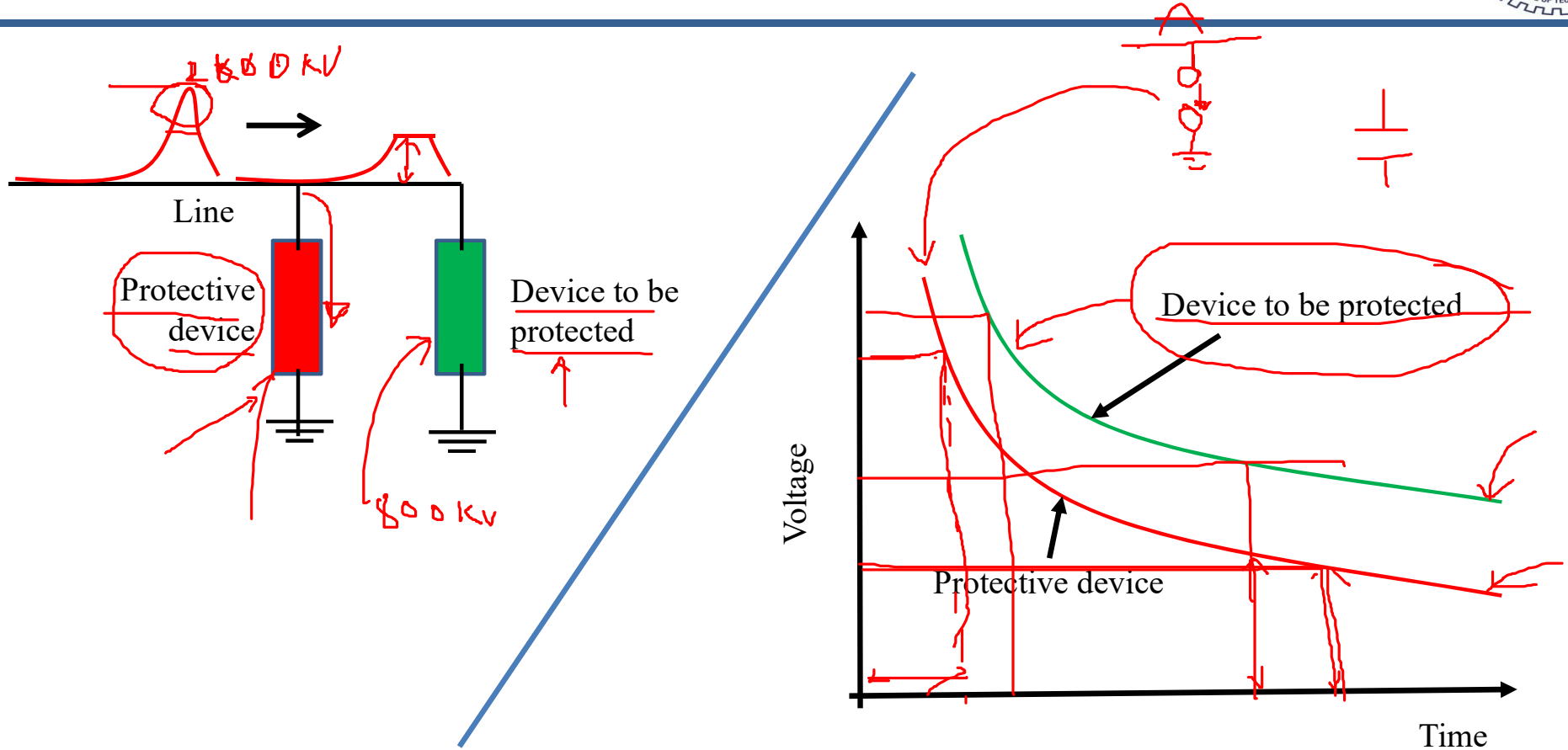
Protection of Transmission Line



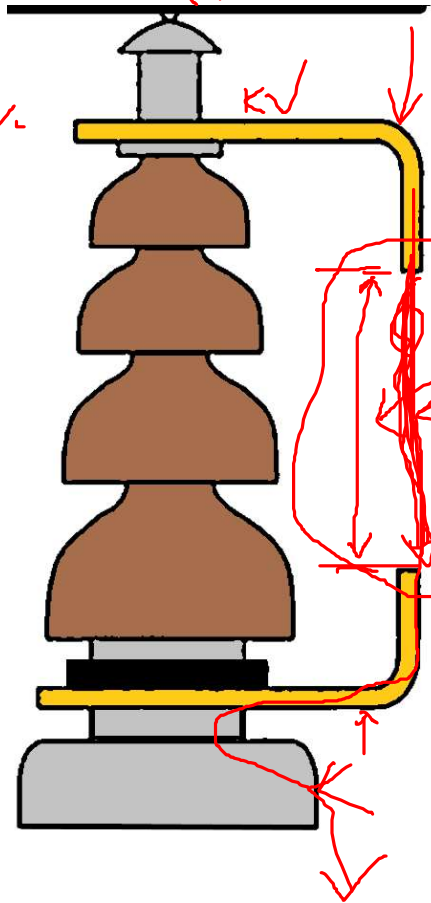
- It is attached from support to support above the transmission line and well grounded at regular interval.
- The protective angle is the angle between the vertical earth wire and the phase conductor which is to be protected.
- The angle between 20° and 30° is quite safe



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



A large graphic with the words "Thank You" in a bold, green, sans-serif font. The text is centered between two stylized blue clouds. Each cloud has a yellow lightning bolt pointing downwards and several blue raindrops falling from its base. The background of the graphic is a light blue with a fine, diagonal line pattern.

Thank You