PPT ON
HIGH VOLTAGE ENGINEERING
VII SEM (IARE-R16)

UNIT 1
OVER VOLTAGES IN ELECTRICAL POWER SYSTEMS

CAUSES OF OVER VOLTAGES

There are two types of causes of over voltage in power system.

- Over voltage due to external causes
- Over voltage due to internal causes
- **Over voltage due to external causes**: This cause of over voltage in power system is the lightning strokes in the cloud.
- This type of over voltages originates from atmospheric disturbances, mainly due to lightning. This takes the form of a surge and has no direct relationship with the operating voltage of the line.
- The potential between the clouds and earth breaks down and lightning flash takes place between the cloud and ground when this voltage becomes 5 to 20 million volts or when the potential gradient becomes 5000V to 10000V per cm.

LIGHTNING ,SWITCHING OVER VOLTAGE

- **Over-voltage-spike**

  Over voltages are caused on power systems due to external and internal influencing factors. The voltage stress caused by over voltage can damage the lines and equipment’s connected to the system
- **Internal Over voltages:**
- These over voltages are caused by changes in the operating conditions of the power system. These can be divided into two groups as below:
- **Temporary over voltages**:
- These are caused when some major load gets disconnected from the long line under normal or steady state condition.

EFFECTS OF OVER VOLTAGES ON POWER SYSTEMS

Over voltage tends to stress the insulation of the electrical equipment's and likely to cause damage to them when it frequently occurs. Over voltage caused by surges can result in spark over and flash over between phase and ground at the weakest point in the network, breakdown of gaseous/solid/ liquid insulation, failure of transformers and rotating machines.

- Switching Impulse or Switching Surge:

  When a no load transmission line is suddenly switched on, the voltage on the line becomes twice of normal system voltage. This voltage is transient in nature. When a loaded line is suddenly switched off or interrupted, voltage across the line also becomes high enough current chopping in the system mainly during opening operation of air blast circuit breaker, causes over voltage in the system.

EFFECTS OF OVER VOLTAGES ON POWER SYSTEMS

- **Voltage Surge:**
- The over voltage stresses applied upon the power system, are generally transient in nature. Transient voltage or voltage surge is defined as sudden sizing of voltage to a high peak in very short duration. The voltage surges are transient in nature, that means they exist for very short duration. The main causes of these voltage surges in power system are due to lightning impulses and switching impulses of the system. But over voltage in the power system may also be caused by, insulation failure, arcing ground and resonance etc.
- The voltage surges appear in the electrical power system due to switching surge, insulation failure, arcing ground and resonance are not very large in magnitude..

CORONA

- **Definition**: The phenomenon of ionisation of surrounding air around the conductor due to which luminous glow with hissing noise is rise is known as the corona effect.
- Corona Discharge (also known as the Corona Effect) is an electrical discharge caused by the ionization of a fluid such as air surrounding a conductor that is electrically charged The corona effect will occur in high voltage systems unless sufficient care is taken to limit the strength of the surrounding electric field.
- Corona discharge can cause an audible hissing or cracking noise as it ionizes the air around the conductors. This is common in high voltage electric power transmission lines. The corona effect can also produce a violet glow, production of ozone gas around the conductor, radio interference, and electrical power loss.

CORONA

- What is the Corona Effect?
- The corona effect occurs naturally due to the fact that air is not a perfect insulator – containing many free electrons and ions under normal conditions. When an electric field is established in the air between two conductors, the free ions and electrons in the air will experience a force. Due to this effect, the ions and free electrons get accelerated and moved in the opposite direction.
- The charged particles during their motion collide with one another and also with slow-moving uncharged molecules. Thus the number of charged particles increases rapidly.

CORONA

- Two factors are important for corona discharge to occur:
- Alternating electrical potential difference must be supplied across the line.
- The spacing of the conductors, must be large enough compared to the line diameter.
- When an alternating current is made to flow across two conductors of a transmission line whose spacing is large compared to their diameters, the air surrounding the conductors (composed of ions) is subjected to dielectric stress.

CORONA

- **Factors Affecting Corona Loss**
- The line voltage of the conductor is the main determining factor for corona discharge in transmission lines. At low values of voltage (lesser than the critical disruptive voltage) the stress on the air is not high enough to cause dielectric breakdown – and hence no electrical discharge occurs.
- With increasing voltage, the corona effect in a transmission line occurs due to the ionization of atmospheric air surrounding the conductors – it is mainly affected by the conditions of the cable as well as the physical state of the atmosphere. The main factors affecting corona discharge are:
- Atmospheric Conditions
- Condition of Conductors
- Spacing Between Conductors

CORONA

Atmospheric Conditions:

- We have proved that the voltage gradient for dielectric breakdown of air is directly proportional to the density of air. Hence in a stormy day, due to continuous air flow, the number of ions present surrounding the conductor is far more than normal, and hence it’s more likely to have electrical discharge in transmission lines on such a day, compared to a day with the fairly clear weather
- **Condition of Conductors:**
- This particular phenomenon depends highly on the conductors and its physical condition. It has an inverse proportionality relationship with the diameter of the conductors. i.e., with the increase in diameter, the effect of corona on power system reduces considerably.

CORONA

- **Spacing Between Conductors**:
- As already mentioned, for corona to occur in the spacing between the lines effectively should be much higher compared to its diameter, but if the length gets increased beyond a certain limit, the dielectric stress on the air reduces, and consequently, the effect of corona reduces as well.
- **Reducing Corona Discharge:**
- Corona discharge always results in power loss. Energy is lost in the form of light, sound, heat, and chemical reactions. Although these losses are individually small, over time they can add up to significant power loss in high voltage networks.

CORONA

- **Corona discharge can be reduced by:**
- **Increasing the conductor size:** A larger conductor diameter results in a decrease in the corona effect.
- **Increasing the distance between conductors:** Increasing conductor spacing decreases the corona effect.
- **Using bundled conductors:** Bundled conductors increase the effective diameter of the conductor – hence reducing the corona effect.
- **Using corona rings:** The electric field is stronger where there is a sharp conductor curvature. Because of this corona discharge occurs first at the sharp points, edges, and corners. Corona rings reduce the corona effect by ‘rounding out’ conductors (i.e. making them less sharp).

CORONA

- **Disadvantages of corona discharge:**
- The undesirable effects of the corona are:
- The glow appear across the conductor which shows the power loss occur on it.
- The audio noise occurs because of the corona effect which causes the power loss on the conductor.
- The vibration of conductor occurs because of corona effect.
- The corona effect generates the ozone because of which the conductor becomes corrosive.
- The corona effect produces the non-sinusoidal signal thus the non-sinusoidal voltage drops occur in the line.
- The corona power loss reduces the efficency of the line.

- The establishment of a potential difference between the conductors of an overhead transmission line is accompanied by the production of an electrostatic flux, whilst the flow of current along the conductor results in the creation of a magnetic field

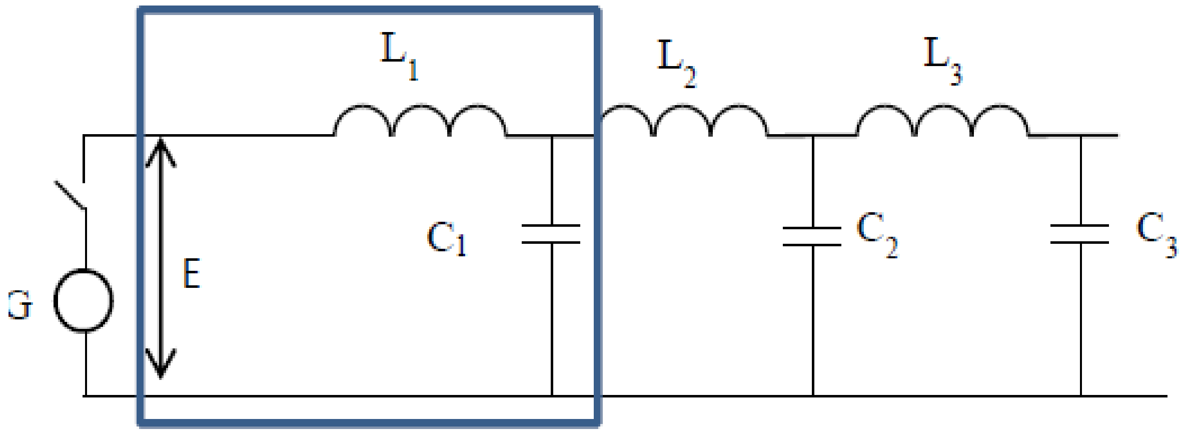


Fig.1

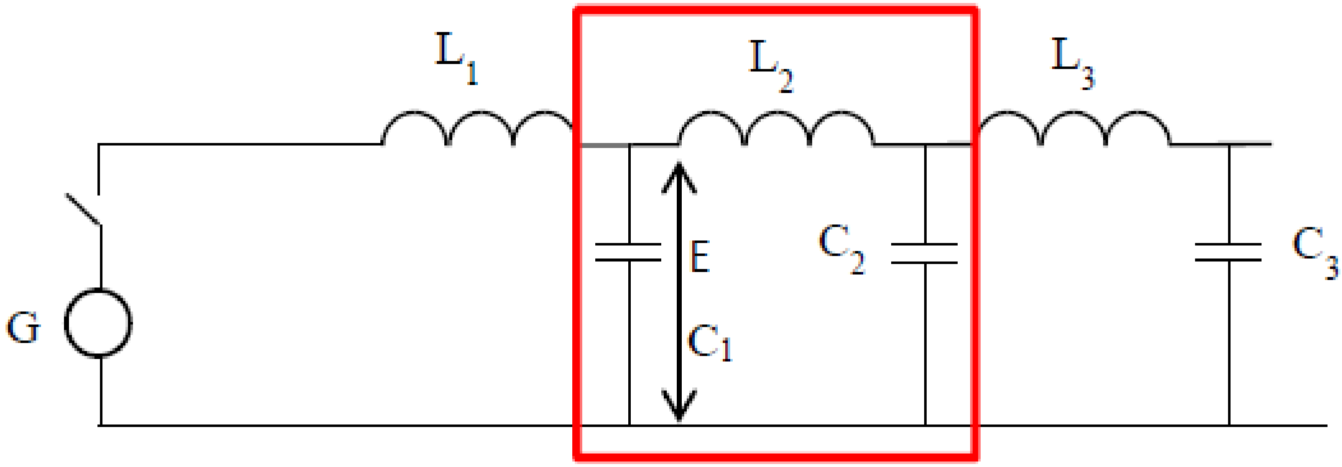


Figure 2.

- **The Open-Circuited Line:**
- Let a source of constant voltage E be switched suddenly on a line open-circuited at the far end. Then neglecting the effect of line resistance and possible conductance to earth, a rectangular voltage wave of amplitude E and its associated current wave of amplitude $I = E/Z_c$ will travel with velocity v towards the open end. Figure 3.a shows the conditions at the instant when the waves have reached the open end, the whole line being at the voltage E and carrying a current I

Figure 3.a

$$\frac{1}{2}LI^2 = \frac{1}{2}Cv^2$$

Whence,

$$e = \sqrt{\frac{L}{C}}I = Z_cI = E$$

Hence, the total voltage at the open end becomes 2E. The open end of the line can thus be regarded as the origin of a second voltage wave of amplitude E, this second wave travelling back to the source with the same velocity v. At some time subsequent to arrival of the initial wave at the open end, i.e. the condition shown in Figure 3.a, the state affairs on the line will be as in Figure 3.b in which the incoming and reflected voltage waves are superposed, resulting in a step in the voltage wave which will travel back towards the source with a velocity v.

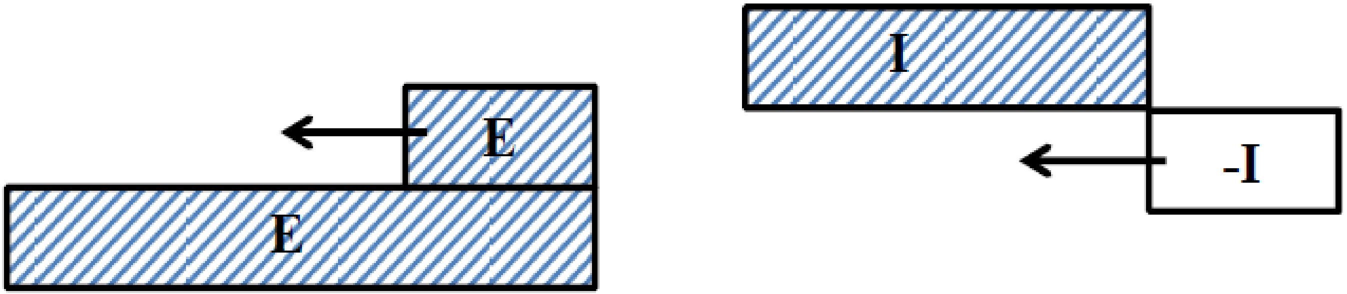


Figure 3.b

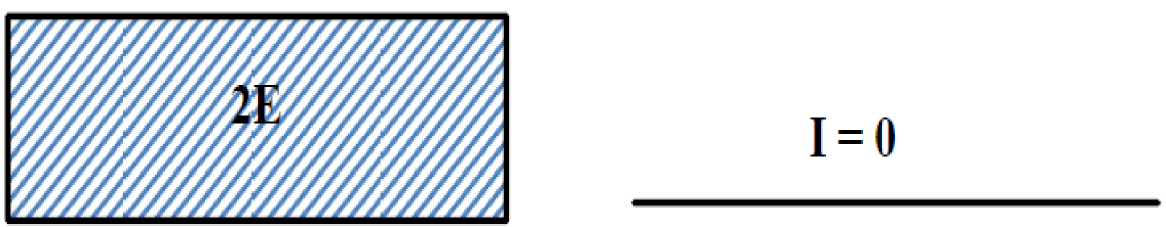


Figure 3.c

TRAVELLING WAVES ON POWER SYSTEMS

- At G, the voltage is held by the source to the value E, it follows that there must be a reflected voltage of –E and associated with it there will be a current wave of –I. After these have travelled a little way along the line, the conditions will be as shown in Figure 3.d.

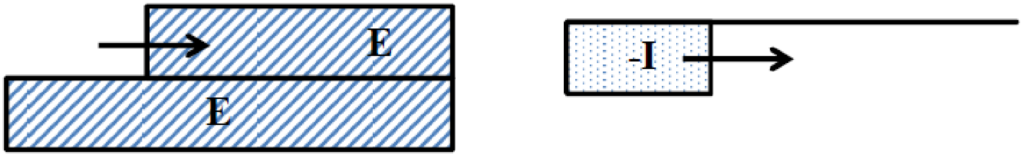


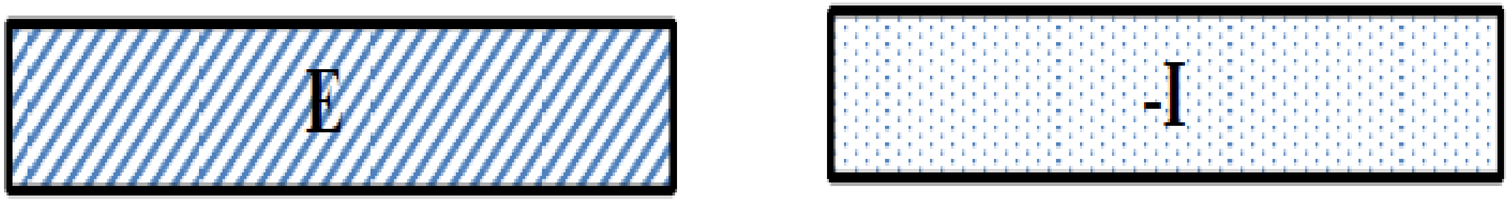
Figure 3.d

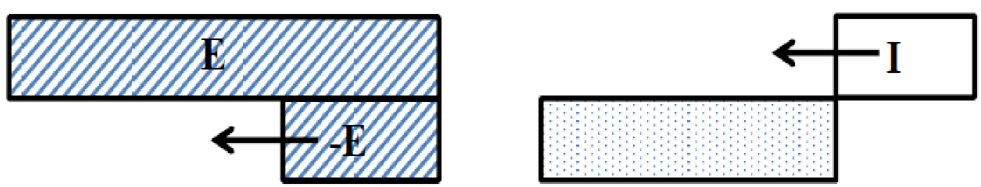
TRAVELLING WAVES ON POWER SYSTEMS

When these reach the open end the conditions along the line will be voltage E and current –I. The reflected waves due to these will be –E and +I and when these have travelled to the end G they will have wiped out both voltage and current distributions, leaving the line for an instant in its original state. The above cycle is then repeated.

When these reach the open end the conditions along the line will be voltage E and current –I. The reflected waves due to these will be –E and +I and when these have travelled to the end G they will have wiped out both voltage and current distributions, leaving the line for an instant in its original state. The above cycle is then repeated.

TRAVELLING WAVES ON POWER SYSTEMS





- The Short-Circuited Line:

  This case, the voltage at the far end of the line must of necessity be zero, so that as each element of the voltage wave arrives at the end there is a conversion of electrostatic energy into electromagnetic energy. Hence, the voltage is reflected with reversal sign while the current is reflected without any change of sign: thus on the first reflection, the current builds up

TRAVELLING WAVES ON POWER SYSTEMS

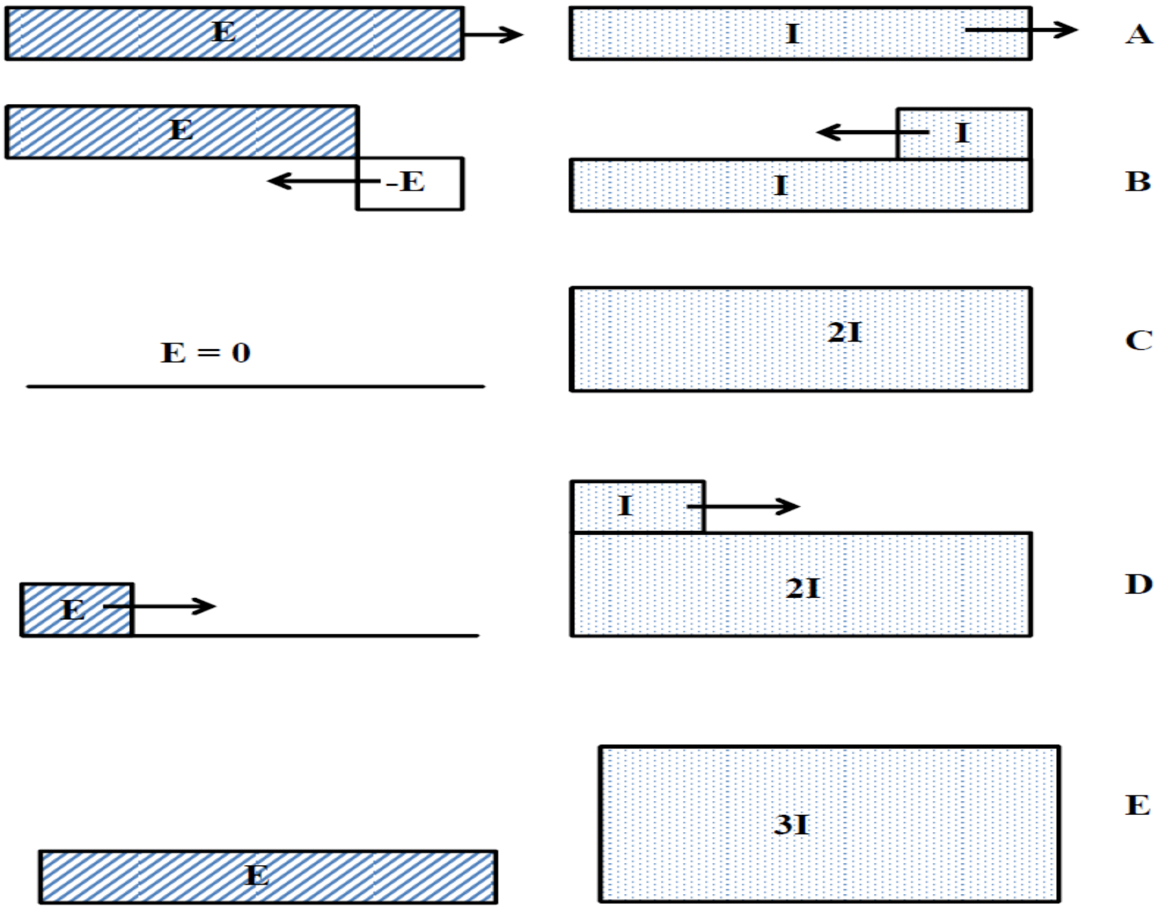


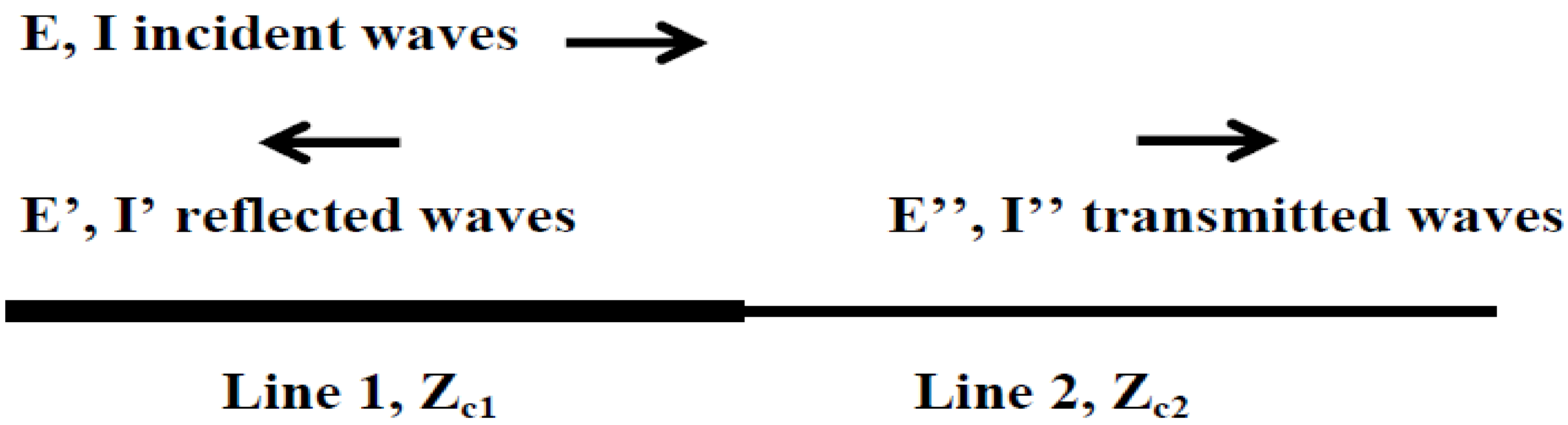
Figure 4

TRAVELLING WAVES ON POWER SYSTEMS

- Junction of Lines of Different Characteristic Impedance:
- If a second line is connected to the termination of the first, the voltage of the reflected wave *at the junction* will depend on the magnitude of Z_{c1} and Z_{c2}.

- With $Z_{c2} = \infty$, we have the case of the open-circuited line. With $Z_{c2} = 0$, the case of the short- circuited line. If $Z_{c2} = Z_{c1}$, the second line can be regarded as a natural continuation of the first and the current and voltage waves pass into Z_{c2} without any change.

TRAVELLING WAVES ON POWER SYSTEMS



the reflection is accompanied by a change in sign of either voltage or current but not both

- Reflection and Refraction at a Bifurcation:
- Let a line of natural impedance Z_1 bifurcate into two branches of natural impedances Z_2 and Z_3, then, as far as the voltage wave is concerned, the transmitted wave will be the same for both branches, since they are in parallel. On the other hand, the transmitted currents will be different in the general case of $Z_3 \neq Z_2$.

TRAVELLING WAVES ON POWER SYSTEMS

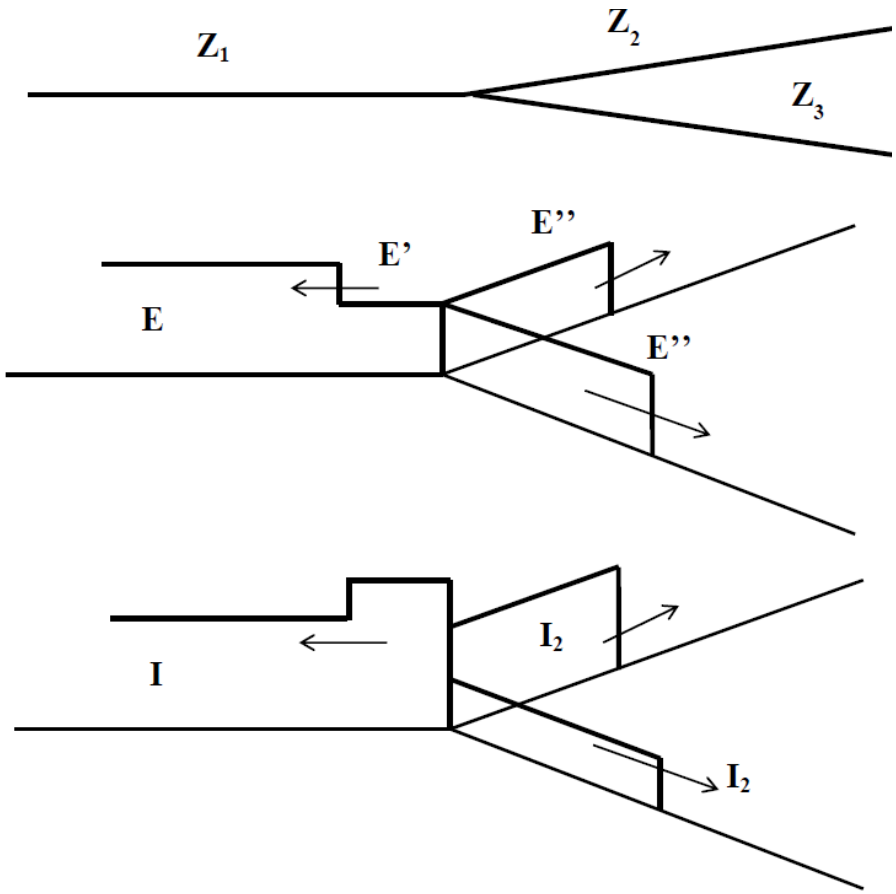


Figure B.1: Effect of a bifurcation on the travelling waves.

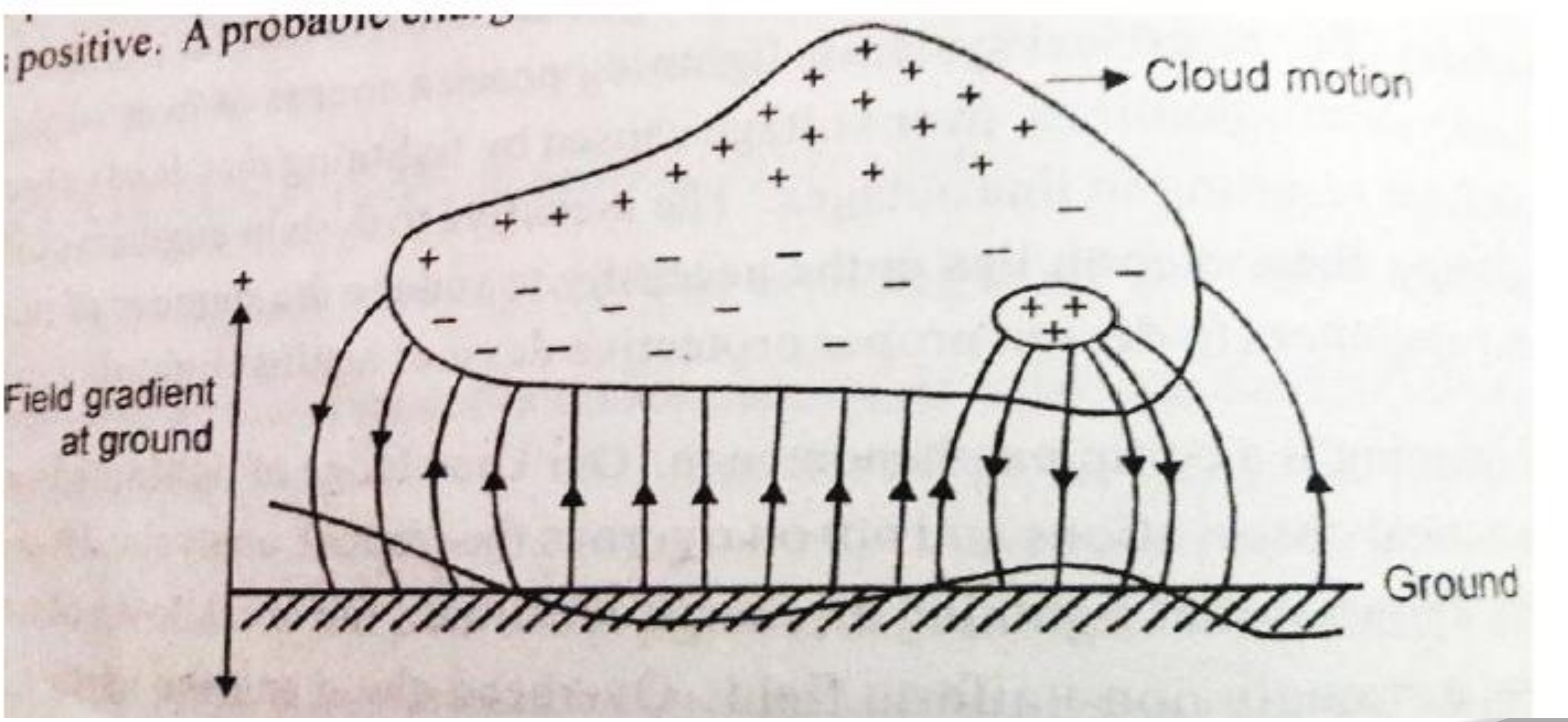
OVER VOLTAGE PROTECTION

- There is always a chance of suffering an electrical power system from abnormal over voltages. These abnormal over voltages may be caused due to various reason such as, sudden interruption of heavy load, lightening impulses, switching impulses etc. These over voltage stresses may damage insulation of various equipments and insulators of the power system.
- **Lightning Arrester:**
- The concept of a lightning arrester is very simple. This device behaves like a nonlinear electrical resistance. The resistance decreases as voltage increases and vice-versa, after a certain level of voltage.

CHARGE FORMATION IN CLOUD

- During thunderstorms, +ve & - ve charges become separated by the heavy air currents with ice crystals in the upper part & rain in the lower parts of the cloud.
- This charge separation depends on the height of clouds, which range from 0.2 to 10Km with their charge centers at a distance of about 0.25 to 2 Km.
- The charge inside the cloud may be as high as 1 to 100c.
- Clouds may have a high potential as 10^7 to 10^8 with field gradients ranging from 100V/cm to 10KV/cm. The energies associated with the cloud discharges may be very high.

CHARGE FORMATION IN CLOUD



CHARGE FORMATION IN CLOUD

- Wilson theory:
  - It is based only on assumption
  - A large no. of ions are present in the atmosphere
  - Many of these ions attach themselves to small dust particles and water particles
  - A normal electric field exists in the atmosphere under fair-weather conditions which is generally directed downwards towards the earth.
  - The intensity of the field is approximately 1 volt/cm at the surface of the earth and decreases gradually with height [at 9500m,it is 0.02V/cm]

CHARGE FORMATION IN CLOUD

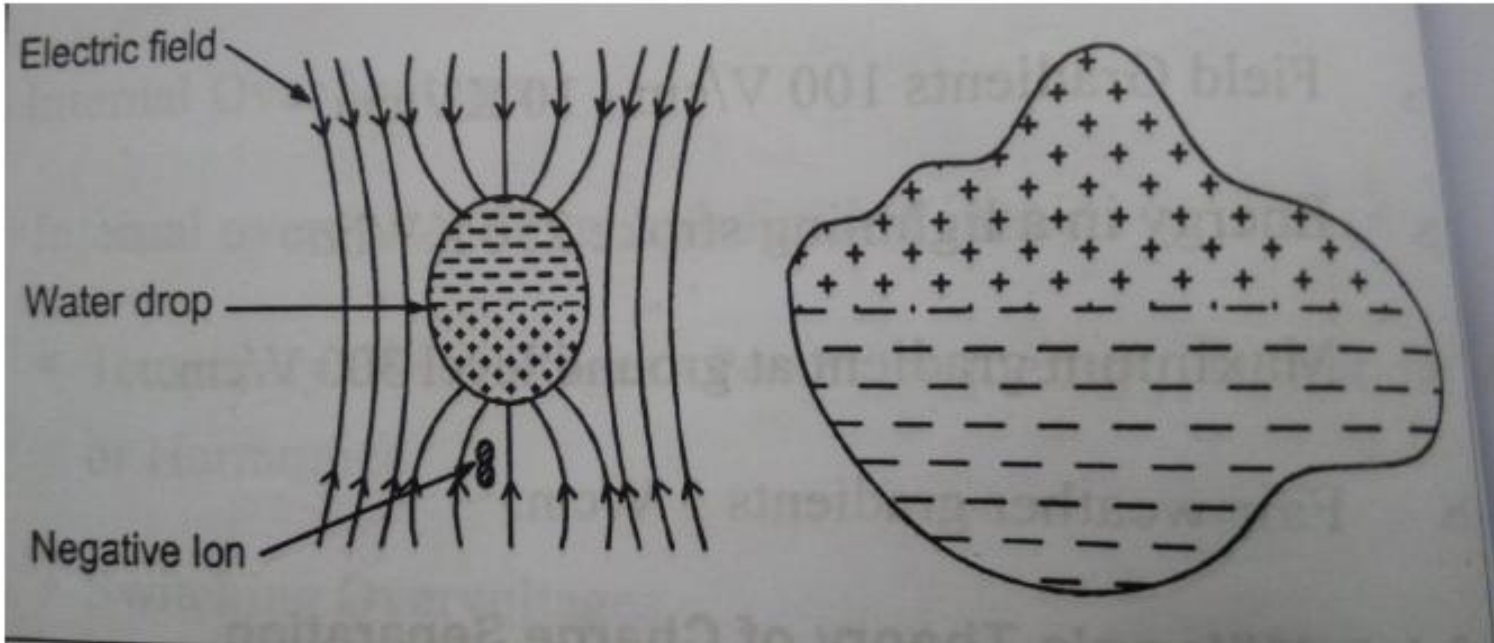


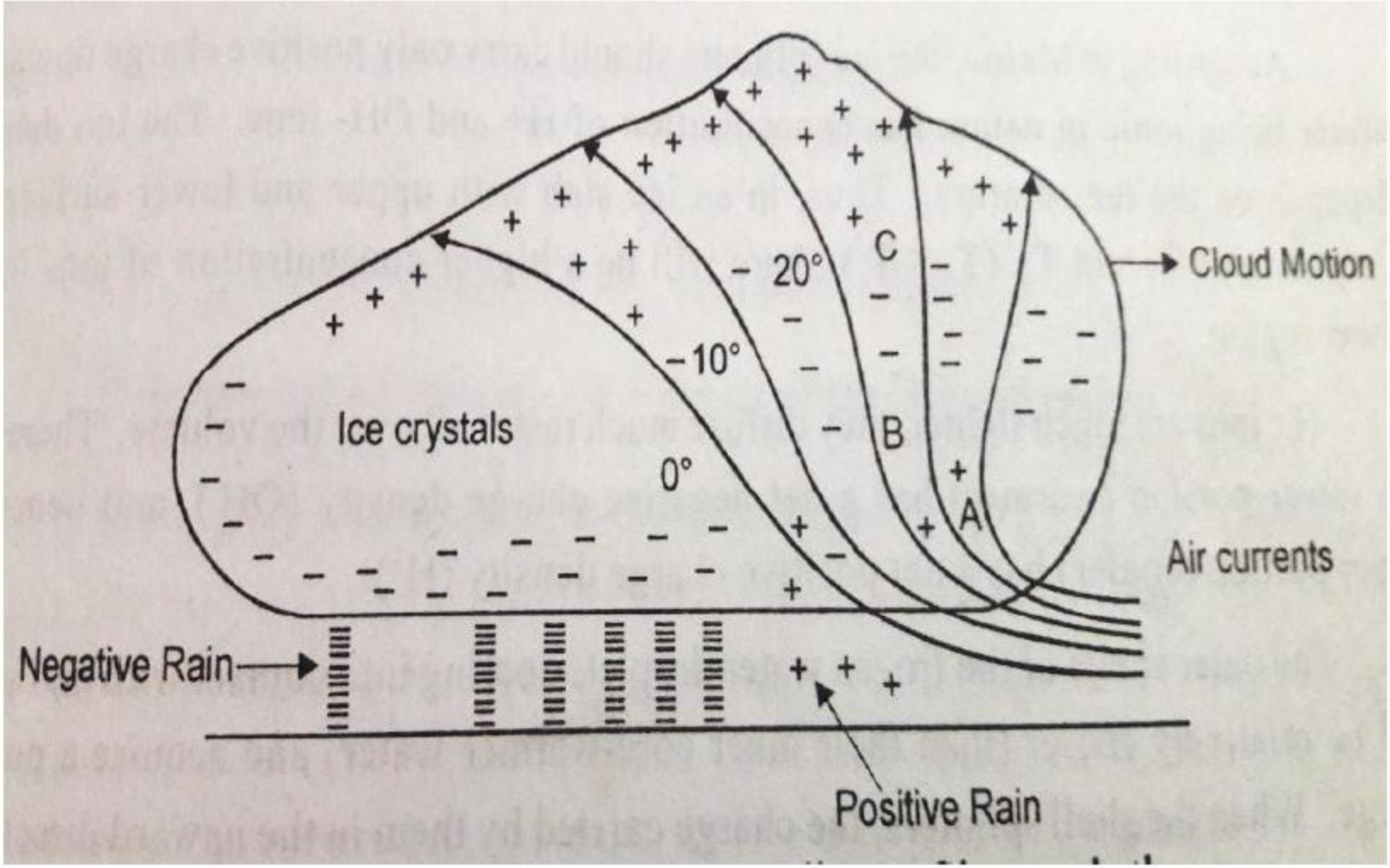
Fig.3.1 (a) Captive of nagative ions by large falling drop

Fig.3.1 (b) Charge seperation in thunder Cloud according to Wilson's theory

CHARGE FORMATION IN CLOUD

- SIMPSONS THEORY:
- 3 essential region-A,B,C
  - Below region A, air currents travel above 800cm/s, & no rain drops fall through.
  - In region A, air velocity is high enough to break the falling raindrops causing +ve charge spray in the cloud & -ve charge in the air.
  - The spray is blown upwards, as the velocity decreases, the positively charged water drops recombine with larger drops & fall again.
  - Thus region A becomes +vely charged & region B becomes–vely charged by air currents.

CHARGE FORMATION IN CLOUD

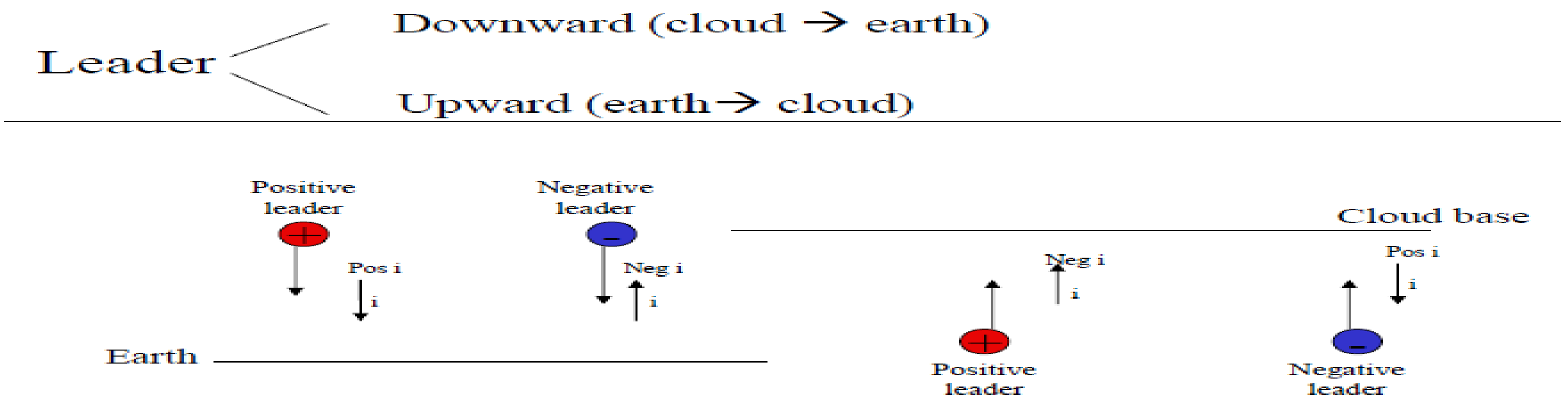


CHARGE FORMATION IN CLOUD

- REYNOLD AND MASON'S THEORY:
- According to this theory, thunder clouds are developed at heights 1 to 2km above ground level& they go up to 14km.
- The temperature is 0°C at 4km & may reach -50°C at 12km.
- Water droplets do not freeze at 0°C & freeze only when temperature is below -40°C & form solid particles on which crystalline ice patterns develop & grow.
- Thundercloud consisting super cooled water droplets moving upwards and large hail stones moving downwards.

STEPPED LEADER

- Stepped Leader:
- The lightning stroke begins when the electric fields exceed breakdown voltage. At the ground the maximum fields get to ~10 kV/m
- • Initially streams of electrons surge from the cloud base toward the ground in steps of 50 to 100 m. • Start and stop steps as the stepped leader progresses toward ground.



STEPPED LEADER

- The stepped leader is:
- Very Faint.
- Essentially invisible to the human eye.
- Produces an ionized channel that will allow for the flow of charge during the remainder of the lightning stroke.

STEPPED LEADER

- The Attachment Process:
- When the stepped leader gets near the ground (~100 m or so) Positive charge moves from the ground up toward the stepped leader -- these are called streamers.
- The streamers may come from almost any pointed object on the ground:
- Trees
- Antennas
- Flagpoles

STEPPED LEADER

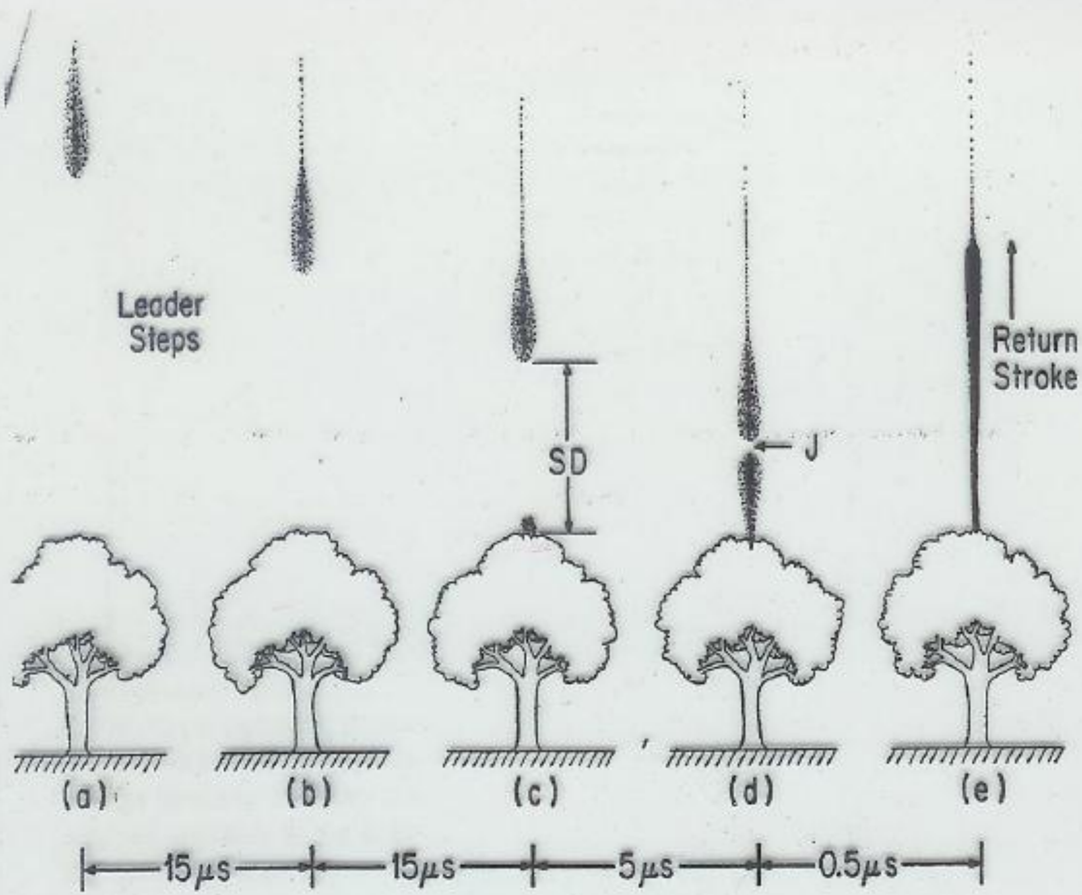
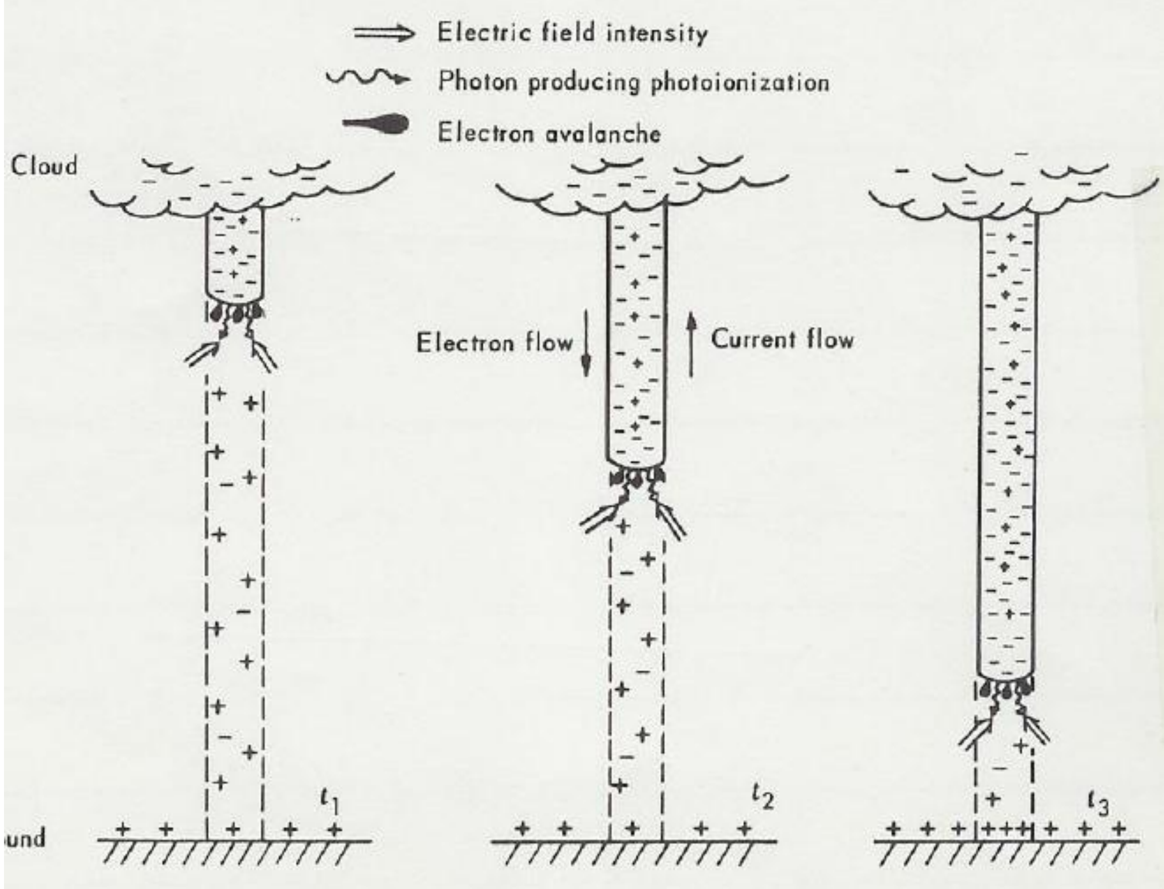


Figure 6.3. Sketch of the luminous processes that occur during a lightning strike. An upward-connecting discharge forms in (c) when the stepped leader is at the striking distance, SD.

DART LEADER

- Approximately 0.04 sec after the return stroke the dart leader travels down the ionized channel without “steps “followed by another return stroke after ~1 msec.
- Another dart leader can occur 0.04 sec after the next return stroke, and so on….May get several sets of dart leader/return stroke pairs. Appears as if the lightning “flashes.”

DART LEADER

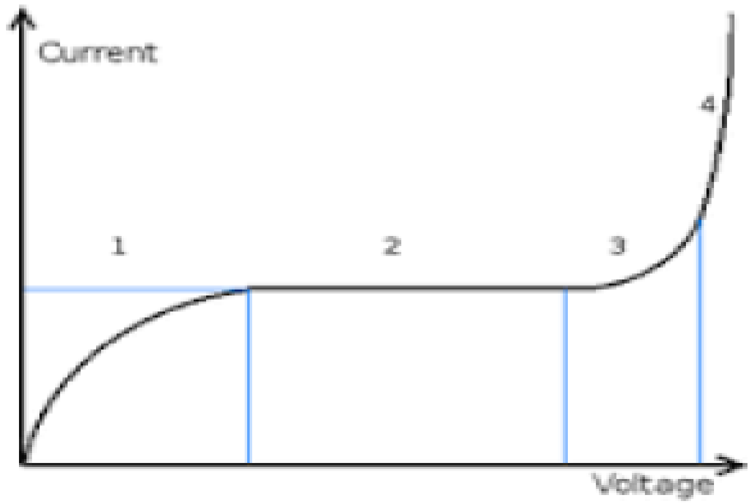


. 7.1b *Diagram showing general features of streamer mechanism as applied to dart leader. The times $t_3 > t_2 > t_1$.*

UNIT 2
DIELECTRIC BREAKDOWN

GASEOUS BREAKDOWN

Gases Electrical breakdown occurs within a gas when the dielectric strength of the gas is exceeded. The voltage that leads to electrical breakdown of a gas is approximated by Paschen's Law.



- **UNIFORM AND NON UNIFORM FIELDS:**

Electric fields are represented by drawing field lines that represent the direction of the field, as well as the strength of the field. More field lines represent higher field strength. In a non-uniform electric field, the field lines tend to be curved and are more concentrated near the charges. In a uniform electric field, since the field strength does not vary, the field lines are parallel to each other and equally spaced. Uniform fields are created by setting up a potential difference between two conducting plates placed at a certain distance from one another. The field is considered to be uniform at the center of the plates, but varies close to the edge of the plates.

CORONA DISCHARGE

- corona discharge is an electrical discharge brought on by the ionization of a fluid such as air surrounding a conductor that is electrically charged. Spontaneous corona discharges occur naturally in high-voltage systems unless care is taken to limit the electric field strength. A corona will occur when the strength (potential gradient) of the electric field around a conductor is high enough to form a conductive region, but not high enough to cause electrical breakdown or arcing to nearby objects.

VACCUM BREAKDOWN

- Experiments have been performed in order to get information about the phenomena preceding the electrical breakdown in small vacuum gaps. Most experiments have been made with impulse voltages of different rise times; some complementary results obtained with alternating voltage are also presented.
- The effect of surface layers on the breakdown voltage and on the pre-breakdown current is discussed. It has been found that the rise time of the voltage affects both the breakdown voltage and the pre-breakdown current.
- The experiments seem to indicate that breakdown in the underlying circumstances is the result of a discharge in metal vapour, originating from the anode

INTRINSIC BREAKDOWN

- When voltages are applied only for short durations of the order of 8 10 s the dielectric strength of a solid dielectric increases very rapidly to an upper limit called the intrinsic electric strength.
- Experimentally, this highest dielectric strength can be obtained only under the best experimental conditions when all extraneous influences have been isolated and the value depends only on the structure of the material and the temperature.
- The maximum electrical strength recorder is 15 MV/cm for polyvinyl-alcohol at -1960 C. The maximum strength usually obtainable ranges from 5 MV/cm. Intrinsic breakdown depends upon the presence of free electrons which are capable of migration through the lattice of the dielectric.

INTRINSIC BREAKDOWN

- Electronic Breakdown
- Intrinsic breakdown occurs in time of the order of 10-8 s and therefore is assumed to be electronic in nature. The initial density of conduction (free) electrons is also assumed to be large, and electron-electron collisions occur. When an electric field is applied, electrons gain energy from the electric field and cross the forbidden energy gap from the valence band to the conduction band

INTRINSIC BREAKDOWN

- Avalanche or Streamer Breakdown
- This is similar to breakdown in gases due to cumulative ionization. Conduction electrons gain sufficient energy above a certain critical electric field and cause liberation of electrons from the lattice atoms by collision. Under uniform field conditions, if the electrodes are embedded in the specimen, breakdown will occur when an electron avalanche bridges the electrode gap

IONIZATION PROCESS

- Townsend’s Theory:
- Townsend’s has consider both primary and secondary process which leads breakdown in gas dielectric medium and proved that increase of electrons in gas medium is not linear but exponential.
- Time Lag In Breakdown Of Gas:
- Time lag of the breakdown in gas insulation is divided into two parts 1) statistical time 2) formative time.
- Statistical time- it is the time elapse between application of voltage to initiation of electron in the gas medium.
- Formative time- it is the time elapse between initiation of electron to formation of avalanche between electrode causing breakdown.

IONIZATION PROCESS

- Streamer’s Theory:
- 1) Townsend’s theory has drawback that it has consider only ionization process as cause of breakdown in gas insulation, but dint consider atmospheric and shape of the medium between the electrodes.
- 2) Townsend’s criteria says that time lag is approximately 10^{-5} seconds but which actually as small as estimated is 10^{-8} seconds.
- 3) Townsend's criteria says that discharge has regular shape but practically discharge

IONIZATION PROCESS

- Paschen's Law:

From the breakdown criteria of Townsend's,

$$1-s[e^{p.d} - 1] = 0$$

$$s[e^{p.d} - 1] = 1$$

where the co-efficient p and s are functions of E/b i.e

$$p/b = g_1(E/b)$$

$$s = g_2(E/b)$$

$$E = V/d$$

Substituting above equations in townsend's criteria,

$$g_2(E/b)[e^{g1(E/b).d} - 1] = 1$$

$$g_2(V/d.b)[e^{g1(V/d.b).d} - 1] = 1$$

- Hence from above equation we can say that applied voltage is the function of produce of pressure and distance.

Liquid As Dielectric And Its Breakdown

- Liquid dielectrics provide two purposes in power system as protection and coolant. The power system equipment like transformer, circuit breakers etc use liquid dielectrics. Liquid dielectric is self healing. Dielectric strength of liquid insulation is somewhat greater than gas medium. The breakdown voltage of liquid dielectric is in the ranges of 10MV/cm to 100MV/cm.
- Pure And Commercial Liquid:
- Pure liquids are the one which has no contaminants in the traces of 1 in 10^9 . commercial liquids are the one which contains impurities like sand particles, gas pockets, air bubbles, dust etc. before taking any liquid insulation into service once purification process is recommendable

Liquid As Dielectric And Its Breakdown

- Process Of Breakdown In Liquid Dielectric:
- The various process which leads to breakdown in the commercial liquid are –
- Suspended particle theory.
- Cavitations and bubble mechanism
- Stressed volume theory.

Suspended particle theory: Here main impurity is dust or sand particles. Let us consider an arrangement of liquid dielectric between two electrodes containing dust particle. To such an arrangement a voltage of E is applied. Then these dust particles gets energized and forming an local electric field. If there are number of dust particles the excited dust particles forms an avalanche between the electrodes which may cause breakdown of liquid insulation if surrounding dust particles filed is very high.

Liquid As Dielectric And Its Breakdown

- Cavitations and the bubble theory-

  Here main impurity is gas bubbles or air particles. Let us consider an arrangement of liquid dielectric between two electrodes containing gas pockets. To such an arrangement a voltage of E is applied. Then these bubbles get energized and elongated. Here there are two methods which lead to avalanche between electrodes.

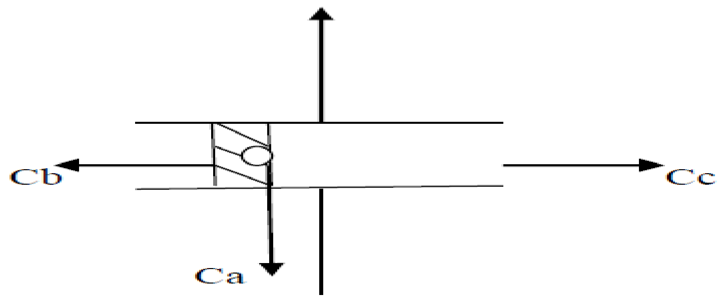
- When bubbles get energized and elongated forms the bridge between the electrodes which may lead to breakdown of liquid insulation.
- When bubble gets energized there may be local breakdown which liberates more bubble and these bubbles forms bridge between electrode causing breakdown.

Liquid As Dielectric And Its Breakdown

- Stressed oil volume theory-
- Here main impurity is weak region containing some impurities. Let us consider an arrangement of oil liquid dielectric between two electrodes containing some weak regions.
- To such an arrangement a voltage of E is applied. The volume of the region which consists of considerable contaminants experiences high stress and leads to local breakdown. As number of stressed oil volumes increases the breakdown strength decreases.
- Hence we can say that breakdown strength and volumes of high stress are inversely proportional

Breakdown in solid insulations

- Solid insulation is one of the strong medium of dielectric, whose dielectric strength is very much greater than gas and liquid insulations. Unlike gas and liquid insulations if the breakdown occurs in solid insulation leads to the permanent damage. The breakdown in solid insulation may occur due to corona, internal voids, treeing and tracking, mechanical stress etc.
- Partial discharge:



INTRINSIC BREAKDOWN

- The intrinsic breakdown may occur when high voltage is applied to the solid insulation for small duration of 10^{-8} seconds. The intrinsic breakdown is caused due to the presence of free electrons in the structure of insulation which may migrate throughout the structure.
- Electronic breakdown:
- Due to the presence of free electrons in the structure of solid insulation, when the high voltage is applied these free electrons participates in the process of ionization electrons are present because of impurities of solid insulations which may increase conductivity of the material.

INTRINSIC BREAKDOWN

- **Treeing and tracking:**
- We know that one of the major phenomena which leads to breakdown of solid insulation surface. If further high voltage is applied continuously the responds on the surface of solid insulation is formed like a treeing.
- **Electro mechanical breakdown:**
- If high voltage is applied to solid insulation the electro static forces may experience by high stress which may exceed mechanical stress of the specimen.

UNIT 3
GENERATION OF HIGH VOLTAGE & CURRENT

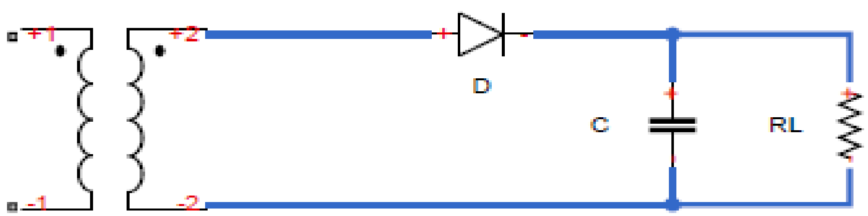
INTRODUCTION

- Once the study of insulation technology is completed, next important part of high voltage engineering is generation of high voltages and high currents. The generation of several voltages and currents, they are
- High DC voltage
- High AC voltage
- High direct current
- High alternating current
- High impulse voltage
- High impulse currents.
- In this unit we are going to study different arrangements to generate high voltage currents.

INTRODUCTION

Generation of High DC Voltage:

- Generally high DC voltage got applications research labs, medical equipment, electronic precipitator etc. high DC voltage generation is as high as 100KV to 200KV. Upto 100KV rectifier circuits can be used with current of 100mA.
- **Half wave rectifier circuit:**
- Half wave circuit consists of only one diode which is of high peak inverse voltage . the arrange for half wave rectification is showı

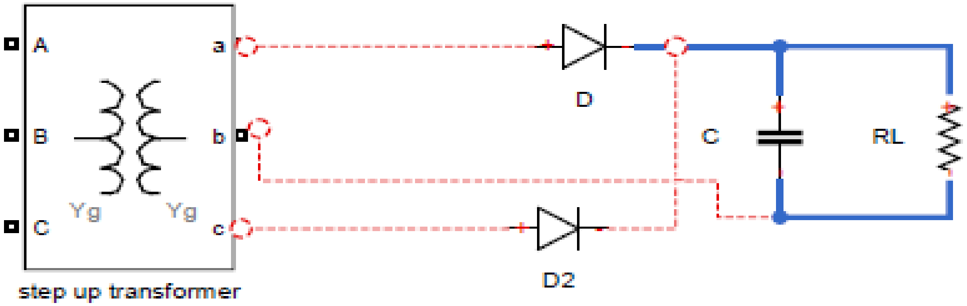


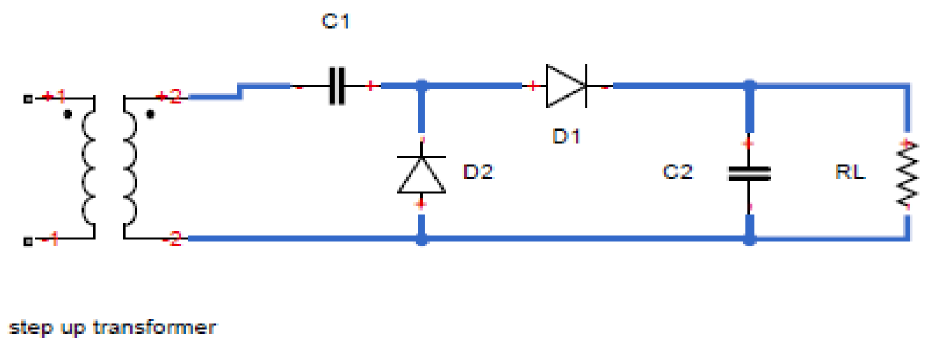
step up transformer

INTRODUCTION

Full wave rectifier circuit: Full wave circuit consists of only two diode which is of high peak inverse voltage . the arrange for full wave rectification

is shown be

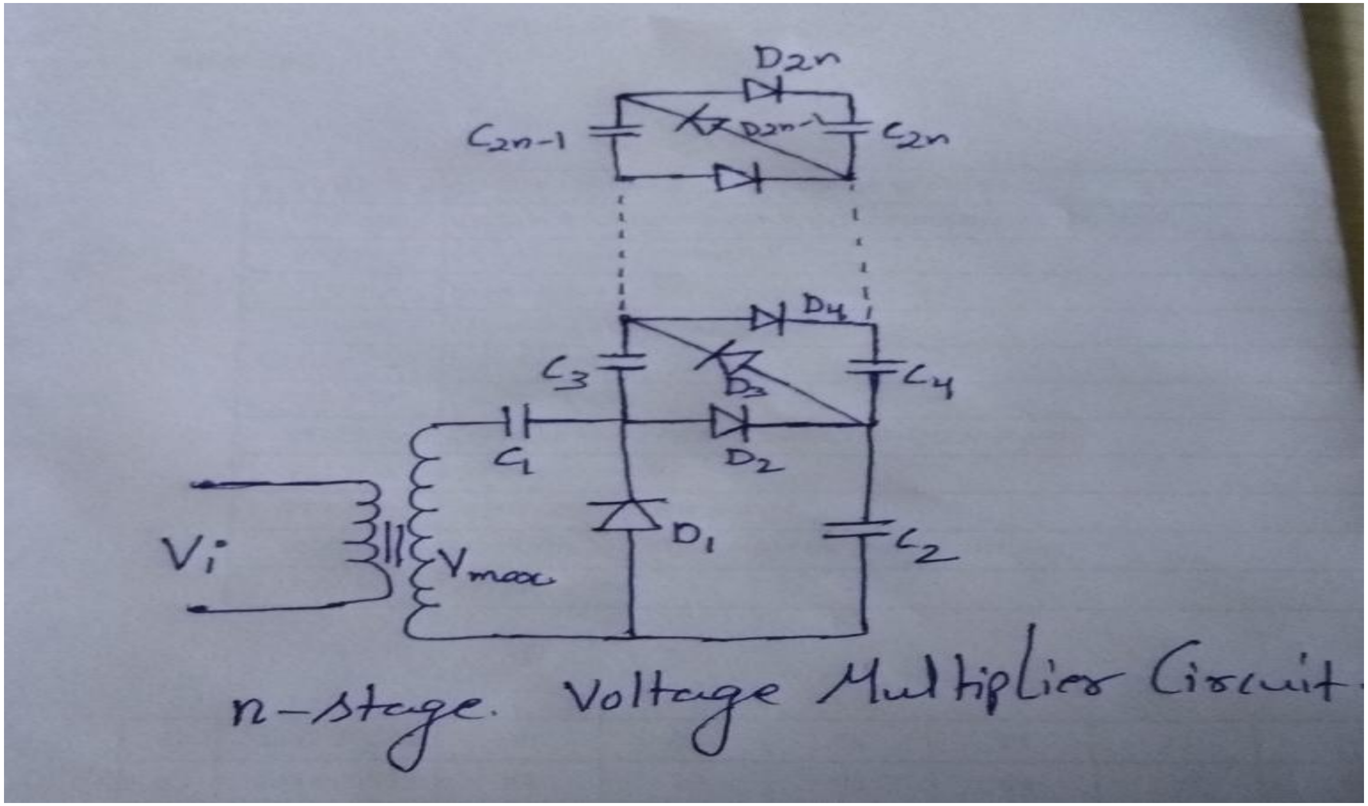




Cockcroft Walton circuit:

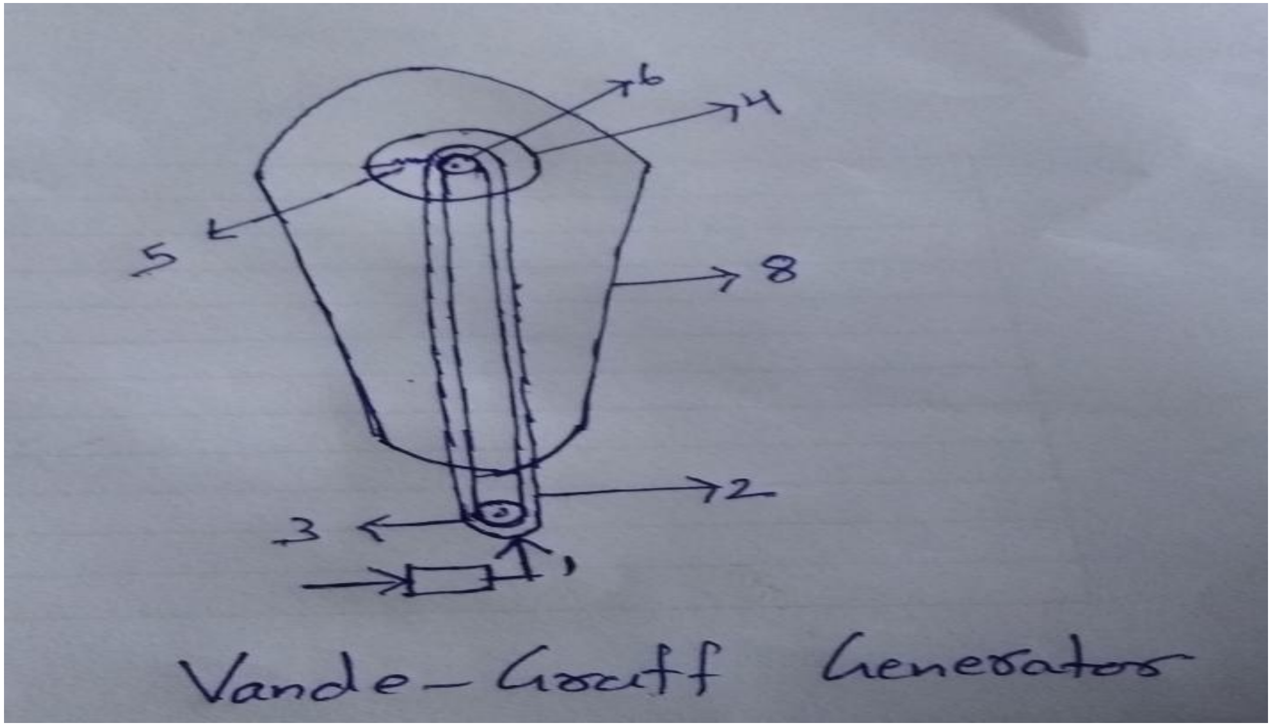
Similar to voltage doubler circuit but here more such stages are cascaded to increase high DC voltage. In the operation voltage multiplier circuit is same as voltage doubler circuit. The Cockcroft Walton circuit is shown below.

Voltage Multiplier Circuit Or Cockcroft Walton Circuit



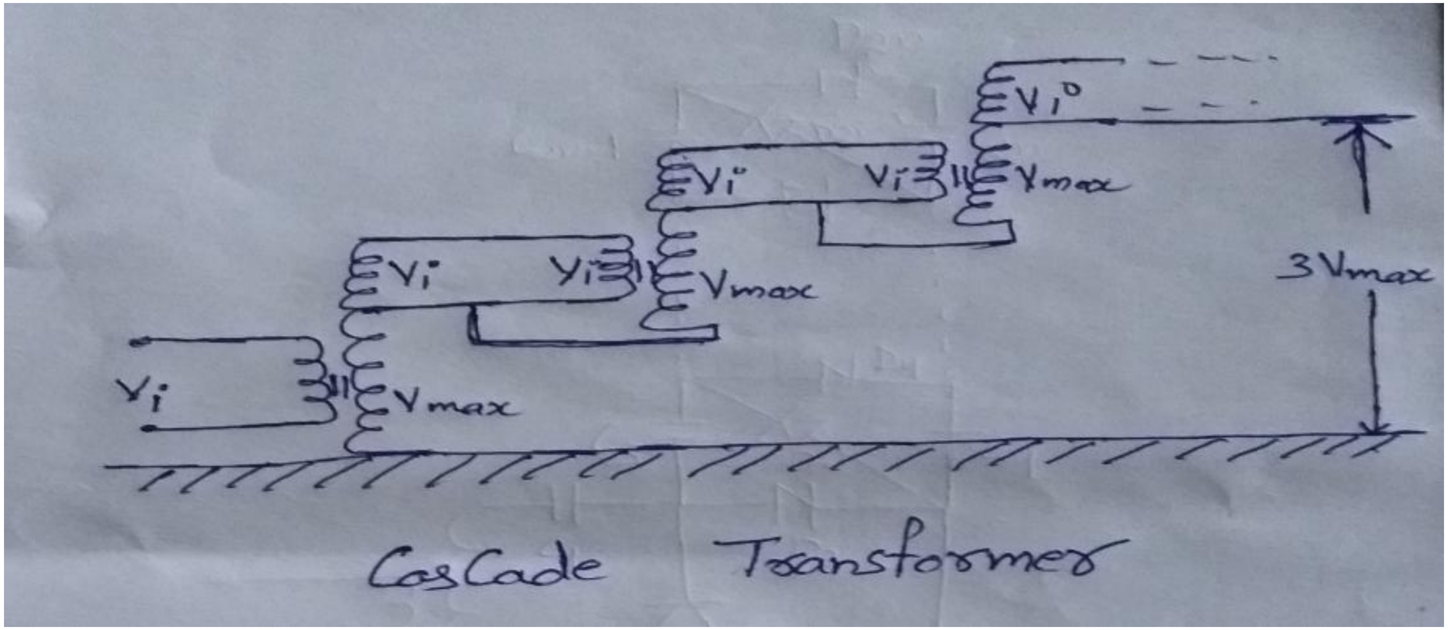
VANDE-GRAFF GENERATOR GENERATOR

- Vande –graff is the name of scientist who invented an generator of high DC voltage based on the principle of electro-static. This generator is used build up to voltage of 10KV to 100KV. The figure of vande-graff generator is shown below.

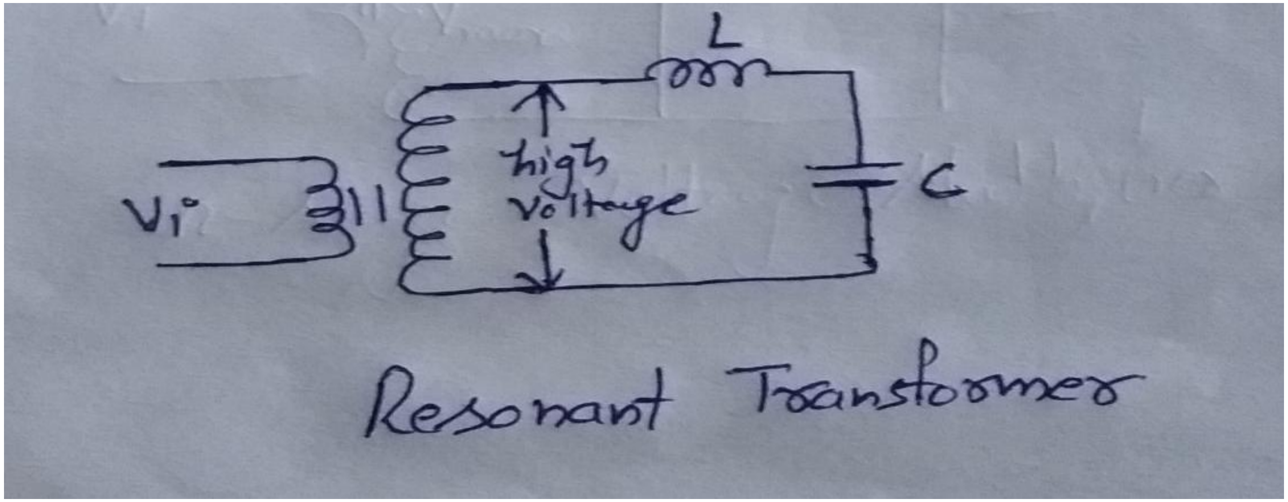


- **Cascade transformer;**

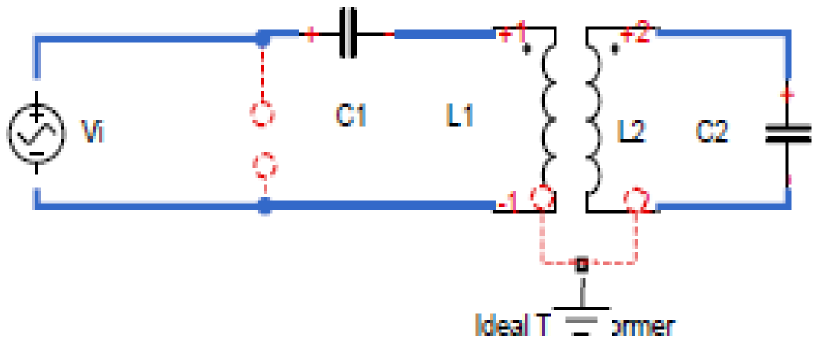
Cascade transformer is an very easy arrangement using which high AC voltage can be generated. This generated voltage helps in testing the insulation of power system equipment.



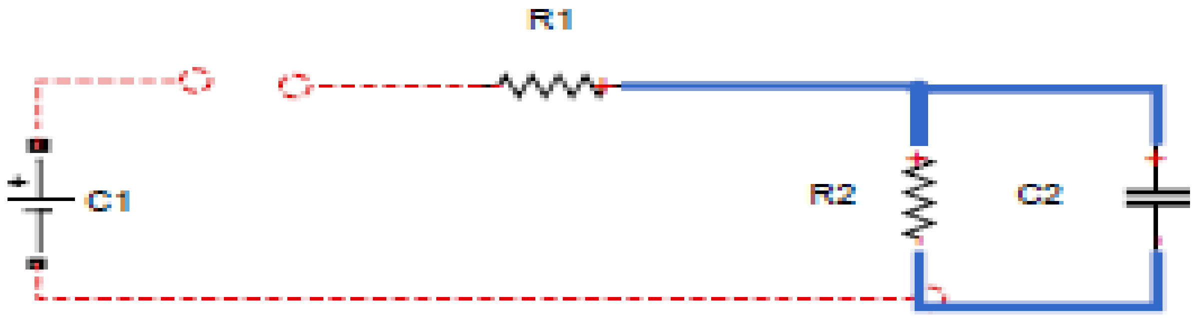
- **Resonant transformer:** Resonant transformer is the arrangement which is used to generate high AC voltage using the principle of electrical resonance. We know that if electrical circuit tin under resonance maximum response will occur. Below diagram is the arrangement of resonant transformer.



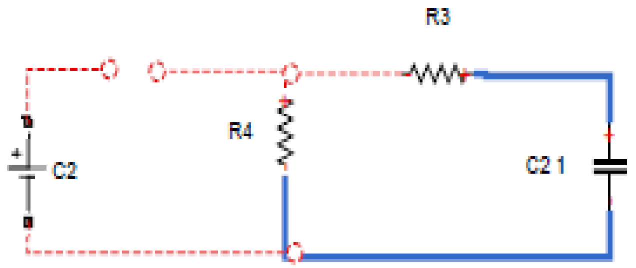
- **Generation high ac voltage with high frequecy:**

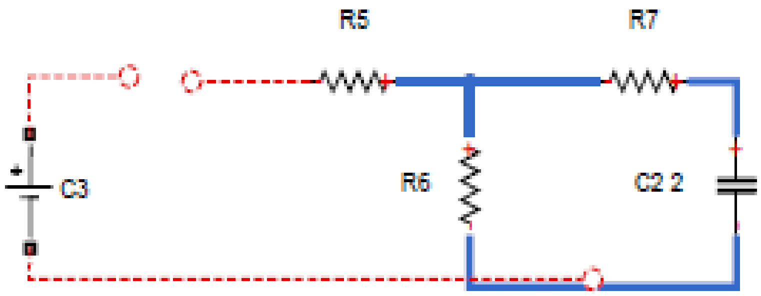


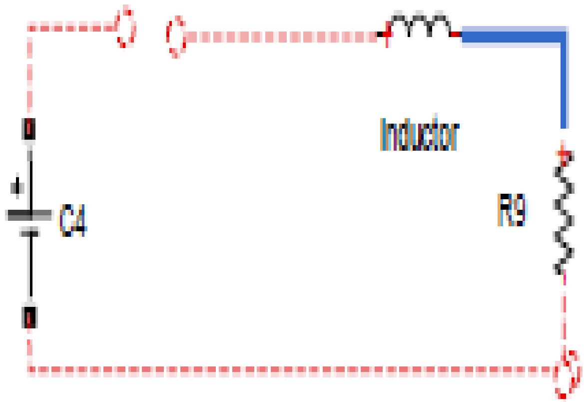
- **Generation of high impulse voltages.**



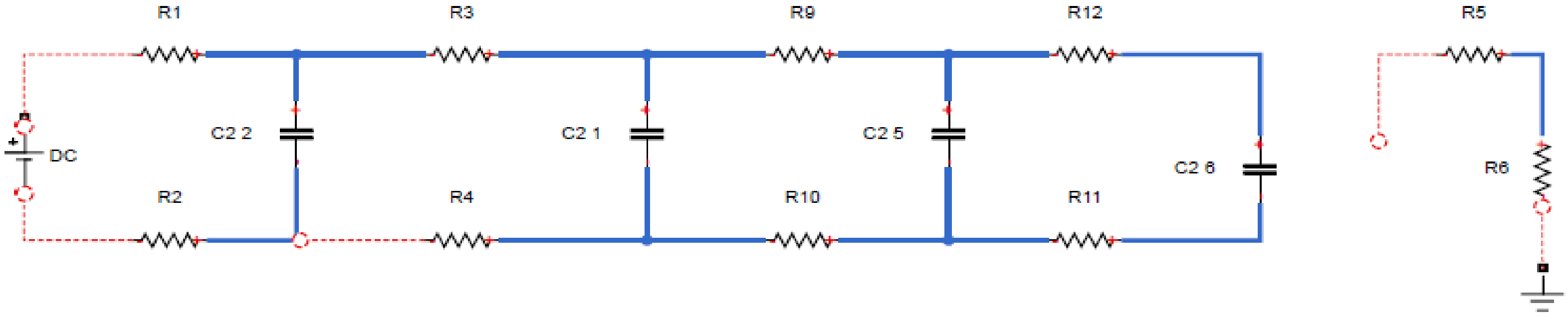
GENERATION OF HIGH VOLTAGE







- **Impulse generator with multiple stages (Marx circuits)**



Operation

- Let R – charging resister also current limiter.
- C – capacitance of the generator
- G – spark gap
- T – test object
- R1 R2 – used for wave shape control.

UNIT 4
MESARMENTS OF HIGH VOLTAGE & HIGH CURRENT

INTRODUCTION

- Various methods to measure the generated voltages and currents are:
- DC voltages:
- Series resistance micro ammeter.
- Resistance potential divider.
- Generation volt meter.
- AC voltages:
- Series impedance ammeter
- Potential divider.
- Potential transformer.
- Spear gaps.

INTRODUCTION

High frequency AC voltage.

- Peak volt meter
- Sphere gap

Methods to measure the high currents.

- Direct currents.
- Resistive shunt.
- Magnetic links.
- Hall effect.

Alternating currents

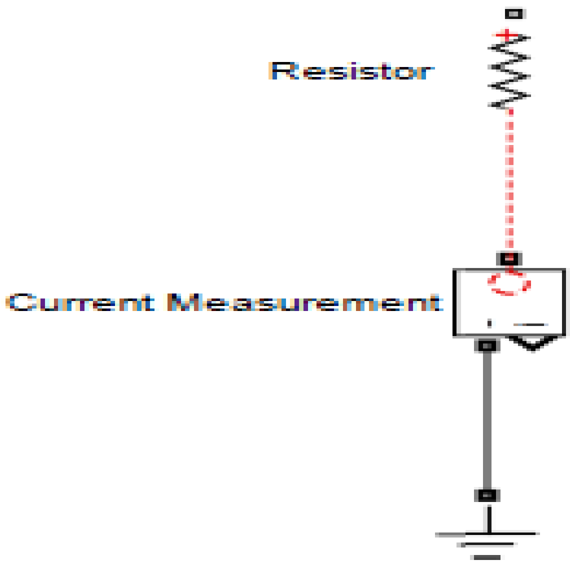
- Resistive shunts.
- Electro magnetic transformers.

INTRODUCTION

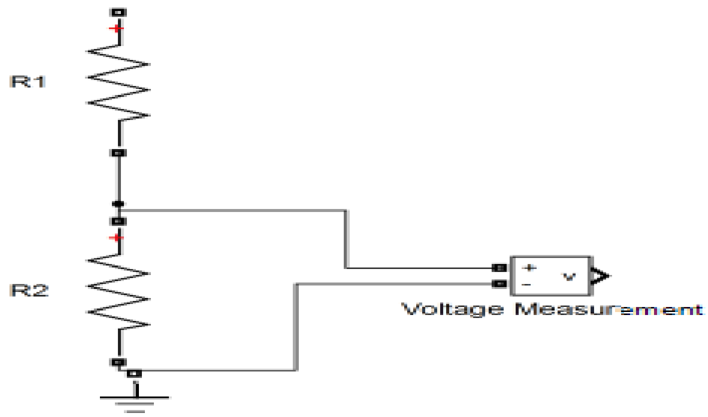
High frequency alternating current

- Resistive shunts.
- Magnetic links.
- hall effect.

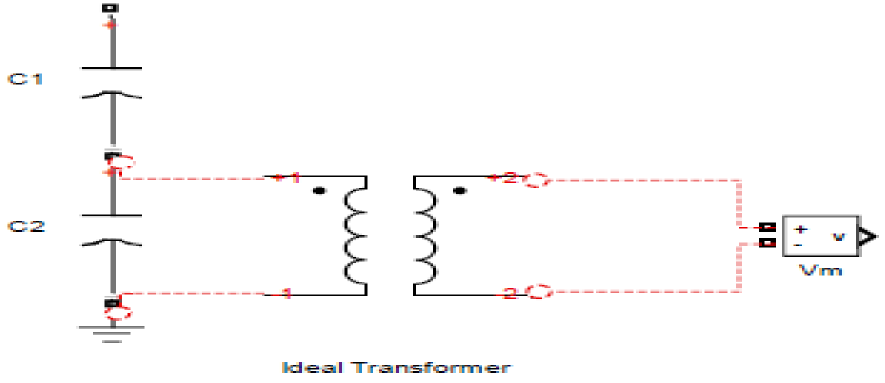
Micro ammeter with series resistance:



Potential divider to measure high DC voltage:



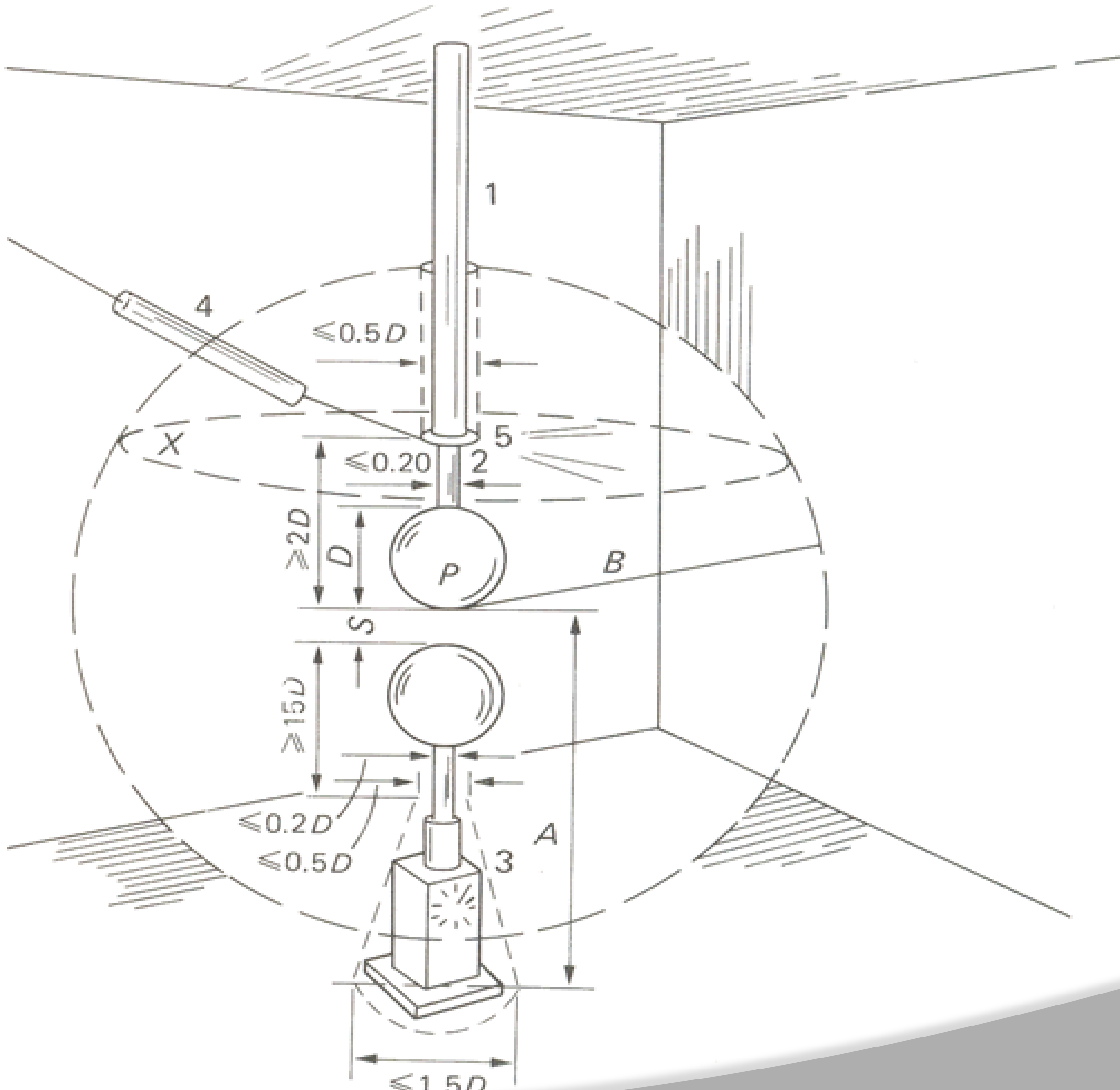
Capacitance voltage transformer to measure high AC voltage.



INTRODUCTION

- Magnetic links :Magnetic links are the metallic strips which are arranged on the drum which is parallel to the current carrying conductor. The remnant magnetism due to current carrying conductor has the influence on magnetic strips. The magnetism experienced by magnetic links can be approximated in terms of current thereby total current can be measure.
- **Sphere Gap**: This is one of the oldest technique adopted for the measurement of all the types (dc =, ac ~ and impulse) high voltages of either polarity. It remained the most widely used method for decades A sphere gap consists of two adjacent metal spheres of equal diameters whose separation gap distance is variable. avalanche and hence the breakdown.

SPHER GAP



SPHER GAP

UNIT 5
HIGH VOLTAGE TESTING & INSULATION COORDINATION

INTRODUCTION

- Insulation co-ordination: It is the process of getting understand of power system equipment with insulation technology for their safe and secure operation. Here insulation co-ordination with power system equipment is required to know the withstand capability of specimens and to avoid chances of failure.
- Basic impulse level (BIL):
- The electrical strength of the insulation what it can withstand without puncture and is the threshold value of lightning surge.
- Basic switching impulse level (BSL)
- The electrical strength of the insulation what it can withstand without puncture and is the threshold value of switch surge.
-

INTRODUCTION

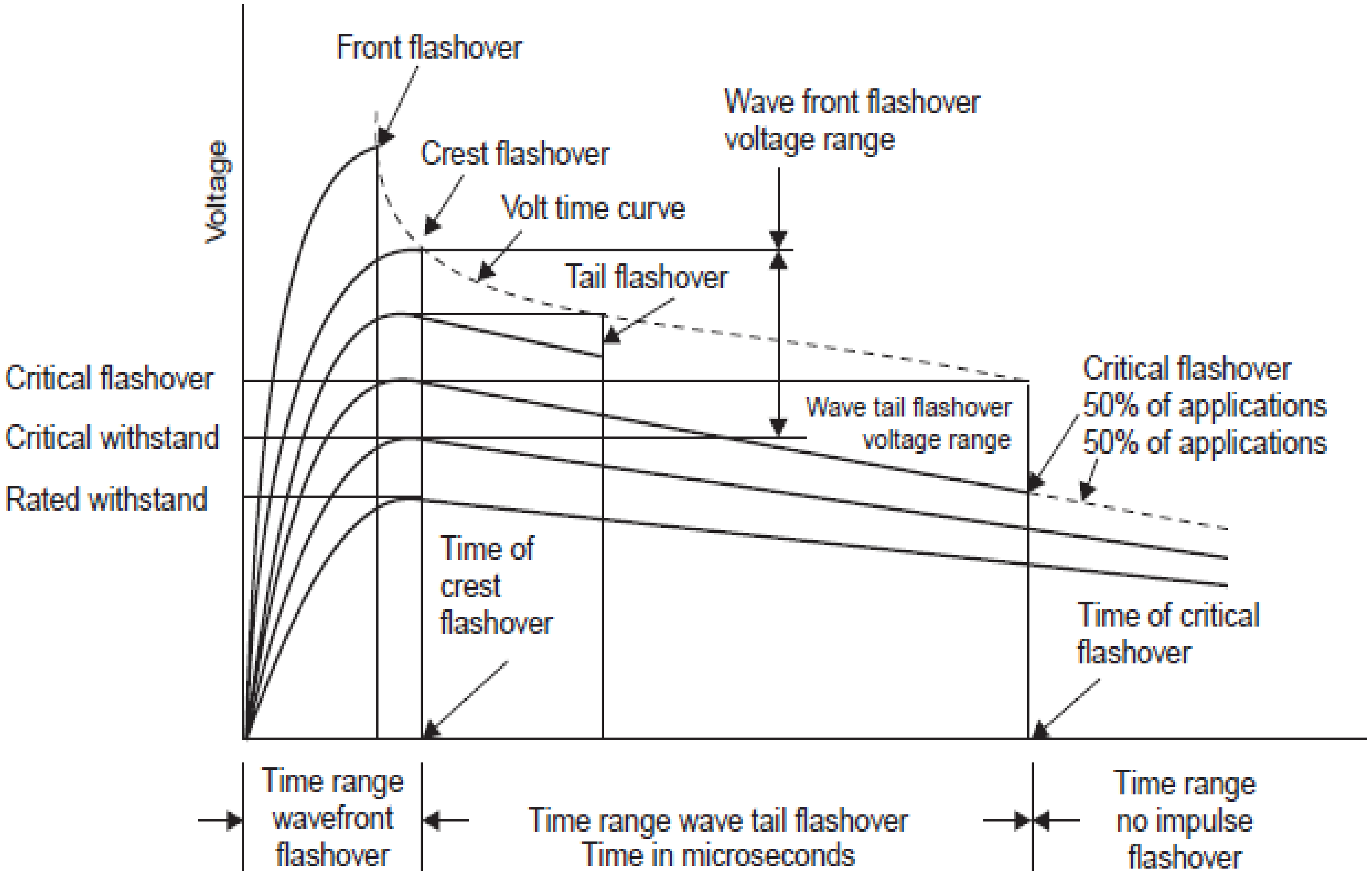
- **Factor of Earthling:**
- It is the ratio of highest RMS value of working frequency phase to earth voltage during during an earth fault to the RMS value of normal frequency phase to phase voltage at the required location without fault .
- This ratio helps in identifying the earthing constraints as view from the fault location.
- Effective Earthing System:
- An power system is said to be effectively earthed if the factor of earthing does not exceed 80% and if it exceeds is not effective.
- It is the maximum value of the switching and impulse testing voltages according to specifications which has 90 percent to withstand without flashover.

INTRODUCTION

- Statistical impulse voltage:
- It is the lightning surge and switch surge overvoltage applied to the power system equipment the maximum value of which has a 2% probability of surplus.
- Secure level of protective devices: This is the highest level of lightning surge and switch surge overvoltage at the terminals of the specimen which should not be exceeded for the normal working condition.
- Need of insulation co-ordination:
- To increase long life and continuity in service.
- To reduce the number of flashovers due to surges.
- For economical installation and operation.

- Surge arresters : Present surge arrester are the gapless ZnO , earlier silicon carbide arrester are used. This zinc oxide surge arrester has exceeded the characteristics of other has it has non-linear resistance behavior. Therefore it is possible to eliminate the series gaps between the individual ZnO block making up the arrester.
- Procedure to select surge arrester-
- estimate the arrester voltage regularly which in general rated voltage.
- Choose the rated voltage of the surge arrester.
- Calculate the normal lightning discharge current.
- Find the long duration required discharged capability
- 4. Determine the required long duration discharge capability.

HIGH VOLTAGE TESTING



HIGH VOLTAGE TESTING

- **Destructive** Testing: Here power systems equipment are tested for their withstand capability under different atmospheric, mechanical, electrical conditions. These are mainly classified into two types – type test, routine test.
- Type test: This test is meant to check the design features of the specimen.
- Routine test: This test is meant to check the quality of individual specimen.
- Testing Of Insulator:
- The testing are again classified as 1) power frequency tests 2) impulse test. Let us test the insulator under power frequency mode.

  Power frequency tests:
- Dry and wet flashover test.

- Dry and wet flashover test- in this test insulator is tested with AC power frequency voltage where the voltage applied continuously increased at rate of 2 percent per second till 75 percent rated voltage is reached. If this test is conducted dry atmospheric conditions it Is named as dry flashover test otherwise wet flashover test. Is the flashover occurs then the insulator fails to operate otherwise pass.
- Wet and dry with stand test-in this test the specified voltage is applied for one minute both in dry and wet condition and to say that test is passed the insulator must withstand that voltage without flashover.

HIGH VOLTAGE TESTING

- Impulse test:
- Impulse withstand test-in this the specified impulse voltage is applied to insulator under dry conditions with both positive and negative voltages. If the insulator with stand for five consecutive attempts then test is passed , but at least for two attempts flashover occurs then test is said to be failed.
- Impulse flashover test- here the specified impulse voltage is applied till the flashover occurs. But it is difficult to identify exact voltage of impulse as its duration is very small. Hence the test is conducted by applying 20% to 80% voltages .
- Pollution test- as insulators are exposed to air they may effected by different pollutants, some of them are sand particles, dust particles, bird excreta, moisture, snow, industrial waste etc.

- Testing Of Bushings:
- Power frequency test:
- Power factor and voltage test- here the specimen is immersed in oil and then set up in Schering bridge . The voltage applied is continuously changes and then capacitance, power factor or loss factor of bushing is calculated. Their by a plot between applied voltage and loss factor is drawn.
- Internal discharge: in this test an bushing is tested for its internal discharge due to cavities in it. The voltage is continuously applied and discharge is observed. the plot between voltage and discharge is drawn to understand the withstand capability of equipment.
- Momentary withstand test- the Indian standard voltage of bushing is applied to it and has withstand without any flashover for 30 seconds.

INSULATION COORDINATION

Testing Of isolators and circuit breakers

The different tests that can be conducted are –

- Overvoltage tests
- Temperature rise test
- Mechanical test
- Short circuit test.
- Short circuit test again classified as ,
- Direct test
- Synthetic test
- Synthetic test again classified as,
- Direct testing the networks or in the field.
- Direct testing the short circuit test lab
- Synthetic testing of circuit breaker

- Testing Of cables:

The different test classified on cables are ,

- Mechanical test
- Thermal duty test
- Dielectric power factor test
- Withstand voltage test at power frequency
- Withstand test impulse voltage
- Internal discharge test
- Life expectancy.
- Power factor and voltage test- here the specimen is immersed in oil and then set up in schering bridge . the voltage applied is continuously changes as 0.5 , 1, 1.66 and 2 times of rated voltage and then capacitance , power factor or loss factor of bushing is calculated.

INSULATION COORDINATION

- Testing Of Transformers:
- The most common equipment which is effected by lightning surges in power system is power transformer. The test on power transformer are-
- Induced over voltage test- the transformer secondary is tested by inducing over voltages for their withstand. The frequency of over voltage can be as high as 100 to 400Hz.
- Partial discharge test- in this test an transformer winding is tested for its internal discharge due to cavities in it. The voltage is continuously applied and discharge is observed. the plot between voltage and discharge is drawn to understand the withstand capability of equipment
- Impulse test- the procedure to conduct impulse test is –
- Applying basic impulse voltage of 75%.

INSULATION COORDINATION

- Impulse test- the procedure to conduct impulse test is –
- Applying basic impulse voltage of 75%.
- One full wave of basic impulse voltage.
- Two chopped waves of rated basic impulse voltage.
- One full wave of basic impulse voltage.
- Applying basic impulse voltage