CAPITAL UNIVERSITY JHARKHAND

HIGH VOLTAGE ENGINEERING

PART 1

1. Discuss different kinds of over voltages and its causes.

Increase in voltage for the very short time in power system is called as the over voltage. it is also known as the voltage surge or voltage transients. The voltage stress caused by over voltage can damage the lines and equipment's connected to the system, there are two types of causes of over voltage in power system.

1. Over voltage due to external causes
2. Over voltage due to internal causes

Transient over voltages can be generated at high frequency (load switching and lightning), medium frequency (capacitor energizing), or low frequency. Over voltage due to external causes: This cause of over voltage in power system is the lightning strokes in the cloud. Now, how lightning strikes are produced. So, when electric charges get accumulated in clouds due to thunder Strom caused due to some bad atmosphere process. 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.

2. Define stepped leader.

The initial streamer of a lightning discharge; an intermittently advancing column of high ion density which established the channel for subsequent return streamers and dart leaders.

Stepped leaders develop within thunderstorm clouds when charge differences between the main region of negative charge in the middle of the thunderstorm and the small region of positive charge near the base of the storm become large.
Stepped leaders start to develop when charge differences in the cloud become too large. When this happens, the insulating capacity of the air brakes down and the negative charge starts moving downward.

3. Define lightning phenomenon.

Lightning is a natural phenomenon which develops when the upper atmosphere becomes unstable due to the convergence of a warm, solar heated, vertical air column on the cooler upper air mass. These rising air currents carry water vapour which, on meeting the cooler air, usually condense, giving rise to convective storm activity.

Pressure and temperature are such that the vertical air movement becomes self-sustaining, forming the basis of a cumulonimbus cloud formation with its centre core capable of rising to more than 15,000 meters.

To be capable of generating lightning, the cloud needs to be 3 to 4 km deep. The taller the cloud, the more frequent the lightning.

The centre column of the cumulonimbus can have updrafts exceeding 120 km/hr, creating intense turbulence with violent wind shears and consequential danger to aircraft. This same updraft gives rise to an electric charge separation which ultimately leads to the lightning flash.

4. Define Iso keraunic level and back flash over.

The keraunic number is a system to describe lightning activity in an area based upon the audible detection of thunder. An isokeraunic map plots contours of equal keraunic number. The keraunic number has been used to set standards for safe design of electrical systems in structures connected to the local power grid.

Back flashover Is the one in which the arc comes from the tower body to the conductor. This happens when the potential of the tower itself became higher than phase potential due to lightning strikes.

When the current of the lightning passes through the tower body if the footing resistance of the tower is high then this current will make very high voltage IRIR and then the tower potential now is higher than the conductors potential (phases) and a back flashover occurs from the tower body which higher in the potential to the conductors which is now lower than the tower body.

5.List out various schemes of protection against over voltages.

There are several protection schemes invented along the line as protection engineers face new challenges with the advancement in power systems. Here, we will discuss the most basic ones.

1. Overcurrent Protection Scheme
2. Differential Protection Scheme
3. Distance Protection Scheme
4. Directional Protection Scheme

6. Define Shielding angle.

The Shielding Angle is defined as the angle between an imaginary vertical line extending downward from the overhead ground wire and an imaginary line connecting the ground wire and phase conductor.

Shielding angles of about 30 degrees is used for majority of transmission lines with tower heights in the range of 25 m. taller lines require smaller shielding angles than 30 degrees or else there will be Shielding Failures; that is, the lightning will bypass the overhead ground wire and strike the phase wire.

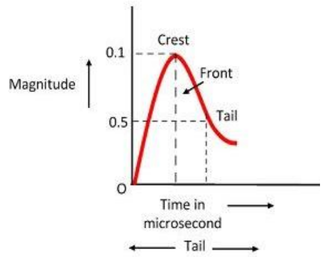
Protection zone of Ground Wire is a cone with apex at the location of Ground Wire and surface generated by line passing through the outermost phase conductor. If two or more Ground Wires are used then protection zone between two adjacent Ground Wires is a semicircle with diameter connection the two Ground Wires.

7. Define corona inception voltage.

Corona inception voltage is the lowest voltage at which continuous corona of specified pulse amplitude occurs as the applied voltage is gradually increased. Corona inception voltage decreases as the frequency of the applied voltage increases. Corona can occur in applications as low as 300V.

8. State the specifications of a travelling wave?

The travelling wave can be represented mathematically in a number of ways. It is most commonly representing in the form of infinite rectangular or step wave. A travelling wave is characterised by four specifications as illustrated in the figure below.



Crest – it is the maximum aptitude of the wave, and it is expressed in kV or kA.

Front – It is the portion of the wave before the crest and is expressed in time from the beginning of the wave to the crest value in milliseconds or µs.

Tail – The tail of the wave is the portion beyond the crest. It is expressed in time from the beginning of the wave to the point where the wave has reduced to 50% of its value at its crest.

Polarity – Polarity of the crest voltage and value. A positive wave of 500 kV crest 1 µs front and 25 µs tail will be presented as +500/1.0/25.0.

9. Define surge impedance of a line?

Surge Impedance is the characteristic impedance of a lossless transmission line. It is also called Natural Impedance because this impedance has nothing to do with load impedance. Since line is assumed to be lossless, this means that series resistance and shunt conductance is negligible i.e., zero for power lines.

This means that, Series Resistance $R = 0$ and Shunt Conductance $G = 0$

As Characteristic Impedance $Z_c = z/y$
where z is series impedance per unit length per phase and y is shunt admittance per unit length per phase.

$z = R + jwL$
$y = G + jwC$

For lossless line, $z = jwL$ and $y = jwC$

Hence according to definition,
Surge Impedance = $Z_s = Z_c = \sqrt{(jwL/jwC)}$
$= \sqrt{(L/C)}$

10. Define attenuation? How they are caused

Attenuation in an electrical system is the loss or reduction in the amplitude or strength of a signal as it passes along its length. As the signal travels through the copper wire conductor some of the signal will be absorbed.

Attenuation is a result of resistance in the conductor and associated dielectric losses which is exaggerated by longer run lengths and higher frequency signals. By improving the dielectric properties of the insulation and increasing the conductor size it will reduce the attenuation.

11. Discuss about ionization?

Ionization, in chemistry and physics, any process by which electrically neutral atoms or molecules are converted to electrically charged atoms or molecules (ions). Ionization is one of the principal ways that radiation, such as charged particles and X rays, transfers its energy to matter.

Ionization by collision occurs in gases at low pressures when an electric current is passed through them. If the electrons constituting the current have sufficient energy (the ionization energy is different for each substance), they force other electrons out of the neutral gas molecules, producing ion pairs that individually consist of the resultant positive ion and detached negative electron. Negative ions are also formed as some of the electrons attach themselves to neutral gas molecules. Gases may also be ionized by intermolecular collisions at high temperatures.

Ionization, in general, occurs whenever sufficiently energetic charged particles or radiant energy travel through gases, liquids, or solids. Charged particles, such as alpha particles and electrons from radioactive materials, cause extensive ionization along their paths. Energetic neutral particles, such as neutrons and neutrinos, are more penetrating and cause almost no ionization. Pulses of radiant energy, such as X-ray and gamma-ray photons, can eject electrons from atoms by the photoelectric effect to cause ionization. The energetic electrons resulting from the absorption of radiant energy and the passage of charged particles in turn may cause further ionization, called secondary ionization. A certain minimal level of ionization is present in the Earth’s atmosphere because of continuous absorption of cosmic rays from space and ultraviolet radiation from the Sun.

12. Define Paschen’s law.

Paschen's law states that the breakdown voltage between electrodes in a gas is a function of the product of the distance and the pressure so that if the distance is doubled the pressure must be halved.

Paschen's law is an equation that gives the breakdown voltage, that is, the voltage necessary to start a discharge or electric arc, between two electrodes in a gas as a function of pressure and gap length.

13. Define gas law.

The gas laws are a group of laws that govern the behaviour of gases by providing relationships between the following:

- The volume occupied by a gas.
- The pressure exerted by a gas on the walls of its container.
- The absolute temperature of the gas.
- The amount of gaseous substance (or) the number of moles of gas.

The gas laws were developed towards the end of the 18^{th} century by numerous scientists (after whom, the individual laws are named). The five gas laws are:

- Boyle’s Law, which provides a relationship between the pressure and the volume of a gas.
- Charles’s Law, which provides a relationship between the volume occupied by a gas and the absolute temperature.
- Gay-Lussac’s Law, which provides a relationship between the pressure exerted by a gas on the walls of its container and the absolute temperature associated with the gas.
- Avogadro’s Law, which provides a relationship between the volume occupied by a gas and the amount of gaseous substance.
- The Combined Gas Law (or the Ideal Gas Law), which can be obtained by combining the four laws listed above.
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Under standard conditions, all gasses exhibit similar behaviour. The variations in their behaviours arise when the physical parameters associated with the gas (such as temperature, pressure, and volume) are altered. The gas laws basically describe the behaviour of gases and have been named after the scientists who discovered them.

14. Outline the concept of corona discharge.

A corona discharge is an electrical discharge caused by the ionization of a fluid such as air surrounding a conductor carrying a high voltage. It represents a local region where the air (or other fluid) has undergone electrical breakdown and become conductive, allowing charge to continuously leak off the conductor into the air.

A corona occurs at locations where the strength of the electric field (potential gradient) around a conductor exceeds the dielectric strength of the air. It is often seen as a bluish glow in the air adjacent to pointed metal conductors carrying high voltages, and emits light by the same mechanism as a gas discharge lamp.

15. Define intrinsic strength?

Intrinsic strength of a solid dielectric is the maximum electric field a material that can withstand without breaking down independent of the size or the shape of the material.

The theoretical dielectric strength of a material is an intrinsic property of the bulk material, and is independent of the configuration of the material or the electrodes with which the field is applied. This "intrinsic dielectric strength" corresponds to what would be measured using pure materials under ideal laboratory conditions. At breakdown, the electric field frees bound electrons.

If the applied electric field is sufficiently high, free electrons from background radiation may be accelerated to velocities that can liberate additional electrons by collisions with neutral atoms or molecules, in a process known as avalanche breakdown.

Breakdown occurs quite abruptly (typically in nanoseconds), resulting in the formation of an electrically conductive path and a disruptive discharge through the material. In a solid material, a breakdown event severely degrades, or even destroys, its insulating capability.

16. Define uniform and non-uniform fields?

Uniformity is defined on the basis of spatial distribution of electric vector field. Electric field is said to be uniform at a point if field in neighbourhood of the point is same as at the point concerned. Otherwise, non-uniform.

If an electric field has the same magnitude and same direction everywhere in a given space then this electric field is uniform, and if either the magnitude or direction or both change then it is a non-uniform electric field in that specified space.

17. Explain the term' 'electron attachment".

Electron attachment is the chemical process whereby an electron is attached to a neutral molecule. Examples include electron photo-attachment to CN to produce CN^- and a photon, and dissociative electron attachment to HCN to produce CN^- and a hydrogen atom.

18. Explore the concept of penning effect.

Penning ionization is a form of chemi-ionization, an ionization process involving reactions between neutral atoms or molecules.[1][2] The Penning effect is put to practical use in applications such as gas-discharge neon lamps and fluorescent lamps, where the lamp is filled with a Penning mixture to improve the electrical characteristics of the lamps.

19. List the merits and demerits of Van de Graaff generator?

Advantages

1. Output is ripple free
2. Flexibility and precision of voltage control.
3. Very high voltage can be easily created.

Disadvantages

1. Vibration is more, hence it is difficult to have accurate electric filed.
2. Output current rating is low
3. Limitations on belt velocity due to its tendency for vibration

20. Explain the superiority of cascaded transformer over two winding transformers used for generation of high ac voltages.

For voltages higher than 400 KV, it is desired to cascade two or more transformers depending upon the voltage requirements. With this, the weight of the whole unit is subdivided into single units and, therefore, transport and erection become easier.

Power supply to the isolating transformers is also fed from the same ac. input. This scheme is expensive and requires more space. The advantage of this scheme is that the natural cooling is sufficient and the transformers are light and compact. Transportation and assembly are easy.

21. Write the different forms of high voltages required for the testing of electrical apparatus.

- High d.c. voltages
- High a.c. voltages of power frequency.
- High a.c. voltages of high frequency.
- High transient or impulse voltages of very shot over voltages, and
- Transient voltages of longer duration such as switching surges.

22. What is the principle of operation of a resonant transformer?

Resonant transformer work on the principle that the load capacitance is variable and for certain loading when the capacitance is equal to inductance of the circuit resonance may occur.

Under this condition then, the current will be very large and limited only by the resistance of the circuit. The waveform of the voltage across the test object will be purely sinusoidal.

23. What is tesla coil?

A Tesla coil is an electrical resonant transformer circuit designed by inventor Nikola Tesla in 1891. It is used to produce high-voltage, low-current, high frequency alternating-current electricity. Tesla experimented with a number of different configurations consisting of two, or sometimes three, coupled resonant electric circuits.

24. Give the basic principle for electrostatic generator?

An electrostatic generator, or electrostatic machine, is an electrical generator that produces static electricity, or electricity at high voltage and low continuous current. The knowledge of static electricity dates back to the earliest civilizations, but for millennia it remained merely an interesting and mystifying phenomenon, without a theory to explain its behaviour and often confused with magnetism.

By the end of the 17th century, researchers had developed practical means of generating electricity by friction, but the development of electrostatic machines did not begin in earnest until the 18th century, when they became fundamental instruments in the studies about the new science of electricity. Electrostatic generators operate by using manual (or other) power to transform mechanical work into electric energy, or using electric currents.

Manual electrostatic generators develop electrostatic charges of opposite signs rendered to two conductors, using only electric forces, and work by using moving plates, drums, or belts to carry electric charge to a high potential electrode.

25. State the components of multistage impulse generator?

A Multistage Impulse Generator Circuit requires several components parts for flexibility and for the production of the required waveshape. These may be grouped as follows:

1.d.c. Charging Set: The charging unit should be capable of giving a variable d.c. voltage of either polarity to charge the generator capacitors to the required value.

2.Charging Resistors: These will be non-inductive high value resistors of about 10 to 100 kilo-ohms. Each resistor will be designed to have a maximum voltage between 50 and 100 kV.

3.Generator Capacitors and Spark Gaps: These are arranged vertically one over the other with all the spark gaps aligned. The capacitors are designed for several charging and discharging operations. On dead short circuit, the capacitors will be capable of giving 10 kA of current. The spark gaps will be usually spheres or hemispheres of 10 to 25 cm diameter. Sometimes spherical ended cylinders with a central support may also be used.

4.Wave-shaping Resistors and Capacitors: Resistors will be non-inductive wound type and should be capable of discharging impulse currents of 1000 A or Each resistor will be designed for a maximum voltage of 50 to 100 kV. The resistances are bifilar wound on non-inductive thin flat insulating sheets. In some cases, they are wound on thin cylindrical formers and are completely enclosed. The load capacitor may be of compressed gas or oil filled with a capacitance of 1 to 10 nF.

26. Define the front and tail times of an impulse wave. What are the tolerances allowed as per the specifications?

Front time T1: is measured as 1.67 times the interval T between the instants when the impulse is 30% and 90% of the peak value. Tail time T2: is measured as the time interval between the virtual origin O1 and the instant when the voltage has decayed to half of peak value.

Tail time T2: is measured as the time interval between the virtual origin O1 and the instant when the voltage has decayed to half of peak value.

The tolerances that can be allowed in the front and tail times are respectively ± 30% and ± 20%. Indian standard specifications define 1.2/50 μs wave to be the standard lightning impulse. The tolerance allowed in the peak value is ± 3%.

27. Differentiate between spark over, flash over and puncture?

Flashover: It is a discharge over the surface of the insulation systems. Puncture or Spark over: It is a discharge through the insulation systems. If the insulation is solid, it could not able to regain its insulation strength after puncture.

28. Mention the different methods of producing switching impulses in test laboratories.

Capacitors previously charged to DC voltage is discharged into a wave shaping network (LR, R1 R2, R3 or other combination) by closing a switch. This gives the desired output (double exponential wave).

1. Impulse generator circuits can be used by suitably modifying the R_1 & R_2.

2. Power Tr or Testing Tr, excited by dc voltages giving oscillatory wave (Tesla tal)

29. Trigatron gap- Explain its functions and operation.

A trigatron is a type of triggerable spark gap switch designed for high current and high voltage (usually 10–100 kV and 20–100 kA, though devices in the mega-ampere range exist as well). It has very simple construction and in many cases is the lowest cost high energy switching option.

It may operate in open air, it may be sealed, or it may be filled with a dielectric gas other than air or a liquid dielectric. The dielectric gas may be pressurized, or a liquid dielectric (e.g., mineral oil) may be substituted to further extend the operating voltage. Trigatrons may be rated for repeated use (over 10,000 switching cycles), or they may be single-shot, destroyed in a single use.

30. List the advantages of series resonant circuit.

The advantages of series resonance circuit can be stated as:

i. The power requirements in KW of the feed circuit are (kVA)/Q where kVA is the reactive power requirements of the load and Q is the quality factor of variable reactor usually greater than 40. Hence, the requirement is very small.
ii. The series resonance circuit suppresses harmonics and interference to a large extent. The near sinusoidal wave helps accurate partial discharge of measurements and is also desirable for measuring loss angle and capacitance of insulating materials using Schering Bridge.
iii. In case of a flashover or breakdown of a test specimen during testing on high voltage side, the resonant circuit is detuned and the test voltage collapses immediately. The short circuit current is limited by the reactance of the variable reactor. It has proved to be of great value as the weak part of the isolation of the specimen does not get destroyed. In fact, since the arc flash over has very small energy, it is easier to observe where exactly the flashover is occurring by delaying the tripping of supply and allowing the recurrence of flashover.
iv. No separate compensating reactors (just as we have in case of test transformers) are required. This results in a lower overall weight.
v. When testing SF6 switchgear, multiple breakdowns do not result in high transients. Hence, no special protection against transients is required.

31. Mention the necessity of generating High DC voltage

High voltages in labs are mainly required in the fields of electrical engineering and applied physics. These high voltages (ac, dc, impulse) are used for many applications.

Few applications: -

electron microscopes and x ray units require high DC voltages of the order of 100 kv or more.

electrostatic precipitator, particle accelerators in nuclear physics require DC voltages of the order of kilo-volts or even mega-volts.

for testing power apparatus rated for extra high transmission voltages 400kV and above, high voltages of one million volts or even more are required.

high impulse voltages are used to simulate the over-voltages that occur in power system due to lightening or switching action.

In the field of electrical engineering the main requirement of high voltages is for insulation testing of various components in power system. This is why there is a need to generate high voltages in laboratories.

32. Discuss the advantages and limitations of generating volt meters.

Advantages of Generating Voltmeters:

- no source loading by the meter,
- no direct connection to high voltage electrode,
- scale is linear and extension of range is easy, and
- a very convenient instrument for electrostatic devices such as Van de Graaff generator and particle accelerators.

Disadvantages of Generating Voltmeters:

- They require calibration,
- Careful construction is needed and is a cumbersome instrument requiring an auxiliary drive

33. Write the advantages and disadvantages of CVT.

Advantages of CVT

- Outstanding fuel efficiency is a major advantage for your Bloomfield and Troy commutes. CVTs are always adjusting, so they keep engine RPMs low and consistent, avoiding the high engine speeds that suck down gasoline.

- CVTs also have lower production costs because they have fewer moving parts than traditional automatics. This is another appealing factor to car manufacturers, and thus to car buyers as well.
- CVTs deliver a smooth ride because the transmission doesn't have to constantly switch gears.

Disadvantages of CVT

- You may feel a delay when you step on the accelerator. That's because, compared to a regular automatic transmission, there's a slight pause as the CVT band adjusts.
- CVTs can be hard to get used to because they just don't feel the same way a traditional automatic doe. The engine sound is monotonous, and you don't feel a connection with the car like you do when you can tell a gear has shifted.
- In spite of the low initial costs of a CVT, repairs can be more expensive because the parts are more costly to replace. And because technicians need special training, it may be harder to find someone that can make the repair. This has become less of an issue as CVTs have become more common.

34. List the drawbacks of resistance potential divider?

A Voltage Divider circuit works perfectly provided then there is nothing attached to the dividing point. In using a Divider circuit (or a potentiometer) the division point must be followed by a very high resistance. The accuracy of the voltage at the dividing point is only as good as the ration between the Input resistance and the output resistance. I.e., A 100000 + 100000-ohm divider would have an output impedance of 50000 ohms and feeding into a 500 Meg-ohm Meter Input will be accurate to (50000/5000000) x 100 = 1.0%.

Voltage Divider Networks are very important in analogue measurements and it is wise to be aware of their limitations.

These limitations mean that a voltage divider is only really any use to feed a very high impedance low drain connection like a voltage reference point, and is little use for actually powering anything.

35. Give the basic principle of generating and electrostatic voltmeter?

An electrostatic voltmeter uses the attraction force between two charged surfaces to create a deflection of a pointer directly calibrated in volts. Since the attraction force is the same regardless of the polarity of the charged surfaces (as long as the charge is opposite), the electrostatic voltmeter can measure DC voltages of either polarity.

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36. List out the advantages of CVT?

Advantages of CVT

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- CVTs deliver a smooth ride because the transmission doesn't have to constantly switch gears.

37. List the general methods used for measurement of high frequency and impulse currents.

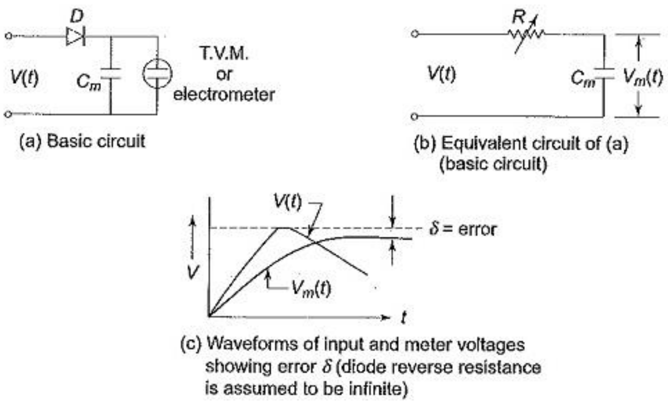
In power system the amplitude of currents may vary between a few amperes to a few hundred kiloamperes and the rate of rise of currents can be as high as 1010A/sec and the rise time can vary between a few micro seconds to a few macro seconds. Therefore, the device to be used for measuring such currents should be capable of having a good frequency response over a very wide frequency band.

The methods normally employed are—(i) resistive shunts; (ii) elements using induction effects; (iii) Faraday and Hall effect devices.

38. List out various techniques for high voltage DC measurement

1. Resistive (Direct)
   a. Current Sense Resistors
   b. Inductor DC resistance
2. Magnetic (Indirect)
   a. Current Transformer
   b. Rogowski Coil
   c. Hall Effect Device
3. Transistor (Direct)
   a. $R_{DS(ON)}$
   b. Ratio-metric

39. Draw the simple circuit of peak reading voltmeter and its equivalent



40. List the factors that are influencing the peak voltage measurement using sphere gap.

- nearby earthed objects,
- atmospheric conditions and humidity,
- irradiation, and
- polarity and rise time of voltage waveforms.

41. Outline the limitations of generating voltmeter?

Disadvantages of Generating Voltmeters:

- They require calibration,
- Careful construction is needed and is a cumbersome instrument requiring an auxiliary drive.

42. Give the principle of mixed potential divider? How is it used for impulse voltage measurements?

Mixed RC Potential Divider use R-C elements in series or in parallel. One method is to connect capacitance in parallel with each R'_1 element. This is successfully employed for voltage dividers of rating 2 MV and above. A better construction is to make an R-C series element connection.

Potential or voltage dividers for high voltage Impulse Voltage Measurements, high frequency ac. measurements, or for fast rising transient voltage measurements are usually either resistive or capacitive or mixed element type. The low voltage arm of the divider is usually connected to a fast-recording oscillograph or a peak reading instrument through a delay cable. A schematic diagram of a potential divider with its terminating equipment is given in Fig. 7.24. Z_1 is usually a resistor or a series of resistors in case of a resistance potential divider, or a single or a number of capacitors in case of a capacitance divider.

43.Define disruptive discharge voltage?

It is that voltage at which the electrical stress in the insulation causes a failure which includes the collapse of voltage and passage of current. In solids, this causes a permanent loss of strength, and in liquids or gases only temporary loss may be caused.

44. Define withstand and flashover voltage?

Flashover – When a discharge takes place between two electrodes (in a gas, liquid or solid) over the surface of the dielectric but not through the volume of the insulator then it is called flashover. It is mostly temporary failure of insulation of the insulator. The dielectric strength of the insulator is recovered completely once the adverse conditions which resulted in flashover are removed.

Withstand Voltage – The voltage which is to be applied to a test object under specified conditions without causing flashover or puncture of the insulator is known as withstand voltage.

45. Define 50% and 100% flashover voltage?

50% Flashover Voltage: This is the voltage which has a probability of 50% flashover, when applied to a test object. This is normally applied in impulse tests in which the loss of insulation strength is temporary.

100% Flashover Voltage: The voltage that causes a flashover at each of its applications under specified conditions when applied to test objects is specified as hundred per cent flashover voltage.

46. Define creepage distance?

The shortest distance along a solid insulation surface between two conductive parts.

47.Define partial discharge?

Partial discharge (PD) is a localized electrical discharge that only partially bridges the insulation between conductors and which may or may not occur adjacent to a conductor.

PD occurs whenever there is a stressed region due to some impurity/cavity inside the insulation or when there is a protrusion outside it.

48. Discuss about BIL in power system insulation coordination?

The minimum level is known as the Basic Insulation Level (BIL) that must be that of all of the components of a system. Insulation values above this level for the lines and equipment in the system must be so coordinated that specific protective devices operate satisfactorily below that minimum level.

In the design of lines and equipment considering the minimum level of insulation required, it is necessary to define surge voltage in terms of its peak value and return to lower values in terms of time or duration. Although the peak voltage may be considerably higher than normal voltage, the stress in the insulation may exist for only a very short period of time.

49. Examine the concept of one minute dry/wet withstand test

Withstand Test: The insulator should be mounted so as to simulate practical conditions. A 1/50 s wave of the specified voltage (corrected for humidity, air density etc.,) is applied. Flashover or puncture should not occur. [If puncture occurs, the insulator is permanently damaged]. The test is repeated five times for each polarity.

Dry One-minute test: The insulator, clean and dry, shall be mounted as specified and the prescribed voltage (corrected for ambient conditions) should be gradually brought up (at power frequency) and maintained for one minute. There shall not be puncture or flash-over during the test.

One-minute Rain test: The insulator is sprayed throughout the test with artificial rain drawn from a source of supply at a temperature within 10o C of the ambient temperature of the neighbourhood of the insulator. The rain is sprayed at an angle of 45 o on the insulator at the prescribed rate of 3 mm/minute. The resistivity of the water should be 100 ohm-m ± 10%. The prescribed voltage is maintained for one minute.

50. Distinguish between flashover and puncture

Flashover: It is a discharge over the surface of the insulation systems.

Puncture or Spark over: It is a discharge through the insulation systems. If the insulation is solid, it could not able to regain its insulation strength after puncture.

PART 1A

1. Explore the mechanism of lightning and mathematical model of lightning.

Lightning, the visible discharge of electricity that occurs when a region of a cloud acquires an excess electrical charge, either positive or negative, that is sufficient to break down the resistance of air.

A brief description of lightning follows. For a longer discussion of lightning within its meteorological context, see thunderstorm electrification in the article thunderstorm.

During the charge formation process, the cloud may be considered to be a non-conductor. Hence, various potentials may be assumed at different parts of the cloud. If the charging process is continued, it is probable that the gradient at certain parts of the charged region exceeds the breakdown strength of the air or moist air in the cloud. Hence, local breakdown takes place within the cloud. This local discharge may finally lead to a situation wherein a large reservoir of charges involving a considerable mass of cloud hangs over the ground, with the air between the cloud and the ground as a dielectric.

When a streamer discharge occurs to ground by first a leader stroke, followed by main strokes with considerable currents flowing, the Mathematical Model of Lightning Stroke may be thought to be a current source of value I_0 with a source impedance Z_0 discharging to earth. If the stroke strikes an object of impedance Z, the voltage built across it may be taken as

$$
\begin{aligned}
V &= I Z \\
&= I_0 \frac{Z Z_0}{Z + Z_0} \\
&= I_0 \frac{Z}{1 + \dfrac{Z}{Z_0}}
\end{aligned}
$$

The source impedance of the lightning channels is not known exactly, but it is estimated to be about 1000 to 3000 Ω. The objects of interest to electrical engineers, namely, transmission line, etc. have surge impedances less than 500 Ω (overhead lines 300 to 500 Ω, ground wires 100 to 150 Ω, towers 10 to 50 Ω, etc.). Therefore, the value Z/Z_0 will usually be less than 0.1 and hence can be neglected. Hence, the voltage rises of lines, etc. may be taken to be approximately $V = I_0 Z$, where I_0 is the Mathematical Model of Lightning Stroke current and Z the line surge impedance.

If a Mathematical Model of Lightning Stroke current as low as 10,000 A strikes a line of 400 Ω surge impedance, it may cause an overvoltage of 4000 kV. This is a heavy overvoltage and causes immediate flashover of the line conductor through its insulator strings.

In case a direct stroke occurs over the top of an unshielded transmission line, the current wave tries to divide into two branches and travel on either side of the line. Hence, the effective surge impedance of the line as seen by the wave is $Z_0/2$ and taking the above example, the overvoltage caused may be only 10,000 (400/2) = 2000 kV. If this line were to be a 132 kV line with an eleven 10-inch disc insulator string, the flashover of the insulator string will take place, as the impulse flashover voltage of the string is about 950 kV for a 2 μs front impulse wave.

The incidence of lightning strikes on transmission lines and sub-stations is related to the degree of thunderstorm activity. It is based on the level of "Thunderstorm days" (TD) known as "Isokeraunic Level" defined as the number of days in a year when thunder is heard or recorded in a particular location. But this indication does not often distinguish between the ground strokes and the cloud-to-cloud strokes. If a measure of ground flashover density (N_g) is obtained, then the number of ground flashovers can be computed from the TD level. From the past records and the past experience, it is found that

$$N_g = (0.1 \text{ to } 0.2)\ \text{TD/strokes/km}^2\text{-year}$$

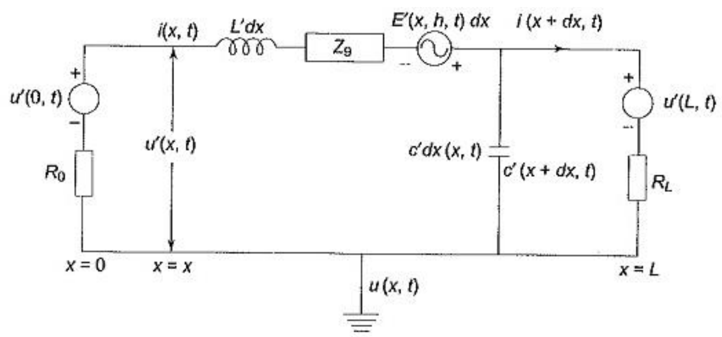
In lightning studies, the strokes to ground are of importance as they induce over-voltages on transmission lines and in nearby objects. Hence, a model based on lightning return stroke is presented here which assumes that the lightning channel is straight, vertical and normal to the ground plane. The return stroke current I (Z, t) is assumed as function of vertical co-ordinate z and time t and the initial current I (o, t) is of importance in engineering applications. The electromagnetic fields associated with the lightning current and the lightning induced voltages are calculated based on the return stroke current equations taken as

$$i\,(z, t) = i\,(t - z/v) \qquad z < vt$$

$$i\,(z, t) = 0 \qquad z > vt$$

where, v is the return stroke velocity assuming that the current pulse propagates without attenuation and distortion in the upward channel. Since the current varies both in space and time, the electric field and magnetic field associated with it can be calculated using Maxwell's equations for time varying fields.

Whenever a transmission line is nearer to the stroke channel there will be a coupling between the line and the stroke channel. The total voltage induced on the line, is computed by solving the coupling equations involving the total induced voltage u (x, t) and the induced current i (x, t) assuming that the transmission line is in the directions. An equivalent circuit for coupling is given by Agrawal et al (Fig. 8.13) from which the voltage at any length x = L can be computed.



2. Explain the various protection of transmission line against different over voltages.

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 equipment and insulators of the power system. Although, all the over voltage stresses are not strong enough to damage insulation of system, but still these over voltages also to be avoided to ensure the smooth operation of electrical power system. These all types of destructive and non-destructive abnormal over voltages are eliminated from the system by means of over voltage protection.

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 cause 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.

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. During insulation failure, a live conductor is suddenly earthed. This may also cause sudden over voltage in the system.

Methods of Protection Against Lightning

These are mainly three main methods generally used for protection against lightning. They are

- Earthing screen.
- Overhead earth wire.
- Lightning arrester or surge dividers.
-

Earthing Screen

Earthing screen is generally used over electrical substation. In this arrangement a net of GI wire is mounted over the sub-station. The GI wires, used for earthing screen are properly grounded through different sub-station structures. This network of grounded GI wire over electrical sub-station, provides very low resistance path to the ground for lightning strokes.

Overhead Earth Wire

This method of over voltage protection is similar as earthing screen. The only difference is, an earthing screen is placed over an electrical sub-station, whereas, overhead earth wire is placed over electrical transmission network. One or two stranded GI wires of suitable cross-section are placed over the transmission conductors. These GI wires are properly grounded at each transmission tower. These overhead ground wires or earth wire divert all the lightning strokes to the ground instead of allowing them to strike directly on the transmission conductors.

Lightning Arrester

The previously discussed two methods, i.e. earthing screen and over-head earth wire are very suitable for protecting an electrical power system from directed lightning strokes but system from directed lightning strokes but these methods cannot provide any protection against high voltage travelling wave which may propagate through the line to the equipment of the sub-station.
The lightning arrester is a devices which provides very low impedance path to the ground for high voltage travelling waves.
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.

3. Derive the expression for velocity of travelling waves on transmission line

Let the voltage wave and current wave travels a distance x in time t. Therefore, the inductance and capacitance of line up to distance x will be Lx and Cx respectively. Let this wave travels a distance dx in time dt.

Since line is assumed to be lossless, whatever is the value of voltage wave and current wave at the beginning, the same will be at any time t. This means that, the magnitude of voltage and current wave at time t will be V and I respectively.

Hence the stored charge in shunt capacitance $Q = VCx$
and the flux in the series inductance $\varnothing = ILx$

But $I = dQ/dt$
$= CVdx/dt$
But dx/dt = velocity of travelling wave = ν (say)
Therefore, $I = CV\nu$ ……. (1)

The voltage developed across the shunt capacitance,
$V = d\varnothing/dt$
$= ILdx/dt$
$= IL\nu$
$\Rightarrow V = IL\nu$ ………. (2)

Dividing equation (1) and (2), we get
$V / I = IL / CV$
$(V/I)^2 = L/C$
$V/I = \sqrt{(L/C)}$

The above expression is the ratio of voltage and current having the dimension of impedance. Therefore, it is called Surge Impedance. Note that Surge Impedance is the square root of ratio of series inductance L per unit length of line and shunt capacitance C per unit length of line. This simply means that this value will remain constant for a given transmission line. This value will not change due to change in length of line. The value of surge impedance for a typical transmission line is around 400 Ohm and that for a cable is around 40 ohm. Notice that the value of surge impedance for cable is less than that of transmission line. This is due to the higher value of capacitance of cable compared to the transmission line.

Velocity of Travelling Wave:
To get velocity of travelling wave, multiply (1) and (2) as below.
$VI = (CV\nu) \times (LI\nu)$
$\nu^2 = 1/LC$
$\nu = \sqrt{(1/LC)}$ ……. (3)

The above expression is the velocity of travelling wave. Since L and C are per unit values, the velocity of travelling wave is constant. For overhead line the values of L and C are given as

$L = 2\times10^{-7}\ln(d/r)$ Henry / m
$C = 2\pi\varepsilon / \ln (d/r)$

From (3), the velocity of travelling wave for overhead line
$\nu = 1 / [\{2\times10^{-7}\ln(d/r)\} \{2\pi\varepsilon / \ln (d/r)\}]^{1/2}$
$= 1/[4\pi\varepsilon x10^{-7}]^{1/2}$
The permittivity of air, $\varepsilon = (1/36\pi) \times 10^{-9}$

Therefore,
$\nu = 1 / [4\pi x(1/36\pi) \times 10^{-9}x10^{-7}]^{1/2}$
$= 3 \times 10^8$ m/sec.

From the above expression, we can have following conclusions:

The velocity of travelling wave for a lossless line is equal to the speed of light.
Since the cable core is surrounded by insulations and sheath, its relative permittivity $\varepsilon_r > 1$ and hence $\varepsilon = \varepsilon_0\varepsilon_r > \varepsilon_0$ (permittivity of air). Therefore, the speed of travelling wave on cable is less than that of transmission line.

4.Discuss elaborately on reflection and refraction of travelling waves

Reflection and Refraction of Travelling Waves:

If a travelling wave arrives at a point where the impedance suddenly changes the wave is partly transmitted and partly reflected. Loading points, line-cable junctions and even faults constitute such discontinuities. Independent waves meeting along a line will combine in accordance with their polarity to provide different voltage and current levels at the meeting point.

It is convenient to adopt a standard sign convention, and in what follows, forward waves of current and voltage are given the same polarity. If the wave is being reflected the corresponding current and voltage waves are given opposite polarity. This may be illustrated by considering waves of current and voltage being transmitted along a line of characteristic impedance Z_C terminated by an impedance Z (Fig. 8.5).

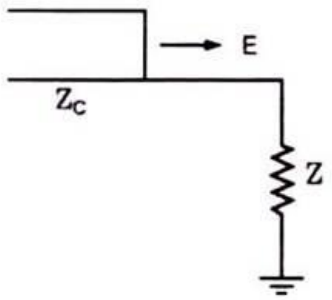


Fig. 8.5. ***Line Terminated Through Impedance Z***

Let E and I represent the incident waves, E_T and I_T represent the transmitted (or refracted) waves and E_R and I_R the reflected waves. The state of affairs is illustrated in Fig. 8.6.

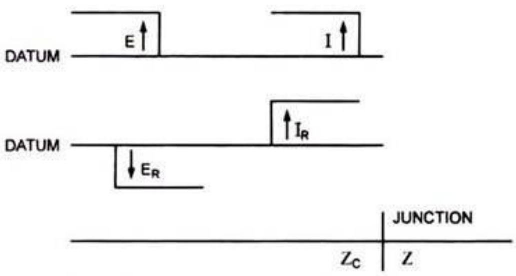


Fig. 8.6. ***Transmission and Reflection at Discontinuities***

The following relations hold good for incident, transmitted and reflected voltage and current waves –

$E = I\,Z_C$ … (8.7a)

$E_T = I_T\,Z$ … (8.7b)

$E_R = -\,I_R\,Z_C$ … (8.7c)

The negative sign in Eq. (8.7c) is because of the fact that E_R and I_R are travelling in the negative direction of x or backwards on the same line.

The transmitted voltage and current will be respectively the algebraic sum of incident and reflected voltage and current waves.

$E_T = E + E_R$ … (8.8a)

$I_T = I + I_R$ … (8.8b)

Substituting the values of I, I_R and I_T from Eqs. (8.7a, b, c) in Eq. (8.8 b), we have –

$E_T/Z = [(E/Z_C) – (E_R/Z_C)]$ …(8.9)

From Eqs. (8.8 a) and (8.9), we have –

$E_T/Z = [(E/Z_C) – (E_T – E/Z_C)]$

or E_T x $Z_C /Z + E_T = 2 E$

or $E_T [1 + (Z_C/Z)] = 2 E$

or $E_T = \{E [2Z/(Z + Z_C)]\}$ …(8.10)

$I_T = (E_T/Z) = [2 E/(Z + Z_C)] = (2 Z_C I/Z + Z_C)$ …(8.11)

$E_R = E_T – E = \{[2 ZE/(Z + Z_C)] – E\} = [E (Z – Z_C)/(Z + Z_C)]$ …(8.12)

or $I_R = (– E_R/Z_C) = [(– E/Z_C)x (Z – Z_C/Z + Z_C)] = [I (Z_C Z/Z_C + Z)]$ …(8.13)

The coefficients $(2Z/Z + Z_C)$ and $(Z – Z_C/Z + Z_C)$ are called coefficients of refraction and reflection respectively.

It will be observed that the transmitted or refracted current and voltage always have positive polarity. The polarity of the reflected waves depends on the magnitude relationship between Z_C and Z. If $Z_C > Z$, the voltage wave is negative and the current wave positive, but vice-versa if $Z > Z_C$.

5. Explain the control measures for over voltage due to switching surge and lightning over voltages.

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. During insulation failure, a live conductor is suddenly earthed. This may also cause sudden over voltage in the system. If emf wave produced by alternator is distorted, the trouble of resonance may occur due to 5th or higher harmonics.

Actually, for frequencies of 5th or higher harmonics, a critical situation in the system so appears, that inductive reactance of the system becomes just equal to capacitive reactance of the system. As these both reactance cancels each other the system becomes purely resistive. This phenomenon is called resonance and at resonance the system voltage may be increased enough.

But all these above-mentioned reasons create over voltages in the system which are not very high in magnitude. But over voltage surges appear in the system due to lightning impulses are very high in amplitude and highly destructive. The effect of lightning impulse hence must be avoided for over voltage protection of power system.

Methods of Protection Against Lightning

These are mainly three main methods generally used for protection against lightning.

They are

- Earthing screen.
- Overhead earth wire.
- Lightning arrester or surge dividers.

Earthing Screen

Earthing screen is generally used over electrical substation. In this arrangement a net of GI wire is mounted over the sub-station. The GI wires, used for earthing screen are properly grounded through different sub-station structures. This network of grounded GI wire over electrical sub-station, provides very low resistance path to the ground for lightning strokes. This method of high voltage protection is very simple and economic but the main drawback is, it cannot protect the system from travelling wave which may reach to the sub-station via different feeders.

Overhead Earth Wire

This method of over voltage protection is similar as earthing screen. The only difference is, an earthing screen is placed over an electrical sub-station, whereas, overhead earth wire is placed over electrical transmission network. One or two stranded GI wires of suitable cross-section are placed over the transmission conductors. These GI wires are properly grounded at each transmission tower. These overhead ground wires or earth wire divert all the lightning strokes to the ground instead of allowing them to strike directly on the transmission conductors.

Lightning Arrester

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This device behaves like a nonlinear electrical resistance. The resistance decreases as voltage increases and vice-versa, after a certain level of voltage. The functions of a lightning arrester or surge dividers can be listed as below. Under normal voltage level, these devices withstand easily the system voltage as electrical insulator and provide no conducting path to the system current. On occurrence of voltage surge in the system, these devices provide very low impedance path for the excess charge of the surge to the ground.

6. Discuss elaborately various sources of Temporary over voltages

Temporary overvoltage's (TOVs) are undamped or little damped power-frequency over voltages of relatively long duration (i.e., seconds, even minutes). This overvoltage is typically caused by faults to ground, resonance conditions, load rejection, energization of unloaded transformers, or a combination of these.

Resonance is a synchronization between a natural oscillation of the power system and the frequency of an external sinusoidal source. This phenomenon leads to increased voltages and/or currents. A variation can be found in what is called ferro-resonance.

This term applies to a wide variety of interactions between capacitors and iron-core magnetizing inductances that again can result in high over voltages and cause failures in transformers, cables, and arresters. On the other hand, the load rejection phenomenon is a sudden three-pole switching event of a system with three similar phase-to ground voltage rises, resulting in the same relative over voltages phase-to-ground and phase-to-phase.

Resonance over voltages may appear also when a line and a transformer are energized together. Re-energizing a transformer can cause high inrush currents due to the nonlinear behaviour of its core. Those currents can have a high magnitude with a significant harmonic content. (TOVs) can be classified according to their frequency of oscillation, being higher, equal or lower than the power frequency.

7. Briefly explain about Corona loss and its effects related to Transmission system

This phenomenon occurs when the electrostatic field across the transmission line conductors produces the condition of potential gradient. The air gets ionized when the potential gradient at the conductor surface reaches the value of 30kV/cm at normal pressure and temperature.

In transmission lines, conductors are surrounded by the air. Air acts as a dielectric medium. When the electric field intensity is less than 30kV/cm, the induced current between the conductor is not sufficient to ionize the air. However, when the voltage of air surrounding the conductor exceeds the value of 30kV/cm, the charging current starts to flow through the air, that is air has been ionized. The ionized air act as a virtual conductor, producing a hissing sound with a luminous violet glow.

Factors Affecting Corona Discharge:

1. Supply Voltage: As the electrical corona discharge mainly depends upon the electric field intensity produced by the applied system voltage. Therefore, if the applied voltage is high, the corona discharge will cause excessive corona loss in the transmission lines. On contrary, the corona is negligible in the low-voltage transmission lines, due to the inadequate amount of electric field required for the breakdown of air.

2. Conductor Surface: The corona effect depends upon the shape, material and conditions of the conductors. The rough and irregular surface i.e., unevenness of the surface, decreases the value of breakdown voltage. This decrease in breakdown voltage due to concentrated electric field at rough spots, give rise to more corona effect. The roughness of conductor is usually caused due to the deposition of dirt, dust and scratching. Raindrops, snow, fog and condensation accumulated on the conductor surface are also sources of surface irregularities that can increase corona.
3. Air Density Factor: Air density factor also determines the corona loss in transmission lines. The corona loss in inversely proportional to air density factor. Power loss is high due to corona in Transmission lines that are passing through a hilly area because in a hilly area the density of air is low.
4. Spacing between Conductors: Design engineers calculate the spacing between the two conductors in the transmission line after careful and extensive research. As the phenomenon of corona discharge is affected by the conductor spacing. If the distance between two conductors is very large as compared to the diameter of conductor, the corona effect may not happen. It is because the larger distance between conductors reduces the electro-static stress at the conductor surface, thus avoiding corona formation.
5. Atmosphere: As corona is formed due to ionization of air surrounding the conductors, therefore, it is affected by the physical state of atmosphere. In the stormy weather, the number of ions is more than normal weather. The decrease in the value of breakdown voltage is followed by the increase in the number of ions. As a result of it, corona occurs at much less voltage as compared to the breakdown voltage value in fair weather.

8. Explain the different theories of charge formation in the cloud.

- Wilsons Theory of charge separation
- Simpsons Theory
- Reynolds and Mason theory

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]

• A relatively large drain drop (0.1 cm radius) falling this field becomes polarised, the upper side acquires a -ve charge and lower side +ve charge.

• Then the lower part of the drop attracts negative charges from the atmosphere.

• Thus, both the positive and negative charges which were mixed up and are now separated.

Simpson's 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.

• In upper region of cloud, the temperature is low & only ice crystals exists.

• The impact of air on these crystals makes them –vely charged, thus the distribution of charge within the cloud is as shown.

Reynold and mason's theory

• According to this theory, thunder clouds are developed at heights 1 to 2km above ground level& they go upto 14km. • The temperature is 0^oC at 4km & may reach -50^oC at 12km.

• Water droplets do not freeze at 0^oC & freeze only when temperature is below -40^oC & form solid particles on which crystalline ice patterns develop & grow.

• Thundercloud consisting supercooled water droplets moving upwards and large hail stones moving downwards.

• The ice splinters should carry only +ve charge upwards.

• Water has H+ &OH-ions, the ion density depends on temperature.

• Lower portion has a net –ve charge density (OH-)& upper portion has a net +ve charge density(H+).

9. Explain the phenomena of electrical conduction in liquids. How does it differ from that in gases?

Conduction, transfer of heat or electricity through a substance, resulting from a difference in temperature between different parts of the substance, in the case of heat, or from a difference in electric potential, in the case of electricity. Since heat is energy associated with the motions of the particles making up the substance, it is transferred by such motions, shifting from regions of higher temperature, where the particles are more energetic, to regions of lower temperature.

The rate of heat flow between two regions is proportional to the temperature difference between them and the heat conductivity of the substance. In solids, the molecules themselves are bound and contribute to conduction of heat mainly by vibrating against neighbouring molecules; a more important mechanism, however, is the migration of energetic free electrons through the solid. Metals, which have a high free-electron density, are good conductors of heat, while nonmetals, such as wood or glass, have few free electrons and do not conduct as well. Especially poor conductors, such as asbestos, have been used as insulators to impede heat flow (see insulation).

Liquids and gases have their molecules farther apart and are generally poor conductors of heat. Conduction of electricity consists of the flow of charges as a result of an electromotive force, or potential difference. The rate of flow, i.e., the electric current, is proportional to the potential difference and to the electrical conductivity of the substance, which in turn depends on the nature of the substance, its cross-sectional area, and its temperature.

In solids, electric current consists of a flow of electrons; as in the case of heat conduction, metals are better conductors of electricity because of their greater free-electron density, while nonmetals, such as rubber, are poor conductors and may be used as electrical insulators, or dielectrics. Increasing the cross-sectional area of a given conductor will increase the current because more electrons will be available for conduction.

Increasing the temperature will inhibit conduction in a metal because the increased thermal motions of the electrons will tend to interfere with their regular flow in an electric current; in a nonmetal, however, an increase in temperature improves conduction because it frees more electrons. In liquids and gases, current consists not only in the flow of electrons but also in that of ions. A highly ionized liquid solution, e.g., saltwater, is a good conductor.

Gases at high temperatures tend to become ionized and thus become good conductors (see plasma), although at ordinary temperatures they tend to be poor conductors. See electrochemistry; electrolysis; superconductivity.

10. Discuss elaborately the principle and operation of impulse current generator

An impulse generator is an electrical apparatus which produces very short high-voltage or high-current surges. Such devices can be classified into two types: impulse voltage generators and impulse current generators.

High impulse voltages are used to test the strength of electric power equipment against lightning and switching surges. Also, steep-front impulse voltages are sometimes used in nuclear physics experiments. High impulse currents are needed not only for tests on equipment such as lightning arresters and fuses but also for many other technical applications such as lasers, thermonuclear fusion, and plasma devices.

The waveshapes used in testing surge diverters are 4/10 and 8/20 μs, the figures respectively representing the nominal wave front and wave tail times. The tolerances allowed on these are ±10% only. Apart from the standard Impulse Current Generator Output Waveform, rectangular waves of long duration are also used for testing.

The waveshape should be nominally rectangular in shape. The rectangular waves generally have durations of the order of 0.5 to 5 ms, with rise and fall times of the waves being less than ± 10% of their total duration. The tolerance allowed on the peak value is +20% and –0% (the peak value may be more than the specified value but not less). The duration of the wave is defined as the total time of the wave during which the current is at least 10% of its peak value.