DMI COLLEGE OF ENGINEERING

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DEPARTMENT OF ELECRTICAL AND ELECTRONICS ENGINEERING

EE 8701 –HIGH VOLTAGE ENGINEERING

UNIT-I OVER VOLTAGES IN ELECTRICAL POWER SYSTEMS

PART – A

1. What are the chief causes of over voltages in electric power system?

1) Lightning over voltages (Natural causes)
2) Switching over voltages (system oriented causes)

2. How are switching over voltages originated in a power system?

Switching over voltages originate in the system itself by the connection and disconnection of circuit breaker contacts or due to initiation or interruptionof faults.

3. What are switching over voltages?

Switching over voltages are highly damped short duration over voltages. They are temporary over voltages of power frequency or its harmonic frequencies.

- They are sustained or weakly damped
- They originate in switching and fault clearing process.

4. For ultra high voltages, perhaps, switching surges may be the chief condition for design considerations. Why?

The magnitudes of lighting voltages appearing on a transmission line do not depend on line design hence lightning performance does not improve with increasing insulation level, that is, the system voltage. On the other hand switching over voltages is proportional to operating voltage. Hence for ultra high voltages switching surges may he the chief condition for consideration.

5. State the parameters and characteristics of the lightning strokes:

1. Amplitude of currents
2. The rate of rise.
3. The probability distribution
4. Wave shape of the lightning voltage and current.
5. Time to peak value.

6. How are lightning strokes on transmission lines classified.

1) Direct strokes
2) Inducted strokes

Direct stroke:

- When thunder cloud directly discharges on to a transmission line tower orline wires, it is called direct stroke. This is the most severe form and this occurs rarely.

Inducted Stroke:

- When thunder storm generates negative charges at its ground end. The transmission line and Tower develop induced positive charges.
- Normally lines are unaffected, because they are insulated by string insulators.

However, because of the high field gradients involved, the positive charge leak from the Tower along the insulator surfaces to the live conductors, after a few micro seconds, (say). When the cloud discharges through some earthed objects other than the transmission line, huge concentration of positive charge is left with.

- The transmission line and earth act as a huge capacitor.
- This may result in a stroke and hence the name inducted lightning stroke.

7. **Give the mathematical Model for lightning:**

Let Io – lightning current (current source)
Zo – source impedance(of the cloud)
Z - object Impedance
V - Voltage built across the object

Tr line : 300 to 500 ohms
Ground wire : 100-150ohms
Tower : 10-50 ohms
Therefore Z/Zo=less and can be neglected.
Therefore V= Io.Z
Where Io = lightning stroke current
Z = surge impedance.

8. What are the Causes for Switching surges?

(1) Making and Breaking of electric circuits.
(2) Initiation or termination of faults.
(3) Energisation and de energisation of cables, capacitors, transformer, Reactors, load etc.

9.What are the effects Switching surges on power system:

. Power system has large Inductance and capacitance.

- Switching surges may create abnormal over voltages (six times)
- Switching surges with a high rate of rise of voltage may cause repeated restriking of the arc between the CB contacts and damage the contacts.
- They have high Natural frequency components and damped normal frequency component.

10.What is Thunder storm days?

Thunder storm days (TD) (is known as the Iso Keraunic level) is defined as the number of days in a year when thunder is heard or recorded in a particular location,

- The incidence of lightning strikes on Tr. Line / substation in related to T.D.
- T.D is =5 to 10 in Brittan
  30 to 50 in USA
  30 t0 50 in India

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12.What are the measures taken to control/ reduce the switching overvoltages?

1. One step or multi step energisation of lines by pre insertion of resistors
2. Phase controlled closing of circuit Breakers with proper systems.
3. Drainage of Trapped charges on long lines (by discharging) before the closing of the lines.
4. Limiting over voltage by surge diverters.

13.What are the causes for power frequency over voltage in a system:

Sudden loss of loads.
Disconnection of inductive loads.
Ferranti effects and unsymmetrical faults.
Saturation in Transformers

14.Name the various methods for protection of Transmission lines against lightning over voltages:

Shielding the over head line using ground wires.
Using ground rods and counterpoise wires
Using protective devices like expulsion gap, protector tubes, surge diverters at appropriate places.

15. What is a ground wire in a Transmission System:

- Ground wire is a conductor run parallel to the main conductors of the transmission line supported on the same tower and earthed every equally and regularly spaced towers.
- It shields the line conductors from induced charges and lightning discharges. The shielding angle should be less than 30.

16. For proper protection how should the ground wire be positioned?

1. They should be positioned at a height above line conductors such that they intercept the lightning stroke.
2. The phase Conductor should be in the protected Zone: within a quarter circle with the radius = the ground clearance and centre at ground wire
3. The shielding angle should be <300
4. There should be no side Flash over
5. Tower footing resistance should be low to prevent back Flesh over.

17. What are counter poise wires ?

- Horizontal wires buried at a depth of 1m in the ground, they may be parallel to the conductors or radial from the tower footing
- They are to reduce tower footing resistance.

18. What are ground rods ?

Additional rods provided driven into the ground near the tower footing and connected to the tower footing to reduce the tower footing resistance [15 mm dia, 3.0 m long, 10 to 16 rods]

19. **What are the characteristics of an ideal surge diverter?**

1) When the line voltage is less than the limiting value the leakage current should be zero.
2) When the line voltage exceeds the limit, it should offer zero impedance irrespective of the wave shape, so that the surge voltage is by passed.
3) Immediately after the passing of surge, and immediately after Normal voltage is returned, it should act again as a perfect insulator.

20.What are the disadvantages of spark gap surge diverter?

1. Depends on atmosphere conditions
2. Arc cleaning to be done after surge flow.

For the same voltage peak, the gap to be set for lightning over voltage is lesser than the gap

UNIT II - ELECTRICAL BREAKDOWN IN GASES, SOLIDS AND LIQUIDS

PART - A

1. Name a few gases used as insulation medium

N2, CO2, CC2F2 (Freon), SF6 (Sulphur Hexa Fluoride)

2. Name the theories explaining breakdown in gaseous insulation

1) Townsends Theory 2) Streamer Theory.

3. What are the physical conditions governing ionization mechanism in gases dielectrics?

1) Pressure
2) Temperature
3) Electrode configuration
4) Nature of electrode surface
5) Availability of initial conducting particles

4.What is primary ionization?

Electron produced at the cathode by some external means, during its travel towards the anode due to the field applied, make collisions with neutral atoms/molecules and liberate electrons & positive ions. The liberated ions make future collisions and the process continue. The electrons and the ions constitute current. This process is called primary ionization.

5.What is secondary ionization?

- The librated positive ions, during the primary ionization process migrate towards cathode bombard and emit secondary electrons from the cathode.
- The excited atoms/molecules, got excited during the collision of initial electrons, emit photons which bombard the cathode & emit secondary electrons
- Metastable (excited particles) bombard the cathode metal surface & produce secondary

6. Define primary ionization co-efficient .(Town-sends first ionization co-efficient)

The average number of ionizing collisions made by an electron per centimeter travel of the electron in the direction of the field is called Town-sends Ist ionization co-efficient .It depends on the gas pressure and E/P

7.What is Town-sends secondary ionization co-efficient

It is the net number of secondary ions produced per incident positive ion or photon or metastable particle

8.What is Spark voltage sparking distance

The voltage applied which creates the above breakdown condition is called spark voltage Vs and the corresponding gap d is called sparking distance.

9.Demerits of Town-sends theory

1. Beyond a p.d > 1000 torr cm, this theory does net explain correctly.
2. Town sends theory says that current growth depends on ionization. But actually it depends on gas pressure and geometry of gap.
3. Town sends mechanism predicts time lag of 10-5 sec. But actually the time lag is 10-8 sec.
4. The discharge form is not as the one predicted by Town-sends theory. It is filamentary & irregular and not “diffused form” as predicted by town-sends.

10.Streamer theory is based on what?

- Streamer theory considers the influence of space charge on the applied field.
- Secondary avalanches are produced from the gap

Transformation from avalanche to streamer occurs when the length of avalanche exceeds a certain value.

11. Explain why Electronegative gas has high breakdown value.

- The molecules of (SF6 gas) electro neg. gases have the property of electron attachment, (i.e., the outermost orbit of the molecules has holes)
- There molecules attach the electrons in the gap to become negative ions

12.Distinguish between BD in uniform field and BD in Non uniform field:

1. In the uniform field, increase in applied voltage produces a Breakdown in the gap in the form of a spark with out any preliminary discharge.
2. In the non uniform field, an increase in applied field, first cause a discharge in the gas around the points where the field is the highest.

13. What are the characteristics of corona discharge

1. It has bluish luminescence.
2. It produces hissing noise.
3. Air surrounding the corona becomes converted to ozone.
4. Creates loss of Power.
5. Create radio interference.
6. It causes deterioration of the insulation surface.

14. What is corona inception field?

The voltage gradient required to produce visual ac corona in air at a conductor surface is called corona inception field.

15. What is Paschens Law?

Paschans law explains the relationship between the Break Down voltage and the product of pressure (p) and gap (d), in the case of Breakdown in gas.

It states that, $V = f(p.d)$ The Breakdown voltage is a function of p.d.

16.What is electrochemical breakdown?

Electrochemical breakdown is a type of dielectric breakdown that occurs when an electric field is applied to a dielectric material in the presence of ions and water.

17. What is Vaccum.

Atmospheric Pressure = 760 torr
High Vacuum = 1 x 10-3 to 1 x 10-6 torr
Very high Vacuum = 1 x 10-6 to 1 x 10-8 torr
Ultra Vacuum = 10 x 10-8 torr & below
For electrical Insulation purposes
Vacuum => High Vacuum=> 1 x 10-3 torr to 1 x 10-6 torr.

18. What is the principle of stressed oil volume Theory in Breakdown liquids.

The breakdown voltage of liquid dielectric depends on the region which is subjected to the highest stress and the volume of liquid contained in the region.

19. What is Time lag for Break Down?

The time difference between the instant of applied voltage and the occurrence of breakdown.

20. What property of SF6 gas is not favorable in electrical approach?

It is not environmentally friendly and it causes global warming. Hence SF6 is used along with Air or other suitable gases.

UNIT II - ELECTRICAL BREAKDOWN IN GASES, SOLIDS AND LIQUIDS

1. What are the different forms of high voltages?

- High DC voltages
- High ac voltages of power frequency
- High ac voltages of high frequency
- High transient or impulse voltage of very short duration
- Transient voltages of longer duration such as switching surges.

2. What are the applications of high voltages?

- Electron microscopes and x-ray units in the order of 100KV or more.
- Electrostatic precipitators
- Testing purposes to simulate over voltages due to lighning and switching.

3. Name the methods used to generate High voltage DC.

- Half and full wave rectifier
- Voltage doubler circuit
- Voltage multiplier circuit
- Van de Graff generator

4. Write the basic principle of Electrostatic machines.

In electrostatic machines, current carrying conductors are moved in a magnetic field, so that the mechanical energy is converted into electrical energy.

5. What are the advantages of Van de graff generator?

- Very high DC voltage
- Ripple free output
- Precision and flexible of control

6. What are the limitations of Van de graff generator?

- Low current output.
- Limitations on belt velocity due to vibration.
- It is difficult to have an accurate grading of electric fields

7. **What are the methods to generate High alternating voltages?**
    - Cascaded Transformers
    - Resonant Transformers

8. **What are the advantages of using cascade transformer with isolating transformer?**
    - Natural cooling is sufficient.
    - Transformer are compact in size
    - Constructional is identical
    - Three phase connection in star or delta is possible

9. **What are the advantages of resonant transformers?**

    - It gives an output of pure sine wave.
    - Power requirement is less.
    - No high power arcing and heavy current surges occur.
    - Cascading is also possible for very high voltages.
    - Simple and compact test arrangement.

10. **What are the advantages of High frequency ac transformers?**

    - The absence of iron core in transformers and hence saving in cost and size.
    - Pure sine wave output.
    - Slow build up of voltage over a few cycles and hence no damage due to switching surge.

11. **Define front time.**

    It is the time required for the response to raise from 10% to 90% or o to 100% of the final value at the very first instant.

12. **What is peak value?**

    The maximum positive deviation of the output with respect to its desired value is known as peak value.

13. **What are the components of multi-stage impulse generator?**
    - DC charging set
    - Charging resistor
    - Generator capacitor or spark gap
    - Wave shaping resistors and capacitors
    - Trigerring system
    - Voltage dividers
    - Gas insulated impulse generators

14. What is the principle of operation of a Cockcroft-Walton voltage multiplier circuit?

Capacitors are charged in parallel and discharged in series to produce a high DC voltage from a low AC voltage.

15. What are the advantages of using a Cockcroft-Walton voltage multiplier circuit?

Simplicity: The circuit is relatively simple to design and build.

Efficiency: The circuit is very efficient, with little power loss.

High voltage output: The circuit can produce very high voltages, even from a low input voltage.

16. What are the disadvantages of using a Cockcroft-Walton voltage multiplier circuit?

Poor voltage regulation: The output voltage of the circuit can vary depending on the load current.

Bulkiness: The circuit can be bulky for high-voltage applications, due to the large capacitors required.

17. What are some applications of the Cockcroft-Walton voltage multiplier circuit?

It is used in particle accelerators, X-ray machines, microwave ovens, and other high-voltage devices.

18. What is a trigatron?

A trigatron is a high-voltage switching device that uses a gas discharge to trigger a main circuit breaker. It is a three-electrode gap switch consisting of a high-voltage spherical electrode, an earthed main electrode, and a trigger electrode through the main electrode.

19. What are the advantages of using a trigatron in high voltage engineering?

Fast switching speed: Trigatrons can switch high voltages very quickly, typically in the order of nanoseconds.

High reliability: Trigatrons are very reliable devices, with a long service life.

High voltage capability: Trigatrons can switch very high voltages, up to several hundred kilovolts.

Compact size: Trigatrons are relatively compact in size, making them suitable for a variety of applications

20. What are the different types of tripping devices used in high voltage engineering?

Common types of tripping devices include overcurrent relays, overvoltage relays, and earth fault relays.

UNIT – IV MEASUREMENT OF HIGH VOLTAGE AND HIGH CURRENTS

PART – A

1. What are the general methods used for measurement of high frequency and impulse currents?

(i) Potential dividers with a cathode ray oscillograph
(ii) Peak voltmeters
(iii) Sphere gaps

2.What are the high voltage d.c measurement techniques used?

Series resistance micro ammeter

Resistance potential divider

Generating voltmeters

Sphere and other spark gaps

3.For what measurement are Hall generators normally used?

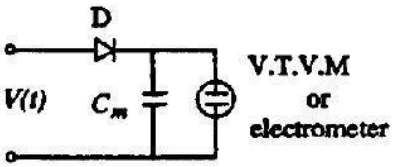
Measurement of high direct currents

Measurement of high frequency and impulse currents.

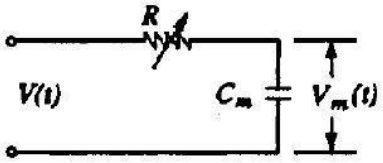
4.What are the types of measuring devices preferred for measurement of impulse currents of short duration?

(iv) Potential dividers with a cathode ray oscillograph
(v) Peak voltmeters
(vi) Sphere gaps

5.Draw the simple circuit of peak reading voltmeter and it's equivalent.



(a) Basic circuit



(b) Equivalent circuit of (a)
(basic circuit)

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

(i) Nearby earthed objects
(ii) Atmospheric conditions and humidity
(iii) Irradiation
(iv) Polarity and rise time of voltage waveform.

7.What are the advantages of CVT measurement in HVAC?

(i)Simple design and easy installation

(ii)Can be used both as a voltage measuring device for meter and relaying purposes and also as a coupling condenser for power line carrier communication and relaying.

(iii)Frequency independent voltage distribution along elements as against conventional magnetic potential transformers which require additional insulation design against surges.

(iv)Provides isolation between the high voltage terminal and low voltage metering.

8.What are the limitations of generating voltmeter?

Need calibration

Careful construction is needed

9.State the demerits of CVT measurement for HVAC measurements.

Voltage ratio is susceptible to temperature variations.

In the presence of capacitance,the problem of ferroresonance occurs in powersystem.

10.What are the methods available for measuring ac voltages of power frequency?

Series impedance ammeters
Potential dividers
Potential transformers
Electrostatic voltmeters
Sphere gaps

11.What are the methods available for measuring dc current?

Resistive shunts with milli ammeter

Hall effect generators

Magnetic links

12.What is generating voltmeter?

A generating voltmeter is a variable capacitor electrostatic voltage generator which generates current proportional to the applied external voltage. The device is driven by an external synchronous or constant speed motor and does not absorb power or energy from the voltage measuring source.

13.What are the advantages and limitations of generating voltmeter?

Advantages:

No source loading by the meter

No direct connection to high voltage electrode

Scale is linear and extension of range is easy

A very convenient instrument for electrostatic device

Limitations:

They require calibration

Careful construction is needed and is cumbersome instrument requiring an auxiliary drive

Disturbance in position and mounting of the electrodes make the calibration invalid.

14.What are the sources that contribute to the error?

The effective value of the capacitance being different from the measured value of C.

Imperfect rectifiers which allows small reverse currents

Non-sinusoidal voltage waveforms with more than one peak or maxima per half cycle.

Deviation of the frequency from that of the value used for calibration.

15.How resistance shunt is usually designed?

Bifilar flat strip design

Coaxial tube or Park's shunt design

Coaxial squirrel cage design.

16.What are the different techniques for impulse current measurement?

Rogowski coil

Magnetic links

Hall generators

Faraday generator

Current transformer

17. What are the challenges of measuring high power frequency alternating currents?

The currents can be very high, which can make it difficult to find a suitable ammeter.

The frequencies can be very high, which can make it difficult to find a suitable ammeter that is accurate at these frequencies.

It is important to take safety precautions when measuring high power alternating currents, due to the risk of electric shock and arc flash.

18. What are some safety precautions that should be taken when measuring high power frequency alternating currents?

Some safety precautions that should be taken when measuring high power frequency alternating currents include:

Wear appropriate personal protective equipment (PPE), such as insulated gloves, safety glasses, and a flame-resistant suit.

Use insulated tools and equipment.

Make sure that the circuit is de-energized before making any connections.

19.What is hall voltage and hall coefficient?

If electric current flows through a metal plate located in a magnetic field perpendicular to it. The charge displacement generates an emf in the normal direction, called the “Hall voltage”. The Hall voltage is proportional to the current I a, the magnetic flux density B and the reciprocal; of the plate thickness, the proportionality constant R is called the “Hall coefficient”.

$V_H = R (Bi / d)$

20.What is meant by resistive shunts.

A resistive shunt is a low-resistance resistor that is connected in parallel with a circuit element to measure its current. The voltage drop across the shunt is proportional to the current flowing through it, and this voltage drop can be measured using a voltmeter to determine the current.

UNIT-V HIGH VOLTAGE TESTING AND INSULATION COORDINATION
PART-A

1.Name the different types of standard tests conducted on high voltage apparatus.

- Type Test - To check the design features
- Routine Test - To check the quality of the individual test piece.
- High Voltage Tests Include
  - Power frequency tests
  - Impulse tests

2.What is the test conducted on bushings?

* Power Factor-Voltage Test
* Internal or Partial discharge Test
* Momentary Withstand Test at Power frequency
* One Minute withstand Test at Power Frequency
* Visible Discharge Test at Power Frequency
* Impulse voltage tests- a. Full wave Withstand Test , b. Chopper Wave withstand Test

3.Define withstand voltage.

The voltage which has to be applied to a test object under specified conditions in a withstand test is called the withstand voltage [as per IS: 731 and IS: 2099-1963].

4.Define impulse voltage.

* Impulse voltages are characterized by,
  - Polarity,
  - Peak value,
  - Time to front and
  - Time to half the peak value after the peak.
* According to IS: 2071 (1973), standard impulse is defined as one with t_f = 1.2μSec, t_t =50 μSec (called 1/50 μSec wave).
* The tolerances allowed are ±3% on the peak value, ±30% in the front time, and ±20% in the tail time.

5. What do you mean by type tests and routine test?

Type Tests:

These tests are intended to prove or check the design features and quality
Type testsare done onsamples when new designs are introduced.

Routine Tests:

Routine tests are intended to check the quality of the individual test piece.

Routine tests are done to ensure the reliability of the individual test objects.

6.Define disruptive discharge voltage.

The Voltage that produces loss of dielectric strength of equipment is called

disruptive discharge voltage. In solid-it is called puncture. In liquid or air-it is called

Flashover.

7.Define creeping distance.

It is the shortest distance on the contour of the external surface of the insulator unit or between two metals fitting on the insulator

8.What is insulation co-ordination?

The process of bringing the insulation strengths of electrical equipment and buses into the proper relationship with expected overvoltages and with the characteristics of the insulating media and surge protective devices to obtain an acceptable risk of failure.

9.Define 50% and 100% flashes over voltage. 50% Flashover Voltage:

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

100% Flashover Voltage:

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

10.Differentiate flashover and puncture.

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

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

11.What are the different tests done on insulators?

Type Test - To check the design features

Routine Test - To check the quality of the individual test piece.

High Voltage Tests Include

Power frequency tests and Impulse tests

12.What is an isolator?

It is an off-load or minimum current breaking mechanical switch.

Explained according to "IS:9921 Part-1, 1981".

Interrupting small currents(0.5A): Capacitive currents of bushings, busbars etc.,

13.What are the test conducted on isolators and circuit breakers?

The main tests conducted on the circuit breakers and isolator switches are

i. Dielectric tests or overvoltage tests,
ii. Temperature rise tests,
iii. Mechanical tests, and
iv. Short circuit tests

14.What is the test conducted on transformer?

* Induced Overvoltage Test
* Partial Discharge Tests
* Impulse Test

15.What are partial discharges?

These are the discharges due to presence of void or any other inclusions inside of the dielectrics. The partial discharges may not be suddenly bridge the electrode; but is increasing with the duration of the operation.

16.What is the test conducted on surge arresters?

* Power frequency spark over test
* Impulse sparkover test
* Residual voltage test
* Impulse current withstand test

17.What is the test conducted on cables?

Different tests on cables are

i. Mechanical tests like bending test, dripping and drainage test, and fire resistance and corrosion tests
ii. Thermal duty tests
iii. Dielectric power factor tests
iv. Power frequency withstand voltage tests
v. Impulse withstand voltage tests
vi. Partial discharge test
vii. Life expectancy tests

18.Why is insulation coordination needed?

* To ensure the reliability & continuity of service
* To minimize the number of failures due to over voltages
* To minimize the cost of design, installation and operation

19.State the principle that is followed in the insulation design of EHV and UHV substations.

In EHV and UHV substations, the insulation design is mainly based on the consideration of switching surges whereas in high voltage substations consider lightning surges.

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

The wet test is carried to satisfy the service condition of the HV apparatus. The test object is subjected to spray of water with the following specifications:

* Precipitation Rate :10% (mm/min)
* Direction of Spray: 45^0 to the vertical
* Conductivity : 100 micro-siemens 10%
* Water Temperature : Ambient 15%