+DHANALAKSHMI SRINIVASAN ENGINEERING COLLEGE-PERAMBALUR

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

EE6002-POWER SYSTEM TRANSIENTS

UNIVERSITY QUESTIONS AND ANSWERS

UNIT-I INTRODUCTION AND SURVEY

PART-A

1. **Define transient.(N/Dec-2016,N/Dec-2014,N/D2011)**

   The power system transient is the outward manifestation of a sudden change in circuit conditions as when a switch opens or closes or a fault occurs on a system.

2. **What are the causes of transients?(N/D2017,A/M2017,M/J2016,A/M2015, N/D2015 ,M/J2012)**

   The various causes of transients can be classified as
   - Internal causes (device switching and arcing)
   - External causes (lightning and poor electrical connections)

Internal Causes:	**External Causes:**
Facility load switches	Lightning strikes
On/off disconnects	Poor or loose connection
Capacitor banks switch	Accidents and Human error.
Tap changing (transformers)	Weather and animals

3. **What are the effects of transients in power systems?(N/D2017,A/M2011)**
   - Under severity, black out of power system will be produced.
   - Lightning transient produced steep fronted wave on transmission line.
   - Travelling wave produced due to transient will shutter the insulations and week poles.
   - Cause damage to windings of transformer and generators.

4. **Write down the importance of transient study in power system planning. (N/D2017,N/D2011)**
   - Designing and planning
   - If severe transients occurred it would end up with partial block-out or total block-out.
   - Switching transients geared to the system voltage cause severe damage.
   - For economic reason also we have to limit and control the switching surges.

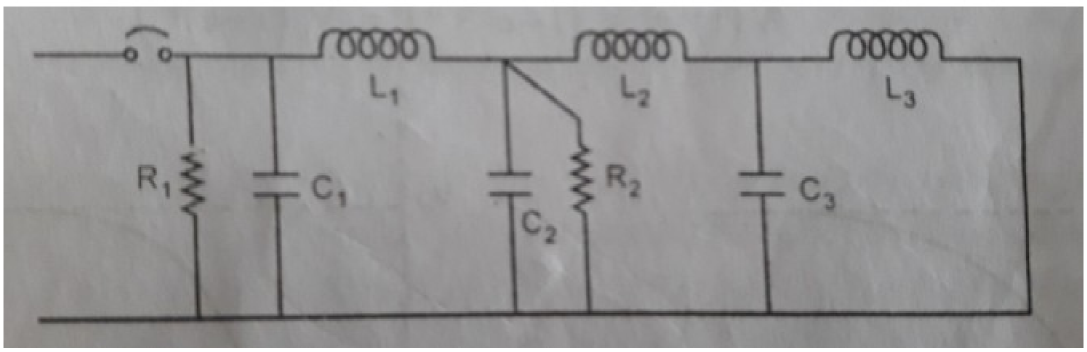
- The transients produced in one region travel towards the remote end and cause difficulties at that region also. Since integrated power system is required.

5. List the types of power system transients. (A/M2017, M/J2014,M/J2012,)

1. Ultra transients 2. Medium fast transients 3. Slow transients

Power system transients based on waveform shapes can be classified in to "**oscillator transients**" and "**impulsive transients**" and "**Multiple transients**"

6. Draw the double frequency transient with an example.(A/M2017,N/D2013)



To determine the recovery transient voltage we have to analysis the circuit. If it is possible to find the source side transient and load side transient ans circuit with natural frequencies.

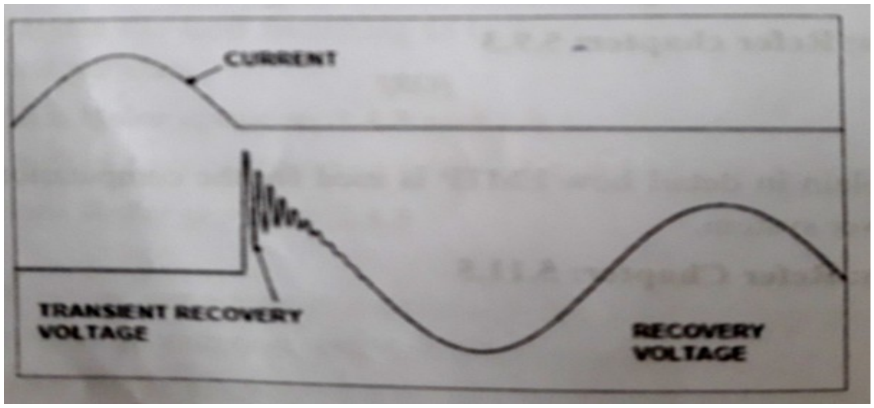
7. A power transformer draws a heavy magnetizing inrush current. Now this current is suddenly interrupted before it reaches natural zero by means of a circuit breaker. What would happen between the contacts of circuit breaker? What do you call this phenomenon?(M/J2016, N/D 2015,)

Current Chopping.

8. Write the basic transform of RLC circuit transient.(A/M 2015)

$I_L(s) = V_c (0)/L.\ 1/s^2+s / T_p+1/T^2$

9. Draw the TRV wave form across the circuit breaker following the interruption of fault current.(M/J 2016).



10. Write the mathematical expression for RLC circuit transient. (N/D2014).

$i(t) = e^{-}\alpha\, t\, (B_1 \cos\omega\, dt + B_2 \sin\omega\, dt)$

$V(t) = (A_1 \cos\omega\, dt + A_2 \sin\omega\, dt)$ for parallel circuit.

11.Find the Laplace transform of 1/s (s+a) (N/D2016)

$1/s(s+\alpha) = 1/s\ .\ 1/s+\alpha$

Inverse Laplace Transform for $1/s(s+\alpha) = 1\ .\ e^{---}\alpha\, t = e^{---}\alpha\, t$

12. Define transient recovery voltage.

A transient voltage is developed across the contacts of a switch when they start to open. This voltage, known as transient recovery voltage (TRV), is present immediately after the current zero, and in actual system its duration is in the order of milliseconds.

13. **What is ground wire?**

Ground wire is a conductor run parallel to the main conductor of the transmission line supported on the same tower and earthed at every equally and regularly spaced towers. It is run above the main conductor of the line.

14**. Define power system transient.**

As per the classic definition in concerned, an instantaneous change in the state leading to a burst of energy for a limited time is termed as a transient event. The causes can be both internal and external, with the aftermath being sequential and affecting the other parts too. As per classification, we have the impulsive and oscillatory transients.

15. **What are the types of power system Transients?**

(a) Based upon origin (b) Based upon the made of generation of transients
(c) Based on transient classification with respect to the frequency group
(d) Classification of transients on frequency ranges
(e) Classification depending on its nature (f) Classification depends on control on t Transients (g) How and where transients are generated,(h) Effects of lightning transients

UNIT-II SWITCHING TRANSIENTS

1. **What is current chopping? (A/M2017, M/J2016, N/D2016, M/J2014, N/D2013, N/D2012, M/J2012)**

   When interrupting low inductive currents such as magnetizing currents of the transformer shunt reactor, the rapid deionization of the contact space and blast effect may cause the current to be interrupted before the natural current zero. This phenomenon of interruption of the current before its natural zero is called **current chopping.**

2. **What do you mean by ferroresonance?(N/D2017,A/M2015,N/D2014, M/J2014,N/D2011, A/M 2011)**

   Ferro resonance or non linear response is a type of resonance in electric circuits which occurs when a circuit containing a non-linear inductance is fed from a source that has series capacitance, and the circuit is subjected to a disturbance such as opening of a switch.

3. **What is resistance switching?(M/J2016, N/D2016, M/J2012, N/D 2011,A/M 2011)**

   A deliberate connection of a resistance in parallel with the contact space (arc) is made to overcome the effect of transient recovery voltage. This is known as resistance switching.

4. **What is the need for resistance switching?(A/M 2008)**

   The shunt resistors are connected across circuit breaker have two functions.

   - To distribute the transient recovery voltage more uniformly across the several breaks.
   - To reduce the severity of transient recovery voltage at the time of interruption by introducing damping in to oscillation.

5. **What is current suppression?**

   When interrupting low inductive currents such as magnetizing currents of the shunt reactor, the rapid deionization of the contact space and blast effect may cause the current to be interrupted before the natural current zero. This phenomenon of interruption of the current before its natural zero is called **current chopping(or) Current suppression.**

6. **What is meant by abnormal switching transients? (A/M2017, M/J2013, N/D2011)**

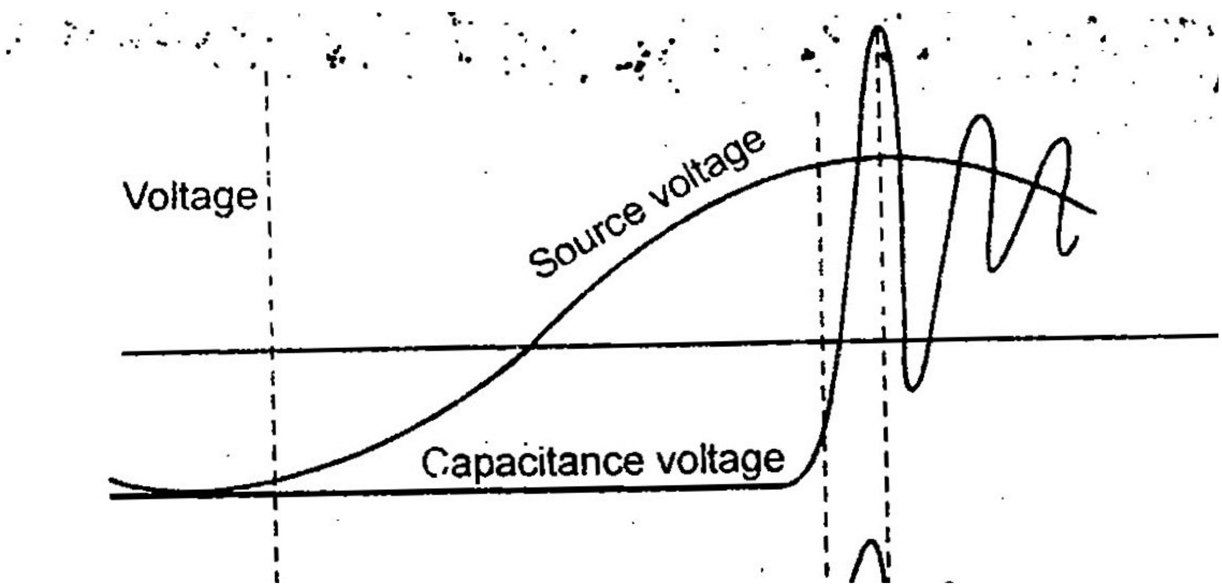
Due to some other circumstances like transients the voltage and current magnitude may rise high. The transient occur due to the trapping of the energy and its subsequent release somewhere in the circuit. Such transients are referred as abnormal current and voltage transients.

7. **Where do double restrike transients arise? What are their implications? (N/D2016, N/D2015)**

When the switch operates in such a circuit it completely divorcés the load from the supply. There after the two halves of the circuit behave independently.

8. **Give a power system example for the occurrence of ferroresonance. (A/M2017, M/J2013)**
   1. Opening one (or) two phases, either intentionally (or) accidently
   2. The cable system had either light load (or) no load.
   3. Common place UD cable service drop from an overhead line.

9. **Sketch the restrike waveform of the capacitance switching.**

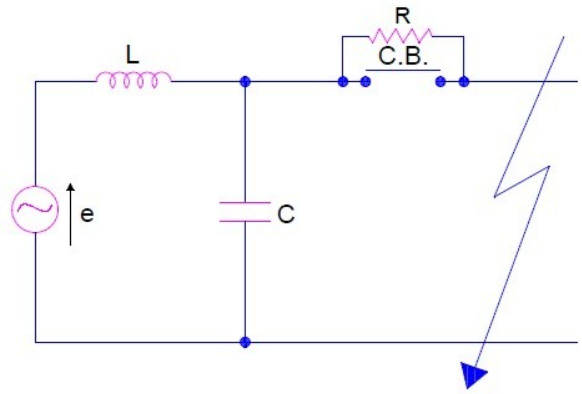


10. **What is the origin of ferro-resonance? What are the undesirable effects? (N/D2016, N/D2015)**

Origin: Non-linear inductance and capacitive components.

Effects: Generation of harmonics the order of harmonics are 5^{th} (or) higher harmonics.

11. **Draw the resistance switching circuit.(M/J2016)**



12.Why multiple restrike occur due to capacitance switching?(N/D2014)

Some capacitance will exist on the source side of the breaker which will introduce higher frequency disturbances. So multiple restrike occur during capacitance swiching.

13.What is meant by multiple restriking transients? (M/J2013)

When a couple of re-ignitions occur is called multiple restrike, very high voltages build up across the interrupting chamber, and it is most likely that a flashover takes place on the outside chamber of the interrupter.

14.Differentiate normal and abnormal switching transients.(N/D2012)

Normal switching transients are circumstances in which voltage or current within the normal peak values Closing switch or circuit in a dominantly capacitive or inductive network results in inrush currents which can cause problems for the protection system.

Abnormal switching transients are circumstances in which voltage or current are far in excess of twice in normal peak values. Insulation of high voltage circuit breakers typically can over voltages up to 2.5 times over its normal voltage.

15.What is capacitance switching? (M/J2008)

The shunt capacitors are employed to correct a lagging power factor, or in some cases, to provide support for the system. In some applications they are switched in and out quite frequently as the system load varies and the system voltage fluctuates.

16.Define arcing ground. (N/D 2007)

If neutral of three phase wires was not earthed in long enough voltage transmission lines a serious problems called acing ground is produced. The arcing ground produces severe oscillations of three to four times the normal voltage.

17. What does the phenomenon of current suppression lead to?(M/J2013)

Rapid deionization of contact space and may cause the current to be interrupted its natural zero.

18. What is meant by switching surges?(N/D-2006)

The disturbance produced by the switching operation in a system which sets up travelling wave which travel along the connected lines to and fro. These disturbances are called switching surges.

19.

UNIT-III LIGHTNING TRANSIENTS

1. What is the significance of tower footing resistance?(A/M 2017,M/J2016, N/D 2013)

- A low value of tower footing resistance results in less voltage stresses across line insulation
- A tower footing resistance of 20Ω for EHV lines and 10Ω for HV lines provides sufficient lightning protection.

2. What is tower footing resistance?(A/M2015, N/D2014, N/D2011)

Tower footing resistance is the resistance offered by tower footing to the dissipation of current. The effective of a ground wire depends to a large extend on the lower footing resistance.

3. **What is ground wire?(N/D2016)**

   It is the conductor run parallel to the main conductor of the transmission line supported on the same tower and earthed at every equally regularly spaced tower. It is run above the main conductor of the line.

4. **How would you modeling a lightning strike?(A/M2017, N/D2015, M/J2014)**

   The modeling of lightning strike behavior and estimation of the subsequent electric discharge is of great practical importance. In this study, a complete two-dimensional physics-based analytic formulation is presented for elevated grounded systems that can be envisioned to be contained within two non-concentric circular domains.

5. **Write the equation for tower footing resistance.(N/D2017)**

   Resistance = $p_{s/}$ 2πR, R = radius of sphere.

6. **What is called charge formation?(A/M2017,A/M2011)**

   During thunderstorms positive and negative charge becomes separated by the heavy air currents with ice crystals in the upper part and rain in the lower part of the cloud. This charge separation depends on the height of clouds which range from 0.2 t 10Km with their charge centers probably at a distance of about 0.25 to 2Km.

7. **What are the protective devices used to protect power system equipments against lightning? (N/D2016, N/D2013, N/D2009)**

   (a) Ground wires (d) Rod Gaps (g) Expulsion gaps
   (b) Surge arresters (e) Surge arresters
   (c) Protective tubes (f) Protective tubes

8. **What are the properties of good transmission line? (N/D2016, N/D2013, N/D2009)**

   (a)Reduce the number of outages

   (b) High ground impedance or tower footing resistance is to be avoided

   (c) Incidence of strokes

   (d) High surge impedance in ground wires, tower structures are to be avoided.

9. **Define isokeraunic level or thunderstorm days.(N/D2016,N/D2009)**

It is the number as the number of days in a year when the thunder is heard recorded in a Particular location.Often it does not distinguish between the ground strokes and the cloud-cloud strokes.110 state the factors influence the lightning induced voltages on transmission lines. The ground conductivity, the leader stroke current and the corona.

10. **What are the types of protection afforded by ground wires? (M/J2016, A/M2015)**

A shield wire reduce the magnitudes of the over voltage associated with nearby strokesAs this effect is due to the coupling between the shield and phases wires, the voltage reduction will occur regardless of the position of the shield wire with respect to the phase conductors.The greater the coupling, the more significant is the voltage reduction. The effectiveness of the shield wires in improving the indirect lightning performance of distribution lines.

11. **What is the rate of charging of thunder clouds? (N/D2014)**

This equation gives rate of charging of thunder Q_s h clouds

$$Qg = Q_s h / v/\lambda[1-e^{-}\lambda t]$$

12. **Mention any two factors which are contributing to good line design.(M/J2014, N/D2013)**

- We try to keep the incidence of strokes to the system to a minimum.
- The objective of good line design is to reduce the number of outages caused by lightning.

13. **Differentiate between direct and indirect lightning stroke.**

Direct lightning stroke is the one which strikes either the phase conductors or the tower or shield (ground wire generates very high voltages in the power lineIndirect lightning stroke is a very high voltage can be generated in the power line due to the stroke which hits the nearby ground. Such strokes are called indirect lightning stroke or induced lightning stroke.

UNIT-IV TRAVELLING WAVES ON TRANSMISSION LINE COMPUTATIO OF TRANSIENTS.

1. **Define lumped parameters.(N/D2017, A/M2010)**

The lumped element (also called lumped parameters (or) lumped components) simplifies the description of the behavior of spatially distributed physical system in to a topology Consisting of discrete entities that a approximate the behavior of the distributed system under certain assumptions.

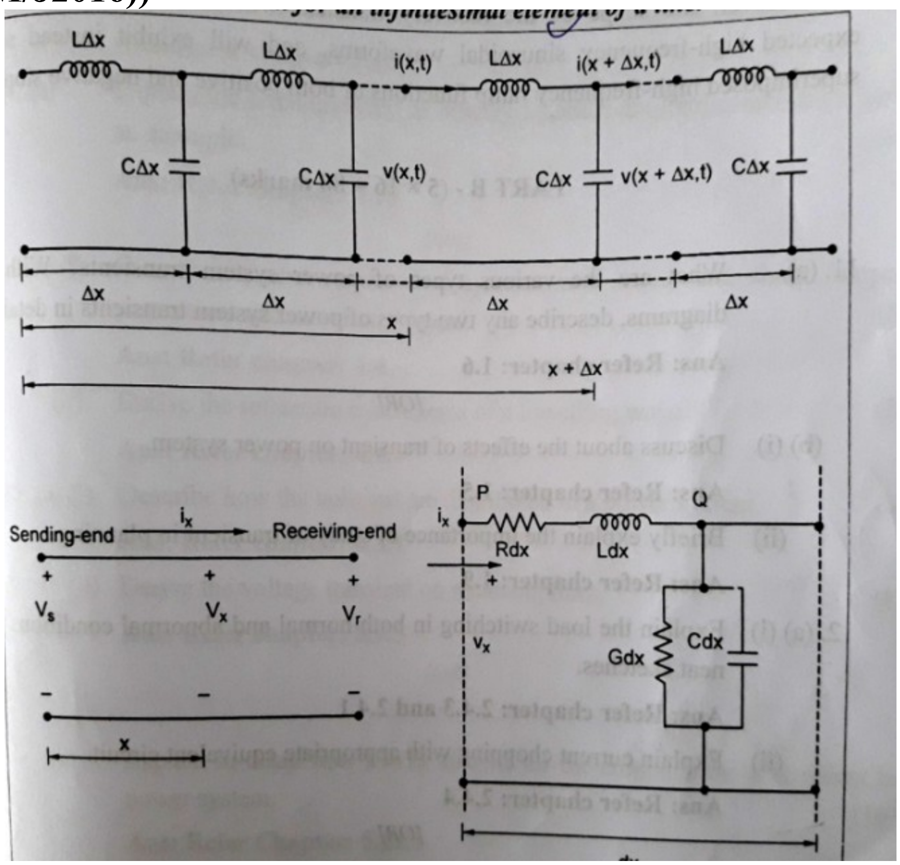
2. **What are the specifications of travelling wave? (N/D2017)**

A travelling wave is characterized by the four specifications Crest of a wave, Front of a wave, Tail of a wave and polarity.

3. **What is the importance of Bewley's Lattice diagram?(A/M2017,N/D2014 A/M2015)**

In a complex electrical network with number of interconnections and with various terminations, the travelling wave initiated by single incident wave will upstart with a considerable rate as the wave splits. Due to this multiple reflection occur. It is possible for the voltage to build up certain points by the reinforcing action of several waves. In order to study such effects, Bewley proposed transient

4. **Draw the equivalentcircuit foran infinitesimal element of a line. (A/M2017, N/D2013,M/J2016))**



5. **What are the standing waves?(A/M-2017, N/D-2014))**

A standing wave, also known as stationary wave, is a wave that remains in a constant position. This phenomenon can occur because the medium is moving in the opposite direction to the wave, or it can arise in astationary medium as a result of interference between two waves travelling in opposite directions.

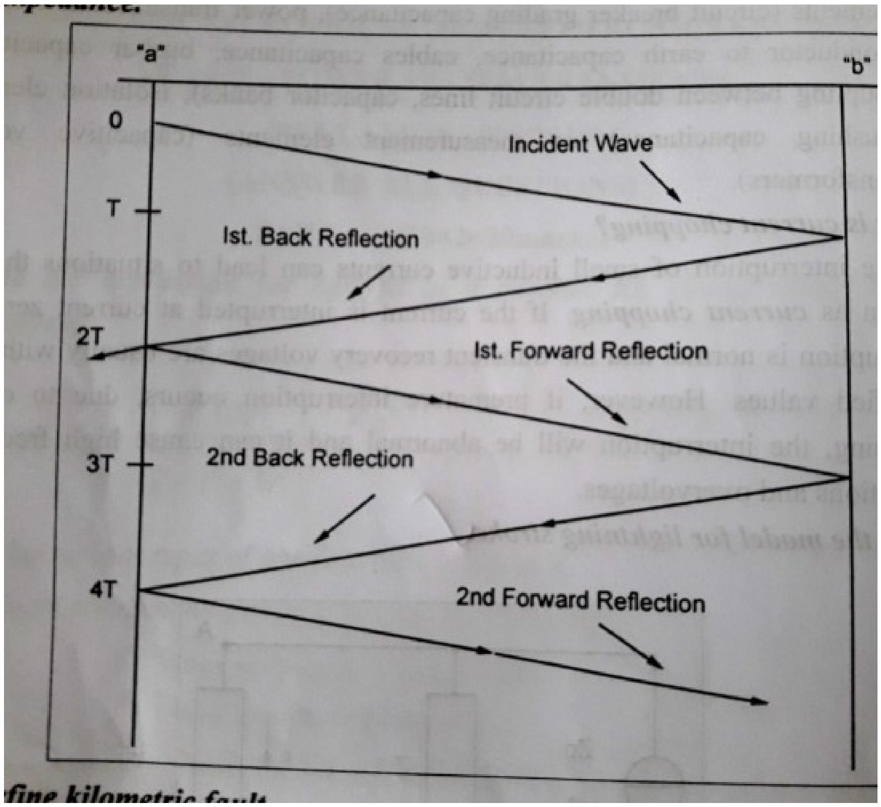
6. **What is attenuation? How they are caused?(A/M2017)**

The decrease in the magnitude of the wave as a propagates along the line is called attenuation. It is caused due to the energy loss in the line.

7. **What are the principles observed in lattice diagram?(N/D2016)**

All waves travel down hill (i.e) in to the positive time. The position of the wave at any instant is given by yhe means of the time scale at the left of the lattice diagram.

8. Draw the neat sketch of Bewley,s Lattice diagram.(M/J2016)



9. What are the damages caused by the travelling waves?N/D2016)

The high peak (or) crest voltage of the surge may cause Flashover in the internal winding their by spoil the windings insulation. The steep wave front of the surge may cause internal flashover between their turns of the transformer.

9. **Define crest and front of a travelling wave.(N/D2016)**

   Crest: The crest of the wave is maximum amplitude of the wave and is usually expressed in KV (or) KA.

   Front: The front of the wave is the portion of the wave before crest and is expressed in time from beginning of the wave to the crest value in ms (or) µs.

10. **What is travelling wave? What is the role of distributed parameters (R,L ,C) in it.(N/D-2015)**

Any disturbance on a transmission line (or) system such as sudden opening or closing of the line, short circuit or s fsult results in the development of over voltages or over current at that point. The disturbance propagaef as a travelling wave to the ends of a line or transmission , such as a substation.

12. Define attenuation and distortion. (N.D-2013)

The decrease in the magnitude of The wave at a propagates along the line is called **attenuation**. The elongation or change of wave shape that occurs called **distortion.**

13.Distinguish between reflection and refraction of travelling waves with expressions.(M/J-2013), (N/D-2012)

a= $[Z_B – Z_A / Z_A+Z_B]$and is called the reflection coefficient $1 \leq a \leq +1$

b= $[2Z_B / Z_B + Z_A]$ and is called the refraction coefficient

14.What are the principles are observed in Bewley’s lattice d iagram.(M/J-2012)

All waves travel down hill (i.e) in to the positive time. The position of the wave at any instant is given by the means of the time scale at the left of the lattice diagram.

14. Define coefficient of reflection.(M/J-2012)

The coefficient of reflection (a) is given by the ratio of reflected wave to the voltage of incident wave of a transmission linedue to the travelling waves caused by switching surges. Coefficient of reflection a $=V_r / V_i$ Where V_r- is the reflected wave,V_i – is the incident wave.

15.What are the specifications of travelling wave?(A/M-2011)

A travelling wave is characterized by the four specifications Crest of a wave, Front of a wave, Tail of a wave & Polarity.

15. Define reflection and refraction.

Whenever there is an abrupt change in the parameters of a transmission line, such as an open circuit or a termination, the travelling wave undergoes a transition, part of the wave is reflected or sent back only a portion is transmitted forward. At the transition point (or) junction, the voltage or current wave may attain a value which can vary from zero to twice its initial valueThe incoming wave is called incident wave and the other waves are called reflected and transmitted (or) refracted waves at the transition point.

16. Define tail and polarity of a wave.

Tail: tail of the wave is a portion beyond the crest, It is expressed in time μs from beginning of the wave to the point. Where the wave has to reduced to 50% of its value at crest.

Polarity: It is polarity of crest voltage or current a positive wave of 500Kvcrest, 1 μs from time and 25 μs tail time will be represented as +500/1.0/25.0.

17. What is the principle of importance of Bewley's lattice diagram.

When a travelling wave reaches a terminal point it may be reflected and transmitted as well. When reflected wave reaches the initiator point, it is reflected form here and these reflections continue although there may occur attenuation of both voltage and current waves. Generally it becomes difficult ti keep track of this successive reflection, but with the use of Bewley's lattice diagram one can know at a glance the portion and direction of voltage and current waves of all successive reflects.

UNIT-V TRANSIENTS IN INTEGRRATED POWER SYSTEM

1. What are the applications of EMTP? (N/D2017)

- The EMTP is a comprehensive computer program designed to solve electrical transient problem in lumpy circuits, distributed circuits.
- This program is capable of solving steady state circuit problems.
- Transient analysis can be carried out in circuits with any arbitrary configuration of lumped parameters. (R,L & C)

2. Define kilometric fault.(or) short line fault (N/D2017,A/M-2013,N/D-2016, A/M-2015, N/D-2015)

Short circuit faults or kilometric faults occurring on a transmission line length between 0.5 to 5km are termed as short line faults or kilometric faults. A fault of this type imposes a highly heavy duty on the circuit breaker, there by selecting its interrupting ability.

3. **Mention any four causes of switching surge.(A/M2017**)
   a) Interruption of low inductive currents by high speed circuit breaker
   b) Interruption of small capacitance current
   c) Ferro resonance
   d) Energization of loaded line

4. **Define switching over voltage factor.(A/M-2017)**

   The peak value of the transient recovery voltage ITRV) can be very high.. In testing and standardization, the damping is expressed by the overvoltage amplitude factor , defined as the ratio between the transient peak value and the steady state value.

5. **What are the effects of load rejection in power systems? .(A/M-2017)**

   Suddenly load rejection on power systems causes the speeding up of generator prime movers. The speed governors and automatic voltage regulates will intervene to restore the normal conditions. Initially both the frequency and voltage increases.

6. **What is the effect of switching surges in integrated power system?(M/J-2016)**

   The disturbance produced by the switching operation is modified by the interconnected system spreads through the system, setting up waves that travel along the lines and reflect to and from the open ends.

7. **Distinguish between line dropping and load rejection.(N/D=2016, A/M-2015)_**

   Voltage drop or line drop in general , on transmission lines the voltage s]simply decreases as one moves from the substation out forward the end of distribution feeder. This change in voltage is known as line dropping.

   In real world, load rejection is when there is a faul on the transmission line which is sensed by the` protection system and trip the circuit **breaker concern during that's** tine the load connected with the feeder and lines are suddenly dropped (i.E) load throw off or load rejection occurs

8. **write the shot notes on EMTP.(M/J 2016)**

   - The EMTP became popular for the calculation of power system transients especially a switching overvoltage from the viewpoint of insulation design and coordination of a transmission line and a substation in 1996.
   - The EMTP development was a part of system analysis computerization including a power/load flow analysis program and a stability analysis program, before the EMTP, a transient network analyzer (TNA)was used.The EMTP was

based on the method of travelling wave analysis in a Hydraulic system, well known as a water hammer.

9. Write the network calculation to model a transmission network of EMTP, (N/D-2016)

[G] [V(T)] = [I(T) – [I]] Where [G] is the nodal conductance matrix

[V(T) is the node voltages

[I(T) is the vector of current sources

[I] is the vector of past history terms.

10. What are the potential advantages of EMTP?

EMTP is a comprehensive computer program defined to solve:

1. Electrical transient problems in lumpy circuits and distributed circuits
2. Steady- state circuit problems
3. Arbitrary configuration of lumped parameters
4. Distributed parameters, transposed (or) untransposed)

11. Mention the features of EMTP.(N/D-2014)

1. Sophisticated computer program for the simulation electromagnetic Electromechanical and control system transients in multiphase power systems.
2. Advanced model of electrical machines
3. Detailed and precise models of lines and cables
4. Complete model of transformers etc.

12. Which software do you suggested to solve electrical transient Problems? (M/J2014)

EMTP- Electro Magnetic Transient Analysis Program

13. Mention the effects of transients when switch is closed?(N/D-2013)

When a switch is suddenly closed immediately prior to the circuit being completed, certain voltage across the switch contacts. At the moment the contacts made by pre striking discharge, this voltage appears

14. What is meant by EMTP? (M.J2013)

The EMTP is a comprehensive computer program designed to solve Electrical transient problems in lumpy circuits, distributed circuits. This program is capable of solving steady state circuit problems, transients analysis can be carried out in circuits. Without any arbitrary configuration of lumped parameters(R,L&C)Transmission lines with distributed parameters, transposed or untransposed can be included in the network

15. Define switching over voltage factor?

The peak value of the transient recovery voltage (TRV) can be very high. In testing and standardization the damping power is expressed by the over voltage amplitude factor, is defined as the ratio between the transient peak value and the steady state value.

EE6002 Power system Transients

PART-B –UNIT-1

1. **Discuss in detail about the adverse effect of transients on power systems.(A/M-2017,N/D-2017)**

The effect of a transient on a specific load will depend on the level of suscebility of that load to one or more of factors.

- Effects on insulation
- Effects on semiconductors
- Effects on electromechanical contacts
- Noise generation

In order to characterize the transients the following factors are considered which is as follows.

a) Peak(or crest) value of the transient
b) Area of the transient
c) Maximum rate of rise of the transient
d) Duration on the transient
e) Frequency on the transient

Some of the effects of Transients on power system.

1. Main issue is accurate working of electronic equipment is less
2. With transients , the efficiency of the equipments/ components is attached.
3. Motors may easily get heated up which leads to insulation failure.
4. IC's may be burnt.
5. In many cases, it is too difficult to detect the fault. Therefore , the life of the device gets shortened.
6. Hysteresis loss is increased and lead to more current being injected in to the motor for the same output.
7. Transient activity is believed to account for 80% of all electrically – related features or downtime or running outages.
8. Effective transient voltage suppression equipment can double or triple of the life of electrical and electronic equipment
9. Transient voltage surge suppression is the most immediately apparent, and the most cost effective means of improving you power quality.
10. A system approach to transient voltage surge suppression can results in gramatic performance in terms of return-on-investment.

2. **Write short notes on RLC circuit transient.(N/D=2017)**

RLC transients When there is a step change (or switching) in a circuit with capacitors and inductors together, a transient also occurs. With some differences: • Energy stored in capacitors (electric fields) and inductors (magnetic fields) can trade back and forth during the transient, leading to possible “ringing” effects. • The transient waveform can be quite different, depending on the exact relationship of the values of C, L, and R. • The math is more involved.

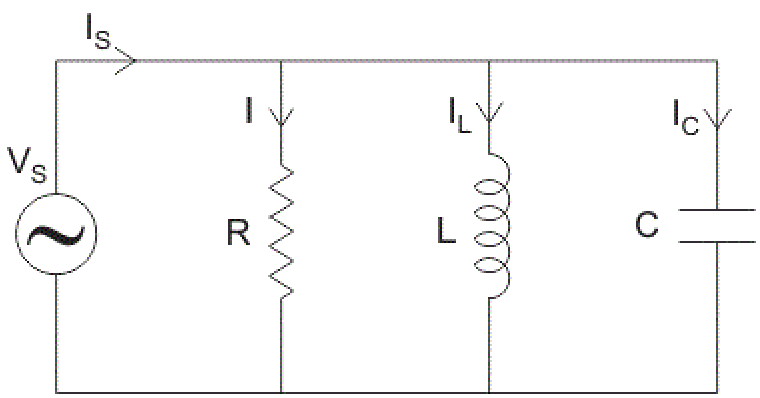
Series RLC Voltage source makes an abrupt change from Vi to Vf at t = 0. 96 = Y5 + Y& + Y/ t < 0: i = 0.
vR = 0. vL = 0. vC = Vi. t >> τ: i = 0.
vR = 0. vL = 0. vC = Vf.

An **RLC circuit** is an electrical circuit consisting of a resistor (R), an inductor (L), and a capacitor (C), connected in series or in parallel. The name of the circuit is derived from the letters that are used to denote the constituent components of this circuit, where the sequence of the components may vary from RLC.

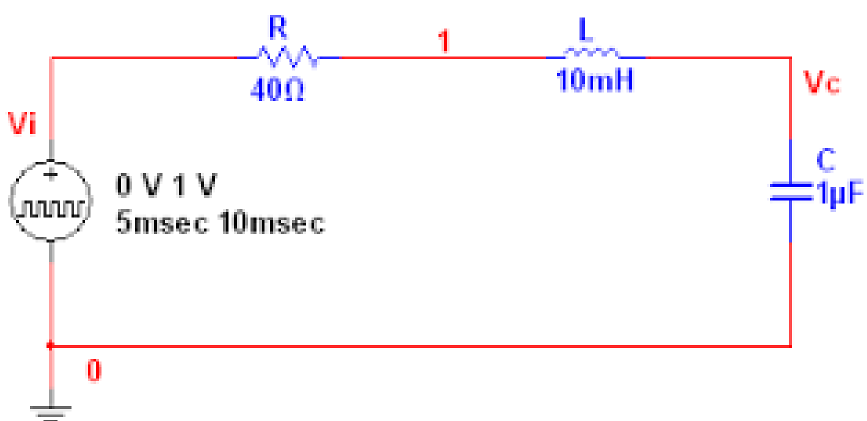
The circuit forms a harmonic oscillator for current, and resonates in a similar way as an LC circuit. Introducing the resistor increases the decay of these oscillations, which is also known as damping. The resistor also reduces the peak resonant frequency. Some resistance is unavoidable in real circuits even if a resistor is not specifically included as a component. An ideal, pure LC circuit exists only in the domain of superconductivity.

RLC circuits have many applications as oscillator circuits. Radio receivers and television sets use them for tuning to select a narrow frequency range from ambient radio waves. In this role, the circuit is often referred to as a tuned circuit. An RLC circuit can be used as a band-pass filter, band-stop filter, low-pass filter or high-pass filter. The tuning application, for instance, is an example of band-pass filtering. The RLC filter is described as a *second-order* circuit, meaning that any voltage or current in the circuit can be described by a second-order differential equation in circuit analysis.

The three circuit elements, R, L and C, can be combined in a number of different topologies. All three elements in series or all three elements in parallel are the simplest in concept and the most straightforward to analyze. There are, however, other arrangements, some with practical importance in real circuits. One issue often encountered is the need to take into account inductor resistance. Inductors are typically constructed from coils of wire, the resistance of which is not usually desirable, but it often has a significant effect on the circuit.

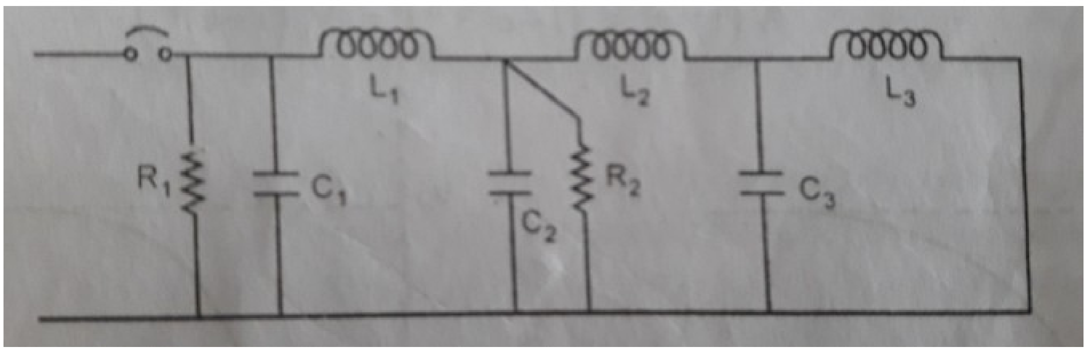


Parallel and series RLC circuits

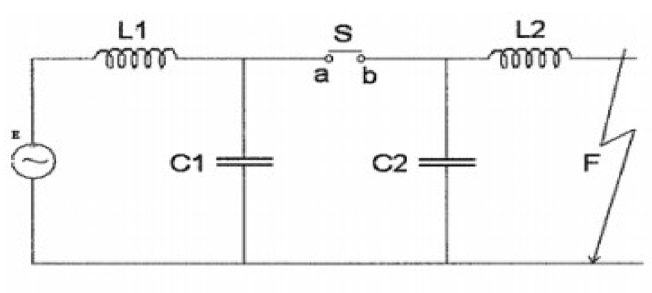


3. Explain the double frequency transients with necessary diagrams. (N/D2017)

Double frequency oscillatory transients The circuit-breaker S may have L and C parameters on its two sides, as shown in Figure 3.3. Before clearance the points a and b are at the same potential. After the fault is cleared, i.e, the arc has been extinguished, both the circuits oscillate at their own natural frequencies, a composite double frequency transient appears across the circuit breaker. There are many double frequency circuits that occur in practice. A circuit breaker clearing as on the secondary side of transformer.In this case L1 represents inductance up to the transformer and l2 the leakage inductance of the transformer, while C1, C2 are the inherent capacitance on either side of the transformer.



To determine the transient recovery voltage we have to analyze the circuit.The initial voltage capacitor using on transforming the equations.



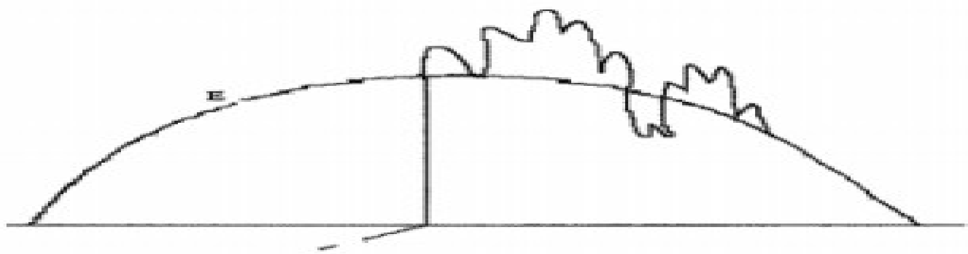


Fig.3.3 Double frequency restriking transient

The frequencies are given by

$$f_{n1} = \frac{1}{2\pi\sqrt{L_1 C_1}} \quad \text{and} \quad f_{n2} = \frac{1}{2\pi\sqrt{L_2 C_2}}$$

The magnitude and the Waveform for the total voltage is proportional to the inductances and is given by :

$$E_{TRV} = E\,[a_1(1-\cos\omega_1 t) + a_2(1-\cos\omega_2 t)]$$

Where $a_1 = L_1/(L_1+L_2)$ and $a_2 = L_2/(L1+L_2)$

$$\omega_1 = \frac{1}{\sqrt{L_1 C_1}} \quad \text{and} \quad \omega_2 = \frac{1}{\sqrt{L_2 C_2}}$$

4. Describe the broad classifications in power system transients. (N/D2017,A/M-2017)

(Or)

What are the various types of power system transients and explain any two types of power system transients.

Depending upon the duration of transients they can be broadly classified in to three groups.

a) Ultra-fast transients
b) Medium fast transients
c) Slow transients

Ultra-fast transients: These types of transients are caused either by lightning or by the abrupt but normal network changes resulting from normal switching operations. These transients are entire electrical in nature and they generally last only for few milliseconds. Such transients give rise to high voltages.

Medium fast transients:

These transients occur due to abrupt short circuit in the system causing abnormal structural changes in the system. It is also entirely electric in nature and are responsible for excessive currents in the system. Short circuit system may be present in the system.

Slow transients:

Slow Transients:

These transients are electromechanical in nature causing mechanical oscillations of rotors of synchronous machines. Such oscillations may cause instability of the interconnected power system by putting some or all of the machines out of synchronism.

(ii) **According to the sources of transients it can be classified as**

- Switching transients and lightning transients

(iii) **Depending on its nature**

1. Impulsive and oscillatory
2. Impulsive low frequency transients
3. Medium frequency transients
4. High frequency transients

- If the main signal is removed, the remaining waveform is the pure component of the transient.when 77% of the peak-peak voltage of the pure component is of one polarity.Each category of transient is subdivided into three types.

The impulsive low frequency transients: An impulsive transients is a sudden change in the steady state condition of voltage, current or both that is unidirectional in polarity . Impulsive transients are normally characterized by their rise and decay times. They are damped quikly by the resistive circuit elements and do not propagate for from their source. The most commom cause of impulsive transients is lightning.

These types are the most common transients recovered on a power system. Easily propagated but they can also amplified by a power system resonance phenomenon . Measurement of this types of transients should be useful for all classes of application.

The medium frequency impulsive transients:

These transients may not propagate as easily as the low frequency types but may cause arcing faults on the power distribution system which result in voltage sag on many user power systems.It is most appropriate to measure these types of transients for trouble shooting and laboratory classes.

High frequency types:

With high amplitude can be observed only near where the phenomenon occurs. The high frequency impulsive transients has duration below 50ns and the frequency of the frequency oscillatory type ranges between 0.5and 5MHZ

Low frequency transients:

Low frequency transients are caused when a discharged power factor correction capacitor is switched on across the line/ The capacitor then resonates with the inductance of the distribution system. The peak of this waveform, in theory.

Extremely fast transients (or) EFTS:

Extremely fast transients have rise and full times faults, such as bad brushes in motors, and aare rapidly damped out by even a few meters of distribution wiring. Standard line filters, included and most all electronic equipment, remove EFTS.

Subsidence transients:

In coupling capacitor voltage transformers and bushing capacitor voltage transformer . the elements L and C contains stored energy. When a disturbance such as a fault occurs on the primary the n subsidence transient is produced. Due to this sudden reduction of voltage produced on the primary , this voltage may be oscillatory or at may be unidirectional. Due to this severe secondary transient is produced.

5.Briefly explain the importance of study of transients in planning.(A/M-2017)

Power system transients are system problems and it is often of broad band nature. The disturbance that is created in one portion of power system will permeate throughout its entire length, and after causing difficulties at points will be reflected back to its origin.

Power system planning is a process in which the aim is in decide on new as well as upgrading existingSystem elements in a system to adequately satisfy the loads for a free seen future and to work properly in any adverse conditions. The possible elements in a system are

1. Generation facilities
2. Substations
3. Transmission lines and / or cables
4. Capacitors
5. Reactors

The transients can be studied from the following angles

- Recognition * Prediction * Mitigation

The models of the power system equipments can be generated on two percepts.

1. **Based on lumped parameters**: Motors, Capacitors, inductors and reactors
2. **Based on distributed system parameters**

It is important that transient simulations and models must reproduce frequency variations, non-linearity, magnetic saturation, surge arresters, characteristics circuit breaker and power line operation.

The transient waveform may contain one or more oscillatory components can be characterized by the natural of this oscillations which are dependent upon the nature of the power system equipment.

Transients are generated due to phenomena internal to the equipment or of atmospheric region. Therefore the transients are inherent in the electrical systems mitigation through surge arresters, transient voltage surge suppressions (TVSS) active and passive filters, chokes, coils, and capacitors, snubber and damping circuits requires knowledge of characteristics of this devices for appropriate analysis.

Standards establish the surge performance of the electrical equipments by application of a number Of test wave shapes and rigorous testing, yet to apply proper strategies and devices for a certain Configuration of a large system This shows that all the three aspects, analysis, recognitions and mitigation are interdependent. The share of analysis being more than +75% After all, a mitigation strategy must again be analysed and the effectiveness be prevent by modeling before implementation

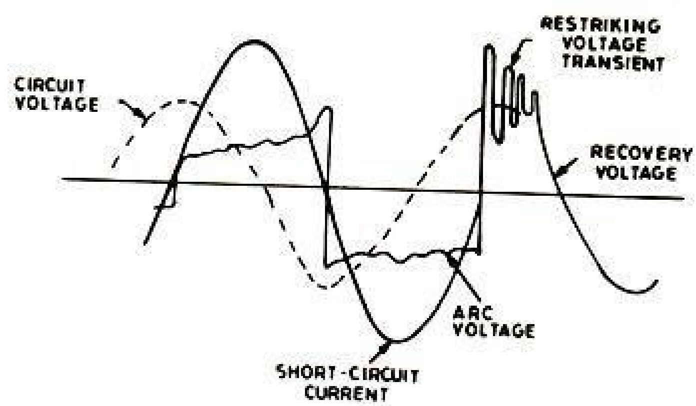
UNIT-II-PART-B

1. Briefly explain about current suppression and current chopping.(N/D-2017)(M/J-2016)

Current Chopping is the phenomenon of making the **current** to zero at regular ... In power lines when surge occurs due to lightning or **switching** operation at that time circuit breaker opens (air blast C.B) and **current** suddenly ...

When breaking low currents (ie) unloaded transformer or reactor magnetizing current, the powerful de-ionizing effect of air blast circuit breaker (CB) causes the current abruptly to zero well before the natural current zero is reached. This phenomenon is called current chopping and it produces high voltage transients across the breaker contacts, The transient over voltage due to current chopping is prevented by resistance switching

While interrupting highly inductive current, like no-load current of transformer, the rapid deionization of contact space and blast effect may cause current interruption before its natural zero. Such an 'interruption of current before its natural zero is termed as "**current chopping**".This phenomenon is more pronounced in case of air-blast circuit breakers which exerts the same deionizing force for all currents within its short-circuit capacity. Even though, the instantaneous value of current being interrupted may be less than the normal current rating of the breaker, it is quite dangerous from the point of view of overvoltages which may result in the system.



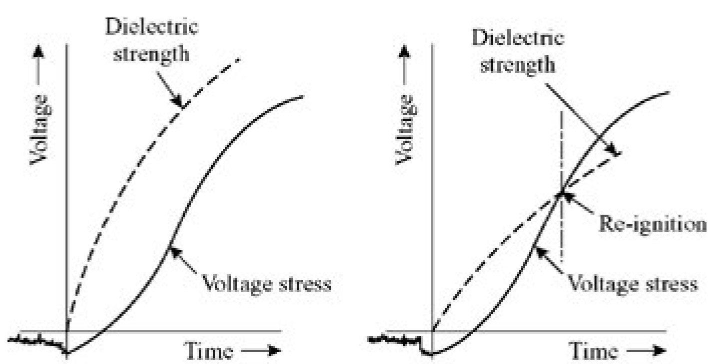
Let,
L = Inductance of the system
C = Capacitance of the system
i =Instantaneous value of arc current
V = Instantaneous value of capacitor voltage (which appears across the breaker when it opens)

The electromagnetic energy stored in the system at the instant before interruption is $1/2(Li^2)$ As soon as the current is interrupted the value of i becomes zero. But, the

electromagnetic energy stored in the system [$1/2(Li^2)$] cannot become zero instantaneously and so it is converted into electrostatic energy [$1/2(CV^2)$] as the system has some capacitance.
According to the principle of energy conversion we have, $1/2(Li^2)=1/2(CV^2)$ & $V=i\sqrt{(L/C)}$

This theoretical value of V is called as "**prospective Voltage or Arc Voltage**". If this voltage is very high when compared with the gap withstanding voltage, then the gap breakdowns and so "the arc restrikes. Again the current is chopped (interrupted) because of high quenching force and so, restriking occurs. This process repeats until the current is suppressed finally without any restrike and this occurs near current zero as shown in the figure.

In actual proactive the voltage across the breaker does not reach dangerously high prospective values of voltage. It is due to the fact that as soon as the breaker voltage increases beyond the gap withstanding voltage, it breaks down and the arc restrikes due to which the voltage across breaker falls to a very low value of arc voltage which can also be seen in the figure. Hence, it can be said that the arc is not an undesirable phenomenon and instead it protects the power system from severe stress on insulation due to overvoltages.



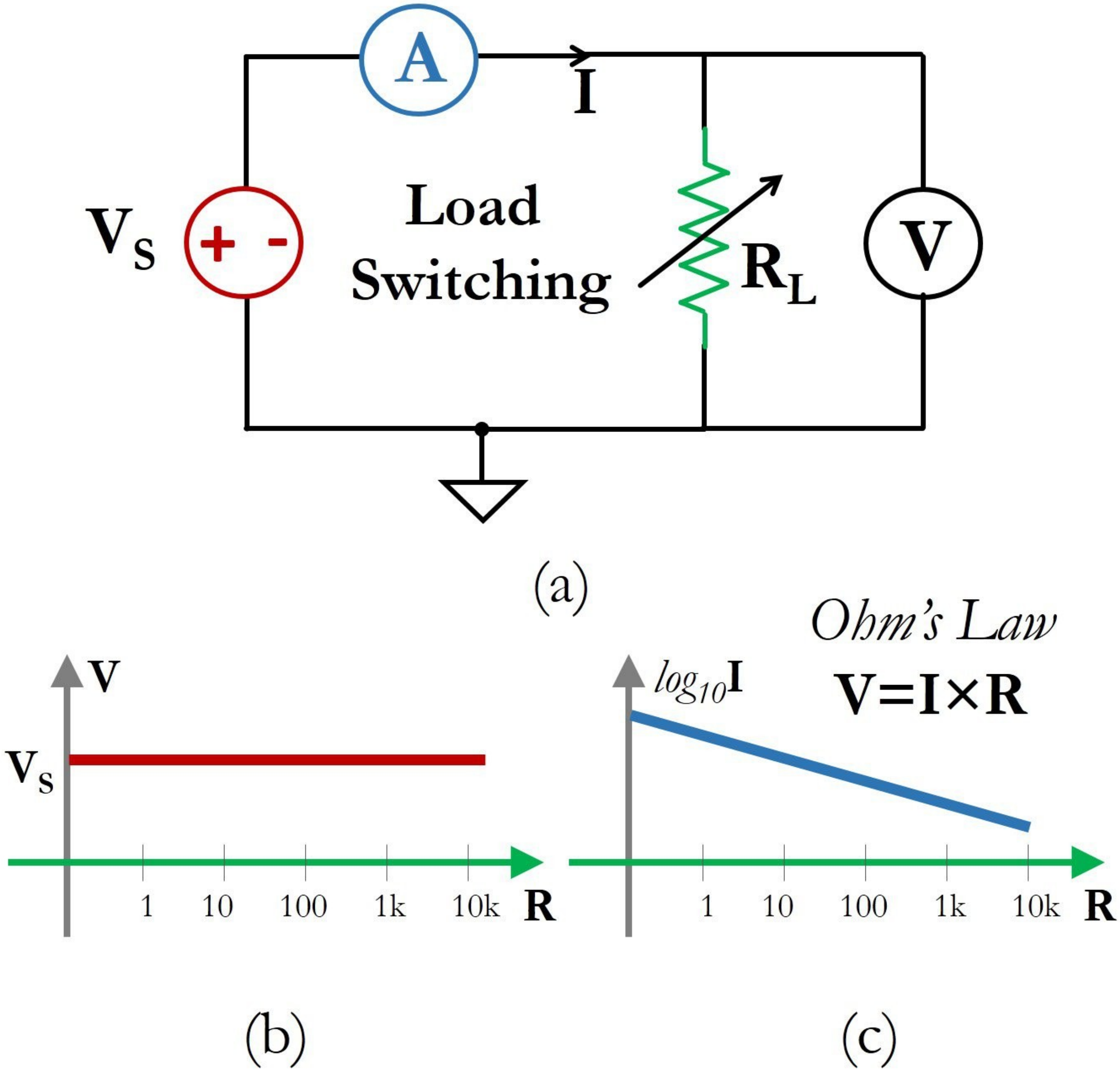
(*a*) Interruption maintained (*b*) Initial interruption followed by dielectric failure

In order to reduce the **phenomenon of current chopping**, the overvoltages are to be reduced. This is possible by connecting voltage— grading (or non—linear) resistors across the circuit breaker contacts during arc interruption. In medium voltage systems, an RC surge absorber is connected across line and ground in between the inductive load and the circuit breaker. As a result, the RC combination absorbs the over voltages.

Current Suppression:

The interruption of small inductive currents can lead to situation that are known as current chopping. If the current is interrupted at current zero, the interruption is normal and the transient recovery voltages are usually within the specified values. However, if premature interruption occurs due to current chopping, the interruption will be abnormal and it can cause high frequency reignitions and over voltages.

2. **Explain load switching with equivalent circuit.(N/D-2017)**
   Loads are frequently switched in power systems. For industrial systems, contactors are designed to switch normal loads, such as motors, pumps, furnaces, and so on, very frequently. In utility power systems, load break switches and circuit switchers are the devices that can interrupt the load current but not the fault current. The frequency of normal load switching in utility systems is usually very low. The impedance of the load circuit being switched can be series combination of resistance and reactance, a parallel combination of resistance and reactance and series combination of resistance and reactance. It is to br known that the recovery voltage is one of the principle factors to be determining the ability of a circuit breaker to clear a circuit successfully.

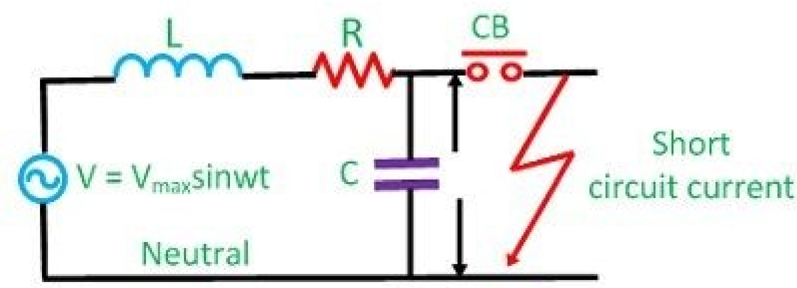


3. Explain about multiple restriking transients.(N/D-2017)

When the current across the contact of the circuit breaker is zero, a high-frequency transient voltage develops in the whole breaker contact and is produced by the sudden distribution of energy between the electric and magnetic field. This transient voltage is called restriking voltage. The voltage appears across the breaker contacts at the moment of final current has a serious influence on the arc extinction process. Under the influence of this voltage, the arc tries to restrike and hence it is named as the restriking voltage.

After the zero current, the arc gets extinguished, if the rate of rising of restriking voltage between the contact is less than the rate at which the dielectric strength of the medium between the contact gains. Immediately after the final current interruption, the voltage that appears across the breaker contacts (transient voltage) superimposed on the power frequency system voltage (recovery voltage).

Considered a simple circuit, having a circuit breaker CB, as shown in the figure below. Let L be the inductance per phase of the system up to the fault point; R be the resistance per phase of the system up to the fault point, and C be the capacitance of the circuit.



Fault and its Equivalent Circuit

Circuit Globe When the fault occurs in the system under fault condition the contacts of the breaker are open, and the capacitance C is short-circuited by the fault, and the short circuit current is limited by the resistance and the inductance.

When the breaker contacts are opened, and the arc certainly quenches at some current zero, a voltage v is suddenly applied across the capacitor and therefore across the circuit breaker contacts. The current i which would flow to the fault is not injected in the capacitor and inductor. Thus

$$i = i_L + i_C$$

$$i = \frac{1}{L}\int v dt + C\frac{dv}{dt} \quad \frac{di}{dt} = \frac{v}{L} + C\frac{d^2 s}{dt^2} \ldots\ldots\ldots\ldots\ldots equ(1)$$

Assuming Zero time at zero currents when t = 0 and the value of current and voltage before opening of circuit breaker is expressed as

$$v = V_{max} coswt \quad \frac{di}{dt} = \frac{V_{max}}{wl} \times w \times coswt$$

$$i = \frac{V_{mt}}{wl} sinwt \quad t = 0; \quad \left|\frac{di}{dt}\right| = \frac{V_{max}}{L}$$

On substituting the above values in equation (1), we get

$$\frac{V_{max}}{L} = \frac{v}{L} + C\frac{d^2v}{dt^2}$$

The solution of the standard equation is

$$v = V_{max}\left[1 - cos\frac{1}{\sqrt{LC}}\right] = V_{max}(1 - 2\pi f_n t) \ldots\ldots\ldots equ(3)$$

From the equation,

$$\frac{1}{\sqrt{LC}} = 2\pi f_n = w_n$$

The above expression is for restriking voltage where V_{max} is the peak value of recovery voltage (phase -to-neutral) t is time is seconds. L is inductance in Henrys, C is the capacitance in farads and v is the restriking voltage in volts. The maximum value of restriking voltage is $2V_{max}$ and occurs at

$$t = \frac{\pi}{w} \text{ or } t = \pi\sqrt{LC}$$

Characteristic of restriking Voltage.

The important characteristic of restriking voltage which affects the performance of the circuit breaker is as follows –

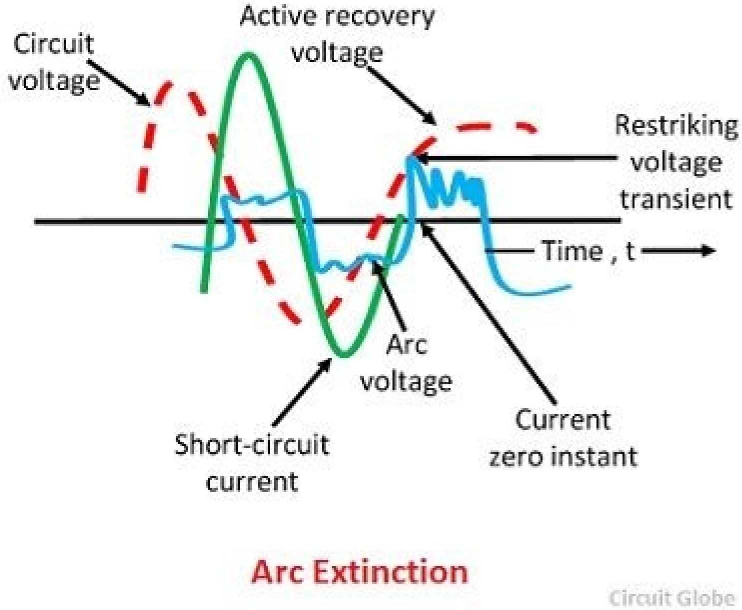
Amplitude Factor – It is defined as the ratio of the peak of transient voltage to the peak system frequency voltage.

The rate of Rising of Restriking Voltage – It is defined as the slope of the steepness tangent of the restriking voltage curve. It is expressed in kV/μs. RRRV is directly proportional to the natural frequency. The expression for the restriking voltage is expressed as

$$RRRV_{max} = \frac{V_{max}}{\sqrt{LC}}$$

The transient voltage vanishes rapidly due to the damping effect of system resistance, and the normal frequency system voltage is established. This voltage across the breakers contact is called recovery voltage.

The waveforms of recovery and the restricting voltage are shown in the figure above. After the current zero, the voltage appearing across the breaker contacts is composed of transient restriking voltage and power frequency recovery voltage.



The waveforms of recovery and the restricting voltage are shown in the figure above. After the current zero, the voltage appearing across the breaker contacts is composed of transient restriking voltage and power frequency recovery voltage.

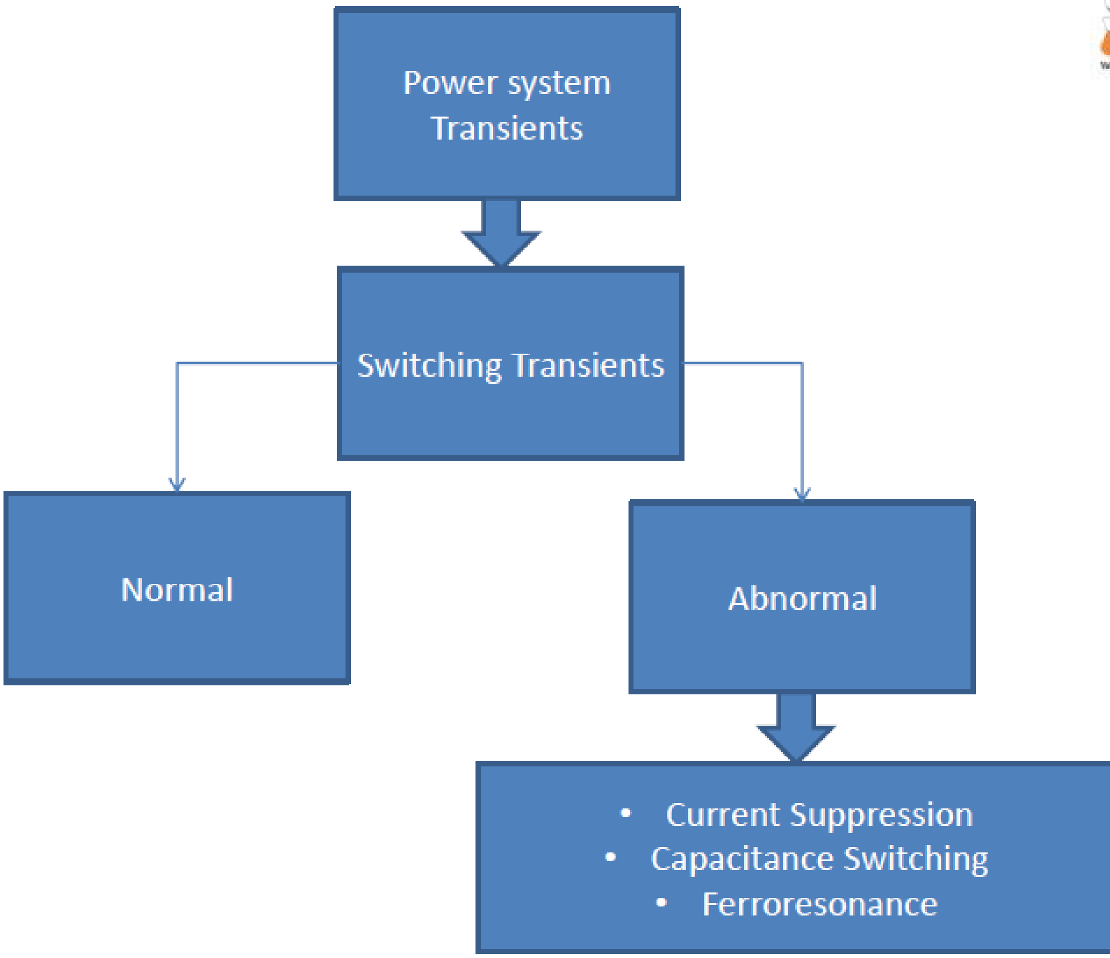
4. **Draw and explain the waveforms for transient voltage across the load under normal and abnormal switching transients**.(N/D-2017)

Normal switching transients:

Due to some other circumstances like transients the voltage and current magnitude may rise high. The transients occur due to the trapping of energy and its subsequent somewhere in the circuit. Such transients are referred as abnormal current and voltage transients.

Abnormal switching transients:

Abnormal switching transients are circumstances in which voltage or current are far in excess of twice its normal peak values. Insulation of high voltage CBs typically can tolerate over voltages up to 2.5 times over its nominal voltage. If the value of the over voltage excesses the limit electrical arcs will be produced between terminals and other metal parts.



The Normal Curve

* The shape of the normal curve is often illustrated as a bell-shaped curve.
*The highest point on the normal curve is at the mean of the distribution.
* The normal curve is symmetric.
*The standard deviation determines the width of the curve.
*The total area under the curve the same as any other probability distribution is 1.

*The probability of the normal random variable assuming a specific value the same as any other continuous probability distribution ....etc

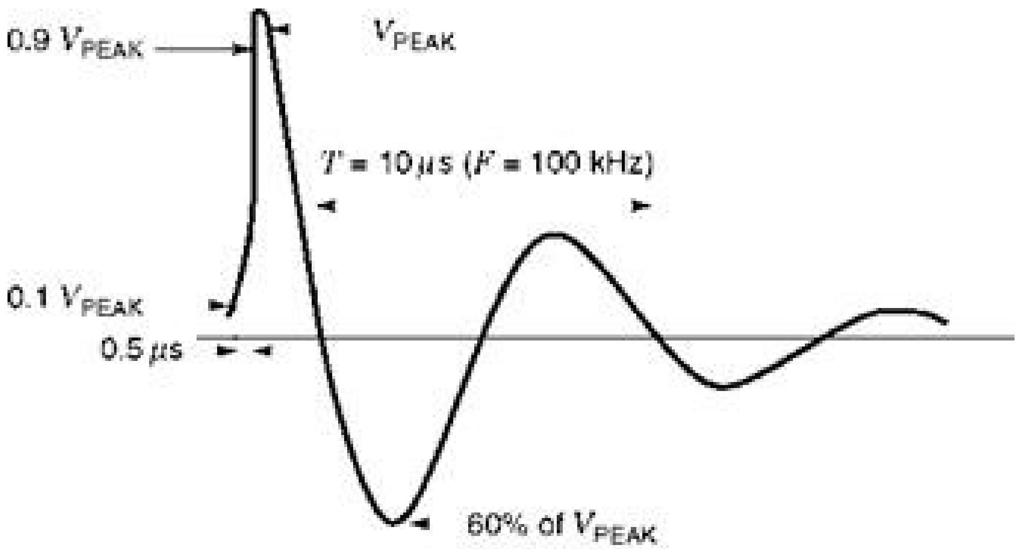


Figure 7. 0.5 μs to 100 kHz ring wave (open-circuit voltage).

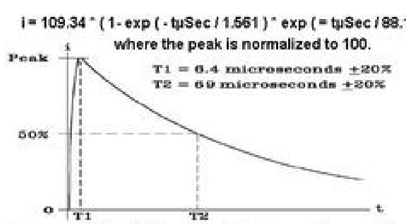


Figure 22-2 Current Waveform 1

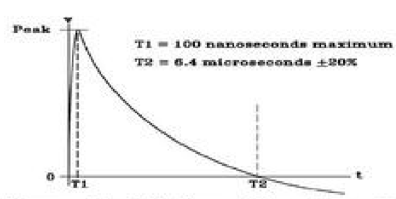


Figure 22-3 Voltage Waveform 2

Multiple equations satisfy this curve description. For example:

Let tau = 5.1559 for which:
v = 100 * (1 - (1 - exp (- tfall / tau)) * (1 + exp) - tfall / (1.4 * tau))))

\- or -

Let tau = 6.2131 for which:
v = 100 * (1 - (1 - exp (- tfall / tau)) * (1 + exp (- tfall / (1.8 * tau))))

etc.

Note: tfall = t - T1 when t > T1

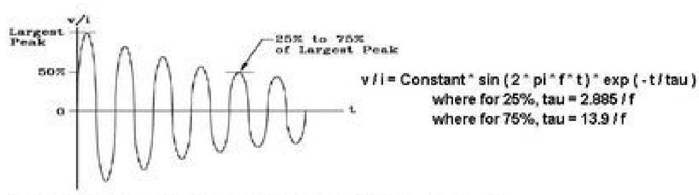


Figure 22-4 Voltage/Current Waveform 3
(Transient 1 & 10 MHz)

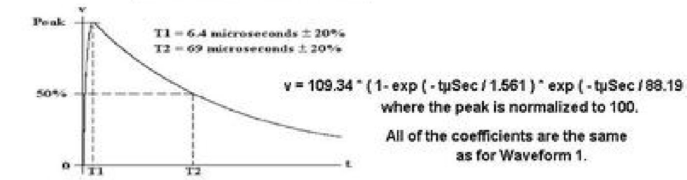


Figure 22-5 Voltage Waveform 4

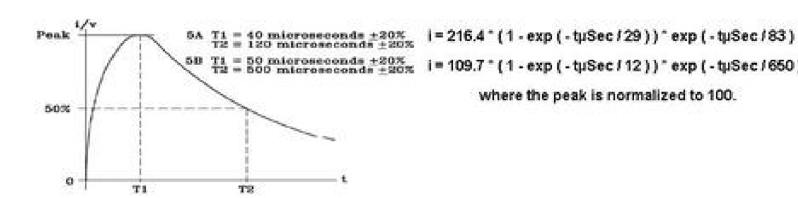
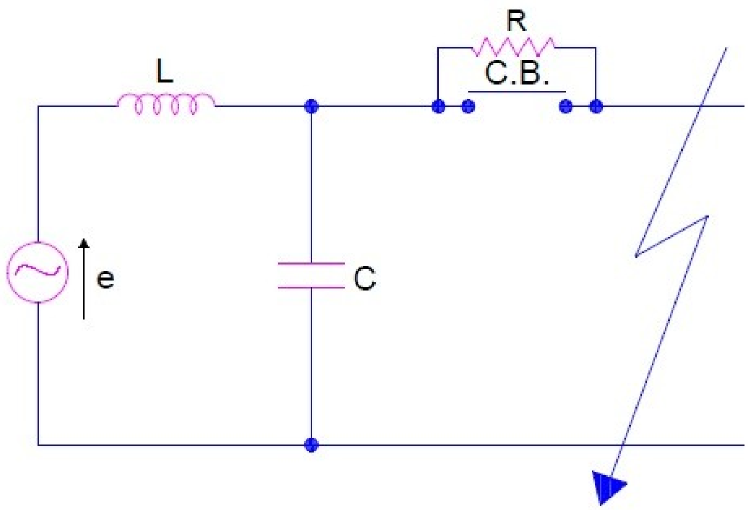


Figure 22-6 Current/Voltage Waveform 5

5. Write short notes on resistance switching.(A/M-2017)

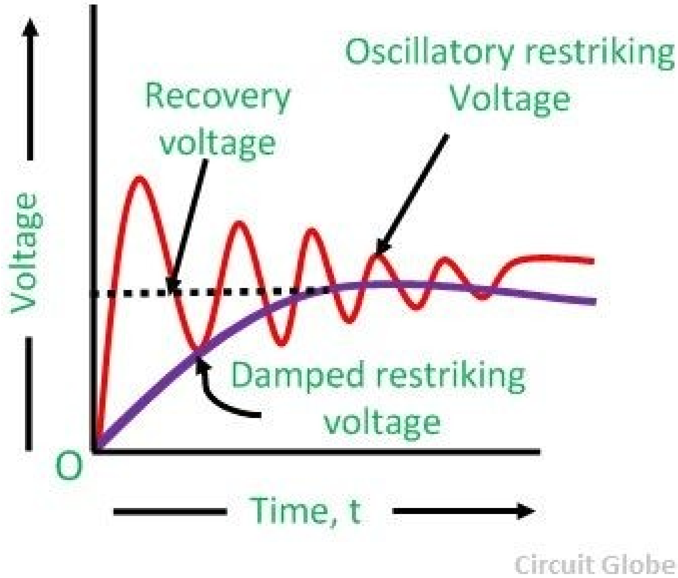
Resistive switching refers to the physical phenomena where a dielectric suddenly changes its (two terminal) **resistance** under the action of a strong electric field or current. The change of **resistance** is non-volatile and reversible.



Resistive switching refers to the physical phenomena where a dielectric suddenly changes its (two terminal) resistance under the action of a strong electric field or current. The change of resistance is non-volatile and reversible. Typical resistive switching systems are capacitor like devices, where the electrode is an ordinary metal and the dielectric a transition metal oxide. An interesting application of resistive switching is the fabrication of novel non-volatile resistive random-access memories (RRAM). This effect is also at the base of the behavior of the so called memristor devices and neuromorphic memories.

The use of resistance switching, resistors can be of value in capacitance swiching or line de-energizing. In the case of resistors being applied, the process of disconnection of the capacitor

Bank or transmission line involves insertion of the resistor or sequential insertion of a number of resistors such that the actual load becomes a series combination of R and C. If the resistor has a low ohmic value, the main interrupting duty is transferred from the main break to the resistor break.



6.Describe briefly about characteristics of Ferro resonance. (A/M-2017)

Ferro resonance or **nonlinear resonance** is a type of resonance in electric circuits which occurs when a circuit containing a nonlinear inductance is fed from a source that has series capacitance, and the circuit is subjected to a disturbance such as opening of a switch.[1] It can cause over voltages and over currents in an electrical power system and can pose to transmission and distribution equipment and to operational personnel.[2]

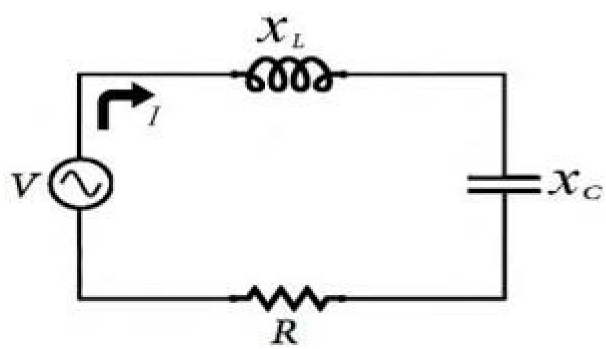
Ferro resonance should not be confused with linear resonance that occurs when inductive and capacitive reactance of a circuit is equal. In linear resonance the current and voltage are linearly related in a manner which is frequency dependent. In the case of Ferro resonance it is characterized by a sudden jump of voltage or current from one stable operating state to another one. The relationship between voltage and current is dependent not only on frequency but also on a number of other factors such as the system voltage magnitude, initial magnetic flux condition of transformer iron core, the total loss in the ferro resonant circuit and the point on wave of initial switching.[2]

Ferro resonant effects were first described in the term "ferro resonance" was apparently coined by French engineer Paul Boucherot in a paper from 1920, where he analyzed the phenomenon of two stable fundamental frequency operating points coexisting in a series circuit containing a resistor, nonlinear inductor and capacitor.

Determination of the Characteristics for Ferro resonance Phenomenon in Electric Power Systems. The term Ferro resonance refers to a special kind of resonance that involves capacitance and iron-core inductance. The most common condition in which it causes disturbances is when the magnetizing impedance of a transformer is placed in series with a system capacitor. This happens when there is an open-phase conductor. Under controlled conditions, ferro resonance can be exploited for useful purpose such as in a constant-voltage transformer. Ferro resonance is different than resonance in linear system elements. In linear systems, resonance results in high sinusoidal voltages and currents of the resonant frequency. Linear system resonance is the phenomenon behind the magnification of harmonics in power systems.

Ferro resonance can also result in high voltages and currents, but the resulting waveforms are usually irregular and chaotic in shape. The concept of ferro-resonance can be explained in terms of linear-system resonance as follows.

Consider a simple series RLC circuit as shown in Fig. 3.6. Neglecting the resistance R for the moment, the current flowing in the circuit can be expressed as follows: E I = j(X − X) Where E = driving voltage XL = reactance of L XC = reactance of C When XL = |XC|, a series-resonant circuit is formed, and the equation yields an infinitely large current that in reality would be limited by R.   Simple series RLC circuit An alternate solution to the series RLC circuit can be obtained by writing two equations defining the voltage across the inductor, i.e. v = jX L I , v =E + j XC I Where v is a voltage variable. Figure 3.7 shows the graphical solution of these two equations for two different reactance's, XL and XL′. XL′ represents the series-resonant condition. The intersection point between the capacitive and inductive lines gives the voltage across inductor EL.



The voltage across capacitor EC is determined as shown in element in the circuit has a nonlinear reactance characteristic like that found in transformer magnetizing reactance. Figure 3.8 illustrates the graphical solution of the equations following the methodology just presented for linear circuits. Intersection 2 is an unstable solution, and this operating point gives rise to some of the chaotic behavior of Ferro resonance. Intersections 1 and 3 are stable and will exist in the steady state value.

Intersection 3 results in high voltages and high currents voltages that can result from this simple series circuit. The same inductive characteristic was assumed for each case. The capacitance was varied to achieve a different operating point after an initial transient that pushes the system into resonance. The unstable case yields voltages in excess of 4.0 pu, while the stable case settles in at voltages slightly over 2.0 pu. Either condition can impose excessive duty on power system elements and load equipment. For a small capacitance, the |XC| line is very steep, resulting in an inductance.

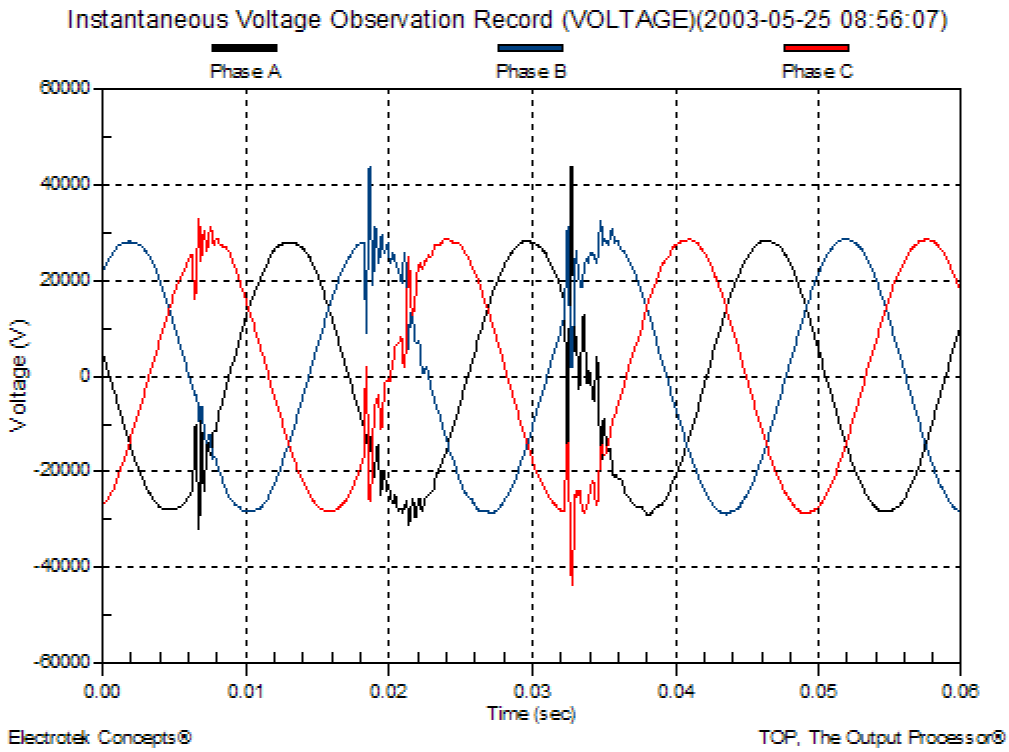
6.What is called capacitance switching?with necessary sketches, explain the capacitance switching with a restrike and multiple restrike (A/M-2017,M/J2016)

Capacitor switching is encountered for all load current **switching** ... Ranges of typical **capacitor switching** currents the Effect of **Multiple Restrikes**,Current.

whenever possible, by means of comparisons with reliable experimental results, a scale model system was developed and implemented with this purpose [5]-[8]. This unique facility enabled tests to be performed under controlled conditions; data obtained from the simulation of a wide variety of situations were used to confirm the validity of the Agrawal et al. model [1] and the Extended Rusck Model (ERM) [8], [9], as well as for the analysis of the lightning electromagnetic pulse response of complex electric power networks [6], [10], [11]. For illustration, comparisons between measured and calculated induced voltage waveforms on a three-phase line with either a shield wire 1 m below the phase conductors (h = 10 m; hg = 9 m) and grounded every 450 m (ground resistance Rg equal to zero) or surge arresters installed on all phases every 450 m (Rg = 200 Ω) are presented in Fig. 1. The detailed simulation 1

Modelling of Restriking and Reignition Phenomena in Three-phase Capacitor and Shunt Reactor Switching Capacitor banks and shunt reactors are frequently switched by circuit-breakers in medium voltage (MV)and high voltage (HV) electricity networks. In receyears there have been explosive failures due to circuit-breaker restriking and reignition consequently there is a need for monitoring techniques that will facilitate the identification and quantification of the onset of more severe restriking. Whilst there has been detailed analyses of single-phase shunt reactor and capacitor bank switching there is a paucity of information about restriking phenomena and reignition in three-phase circuits for the correlation of system problems with specific waveform characteristics to develop the necessary identification algorithms for proactive monitoring of circuit-breakers' condition. This paper describes the modelling restriking and reignition occurring during three-phase capacitor bank and shunt reactor switching using the Alternative transient Information from the ATP models and data resulting from the simulations are examined with a view to developing an intelligent diagnostic system with logging and alarm features. This modelling method can be easily applied with different data from the different methods

Electric curves, circuit breakers and networks. Capacitor banks and shunt reactors are frequently networks, since their connection to the networks is essential for reactive compensation reasons, switched in medium voltage (MV) and high voltage (HV) electricity improving the power quality locally. The term "restrike" is defined as a re-establishment of the current, one-quarter cycle or longer, following interruption of a capacitive current at a normal current zero [1]. A resignation occurs when a current is at current zero and then re-establishesitself within one-eight of a power frequency cycle [2]. When there has been detailed analyses of single-phase .


Instantaneous Voltage Observation Record (VOLTAGE)(2003-05-25 08:56:07)
Phase A
Phase B
Phase C
60000
40000
20000
0
-20000
-40000
-60000
Voltage (V)
0.00
0.01
0.02
0.03
0.04
0.05
0.06
Time (sec)
Electrotek Concepts®
TOP, The Output Processor®

UNIT-III PART-B

1. Explain the Lightning phenomenon. (N/D-2017)

In the majority of cases, the **lightning** strike (or cloud-to-ground) is downward-moving. The discharge **phenomenon** is initiated by a success of pre-discharges from the cloud to the ground, progressing in a series of steps (stepped leader).

As an electrical storm builds, various mechanisms create a stratified charge within the storm cloud, with an electrical charge at the base of the cloud. Since we are mostly concerned with cloud-to-ground lightning, we are concerned primarily with the charge on the base on the storm, as that charge induces a "shadow" of opposite charge on the surface of the earth beneath it.

As the storm charge builds, so does the cloud base charge. Since like charges repel, and opposite charges attract, the cloud base charge induces an opposite charge on the surface of the earth beneath it – it pushes away the same charge and pulls in the opposite charge. The cloud base charge attracts, or pulls, on the ground charge, trying to pull it off the surface of the earth. It is this tendency for the storm base charge and the ground charge to equalize through the intervening air which causes cloud-to-ground lightning.

As the storm cloud travels over the earth's surface, it drags this ground charge along beneath it. When the ground charge reaches your facility, the storm cloud charge pulls it up on, and begins concentrating ground potential on your facility. If, before the storm cloud travels away, it manages to concentrate enough ground potential on your facility so that the difference in potential between the storm cloud base charge and the charge on your facility exceeds the dielectric strength, or resistance, of the intervening air, the air breaks down electrically, and a potential equalizing arc occurs; a lightning strike.

Since we are concerned with lightning strikes to objects and structures on the surface of the earth, and some 95% of all ground strikes are negative cloud-to ground lightning, for the purpose of this discussion we will describe negative cloud-to-ground lightning.

2. Discuss the interaction between lightning and power system. (N/D-2017)(A/M-2017)

When a lightning strikes a power line, a current is injected into the power system.

- What voltages this current will give rise to, depend upon its wave shape and the impedance through which it flows.

• According to this concept, current coming into a line by lightning stroke from a cloud disappears into the ground either by flashover of line insulators, or by operation of a protective device or through the ground wires giving an induced path to the ground.

• On the ground or objects on the ground such as transmission line, charge is induced by charges in the cloud & are bound by it.

• Whenever the charges in the cloud move due to motion of the cloud or redistribute due to cloud flashes, the induced the induced charges on the ground or the lines also move and redistribute.

Introduction :

Lighting is an essential service in all the industries. The power consumption by the industrial lighting varies between 2 to 10% of the total power depending on the type of industry. Innovation and continuous improvement in the field of lighting, has given rise to tremendous energy saving opportunities in this area. Lighting is an area, which provides a major scope to achieve energy efficiency at the design stage, by incorporation of modern energy efficient lamps, luminaries and gears, apart from good operational practices. 8.2 Basic Terms in Lighting System and Features Lamps Lamp is equipment, which produces light. The most commonly used lamps are described briefly as follows:

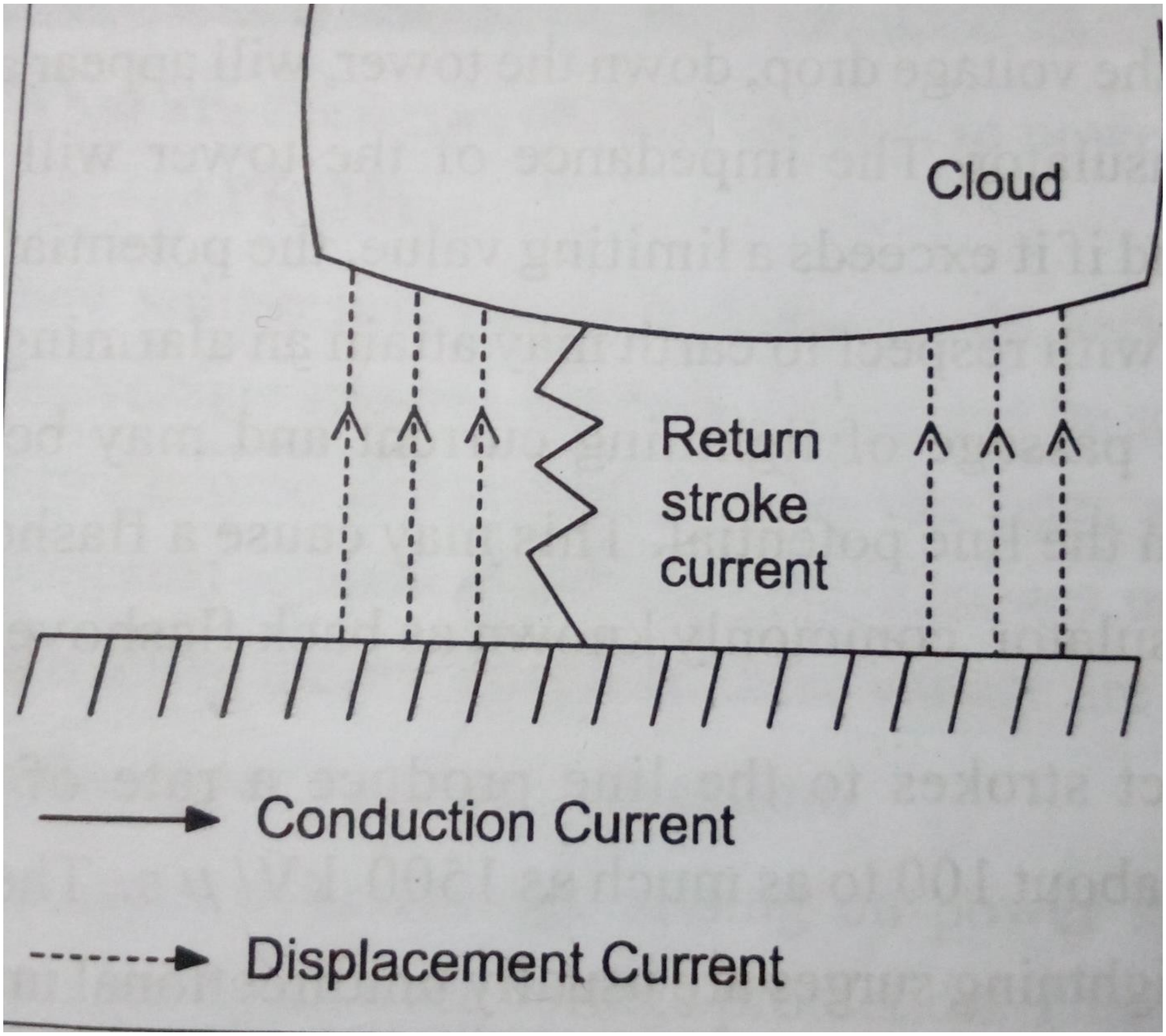
• Incandescent lamps: Incandescent lamps produce light by means of a filament heated to incandescence by the flow of electric current through it. The principal parts of an incandescent lamp, also known as GLS (General Lighting Service) lamp include the filament, the bulb, the fill gas and the cap.

• Reflector lamps: Reflector lamps are basically incandescent, provided with a high quality internal mirror, which follows exactly the parabolic shape of the lamp. The reflector is resistant to corrosion, thus making the lamp maintenance free and output efficient.

• Gas discharge lamps: The light from a gas discharge lamp is produced by the excitation of gas contained in either a tubular or elliptical outer bulb. The most commonly used discharge lamps are as follows

- Fluorescent tube lamps (FTL)
- Compact Fluorescent Lamps (CFL)
- Mercury Vapour Lamps
- Sodium Vapour Lamps
- Metal Halide Lamps Luminaire

Luminaire is a device that distributes, filters or transforms the light emitted from one or more lamps. The luminaire includes, all the parts necessary for fixing and protecting the lamps, except the lamps themselves. In some cases, luminaires also include the necessary circuit auxiliaries, together with the means for connecting them to the electric supply. The basic physical principles used in optical luminaire are reflection, absorption, transmission and refraction.



3. What are the factors contributing to good line design.(N/D-2017)

In order to reduce the hazard that lightning poses to power systems, certain factors that determine the line performance must be understood.

- The objective of good line design is to reduce the number of outages caused by lightning.
- First we try to keep the incidence of stokes to the system to a minimum
- Then we try to minimize the effects of those strokes that do terminate on the system.
- Lightning problems can be eliminated if all transmission was through tunnels atleast 20ft under the ground.
- Tall towers are more vulnerable than low goal post- like structures. In order to prevent the lightning, some adequate clearances must be provided.
- High ground impedance or tower footing resistance are to be avoided.
- High surge impedance in ground wires, tower structures are to be avoided.

4. Explain the characteristics of Lightning strokes. **.(N/D-2017)**

CHA STROKRACTERISTICS OF LIGHTNING STROKES

- Amplitude of the currents

- Rate of rise
- Probability of distribution of the above
- Wave shapes of the lightning voltages & currents
- Time to peak value & its rate of rise

Specifications:

- peak amplitude-5000kv in a transmission line
- Front time -2 to 10 microseconds
- Time – 20 to 100 microseconds
- Rate of rise of voltage – 1Mv/ microsecond

CH ARACTERISTICS OF LIGHTNING STROKES

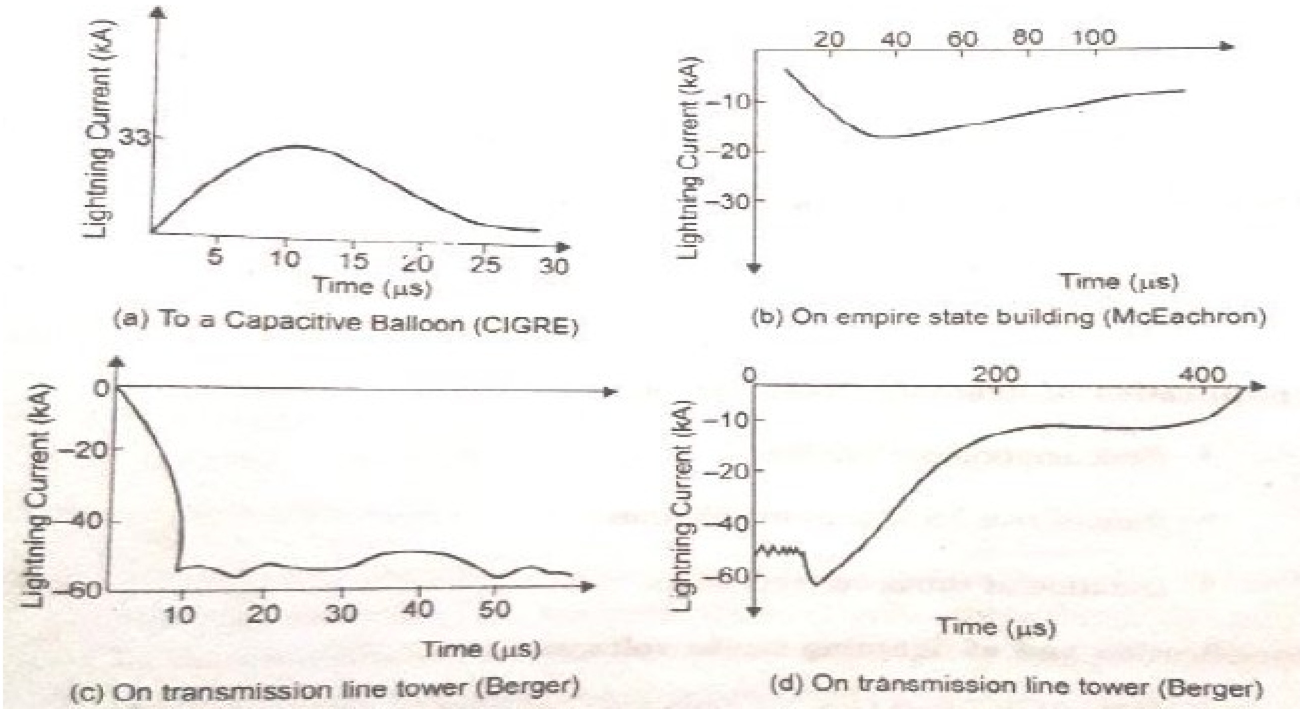
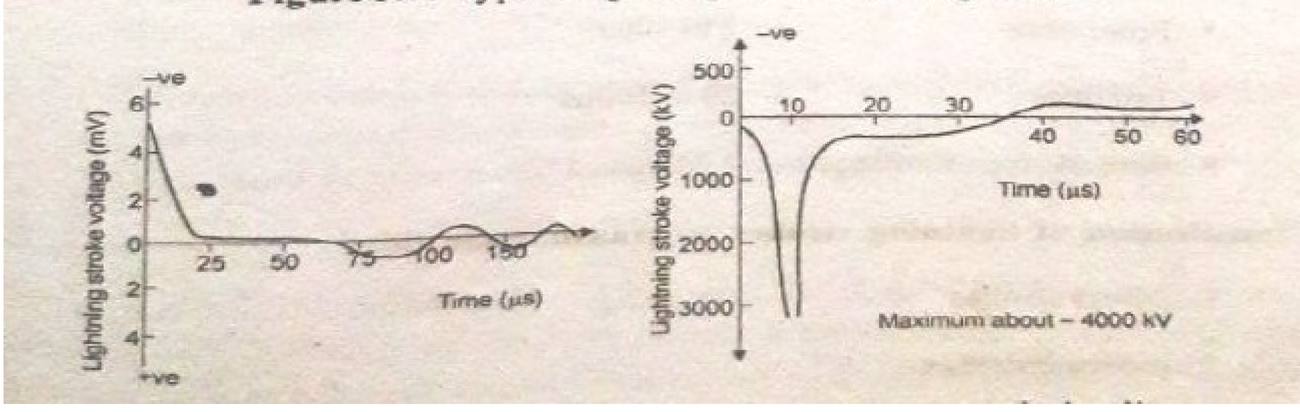


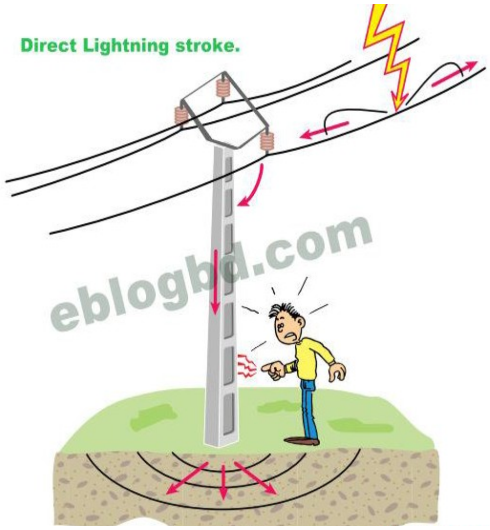
Figure 3.7: Typical lightning current oscillograms



CHARACTERISTICS OF LIGHTNING STROKES ON TRANSMISSOIN LINE

• Direct stroke

When the thunder cloud directly discharges onto a transmission line tower or line wires is called a direct stroke. Direct lightning strike The lightning strike directly falls upon the over head line or electrical equipment. This sudden current injection creates voltage surges, traveling wave that propagates through the line make impact on other equipments.



5. Write short notes on tower footing resistance(A/M-2017)`

Tower footing resistance (Rt) is the resistance offered by the metal parts of the tower+ the ground resistance. It is important for the protection against Surge Voltages. If it is high then even if a lightning hits the earth wire and travels through the tower to earth, the voltage developed at the cross arm of the tower (which is normally at zero potential) could be so high as to produce a '***Back Flash-Over***' thus transferring the surge that should have been discharged to ground, to the phase conductors and travelling on either side towards the power transformers, C.B s, switches, bus bars etc.

Tower footing resistance is the resistance offered by tower footing to the dissipation of current. The effective of a ground wire depends to a large extend on the tower footing resistance. The tower top potential depends on this resistance.

Significance of the tower footing resistance:

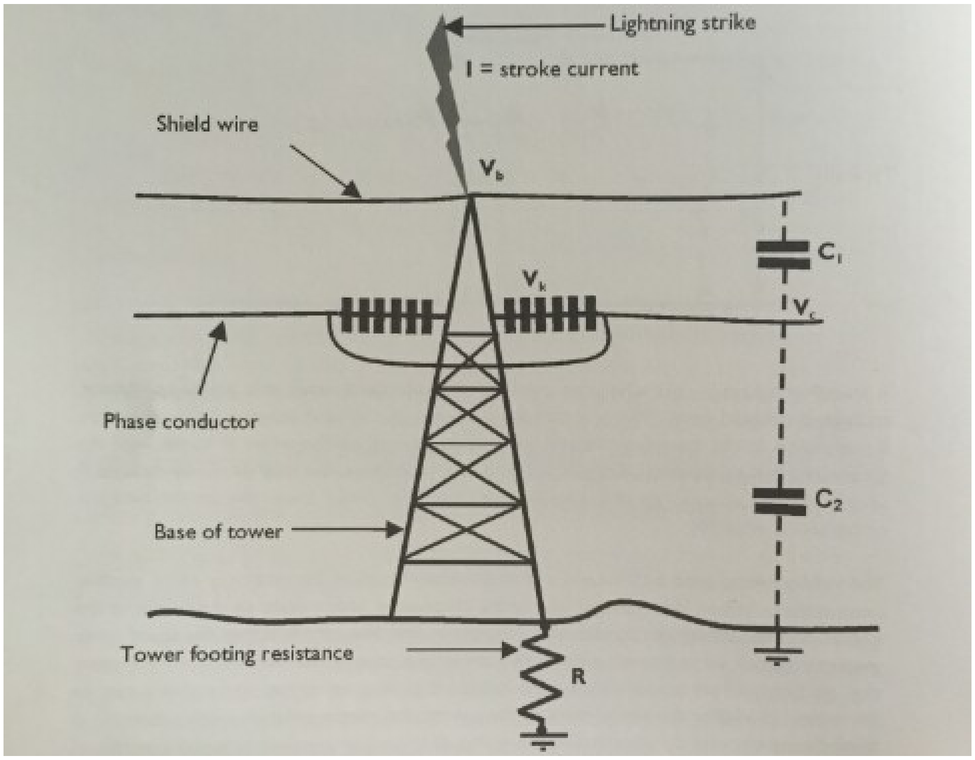
- A low value of tower footing resistance results in less voltage stresses across line insulation.
- A tower footing resistance of 20Ω for EHV lines and 10Ω for HV lines provides sufficient lightning protection.

Tower footing resistance depends on

i) Types of electrode configuration employed

ii) Soil resistivity.

Diagram of Tower Footing Resistance



6. What are the theories of charge formation in the clouds, Explain them in detail.(A/M-2017)

According to the Simpson's theory, there are there are three essential regions in the cloud to be considered for charge formation. Below region A, air currents travel ground cloud motion field gradient at ground above 800 cm/, and no rain drops fall through. In region A air velocity is high enough to break the falling rain drops causing a positive charge spray in the cloud and negative charge in the air.The spray is blown upwards, but as the velocity of air decreases., the positively charged water becomes predominantly positively charged.

While region B above it, becomes negatively charged by air currents. In the upper region in the cloud, the temperature is low and only ice crystals exist. The impact of air on these crystals make them negatively charged, thus the distribution of charge within the cloud becomes as shown.

Reynolds and Mason theory:

Thunder clouds are developed at heights from 1 km to 14 km above ground level • For thunder clouds and charge formation air currents, moisture and specific temperature range are required . • The air currents controlled by the temperature gradient move upwards carrying moisture and water droplets. • Temp – 0 o C @ 4 km Ht, reaches -50 o C @ 12 km Ht • Water droplets freeze below -40 o C 54 The effective freezing temperature range is around - 33 0 C to - 4O 0 C.

• The water droplets in the thunder cloud are blown up by air currents and get super cooled over a range of heights and temperatures.

• The crystals grow into large masses and due to their weight and gravitational force start moving downwards.

• Thus, a thunder cloud consists of super cooled water droplets moving upwards and large hail stones moving downwards.

• When the upward moving super cooled water droplets act on cooler hail stone, it freezes partially, i.e. the outer layer of the water droplets freezes forming a shell with water inside.

• When the process of cooling extends to inside warmer water in the core, it expands, thereby splintering and spraying the frozen ice shell.

The splinters being fine in size are moved up by the air currents and carry a net positive charge to the upper region of the cloud.

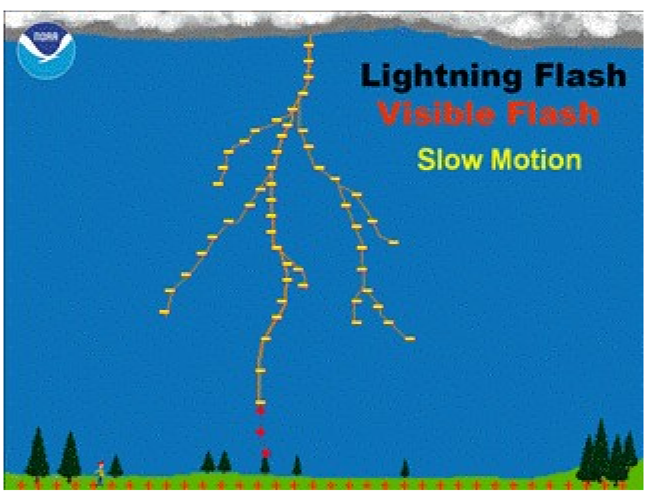
• The hail stones that travel downwards carry an equivalent negative charge to the lower regions of the cloud and thus negative charge builds up in the bottom side of the cloud.

• According to Mason , the ice splinters should carry only positive charge upwards

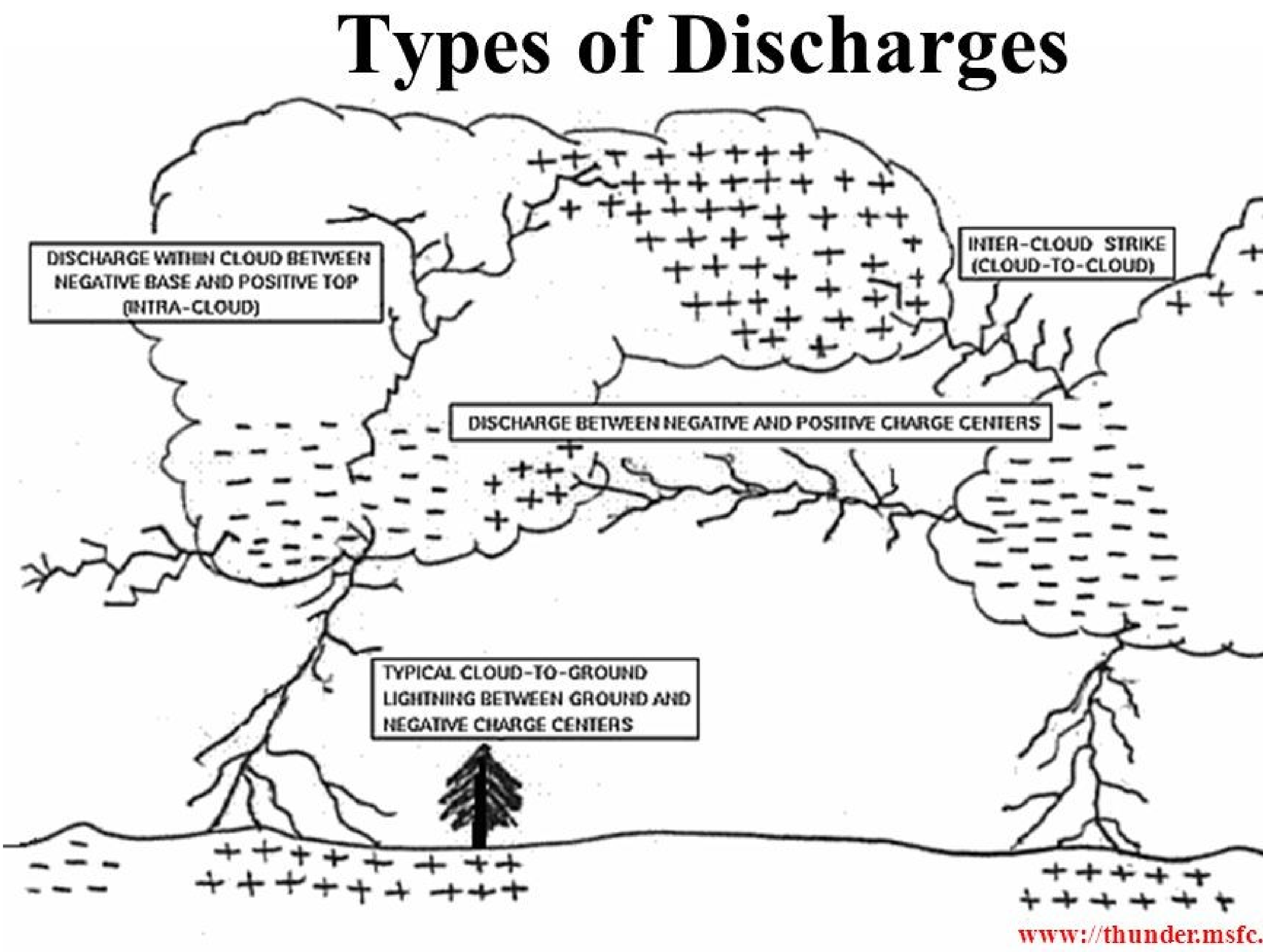
. • Water being ionic in nature has concentration of H + and OH - ions.

• The ion density depends on the temperature.

• In an ice slab with upper and lower surfaces at temperatures T 1 and T 2 , (T 1 < T 2), there will be a higher concentration of ions in the lo wer region.



7. Explain the mechanism of lightning discharge.(A/M-2017)



The electro oxidation behavior of BH_4^- on electro catalytic Pt, hydrolytically active Ni, and no catalytic Au electrodes were comparatively reexamined and a more generalized reaction mechanism was proposed to explain the very different anodic properties of BH_4^- on the different metal electrodes. In this mechanism, the anodic reaction behavior of BH_4^- are determined by a pair of conjugated reactions: electrochemical oxidation and chemical hydrolysis of BH_4^-, the relative rates of which depend on the anodic materials, applied potentials, and chemical states of the anodic surfaces.

At Pt surface, the electron number of BH_4^- oxidation increases with the increased potential polarization, while the actual electron number of BH_4^- oxidation on Ni electrode is 4 at most due to the poor electro catalytic activity of the oxidized Ni surface and the strong catalytic activity of metallic Ni for chemical recombination of the adsorbed H intermediate. On the hydrolytic−inactive Au surface, the anodic reaction of BH_4^- can proceed predominately through direct electrochemical oxidation, delivering a near 8e discharge capacity.

Industrial ozone generation uses a special high pressure, low temperature electrical discharge which is referred to as the dielectric barrier discharge or silent discharge. The filamentary structure of this discharge and the properties of individual micro discharges are discussed. The main reaction paths for the excited atomic and molecular species in oxygen and air are identified. Possible approaches to obtain high power densities, high ozone generating efficiencies or high ozone concentrations are discussed.

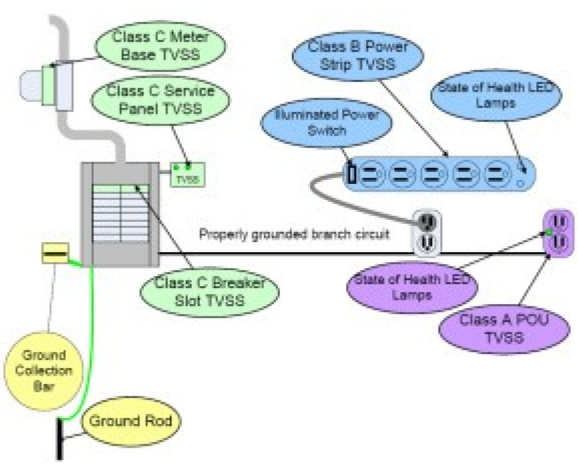
8. **With a neat diagram, explain the protection offered by the ground wires. (A/M-2017)**

Protected Ground Wire

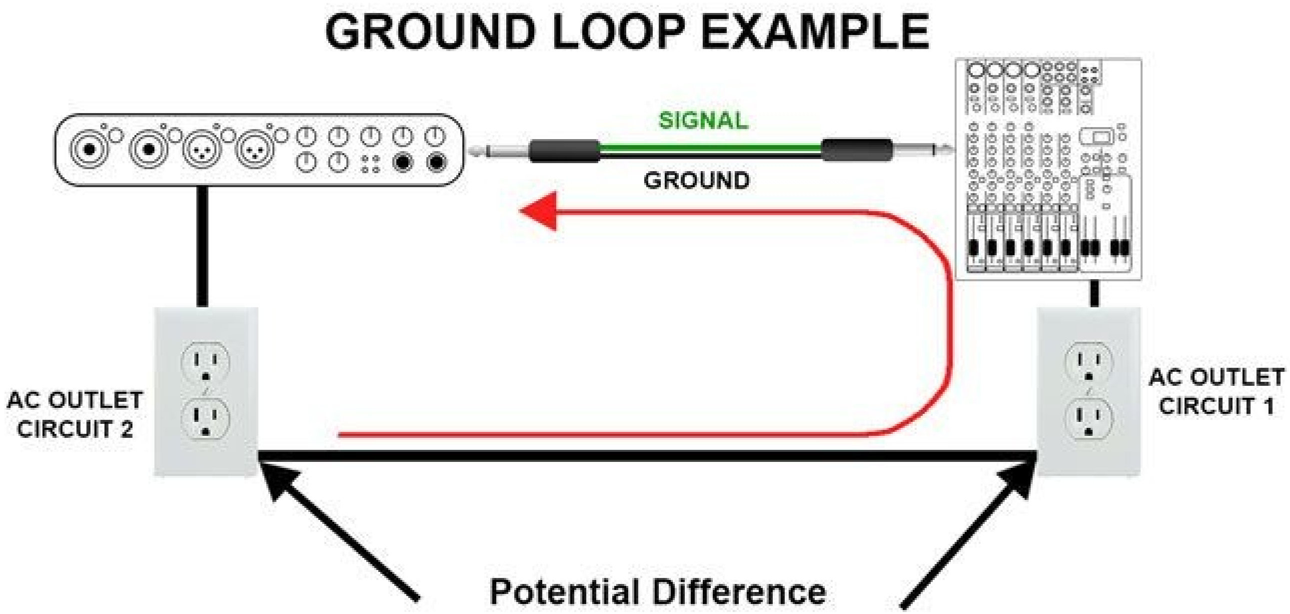
- Protected Copper Ground Wire.
- Black Polyethylene Covered.
- Solid Soft Copper Conductor

Applications

The solid grounding wire is covered with a heavy wall thermoplastic material to enhance public safety by providing mechanical protection for the pole ground wire. South wire Protected Ground Wire is designed to eliminate the need for additional protection such as conduit or oak molding. This product is also suitable for use as a covered overhead transformer leads.



Approaching surge protection with tiers serves to create layers of filtering . ANSI and IEEE acknowledge 3 tiers, A, B and C. Each level is recognized to provide protection for a defined application. Look at the following drawing to visualize the different tiers and location of the protection device. Class C is located at the service entrance or meter, Class B serves sub-panels and points of distribution (power strips), and Class A provides protection at the source or point of use (POU).



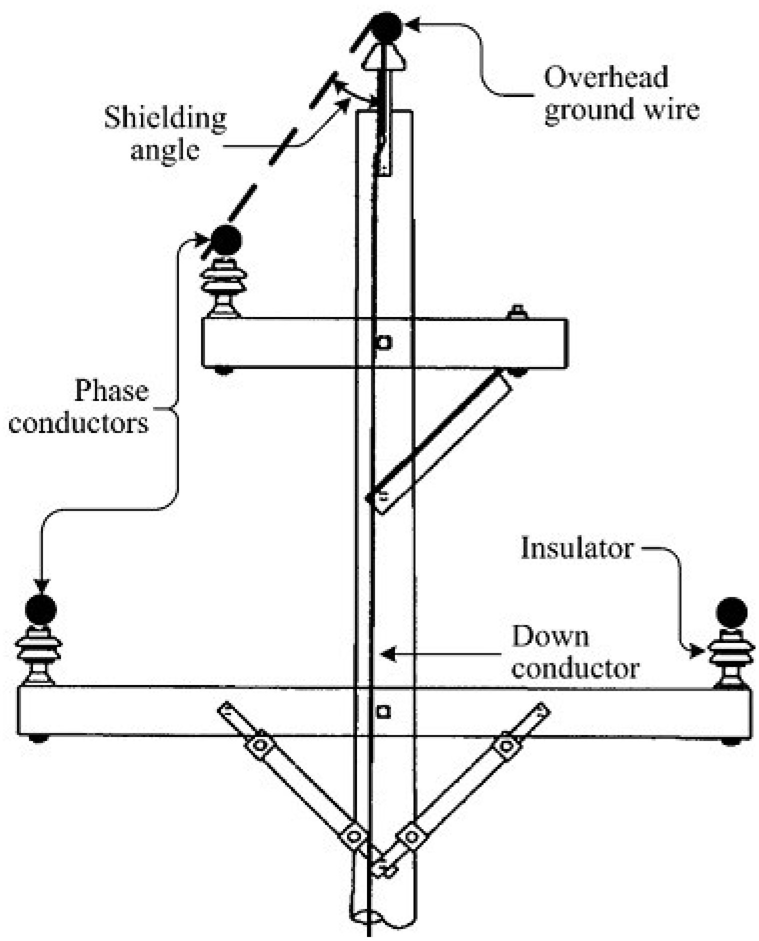
When a line is shielded, the lightning strikes either the tower or the ground wire. The path for drainage of the charge and lightning current is

(a) Through the tower frame to the ground
(b) Through the ground line in opposite directions from the point of striking

Thus the ground wire reducing the instantaneous potential to which the tower top rises considerably, as the current path is in three directions. The instantaneous potential to which tower top can rise is $V_T = I_O Z_T / [1+Z_T / Z_S]$

Where Z_T Surge impedance of the tower Z_S Surge impedance of the ground.

If the surge impedance of the tower, which is the effective tower footing resistance, is reduced, the surge voltage developed is also reduced considerably. This is accomplished by providing ground rods and counter-poise wires connected in tower legs as the tower foundation.



8. What are the mechanisms by which lightning strokes develop and induce over voltage on over head power lines? (N/D-2016)

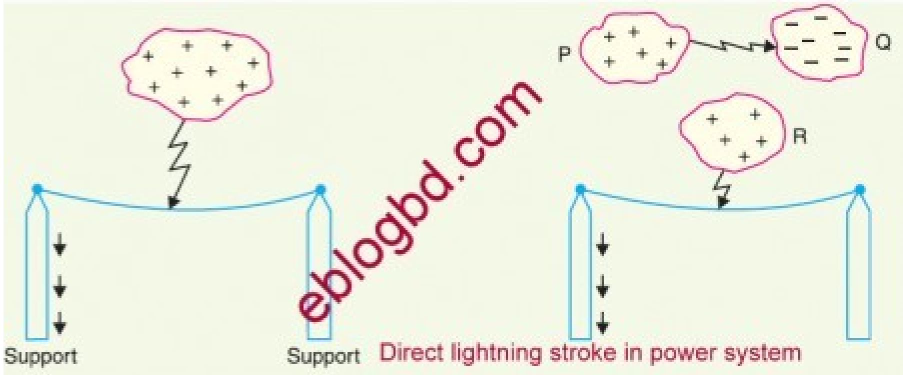
A **lightning** strike is an electric discharge between the atmosphere and an Earth-bound object. They mostly originate in a cumulonimbus cloud and terminate on the ground, called cloud to ground (CG) **lightning**.

This is overcome by "lightning", a complex process referred to as the lightning "flash".

- Electrical field generation.
- Lightning leaders.
- Upward streamers.
- Attachment.
- Discharge.
- Cloud to ground (CG)

- Cloud to cloud (CC) and intra-cloud (IC)
- Observational variations.

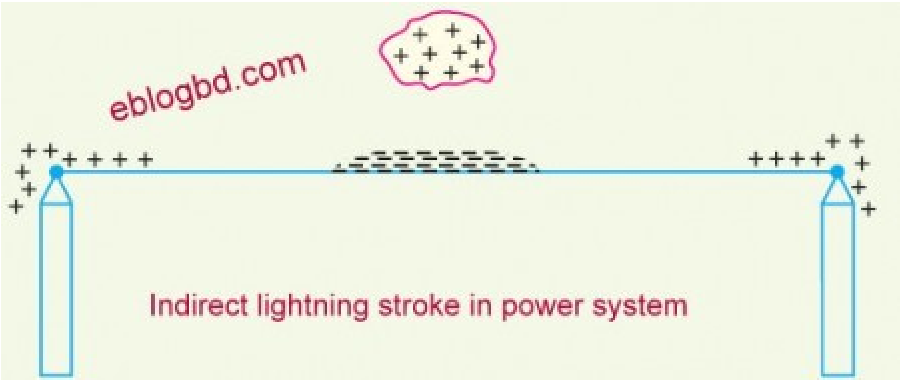
Direct lightning stroke



A lightning stroke is defined as a direct stroke if it hits either tower or the shield wire or the phase conductor. This is illustrated in fig. The tower flashes over by direct hit either to the tower or shield wire along the span it is called backlash.If the insulator string over by a strike to the phase conductor, it is called a shielding failure for a line shielded by shield wires.

Of course, for an unshielded wire, insulator flashover it caused by backflash when the stroke hits the tower or by direct contact with the phase conductor.It varies according to the type of the applied voltage, eg DC,AC, Lightning or switching surgesFor the purpose of lightning performance, insulation strength has been defined.

Indirect Lightning Stroke



The voltage induced on a line by an indirect lightning stroke has four components.

- The charged cloud above the line induces bound charges on the line, while the line itself it held electro statically.
- The charges lowered by the stepped leader further further induce charges on the line.
- The residual charges in the return stroke induce the electrostatic field in the vicinity of the line and hence induced voltage on it.

- The rate of change of current in the return stroke produces a magnetically induced voltage on the line.

PART- B-UNIT-IV

1. Explain in detail about line dropping and load rejection.(N/D-2017)

Load Rejection:

When the line is connected to a major load on a generating station, sudden load rejection will result in over speeding of the machines and rise in voltage until such times as this can be checked by the governors and exciters.The amplitude of the over voltage can be evaluated approximately as specified.

$$V = E\, X_c / X_{c} - X_s$$

Where E is the voltage behind the transient reactance, which is assumed to be constant over the sub transient period and its value before the incident, X_s is the transient reactance of the generator in series with the transformer reactance, and X_c the equivalent capacitive input reactance of the system.

Sudden load rejection:

The power frequency over voltages occur in a large power systems.EHV systems of 400KV and above. The main causes for power frequency and its harmonic over voltages are;

a).sudden load rejection

b).Disconnection of inductive loads (or) connection of capacitive loads.

c) .Ferranti effect

d).Saturation in transformers

sudden load rejection on large power systems causes the speeding up of generator prime movers. The normal conditions. Initially both the frequency and voltage increases.

The approximate voltage rise, neglecting losses etc may be taken a

$$\frac{\left(1-\frac{f}{fo}\right)xs}{xc}$$

$$v=\frac{f}{fo}E' ¿$$

Where,

X_S- Reactance of the generator

X_C - Capacitive reactance of line at open

E-Voltage generated before over speeding and load rejection

F_o -Instantaneous increased frequency

f - Normal frequency

The voltange at the sending end is affected by line length short circuit MVA at sending end bus and reactive power generator of the line.shunt reactors may reduce the voltage to 1.2 to 1.4 p.u.

Line dropping:

If a source is stiff, a high percentage of the of the source voltage is impressed across the line at the time breaker closes to energies a transmission line. If the line is open at the far end ,or terminated in load such as an unloaded transformer, the voltage wave will double at the remote end

Sometimes a line switched with the transformer at the remote end still connected. the line has a path through the magnetizing impedance of the transformer, by which it can discharge. However, as long as the transformer core is unsaturated, this represents a high impedance and the discharge is very slow. But the transformer core runs in to saturation the impedance drops abruptly and the discharge is very rapid. Once again, as the core comes out of saturation, the voltage will level out.

During the restrike, the voltage across the switch will be divided in to the source side and to the line based on their respective surge impedance. The wave level up and down the line corresponding to the oscillatory of the bank in thecase of lumped capacitance.

Sometimes a line is switched with transformer at line end, In this case, the Itrapped charge dissipate through the magnetizing impedance of the transformer. Until saturation of transformer core, transformer offers high impedance and the discharge is slow. But the impedance drops abruptly when the core runs in to saturation.

2.**Explain about the voltage transients on closing and reclosing lines. (N/D-2017)**

$$V = R/¿ \quad 1+ \frac{Z}{} \quad R¿v$$

And source voltage across the source,

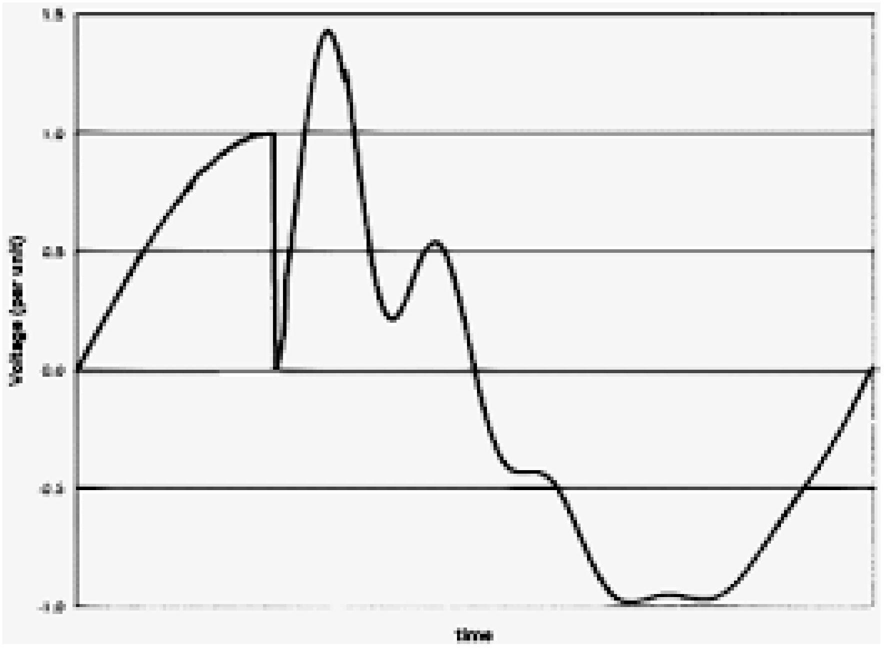
$V = Z$ 1/(R+Z1) $V(S)=¿$ Since,R>>Z1,most of the voltage across will appear across

Case;1 when a switch is closed $\frac{Z1(S)}{R+Z1(S)}$ (v/s) the line.

This voltage will travel down the line as a wave and be reflected from its remote end returning to the source.

To reduce the closing voltage transients the resistance is pre-inserted.the pre-insertion share the voltage. When a switch is closed immediately prior to the circuit being completed a certain voltage exists across the switch contacts.

At the moment the contacts made by pre striking discharge, this voltage disappears, If the instantaneous voltage is V,a fraction of Vl, will momentarily appears across the line,



case;2 Reclosing lines

In an utility system a breaker is reclosed as rapidly as possible, after it fault is of a transient nature. It improves the overall stability of the system.

3.Briefly explain the following:

Over voltages induced by faults

When the lightning strikes one conductor line, then the waves will be developed. there are two pair of waves in either direction on both lines, due to these waves, the current injected into the line by lighting stroke get dispersed. The surges on the adjacent conductor were including by electromagnetic coupling.

Over voltage due to ground fault

The overvoltage are induced when ground fault occurs on one of he conductor Due to the occurrence of ground fault,instead of a current being injected,a voltage is suddenly applied. The voltage due to fault is equal and opposite to that of existing voltage on the conductor at that time

For the protection of circuits from overvoltage caused by faults, the circuit breakers must be carefully designed

A line to ground fault can produce an overvoltage on an unfaulted phase as high as2.1time the normal line to natural voltage on a three phase line. The oscillogram of line-to- ground voltage obtained on TNA(Transient Network Analyser) at midpoint of 180mile,three phase line for single line-to-ground fault at that point.

From the oscillogram,it is observed that the maximum overvoltage occurs at the midpoint of the line .The overvoltage decreases slowly as fault location changes, but the maximum remains above 1.75 pu for location over about 67% of the line length.

4) Switching surges on an integrated system (M/J-2016)

The disturbance produced by the switching operation in a system spreads through out the integrated system by setting up travelling waves.They travel along the connected lines and reflect to and fro as discontinuities are encountered.

Consider the following system

There are buses at 138 KV and 345KV interconnected by auto transformer.The 138KV bus is fed through the genetor transformer.There are line and/or ies connected to both buses The circuit in can be redrawn using a single phase respresentation and the significantcapacitances are included as If one of the CB, in 345KV is opened to clear a fault on its line, the switching operation will evoke a response from both the line and the systemIf the impedance are reduced to acommon voltage base,then the circuit becomes as in.In this circuit the lines the lines are respresented by the resistor R1and R2.The resistance R1 effectively suppresses all oscillations.
The following values which are referred to 345KV are typical.

C1=0.025 µf L1=0.11H R1=80Ω(4 parallel line with z0=320Ω)

C2=0.32µf L2=0.11H

C3=0.006µf L3=0.04H R2=670Ω

C1=capacitance of 345KV bus
C2=capacitance of 138KV bus

C3=capacitance of generator bus
L1=Inductance of autotransformer
L2=Inductance of generator transformer
L3=Generator inductance
R1 and R2=Parellel surge impedances of lines
A significant surge impedance in this circuit is,

$$\left(\frac{L1}{C1}\right)^{\wedge}\frac{1}{2}=\left(0.\frac{11}{2}.5*10^{\wedge}-8\right)^{\wedge}\frac{1}{2}=2100\,\Omega$$

The 80Ω of 345KV lines is much lower than this value,it will over damp the circuit.
The source circuit can be replaced with little error by a parallel load resistance circuit in which

L=L1+L2+L3 and R=R1
The response of a parallel RL circuit to ramp I0(t) is given by

$$V(S)=\frac{RI}{S\left(S+\frac{R}{L}\right)}$$ in operational form

$$V(t)=LI\left(1-e^{\wedge}-\frac{Rt}{l}\right) as\,a\,time\,function$$

Here the time constant, $\frac{L}{R}=0.\frac{22}{80}=2.75*10^{\wedge}-3$ se

Hence V(t)=Vp(1-e^-364t).A voltage of this form will travel down each of the connected lines
If the capacitances is included then there is a delay τ is introduced in this lines
If the C is increases then the delay also increases.In most cases delay will be quite short.

5.Explain in detail how EMTP is used for the computation of transients in power system. (N/D-2016,

The EMTP is a comprehensive computer program designed to solve electrical problems in lumpy circuits, distributed circuits. this program is capable of solving steady state circuit problems .transient analysis can be carried out in circuits with any arbitrary configuration of lumped parameter(R,L,C).Transmission lines with distributed parameters **tr**ansported or untransformed can be included in the network. In order to perform transient analysis, it is often to a good idea obtain a steady state solution first to check on the validity of the network representation and also obtain initial conditions for the transient study.
Formulation and method of solution for the EMTP
Lossless line The wave equation of a single phase line using.

5.Write short note on the following:

(i) Kilometric fault

Faults occurring between a few kilometers to some hundreds of kilometers from the breaker are termed 'Short Line faults (SLF) or 'Kilometric faults'. For such faults, the line impedance limits the current and consequently, supports some of the system voltage. The generated voltage is divided on either side of the breaker in proportion to the impedance of the line and the source.

Short circuit faults or kilometric faults occurring on a transmission line length between0.5 to 5 km are termed as short line faults or kilometric faults. A fault of this type imposes a highly heavy duty on the circuit breaker, there by affecting its interrupting ability.

***ii)* Over voltage induced by faults.**

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observed that the maximum overvoltage occurs at the midpoint of the line .The overvoltage decreases slowly as fault location changes, but the maximum remains above 1.75 pu for location over about 67% of the line length.

6.Describe in detail about the causes of over voltages due to various faults occurring in power system.(N/D-2016)

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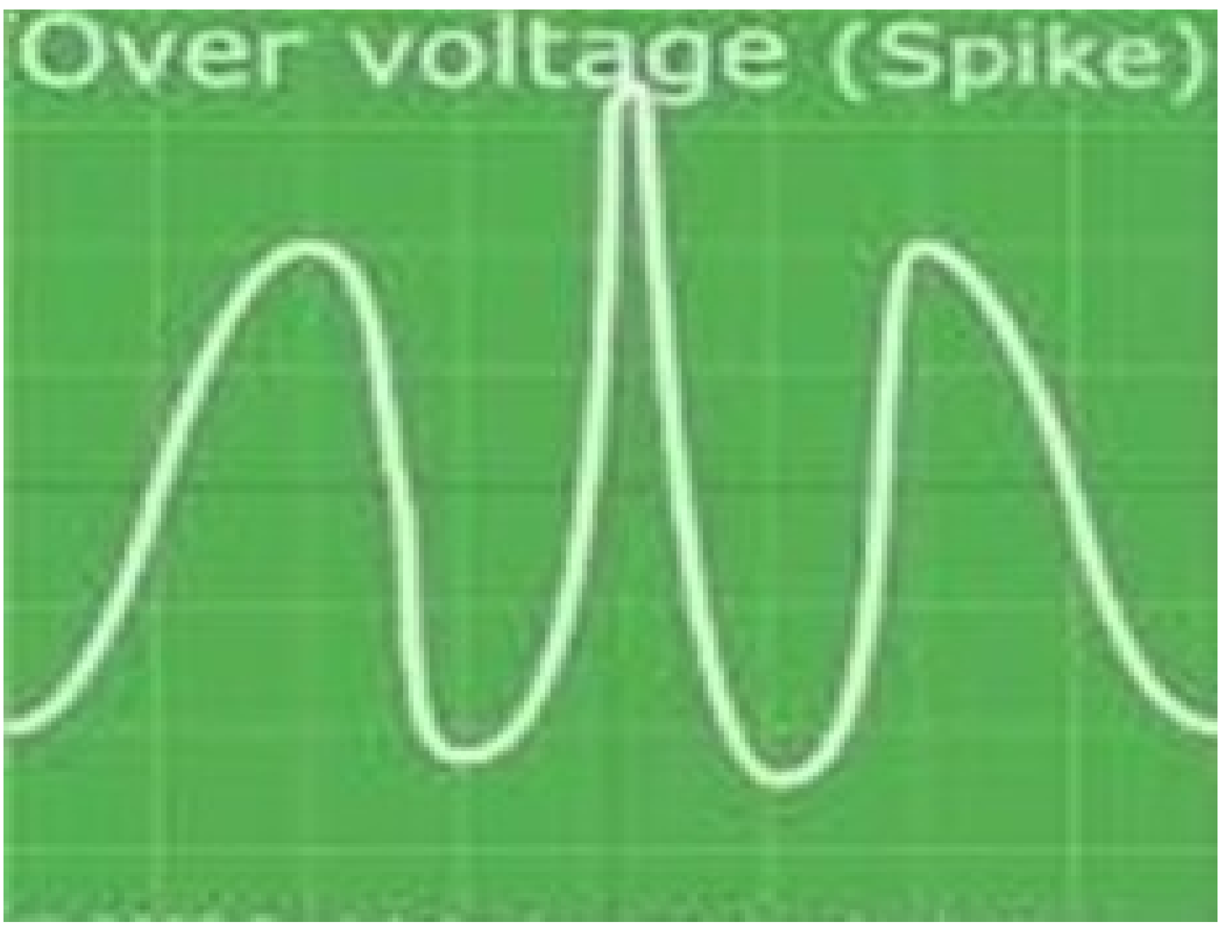


Over voltages are caused on power systems due to external and internal influencing factors. The voltage stress caused by over voltage can damage the lines and equipment's connected to the system. Over voltages arising on a system can be generally classified into two main categories as below.

EXTERNAL OVER VOLTAGES

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. It may be due to any of the following causes: ow:

a) *Direct lightning stroke*
b) *Electromagnetically* induced over voltages due to lightning discharge taking place near the line, called 'side stroke'.
c) Voltages induced due to atmospheric changes along the length of the line.
d) *Electrostatically* induced voltages due to presence of charged clouds nearby.
e) Electrostatically induced over voltages due to the frictional effects of small particles like dust or dry snow in the atmosphere or due to change in the altitude of the line.

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:

1. Switching over voltages or Transient over operation voltages of high frequency:

This is caused when switching operation is carried out under normal conditions or when fault occurs in the network. When an unloaded long line is charged, due to Ferranti Effect the receiving end voltage is increased considerably resulting in over voltage in the system. Similarly when the primary side of the transformers or reactors is switched on, over voltage of transient nature occurs.

2. 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.

Causes and Effects of Transient Voltages

- -Transient activity is believed to account for 80% of all electrically-related downtime
- Lightning accounts at least 5% of Insurance claims and costs an average of $13,000per occurrence.
- Effective transient voltage suppression equipment can double or triple the life of electrical and electronic equipment.
- A systems approach to transient voltage surge suppression can result in dramatic performance in terms of return-on inv
-

Characteristics of the Transient Voltage

The most common transient, is the "oscillatory transient" .
It is sometimes described as a "ringing transient". This type of transients is characterized by swings above and below
Even these transients can be broken up into other categories identified by their frequency.

1. Mid-to-Low Frequency Transients, like lightning and utility capacitor switching propagate (travel) very well on electrical systems. Higher amplitudes tend to be damped by the building's distribution system at voltages above 16,000 volts.There is almost no damping below 10,000 volts.

2. High Frequency transients, however, are usually only seen near the source.

This means thatsurge suppression equipment installed a distance away will never see the effect.

It is for this reason that multiple suppressors are recommended within the various faults

Protecting susceptible electronic equipment from AC power line disturbances is a major concern for most people, whether their business environment is commercial or industrial. No matter what the setting, computers are subject to data errors, crashing, and even damage or destruction by voltage transients as a result of an absence or misapplication of protective devices. Similarly, programmable logic

SWITCHING OVERVOLTAGES

These surges are generated in electrical lines, mainly due to the following two reasons:

Electrical switching of large machinery: Electrical motors are very inductive loads whose connection and disconnection can cause surges. There are other processes capable of producing surges, like the turning on/off of a welding arch and the connection and disconnection of power electronic devices. ¾ Operation and fault in power supply network:

In the case of short-circuit at any point in the network, the circuit breakers will respond by opening and the following auto-reclosing, in the case of it being a temporary fault. Such faults can generate surges typical in the connection of inductive loads. Mechanisms of propagation

The prevailing mechanism of switching over voltages is conduction, because it starts in the

There always exists a capacitive coupling, also called stray capacity, between every pair of conductors. Over voltages due to capacitive coupling become more important as the voltage waveform velocity increases.

PART- B-UNIT-V

1. Explain in detail about line dropping and load rejection.(N/D-2017)

Load Rejection:

When the line is connected to a major load on a generating station, sudden load rejection will result in over speeding of the machines and rise in voltage until such times as this can be checked by the governors and exciters. The amplitude of the over voltage can be evaluated approximately as specified.

$$V = E\, X_c / X_c - X_s$$

Where E is the voltage behind the transient reactance, which is assumed to be constant over the sub transient period and its value before the incident, X_s is the transient reactance of the generator in series with the transformer reactance, and X_c the equivalent capacitive input reactance of the system.

Sudden load rejection:

The power frequency over voltages occur in a large power systems.EHV systems of 400KV and above. The main causes for power frequency and its harmonic over voltages are;

a).sudden load rejection
b).Disconnection of inductive loads (or) connection of capacitive loads.
c) .Ferranti effect
d).Saturation in transformers

sudden load rejection on large power systems causes the speeding up of generator prime movers. The normal conditions. Initially both the frequency and voltage increases.

The approximate voltage rise, neglecting losses etc may be taken a

$$\frac{\left(1-\frac{f}{fo}\right)xs}{xc}$$

$$v=\frac{f}{fo}E'¿$$

Where,

X_S- Reactance of the generator

X_C - Capacitive reactance of line at open

E-Voltage generated before over speeding and load rejection

F_o -Instantaneous increased frequency

f - Normal frequency

The voltage at the sending end is affected by line length short circuit MVA at sending end bus and reactive power generator of the line shunt reactors may reduce the voltage to 1.2 to 1.4 p.u.

Line dropping:

If a source is stiff, a high percentage of the of the source voltage is impressed across the line at the time breaker closes to energies a transmission line. If the line is open at the far end ,or terminated in load such as an unloaded transformer, the voltage wave will double at the remote end

Sometimes a line switched with the transformer at the remote end still connected. the line has a path through the magnetizing impedance of the transformer, by which it can discharge. However, as long as the transformer core is unsaturated, this represents a high impedance and the discharge is very slow. But the transformer core runs in to saturation the impedance drops abruptly and the discharge is very rapid. Once again, as the core comes out of saturation, the voltage will level out.

During the restrike, the voltage across the switch will be divided in to the source side and to the line based on their respective surge impedance. The wave level up and down the line corresponding to the oscillatory of the bank in the case of lumped capacitance.

Sometimes a line is switched with transformer at line end, In this case, the It rapped charge dissipate through the magnetizing impedance of the transformer. Until saturation of transformer core, transformer offers high impedance and the discharge is slow. But the impedance drops abruptly when the core runs in to saturation.

2.Explain about the voltage transients on closing and reclosing lines. (N/D-2017)

Case;1 when a switch is closed

When a switch is closed immediately prior to the circuit being completed a certain voltage exixts across the switch contacts.

At the moment the contacts made by pre striking discharge, this voltage disappears, If the instantaneous voltage is V,a fraction of Vl, will momentarily appears across the line,

$$V = R/¿ \quad Z \quad 1+ \quad R¿v$$

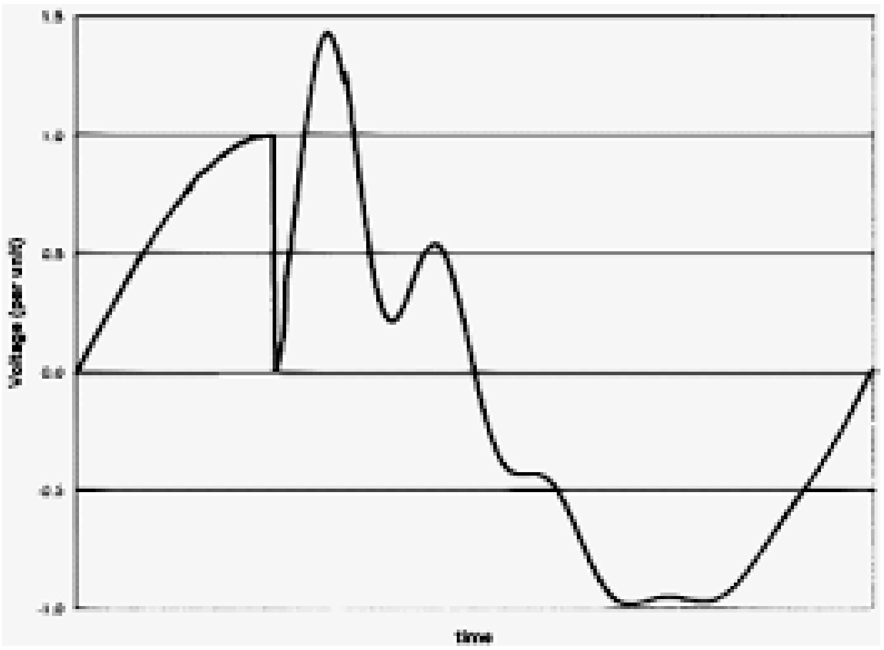
And source voltage across the source,

$$V = Z \quad 1/(R+Z1) \qquad V(S) = \frac{Z1(S)}{R+Z1(S)} \quad (v/s)$$

Since,R>>Z1,most of the voltage across will appear across the line.

This voltage will travel down the line as a wave and be reflected from its remote end returning to the source.

To reduce the closing voltage transients the resistance is pre-inserted.the pre-insertion share the voltage.



case;2 Reclosing lines

In an utility system a breaker is reclosed as rapidly as possible, after it fault is of a transient nature. It improves the overall stability of the system.

3.Briefly explain the following:

Over voltages induced by faults

When the lightning strikes one conductor line, then the waves will be developed. there are two pair of waves in either direction on both lines, due to these waves, the current injected into the line by lighting stroke get dispersed. The surges on the adjacent conductor were including by electromagnetic coupling.

Over voltage due to ground fault

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4) Switching surges on an integrated system (M/J-2016)

The disturbance produced by the switching operation in a system spreads through out the integrated system by setting up travelling waves. They travel along the connected lines and reflect to and fro as discontinuities are encountered.

Consider the following system

There are buses at 138 KV and 345KV interconnected by auto transformer.The 138KV bus is fed through the genetor transformer.There are line and/or ies connected to both buses

The circuit in can be redrawn using a single phase respresentation and the significantcapacitances are included as

If one of the CB, in 345KV is opened to clear a fault on its line, the switching operation will evoke a response from both the line and the system

If the impedance are reduced to a common voltage base, then the circuit becomes as in.In this circuit the lines the lines are represented by the resistor R1and R2.The resistance R1 effectively suppresses all oscillations. The following values which are referred to 345KV are typical.

C1=0.025 µf L1=0.11H R1=80Ω(4 parallel line with z0=320Ω)

C2=0.32µf L2=0.11H

C3=0.006µf L3=0.04H R2=670Ω

C1=capacitance of 345KV bus
C2=capacitance of 138KV bus
C3=capacitance of generator bus
L1=Inductance of autotransformer
L2=Inductance of generator transformer
L3=Generator inductance
R1 and R2=Parellel surge impedances of lines

A significant surge impedance in this circuit is,

$$\left(\frac{L1}{C1}\right)\hat{}\frac{1}{2}=\left(0.\frac{11}{2}.5*10\hat{}-8\right)\hat{}\frac{1}{2}=2100\,\Omega$$

The 80Ω of 345KV lines is much lower than this value,it will over damp the circuit.
The source circuit can be replaced with little error by a parallel load resistance circuit in which L=L1+L2+L3 and R=R1
The response of a parallel RL circuit to ramp I0(t) is given by

$$V(S)=\frac{RI}{S\left(S+\frac{R}{L}\right)}$$ in operational form

$$V(t)=LI\left(1-e^{\wedge}-\frac{Rt}{l}\right) as\,a\,time\,function$$

Here the time constant,

$$\frac{L}{R}=0.\frac{22}{80}=2.75*10^{\wedge}-3 \quad \text{sec}$$

Hence V(t)=Vp(1-e^-364t).A voltage of this form will travel down each of the connected lines
If the capacitances is included then there is a delay τ is introduced in this lines
If the C is increases then the delay also increases.In most cases delay will be quite short.

5.Explain in detail how EMTP is used for the computation of transients in power system. (N/D-2016,

The EMTP is a comprehensive computer program designed to solve electrical problems in lumpy circuits, distributed circuits. this program is capable of solving steady state circuit problems .transient analysis can be carried out in circuits with any arbitrary configuration of lumped parameter(R,L,C).Transmission lines with distributed parameters transported or untransformed can be included in the network. In order to perform transient analysis, it is often to a good idea obtain a steady state solution first to check on the validity of the network representation and also obtain initial conditions for the transient study.

Formulation and method of solution for the EMTP

Lossless line

The wave equation of a single phase line,

6.Write short note on the following:

(i) Kilometric fault

Faults occurring between a few kilometers to some hundreds of kilometers from the breaker are termed ‘Short Line faults (SLF) or ‘Kilometric faults’. For such faults, the line impedance limits the current and consequently, supports some of the system voltage. The generated voltage is divided on either side of the breaker in proportion to the impedance of the line and the source.

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