PAVENDAR BHARATHIDASAN

INSTITUTE OF INFORMATION TECHNOLOGY

(Approved by AICTE & Affiliated to Anna University)

An ISO 9001:2008 Certified Institution

Learning for Excellence

QUESTION BANK

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

Year: III

Sem: VI

Subject code: EE2353

Subject name: High Voltage Engineering

PREPARED BY,

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UNIT I

1. **State the different types of over voltages occurring in power system and mention their magnitude.**

   (i) Switching an open ended line with

   a) Infinite bus as source with trapped charges on line. - 4.1

   b) Infinite bus as source with trapped charges on line. -2.6

   c) Deenergizing an unfaulted line with a line to ground fault. – 1.3

   d) Deenergizing an unfaulted line with a restrike in the circuit breaker – 2.7

   (ii) a) Switching a 500 kV line through an auto transformer 220 kV / 500 kV

   b) Switching a transformer terminated line. – 2.2

   c) Series capacitor compensated line with 50 % compensation. – 2.2

   d) Series capacitor compensated line with shunt reactor compensation. - 2.6

   (iii) High speed reclosing of the line after fault clearance. – 3.6

2. **Define indirect stroke.**
   In indirect stroke a negative charge in a cloud cause bound positive charges on the conductor of a nearby transmission line.
3. **What are the techniques to be adopted for controlling the switching over voltages?**
   a) Installation of shunt reactors.
   b) Use of pre insertion resistor.
   c) Synchronous reclosing and simultaneous operation of CB at both end.
   d) Use of surge arrester and elimination of trapped charges by line shunting after opening by means of earthling switch.
   e) Use of surge absorber or resistance switching.
4. **What is a surge arrester?**
   Surge arrester is a revolutionary advanced surge protective device for power system. It is constructed by a series connection of zinc oxide elements having a highly non linear resistance.
5. **What are the causes of power frequency over voltages?**
   The causes for power frequency and harmonic over voltages in EHV and UHV systems are:
   Sudden load reflection (loss of loads)
   a) Disconnection of inductive loads or connection of capacitive loads.
   b) Ferranti effect.
   c) Unsymmetrical faults.
   d) Saturation in transformers, etc,
   e) Tap charging operations.
6. **What are the causes of over voltages in power system?**

The causes of over voltages in power system may be internal cause or external cause.

Internal causes of over voltages are

a) Switching Transients
b) Arcing ground
c) Insulation failure
d) Resonance

External cause for over voltages are Lightning.

7. What are the different types of fault that may occur on power lines?

i) Symmetrical faults - 3Φ fault (LLLG)

ii) Unsymmetrical faults

a) L-G fault
b) L-L fault
c) L-L—G fault

8. Explain why a simple spark gap cannot offer full protection against over voltages.

There is no current limiting device provided so as to limit the current after spark over. Hence a series resistance is often used. Without a series resistance the sparking current may be very high

Ant the applied impulse voltage collapses to zero thus creating steep step voltage which sometime proves to be dangerous to the apparatus to be protected such as transformer or machine. Their flash over characteristics depends on the atmospheric condition, polarity of wave and wave shape.

9. What is insulation co-ordination?

Insulation co-ordination means the correlation of the insulation of various equipments in a power system to be insulation of protective devices used for the protection of those equipments against over voltage.

10. Name the sources of switching surges.

a) Opening and closing of switchgears.
b) In circuit breaker operation, switching surges with a high rate of rise voltage may cause repeated restriking of the arc between the contacts of the CB.
c) High natural frequencies of the system.
d) Damped normal frequency voltage components.
e) Restriking and recovery voltage with successive reflected waves from terminations.

11. Define surge impedance of transmission line.

The characteristic impedance of a line is the surge impedance of transmission line. It is given by

$Z_0 = \sqrt{R + jwL / G + jwC}$

12. Mention the different kinds of over voltages.

a) Over voltage due to lightning.
b) Over voltage due to switching transients.
c) Over voltage due to arcing ground.
d) Over voltage due to insulation failure.
e) Over voltage due to resonance.

13. **What is meant by switching surges? Mention the approximate magnitude of switching surges and their frequency.**
    The switching voltage surges, occur during and closing of unload EHV Ac lines breaking inductive loads, breaking capacitive loads etc.
    The switching voltage surges are of comparatively longer duration 2500 μs lower rate of rise. The peak value of switching surge is expressed in terms of switching over voltage factor. Switching surges can be of the order 2 to 3.3 pu and will have the magnitudes of the order 1200 kV to 2000 kV.

UNIT II

1. **Define Gas Law.**

It consists of many laws. The following laws are very important.

a) Charle's law P α T Volume is constant
b) Boyle's law P α 1/V T is constant

General equation: PV = nRT
Where
P-pressure ; V-Volume; n-number of moles; R-molar gas constant; T-temperature.

2. **What is Paschen's law?**

$f_2(V|pd)[\exp[pdf1(V|pd)) - 1]] = 1$

This equation shows a relationship between V and pd , and implies that the breakdown voltage varies as a product pd varies knowing the nature of functions f_1 and f_2 we can rewrite this equation
V = f (pd)
Where
P - Gas pressure f - function
d - the electrode of dp V - Voltage

3. **Which insulation is used in high voltage circuit breakers of large power rating?**
    Now a day's most of all circuit breakers that are in operation use SF6 gas or vacuum as insulating medium. SF6 circuit breakers are manufactured up to the higher transmission voltage of 800 kV and current range of 63 kA and 80 kA. However it is an expensive gas and at the normal operating pressure of 6 bar it condenses at temperatures lower than 20°C.
4. **What is Time lag in the breakdown of dielectrics?**
    The time that elapses between the application of the voltage to a gap sufficient to cause breakdown and actual breakdown is called time lag.
5. **Define uniform and non uniform field and give examples of each.**
    In uniform field the applied field remains constant across the gap. Example: The field between the two plane electrodes.
    In non uniform field the applied field varies across the gap.
    The examples are coaxial cylinders, point- plane and the sphere plane gaps.
6. **Define the following as applied to high voltage breakdown.**
    a) Internal and External insulation
    b) Flashover

a) Internal and External insulation

Disruptive discharge voltage produces the loss of dielectric strength of insulation. It is the voltage at which the electrical stress in the insulation causes a failure which includes the collapse of voltage and passage of current.

b) Flashover

When discharge takes place between two electrodes in gas or liquid over a solid surface on air it is called flashover.

7. Define the following as applied to disruptive voltage.

a) Flashover voltage

b) Spark over voltage

a) Flashover

When discharge takes place between two electrodes in gas or liquid over a solid surface on air it is called flashover.

b) Spark over voltage

The voltage between two spheres on sphere gap is raised till a spark passes between two spheres. The value voltage of spark over depends upon the dielectric strength of air, size of sphere and distance between the sphere and other factors.

8. What is meant by Townsend discharge and explain its main feature?

When the voltage between anode and cathode is increased the current in the anode equals the current in the external circuit. Therefore the current becomes infinitely large under the above mentioned condition but practically it is limited by the resistance of external circuit and practically by the voltage drop in the arc. The condition $Ve^{\alpha c} = 1$ defines the condition for the beginning of spark and is known Townsend criterion for spark formation or breakdown.

9. What are the different theories related with liquid dielectric breakdown?

The first theory is extension of gaseous breakdown based on the avalanche ionization of atoms caused electron collision in the applied field. The second theory is based on the fact the presence of foreign particles in liquid insulation is polarizable and is of higher permittivity than the liquid.

10. Distinguish between insulators and dielectrics and give examples for each.

A dielectric is a non conducting substance ie, an insulator. Although the dielectric and insulator are generally considered synonymous the term dielectric is more often used to describe the material where the dielectric polarization is important like the insulating material between the metallic plates of a capacitor while insulator is more often used when the material is being used to prevent a current flow across it.

Examples of insulators: Glass and porcelain

Examples of dielectric: Paper and Mica

11. What are Meta stable atoms? How they are ionizing the gaseous dielectric medium?

A Meta stable atom or a molecule is an excited particle whose life time is very large (10^{-3} sec) compared to the life time of an ordinary particle. Meta stables have a relatively high potential energy and are therefore able to ionize neutral particles.

12. Define formative time lag.

After the appearance of the electron a time t_f is required for the ionization processes to develop fully to cause the breakdown of the gap and this time is called formative time lag.

13. What is composite dielectric?

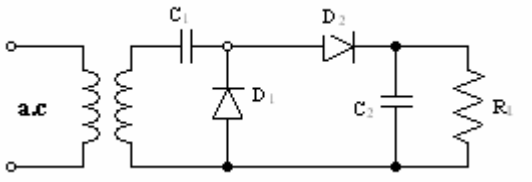
It is difficult to imagine complete insulation system in electrical equipment which does not consist of more than one type of insulation. If insulation as a whole is considered, it will be found that more than one insulating material is used. These different materials can be in parallel with each other such as air or SF6 in parallel with solid insulation or in series with one another. Such insulation systems are called composite dielectrics.

UNIT III

1. **Give some uses of HVDC.**
   Generation of high d.c voltages is mainly required in research work in the areas of pure and applied physics. Sometimes high direct voltages are needed in insulation tests on cables and capacitors. Impulse generator charging units also require HVDC of about 100 to 200 kV. Normally for the generation of dc voltages of up to and the output currents are about 100 mA.

2. **What are the applications of impulse current wave forms of high magnitude?**
   Generation of impulse current waveforms of high magnitude (100 kA peak) find application in test work as well as in basic research or non linear resistors, electric arc studies relating to electric plasmas in high current discharges.
3. **How are capacitances connected in an impulse current generator?**
   For producing impulse currents of large value a bank of capacitors are connected in parallel and are charged to a specified value and are discharged through a series R.L circuit.

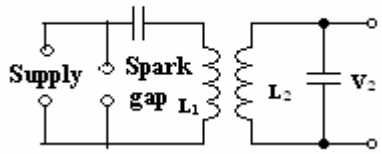
4. **What type of wave form will be available in impulse current generator output?**
   Damped wave or damped oscillatory wave.
5. **Draw a circuit diagram of simple voltage doublers.**



6. **Write the expressions to find the optimum number of stages and % ripple in a voltage multiplier circuits.**
   Optimum number of stage = $\sqrt{V_{max} f_c} / I$

   I = load current and opt % ripple voltage = $[nI_1 / f_c]$

7. **Draw a simple Tesla Coil equivalent circuit for generation of high frequency A.C high voltage.**



8. **Write an expression to find the % ripple and % voltage regulation in a multi stage voltage multiplier circuit.**

   % ripple $= \frac{I_1 \; n(n+1)}{f_c \quad 2}$

   % regulation $= I_1 / f_c [(2/3)n^3+n^2-n/6]$

9. **Explain the superiority of cascaded transformer over two winding transformer.**
   a) Natural cooling is sufficient.
   b) Transformers are compact in size, so the transportation and assembly is easy.
   c) Construction is identical.
   d) Three phase connection in star or delta is possible.

10. **An impulse generator has 10 stages with capacitors rated 0.15 µF and 150 kV per stage. The load capacitor is 1000 pf. Find the front and tail resistance to produce an impulse of 1.2 / 50 µs (approximate formula).**

    G.D

    Number of stage = 10

    solution

    C_1 = Generator capacitance = [0.15/10] = 0.015 µF

    C_2 = Load capacitance = $[1000/10^{12}] = 10^{-9}$ F

    To find Front resistance

    Front time = 1.2 µ sec

    t_1 = 3 * time constant when neglecting R_2

    $t_1 = 3 * R_1[C_1C_2/C_1 + C_2]$

    R_1 = 426.67 Ω

    Tail time t_2 = 50 µ sec

    $t_2 = 0.7(R_1 + R_2) (C_1 + C_2)$

    R_2 = 4037.63 Ω

11. **Define the specification of impulse voltage as per Indian standard.**

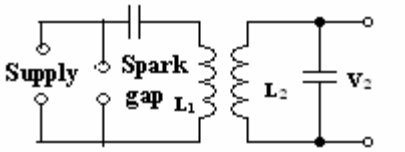
    Standard impulse have a rise time of 0.5 µ s and 10 µ s and decay time of 50 % of peak value and of the order of 30 to 200 µ s.

12. **What is the need for generating impulse currents?**

    Generation of impulse current waveforms of high magnitude find application in testing work as well as in basic research in nonlinear resistors electric arc studies and studies relating to electric plasmas in high current discharges.

13. **What is a tesla coil?**

Tesla coil is a high frequency resonant transformer. It is a doubly tuned resonant circuit as shown in the following figure.



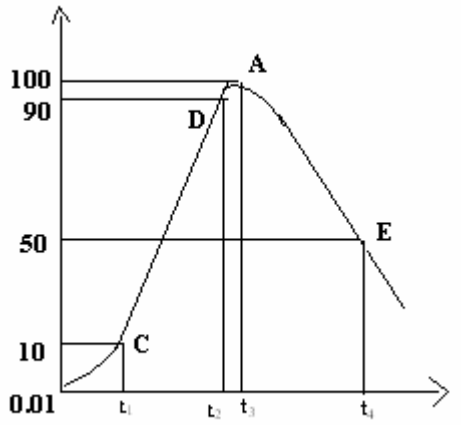
14. What are the factors influencing the measurements using sphere gap?

The factors influencing the measurements using sphere gap

a) Influence of nearly earthed objects.
b) Influence of humidity.
c) Influence of dust particles

15. Define the front and tail times of an impulse wave.

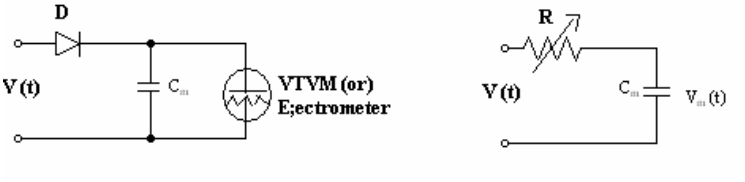
Referring to wave shape the peak value A is fixed and referred to as 100 % value. The points corresponding to 10 % and 90 % of peak values are located in the front time portion points C & D. The line joining these points is extended to cut the time axis at 0.1. Here 0.1 is taken as the virtual origin. 1.25 times the interval between times t_1 and t_1 corresponding to points C 7 D is defined as front time 1.25[o_1 t_1 = o_2 t_2]. The point E is located on the wave tail corresponding to 50 % of peak value and ot_4 is defined as the tail time.



UNIT IV

1. **What are the general methods used for measurement of high frequency and impulse currents?**
   The following methods used for measurement of high frequency and impulse currents
   a) Potential divider with a cathode ray oscilloscope.
   b) Peak voltmeters.
   c) Sphere gaps
2. **What is the high voltage d.c measurement techniques used?**
   The following techniques are used for measurement of high voltage dc.
   a) Series resistance micro ammeter
   b) Resistance potential-divider
   c) Generating voltmeter
   d) Sphere and other spark gaps
3. **For what measurement are Hall generators normally used?**
   These are used for measurement of high direct currents. It can be used for measurement of unidirectional a.c impulse current also.

4. **What type of measuring devices are preferred for measurement of Impulse currents of short duration?**
   Park's tubular shunt (or) coaxial tube is preferred for measurement of impulse current of short duration.
5. **Draw the simple circuit of peak reading voltmeter and its equivalent.**



6. **List the factors that are influencing the peak voltage measurement using sphere gap.**
   The following are the factors
   a) Nearby earthed objects
   b) Atmospheric conditions and humidity
   c) Radiation
   d) Polarity and rise time voltage of waveforms.
7. **What are the advantages of CVT measurement in HVAC?**
   a) Simple design and easy installation
   b) Can be used both as a voltage measuring device for meter and relaying purpose and as a coupling condenser for power line carrier communication and relaying
   c) Frequency independent voltage distribution along elements as against conventional magnetic potential transformer which require additional insulation design
   d) Provides isolation between the high voltage terminal and low voltage testing.

8. **Why do we resort to statistical approach during breakdown due to impulse voltage?**

   The test is done with the specified voltage usually the probability failure is 40 % and 60 % failure values or 0 % and 80 % value since it is difficult to adjust the test for the exact 50 % flashover values. The average value of upper and lower limit is taken.

9. **State the demerits of CVT measurement for HVAC measurements.**
   a) Voltage ratio is susceptible to temperature variations.
   b) In the presence of capacitance and choke, the problem of ferro-resonance occurs in power system.

10. **What are high current shunts mention their design criterion?**

    The most common method employed for high impulse current is a low ohmic pure resistive shunt. The resistance shunt is usually designed in the following manner to reduce the stray effects.
    a) Bifilar flat strip design
    b) Coaxial cable or parts shunt design
    c) Coaxial squirrel cage design.

11. **Why are capacitive voltage dividers preferred for AC high voltage measurements?**

    The high voltage dividers are preferred for high ac voltage measurement because the capacitance ratio is independent of frequency.

12. **Calculate the correction factors for atmospheric conditions, if the laboratory temperatures is 37°C, the atmospheric pressure is 750 mm Hg and the wet bulb temperature is 27°C.**

    Solution:
    1013 millibar = 760 mm
    750 mm = 1013/7660 *750 = 1000 millibar
    Correction factor = $\frac{0.296 * 1000}{273 + 37}$ = 0.955

13. **Explain the merits and demerits of analog and digital techniques used for high voltage measurements.**

    Information storage is easy that is accomplished by special switching circuit that latches on information and holds it for as long as necessary. Accuracy and precision are greater. Digital system can handle as many digits of precision as you need simply by adding more switching circuits.
    Analog system is cheaper and involves less complex circuitry.

14. **What are the general methods used for measurement high frequency and impulse currents?**

    The following methods are used
    a) Resistive shunts
    b) Magnetic potentiometer or Rogowski coils
    c) Magnetic links
    d) Hall Effect generator.

UNIT 5

1. **What are tests conducted on insulators?**
   i) Power frequency voltage test
   ii) Impulse voltage test
   Power frequency test can be classified into
   a) Dry and wet flashover tests
   b) Wet and dry withstand tests (one minute)
   Impulse tests can be classified into
   a) Impulse withstand voltage test
   b) Impulse flashover test
   c) Pollution testing.
2. **What are test conducted on Bushings?**
   i) Power frequency voltage test
   ii) Impulse voltage test
   Power frequency test can be classified into
   a) Power factor voltage test
   b) Internal or partial discharge test
   c) Momentary withstand test at power frequency
   d) One minute wet withstand test at power frequency test
   e) Visible discharge test at power frequency
   Impulse voltage tests can be classified into
   a) Full wave withstand test
   b) Chopped wave withstand and switching surge test
   Temperature rise and thermal stability tests are also used for testing of bushings.
3. **Define withstand voltage.**
   The voltage which has to be applied to attest object under specified condition in a withstand test is called the withstand voltage.

4. **Define impulse voltage.**
   Impulse voltage is characterized by polarity. Peak value, time to front and time to half the peak value after the peak. The time to front is defined as 1.67 times to time between 30 5 and 90 % of the peak value in the rising portion of the wave. According to [s : 207] (1973) standard impulse is defined as one with t_f = 1.2 μs, t_t = 50 μs (called 1.250 μs wave). The tolerances allowed are ±3 % on the peak value, ±30 % in the front time (t_f), and ±20 % in the tail time (t_t).
5. **Differentiate type test and routine test.**
   Routine test is not to flash over the insulator but rather to detect existing fault before the insulator is put in service .Type test cover those features that are important to the purchaser such as dry and wet flash over, puncture voltage, tensile strength.
6. **Define Disruptive discharge voltage.**

This is defined as the voltage which produces the loss of dielectric strength of an insulation. It is that voltage at which the electrical stress in the insulation causes a failure which includes the collapses of voltage and passage of current.

7. **What are the atmosphere correction factor and mention their influence in high voltage testing.**

   Actual air density during measurement differs due to temperature and pressure variation.

   Spark over voltage depends upon the air density factor

   Spark over voltage $V = KV_0$

   Where ,K = Correction factor related to air density factor'd'

   V_0 = Spark over voltage under standard temperature and pressure.

   $d = P/P_0[(273 + t_0) / (273 + T)]$

   Where

   K is a function of air density factor d

   P = air pressure at test condition

   P_0 = air pressure at standard condition

   t_0 = temperature at standard condition

   T = temperature at test condition

8. **Explain the role of Bureau of Indian standards in high voltage testing.**

   All the EHV equipment voltage are governed by Indian standard specification issued by Bureau of Indian standards in our country.

   For different transmission voltages the test voltages are given in a tubular form.

9. **Define insulation co- ordination.**

   Insulation co-ordination of suitable values for the insulation levels of the various components in any electrical system and their management in a rational manner is called insulation co-ordination Insulation co-ordination of the insulation of the electrical equipment and circuits with the characteristics of the protective devices in such a manner that the insulation is well protected from the excessive over voltages.

10. **What is the significance of impulse tests?**

    Impulse test are done on insulator to ensure reliability of individual test objects and quality and consistency of material used in their manufacture and done on transformers is to determine the ability of the insulation of transformers to withstand the transient voltages due to lightning.

11. **Name the different types of tests conducted on high voltage apparatus.**

    Dry -Wet flashover test and Dry -Wet withstands test are the two types of tests conducted on high voltage apparatus.

12. **Explain the reasons for conducting wet tests on high voltage apparatus and give the specifications of the water used for wet tests.**

    Wet tests are to provide a criterion based on experience that a satisfactory service operation will be obtained.

    Conductivity of water 100 microsiemens ± 10 %

    Water temperature ambient ± 15 %

13. **Define creepage distance.**

    It is the shortest distance of contour of the external surface of the insulator unit or between two metal fittings on the insulator.

14. **Give the Indian standard reference atmospheric conditions for high voltage testing.**
    a) Temperature - 27°C
    b) Pressure - 1013 millibars (or 70 torr)
    c) Absolute humidity – 17 gm/m^3
15. **Define safety margin as applied to be insulation co-ordination.**
    Safety margin applied to insulation co-ordination is the basic insulation level of equipment is defined as the peak voltage of 1.2 / 50 μs wave which does not cause insulation to fail. The definition of a surge (1.2 / 50 μs) indicates a surge which reaches its peak value in 1.2 μs and decays to half the peak in 50 μs.

16 marks

Unit - I

1. Draw the cross sectional view of non linear resistor lightning arrester (valve type) and explain its operation in detail and its V-I characteristics.
2. Discuss mechanism of lightning stroke and over voltages on transmission lines and give its mathematical model.
3. Explain Townsend's first and second ionization process and derive the equation.
4. Explain different theories of charge formation in clouds.
5. What are the methods to control over voltages?

Unit - II

1. State the criteria for sparking potential and hence obtain the relation between sparking potential and (PD) values (Paschens law). Discuss nature of variation of sparking potential with PD values.
2. Explain breakdown mechanism on solid dielectric.
3. Explain breakdown mechanism on vacuum dielectric.
4. Explain breakdown in non uniform fields and corona discharge.

Unit - III

1. starting from basic marx circuit develop the circuit of modern multistage impulse generator and explain its operation.
2. Discuss significance of various parameters.
3. Explain vandegraff generator.
4. Explain cascade transformer connections and resonant transformer.

Unit - IV

1. Explain measurements of very high voltages using sphere gaps. Mention merits and de merits of using sphere gaps.
2. Explain electro static voltmeter for HVAC measurements. Give its advantages and disadvantages.

3. Explain generating voltmeter for measuring high DC voltage.
4. Explain Capacitance voltage transformer.
5. Explain hall generator.

Unit -V

1. Explain testing of transformer.
2. Explain testing of insulator.
3. Explain testing of isolators and circuit breakers.