CAUSES OF OVER VOLTAGES AND ITS EFFECT ON POWER SYSTEMS

Examination of over voltages on the power system includes a study of their magnitudes, shapes, durations, and frequency of occurrence. The study should be performed at all points along the transmission network to which the surges may travel.

Types of Overvoltage

- The voltage stresses on transmission network insulation are found to have a variety of Origins.
- In normal operation AC (or DC) voltages do not stress the insulation severely.
- Over voltage stressing a power system can be classified into two main types:

External overvoltage: generated by atmospheric disturbances of these disturbances, lightning is the most common and the most severe. **Internal over voltages**: generated by changes in the operating conditions of the network.

Lightning Over voltages

Lightning is produced in an attempt by nature to maintain dynamic balance between the positively charged ionosphere and the negatively charged earth.

Over fair-weather areas there is a downward transfer of positive charges through the global air-earth current. This is then counteracted by thunderstorms, during which positive charges are transferred upward in the form of lightning. During thunderstorms, positive and negative charges are separated by the movements of air currents forming ice crystals in the upper layer of a cloud and rain in the lower part.

The cloud becomes negatively charged and has a larger layer of positive charge at its top. As the separation of charge proceeds in the cloud, the potential difference between the centers of charges _increases and the vertical electric field along the cloud also increases. The total potential difference between the two main charge centers may vary from l00 to 1000 MV. Only a part of the total charge-several hundred coulombs is released to earth by lightning; the rest is consumed in inter cloud discharges. The height of the thundercloud dipole above earth may reach5 km in tropical regions. Established by a stepped discharge called a leader stroke. The leader is initiated by a breakdown between polarized water droplets at the cloud base caused by the high electric field, or a discharge between the negative charge mass in the lower cloud and the positive charge pocket below it. (Figure 1.2) As the downward leader approaches the earth, an upward leader begins to proceed from earth before the former reaches earth. The upward leader joins the downward one at a point referred to as the striking point. This is the start of the return stroke, which progresses upward like a travelling wave on a transmission line.

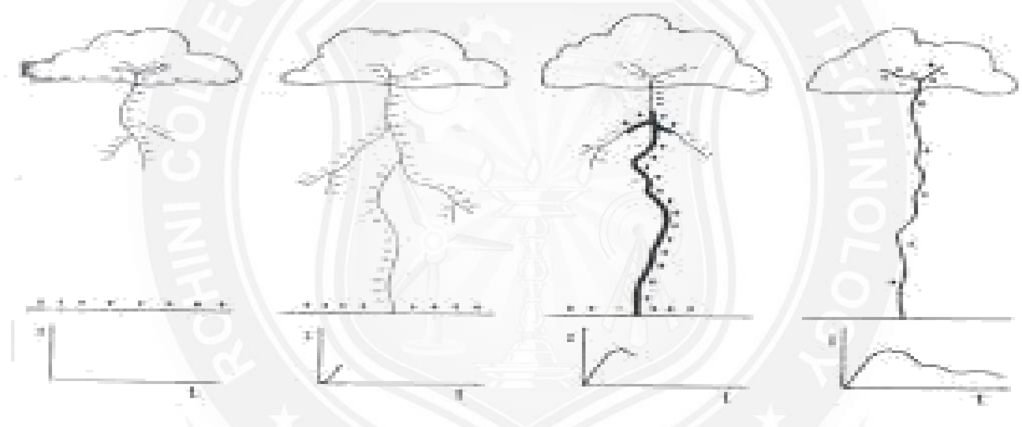

Figure: 1.2.1 Developmental Stages Of A Lighting Flash And The Corresponding Current Surge

[Source: "High Voltage Engineering" by C.L. Wadhwa, page: 56]

LIGHTNING PHENOMENON

At the earthling point a heavy impulse current reaching the order of tens of kilo amperes occurs, which is responsible for the known damage of lightning. The velocity of progression of the return stoke is very high and may reach half the speed of light. he corresponding current.

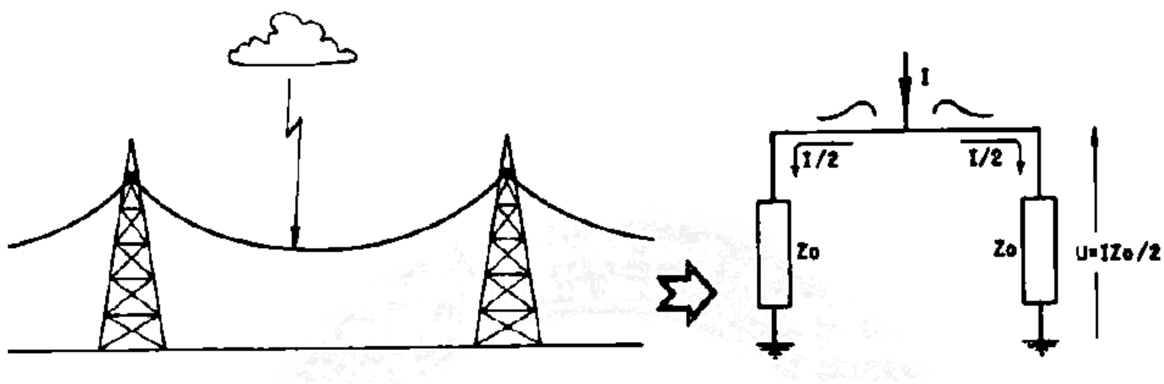

Figure 1.2.2 Developmental Lighting over voltage

[Source: "High Voltage Engineering" by C.L. Wadhwa, page: 59]

EFFECT OF LIGHTNING

The impedance of the lightning channel itself is much larger than 1/2Zo (it is believed to range from l00to 3000 Ω).

- Lightning voltage surge will have the same shape characteristics.
- In practice the shapes and magnitudes of lightning surge waves get
- modified by their Reflections at points of discontinuity as they travel along
- transmission lines.
- Lightning strokes represent true danger to life, structures, power systems, and Communication networks.

Lightning is always a major source of damage to power systems where equipment Insulation may break down, under the resulting overvoltage and the subsequent high- Energy discharge.

Lightning has been a source of wonder to mankind for thousands of years. Scotland points out that any real scientific search for the first time was made into the phenomenon of lightning by Franklin in18th century. Before going into the various theories explaining the charge formation in a thunder cloud and the mechanism of lightning, it is desirable to review some of the accepted facts concerning the thunder.

Raindrops elongate and become unstable under an electric field, the limiting diameter being0.3 cm in a field of 100 kV/cm. A free falling raindrop attains a constant velocity with respect to the air depending upon its size. This velocity is 800 cms/sec. for drops of the size 0.25 cm dia. and is zero for spray. This means that in case the air currents are moving upwards with a velocity greater than 800 cm/sec, no rain drop can fall. Falling raindrops greater than 0.5 cm in dia become unstable and break up into smaller drops. When a drop is broken up by air currents, the water particles become positively charged and the air negatively charged. When ice crystal strikes with air currents, the ice crystal is negatively charged and the air positively charged.

Wilson’s Theory of Charge Separation Wilson‘s theory is based on the assumption that a large number of ions are present in the atmosphere. Many of these ions attach themselves to small dust particles and water particles. It also assumes that an electric field exists in the earth‘s atmosphere during fair weather which is directed downwards towards the earth (Figure.1.4 (a)). The intensity of the field is approximately 1 volt/cm at the surface of the earth and decreases gradually with height so that at 9,500 m it is only about 0.02 V/cm. A relatively large raindrop (0.1 cm radius) falling in this field becomes polarized, the upper side acquires a negative.

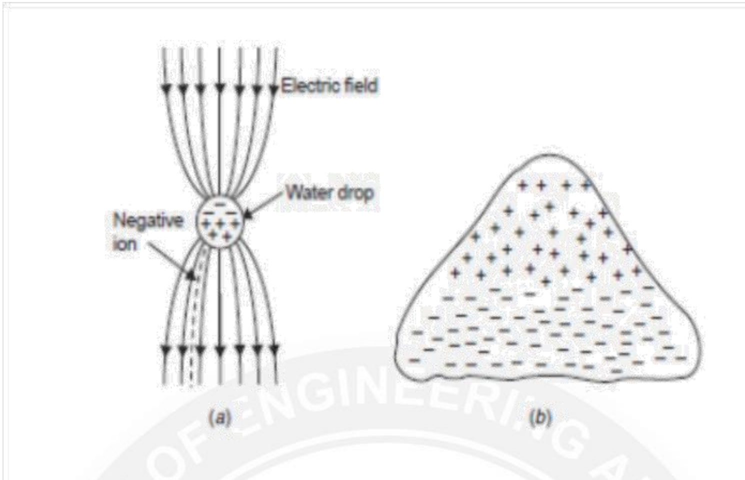

Figure:1.2.3 (a) Capture of negative ions by large falling drop (b) Charge separation in a thunder cloud according to Wilson's theory.

[Source: "High Voltage Engineering" by C.L. Wadhwa, page: 61]

Wilson's Theory of Charge Separation

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polarized, the upper side acquires a negative charge and the lower side a positive charge. Subsequently, the lower part of the drop attracts –ve charges from the atmosphere which are available in abundance in the atmosphere leaving a preponderance of positive charges in the air.

The upwards motion of air currents tends to carry up the top of the cloud, the +ve air and smaller drops that the wind can blow against gravity. Meanwhile the falling heavier raindrops which are negatively charged settle on the base of the cloud. It is to be noted that the selective action of capturing –ve charges from the atmosphere by the lower surface of the drop is possible. No such selective action occurs at the upper surface. Thus in the original system, both the positive and negative charges which were mixed up, producing essentially a neutral space charge, are now separated.

Thus according to Wilson‘s theory since larger negatively charged drops settle on the base of the cloud and smaller positively charged drops settle on the upper positions of the cloud, the lower base of the cloud is negatively charged and the upper region is positively charged (Figure.1.4 (b)). **Simpson's and Scarse Theory** Simpson‘s theory is based on the temperature variations in the various regions of the cloud. When water droplets are broken due to air currents, water droplets acquire positive charges whereas the air is negatively charged. Also when ice crystals strike with air, the air is positively charged and the crystals negatively charged. The theory is explained with the help of Figure.

cloud according to Simpson‘s theory Let the cloud move in the direction from left to right as shown by the arrow. The air currents are also shown in the diagram. If the velocity of the air currents is about 10 m/sec in the base of the cloud, these air currents when collide with the water particles in the base of the cloud, the water drops are broken and carried upwards unless they combine together and fall down in a pocket as shown by a pocket of positive charges (right bottom region in Fig. 7.23). With the collision of water particles we know the air is negatively charged and the water particles positively charged. These negative charges in the air are immediately absorbed by the cloud particles which are carried away upwards with the air currents. The air currents go still higher in the cloud where the moisture freezes into ice crystals.

The air currents when collide with ice crystals the air is positively charged and it goes in the upper region of cloud whereas the negatively charged ice crystals drift gently down in the lower region of the cloud. This is how the charge is separated in a thundercloud. Once the charge separation is complete, the conditions are now set for a lightning stroke.

Mechanism of Lightning Stroke Lightning phenomenon is the discharge of the cloud to the ground. The cloud and the ground form two plates of a gigantic capacitor and the dielectric medium is air. Since the lower part of the cloud is negatively charged, the earth is positively charged by induction. Lightning discharge will require the puncture of the air between the cloud and the earth. For breakdown of air at STP condition the electric field required is 30 kV/cm peak. But in a cloud where the moisture content in the air is large and also because of the high altitude (lower pressure) it is seen that for breakdown of air the electric field required is only 10 kV/cm. The mechanism of lightning discharge is best explained with the help of Fig. 1.6. After a gradient of approximately 10 kV/cm is set up in the cloud, the air surrounding gets ionized. At this a streamer (Fig. 1.6(a)) starts from the cloud towards the earth which cannot be detected with the naked eye; only a spot travelling is detected.

The current in the streamer is of the order of 100 amperes and the speed of the streamer is0.16 m/μ sec. This streamer is known as pilot streamer because this leads to the lightning phenomenon. Depending upon the state of ionization of the air surrounding the streamer, it is branched to several paths and this is known as stepped leader (Fig.1.6(b)). The leader steps are of the order of 50 m in length and are accomplished in about a microsecond. The charge is brought from the cloud through the already ionized path to these pauses. The air surrounding these pauses is again ionized and the leader in this way reaches the earth (Fig.1.6(c)).Once the stepped leader has made contact with the earth it is believed that a power return stroke(Fig. 1.6(c)) moves very fast up towards the cloud through the already ionized path by the leader. This streamer is very intense where the current varies between 1000 amps and 200,000 amps and the speed is about 10% that of light. It is here where the –ve charge of the cloud is being neutralized by the positive induced charge on the earth (Fig.

1.6 (d)).

It is this instant which gives rise to lightning flash which we observe with our naked eye. There may be another cell of charges in the cloud near the neutralized charged cell. This charged cell will try to neutralize through this ionized path. This streamers known as dart leader (Fig.1.6 (e)). The velocity of the dart leader is about 3% of the velocity of light. The effect of the dart leader is much more severe than that of the return stroke. The discharge current in the return streamer is relatively very large but as it lasts only for a few microseconds the energy contained in the streamer is small and hence this streamer is known as cold lightning stroke whereas the dart leader is known as hot lightning stroke because even though the current in this leader is relatively smaller but it lasts for some milliseconds and therefore the energy contained in this leader is relatively larger.

It is found that each thunder cloud may contain as many as 40 charged cells and a heavy lightning stroke may occur. This is known as multiple stroke. 1.2.3 Line Design Based On Lightning The severity of switching surges for voltage 400 kV and above is much more than that due to lightning voltages. All the same it is desired to protect the transmission lines against direct lightning strokes. The object of good line design is to reduce the number of outages caused by lightning. To achieve this following actions are required. (I) The incidence of stroke on to power conductor should be minimized. (ii) The effect of those strokes which are incident on the system should be minimized.

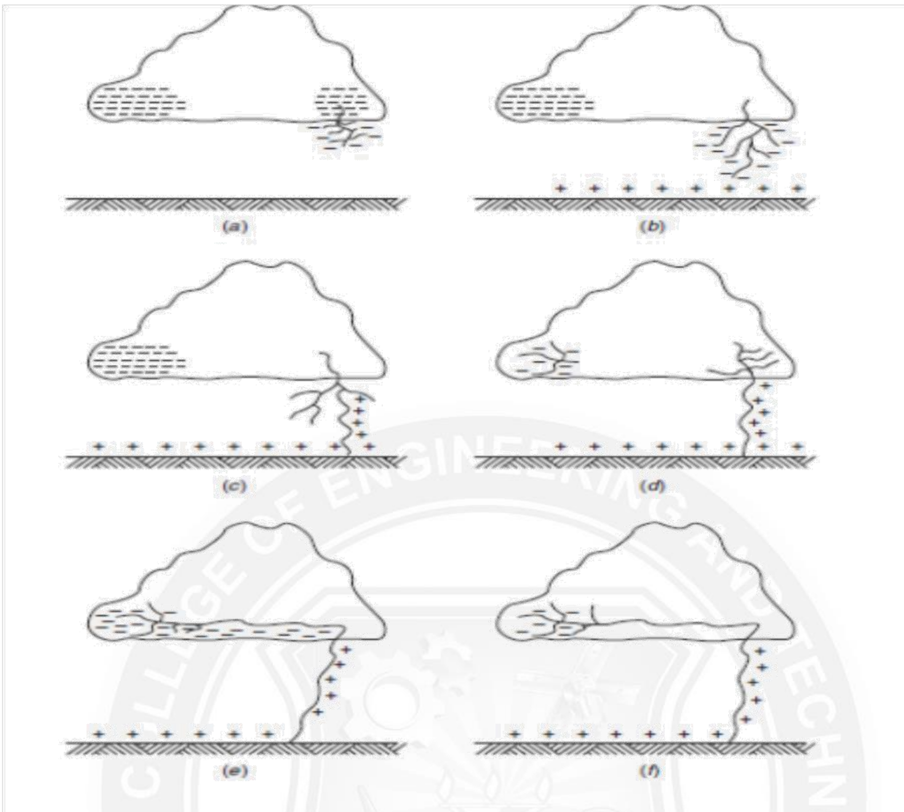

Figure 1.2.4 Lightning mechanism

[Source: "High Voltage Engineering" by C.L. Wadhwa, page: 66]