EE8701 HIGH VOLTAGE ENGINEERING

UNIT - I

OVER VOLTAGES IN ELECTRICAL POWER SYSTEMS

LIGHTING

- Causes of over voltage
- Lightning phenomenon
- Charge formation of Lightning
- Rate of Charging of thunder cloud
- Mechanism of lightning strokes
- Characteristics of Lightning strokes

LIGHTING

- Factors contributing to good line design
- Protection afforded by ground wires.
- Tower footing resistance
- Interaction between lightning and power system
- Mathematical model of Lightning

Causes of Lightning

- Lightning phenomenon

  - peak discharge in which charge accumulated in the cloud into neighbouring cloud or to the ground

- Electrode separation – cloud to cloud or cloud to ground is about 10 km or more

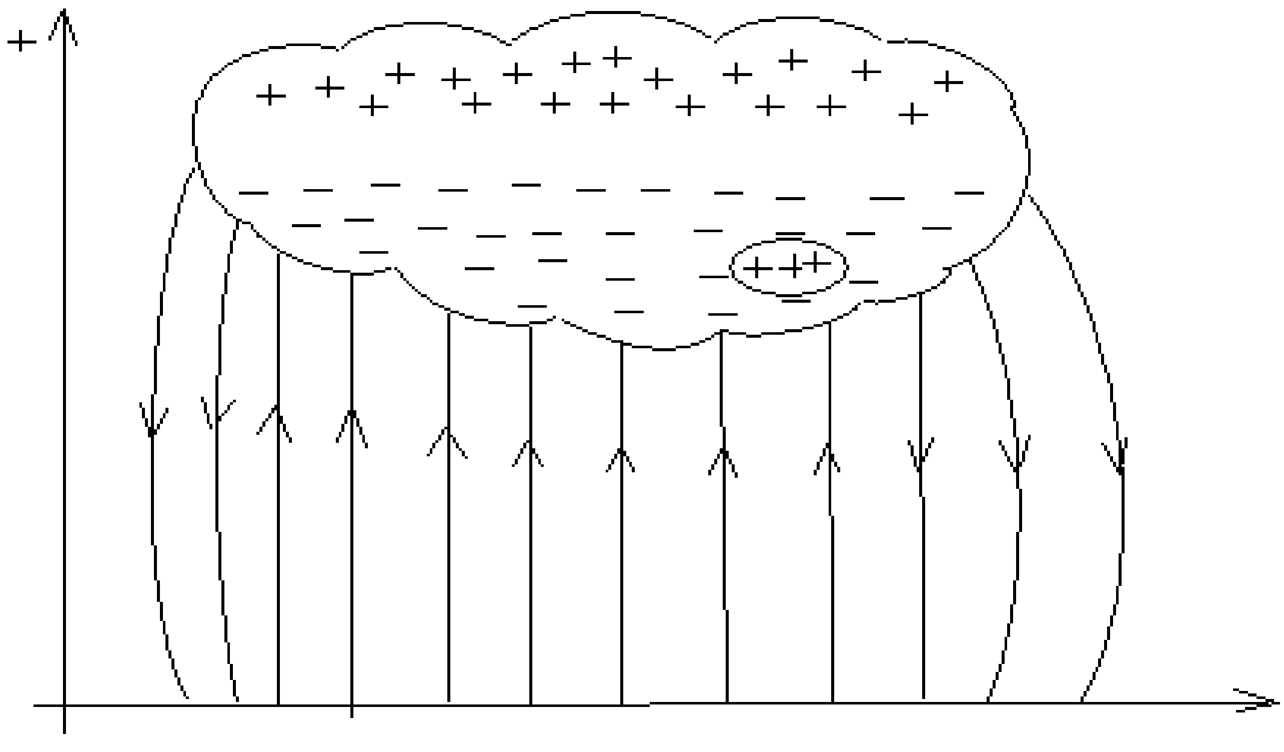
CHARGE FORMATION OF CLOUD

- Positive and negative charges become separated by heavy air current with ice crystals in the upper part and rain in the lower region.
- Charge separation depends on height of cloud (200 – 10,000m).
- Charge centers at a distance about 300 – 2km

CHARGE FORMATION OF CLOUD

- Charge inside the cloud – 1 to 100 C
- Cloud potential – 10^7 to 10^8 V
- Gradient within a cloud – 100 V/cm
- Gradient at initial discharge point – 10kV/cm
- Energy at discharge – 250 kWhr

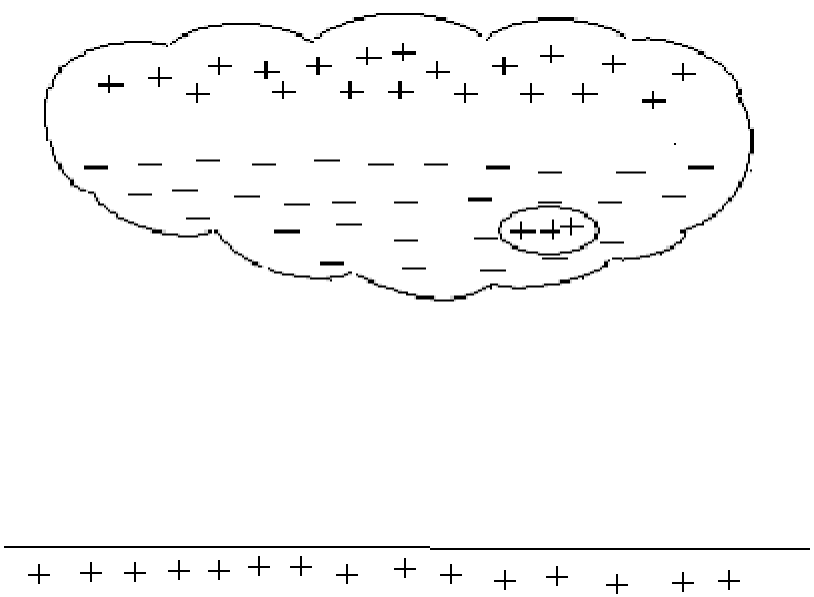
CHARGE FORMATION OF CLOUD

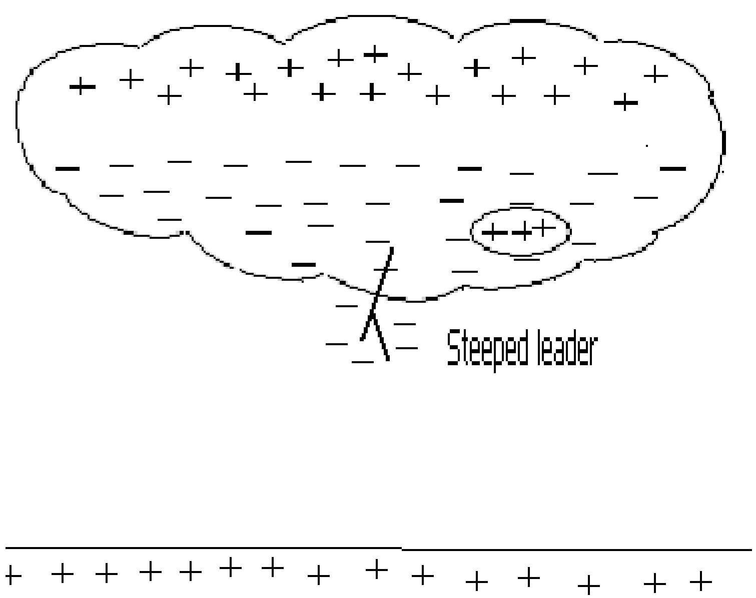


MECHANISM OF LIGHTNING FLASH

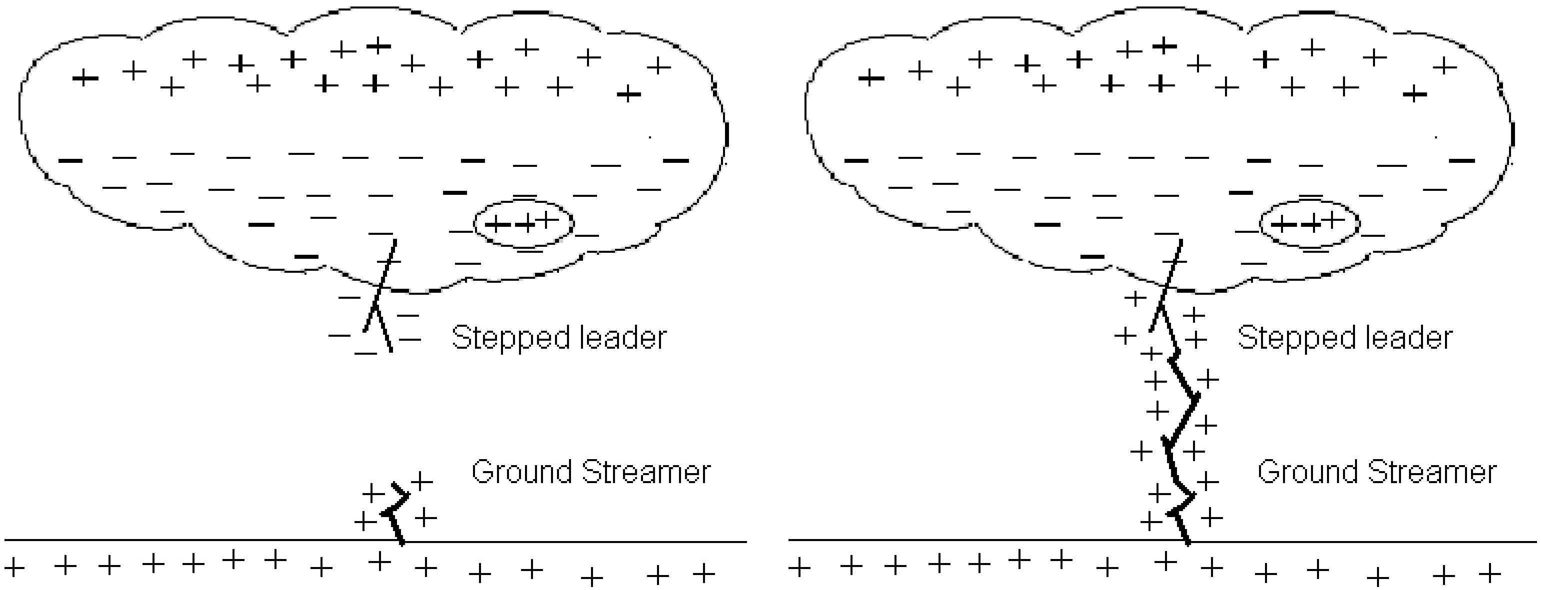
- Pilot streamer and Stepped leader
- Ground streamer and return stroke
- Subsequent strokes

PILOT STREAMER AND STEPPED LEADER





GROUND STREAMER AND RETURN STROKE



CHARACTERISTICS OF LIGHTNING STROKES

- Current-time characteristics
- Time to peak or Rate of rise
- Probability distribution of current and time
- Wave shapes of lightning voltage and current

LIGHTNING CURRENT

- Short front time - 10μs
- Tail time – several ms.

RATE OF RISE

- 50% lightning stroke current – greater than 7.5kA/μs.
- 10% lightning strokes current – exceeds 25 kA/μs.
- Stroke current above half value – more than 30μs.

SURGE VOLTAGE

- Maximum surge voltage in transmission line – 5MV
- Most of the surge voltage is less than 1000 kV on line.
- Front time – 2 to 10 μs
- Tail time – 20 to 100 μs
- Rate of rise of voltage – 1MV/ μs

LIGHTNING STROKES

- Direct stroke

  directly discharges on to transmission line or line wires

- Induced stroke

  cloud generates negative charge at its base, the earth object develop induced positive charge

OVER VOLTAGE DUE TO SWITCHING SURGES

INTRODUCTION

- In switching, the over voltage thus generated last for longer durations and therefore are severe and more dangerous to the system
- The switching over voltages depends on the normal voltage of the system and hence increase with increased system voltage

ORIGIN OF SWITCHING SURGES

- Making and breaking of electric circuits with switchgear may results in abnormal over voltages in power systems having large inductances and capacitances.
- over voltages may go as high as 6 times the normal power frequency voltage.

ORIGIN OF SWITCHING SURGES

- In circuit breaking operation switching surges with a high rate of rise of voltage may cause repeated restriking of the arc between the contacts of a circuit breaker, thereby causing destruction of the circuit breaker contacts.
- Switching surges may include high natural frequencies of the system, a damped normal frequency voltage component, or restriking and recovery voltage of the system with successive reflected waves from terminations.

CHARACTERISTICS OF SWITCHING SURGES

- De-energizing of transmission lines, cables, shunt capacitor, banks, etc.
- Disconnection of unloaded transformers, reactors, etc.
- Energization or reclosing of lines and reactive loads.
- Sudden switching off of loads.
- Short circuit and fault clearances.
- Resonance phenomenon like ferro-resonance, arcing grounds, etc.

CONTROL OF OVERVOLTAGES DUE TO SWITCHING

- Energization of transmission lines in one or more steps by inserting resistances and withdrawing them afterwards.
- Phase controlled closing of circuit breakers.
- Drainage of trapped charges before reclosing
- Use of shunt reactors.
- Limiting switching surges by suitable surge diverters.

PROTECTION AGAINST OVERVOLTAGS

- Minimizing the lightning overvoltages are done by suitable line designs,
- Providing guard and ground wires,
- Using surge diverters.

PROTECTION AGAINST OVERVOLTAGS

- Shielding the overhead lines by using ground wires above the phase wires,
- Using ground rods and counter-poise wires,
- Including protective devices like explosion gaps, protector tubes on the lines, and surge diverters at the line terminations and sudstations

UNIT - II

ELECTRICAL BREAKDOWN IN GASES, SOLIDS AND LIQUIDS.

GASEOUS BREAKDOWN IN UNIFORM FIELDS

In uniform fields, the Townsend's criterion for breakdown in electropositive gases is given by the following equation,

$$\gamma\,(e^{\alpha d} - 1) = 1$$

$$\alpha d = \ln\,(1/\gamma + 1)$$

- where the coeffici ictions of *E/p* and are given as follows

$$\alpha = p\, f_1\left(\frac{E_0}{p}\right) \qquad \gamma = f_2\left(\frac{E_0}{p}\right)$$

GASEOUS BREAKDOWN IN UNIFORM FIELDS

where *E0* is the applied electric field, and *p* the gas pressure. In a uniform field electrode system of gap distance *d,*

$$E_b = \frac{U_b}{d}$$

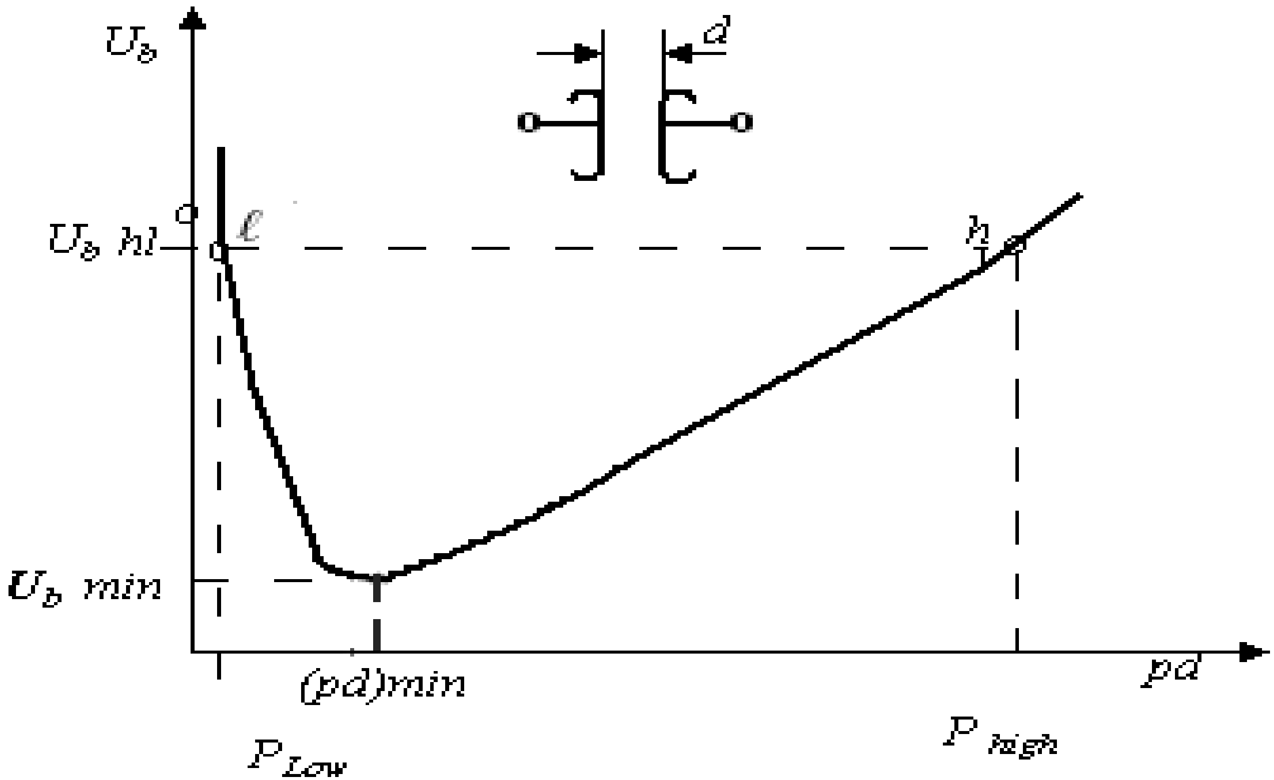
Ub is the breakdown voltage and Eb the corresponding field intensity. Eb is equal to the electric strength of the dielectric under given conditions.

When the applied field intensity E0 = Eb

$$f_2\left(\frac{U_b}{pd}\right)\left\{\exp\left[pdf_1\left(\frac{U_b}{pd}\right)\right]-1\right\}=1$$

$$U_b = f(pd)$$

GASEOUS BREAKDOWN IN UNIFORM FIELDS



BREAKDOWN IN LIQUID DIELECTRICS

- A very large number of external factors affect the breakdown strength of liquid dielectrics.
- For example, electrode configuration, their material, size and surface finish, the type of voltage, its period of application and magnitude, the temperature, pressure, purification of the liquid and its ageing condition.

BREAKDOWN IN LIQUID DIELECTRICS

- Dissolved water, gas or the presence of any other form of contamination and sludge also affect the breakdown strength considerably.
- It is, therefore, not possible to describe the breakdown mechanism by a single theoretical analysis which may take into account all known observed factors affecting the breakdown.

CORONA DISCHARGE

- The field is non-uniform, an increase in voltage will first cause a discharge in the gas to appear at points with highest electric field intensity, namely at sharp points or where the electrodes are curved or on transmission lines. This form of discharge is called a corona discharge and can be observed as a bluish luminescence.

CORONA DISCHARGE

- This is accompanied by a hissing noise.
- The air surrounding the corona region becomes converted into ozone.
- It is responsible for considerable loss of power from high voltage transmission lines,
- It leads to the deterioration of insulation due to the combined action of the bombardment of ions and of the chemical compounds formed during discharges.
- It also gives rise to radio interference.

BREAKDOWN IN NON-UNIFORM FIELDS

- The breakdown voltages were also observed to depend on humidity in air.
- In rod gaps the fields are non-uniform.
- In the case of sphere gaps the field is uniform
- In sphere gaps, the breakdo0wn voltage do not depend on humidity and are also independent of the voltage waveform
- The formative time lag is quite small (~0.5µs) even with 5% over-voltage.

VACUUM BREAKDOWN

It can be broadly divided into following categories

- Particle exchange mechanism.
- Field emission mechanism.
- Clump theory

CONDUCTION & BREAKDOWN IN COMMERCIAL LIQUIDS

- Suspended particle mechanism
- Cavitation and bubble mechanism
- Stressed oil volume mechanism
- Thermal mechanism of breakdown

BREAKDOWN IN SOLID DIELECTRICS

- Chemical & electrochemical deterioration & breakdown
- Breakdown due to treeing and tracking
- Breakdown due to internal discharges

BREAKDOWN IN COMPOSITE DIELECTRICS

- Mechanism of breakdown in composite dielectric

  1. Short-term breakdown

  2. Long-term breakdown

CONDUCTION & BREAKDOWN IN PURE LIQUIDS

- Low electric fields less than 1 kV/cm are applied, conductivities of 10^{-18}–10^{-20} mho/cm are obtained.
- These are due to impurities remaining after purification
- When the fields are high the currents not only increase rapidly.

UNIT III

GENERATION OF HIGH VOLTAGES AND HIGH CURRENTS

GENERATION OF HIGH D.C VOLTAGE

DIFFERENT METHODS TO GENERATE HIGH D,C VOLTAGE:

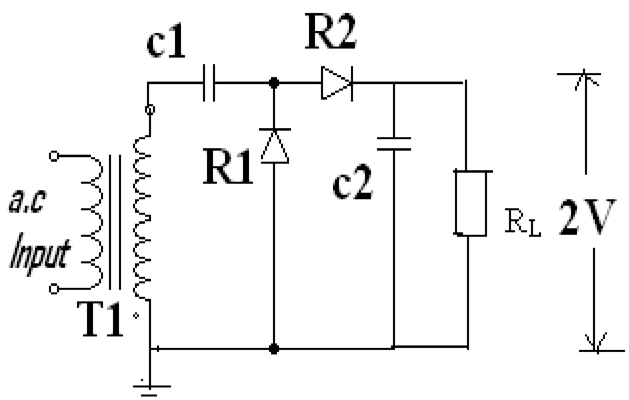
1. Half and full wave rectifier circuits
2. Voltage doubler circuits
3. Voltage multiplier circuits
4. Van de Graaff generator

HALF AND FULL WAVE RECTIFIER CIRCUITS

- This method can be used to produce DC voltage up to 20 kV
- For high voltages several units can be connected in series
- For the first half cycle of the given AC input voltage, capacitor is charged to Vmax and for the next half cycle the capacitor is dischar5ged to the load
- The capacitor C is chosen such that the time constant CR_l is 10 times that of AC supply

VOLTAGE DOUBLER CIRCUIT

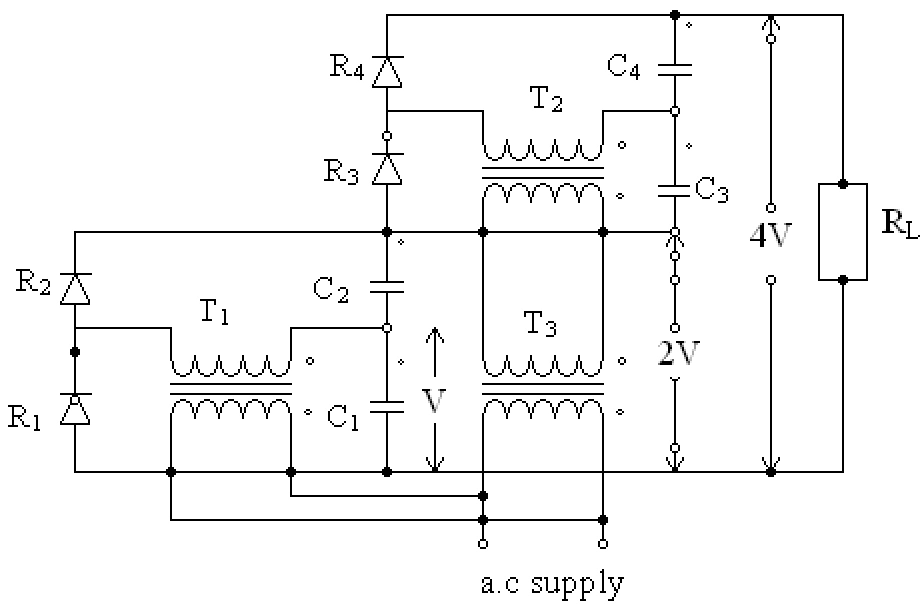
- In this method, during –ve half cycle, the Capacitor $C_1$is charged through rectifier R to a voltage $+V_{max}$. During next cycle. C_1rises to $+2V_{max}$.
- $C_{2.}$is charged to $2V_{max.}$
- Cascaded voltage doublers can be used for producing larger output voltage



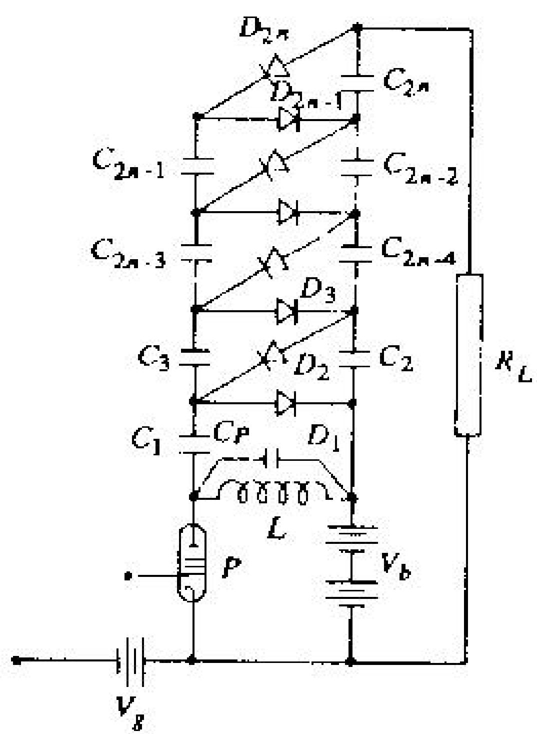
Simple voltage doubler

CASCADED VOLTAGE DOUBLERS

- Cascaded voltage doublers can be used for producing larger output voltage

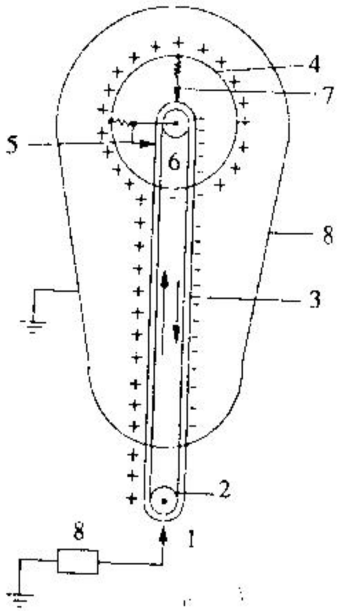


VOLTAGE MULTIPLIER CIRCUITS



- Here n no. of capacitors and diodes are used.
- Voltage is cascaded to produce output of $2nV_{max}$.
- Voltage multiplier circuit using Cockcroft-Walton principle can be used.

VAN DE GRAFF GENERATOR



Van de Graaff generator

- In electrostatic machines charged bodies are moved in an electrostatic field
- If an insulated belt with a charge density δ moves in an electric field between two electrodes with separation 's'
- If the belt moves with a velocity v then mechanical power require to move the belt is P=F.v=V.I

1. Lower spray point
2. Motor driven pulley
3. Insulated belt
4. High voltage terminal
5. Collector
6. Upper pulley insulated from terminal
7. Upper spray point
8. Earthed enclosure

Electrostatic generator

- It consists of a stator with interleaved rotor vanes forming a variable capacitor and operates in vacuum
- The power input into the circuit $P=VI=CVdV/dt+V^2dC/dt$
- The rotor is insulated from the ground,maintained at a potential of +V.
- The rotor to stator capacitance varies from C_0 to C_m
- Stator is connected to a common point between two rectifiers across –E volts.
- As the rotor rotates, the capacitance decreases and the voltage across C increases.
- Output voltage of 1MV can be generated.

GENERATION OF HIGH ALTERNETING VOLTAGES

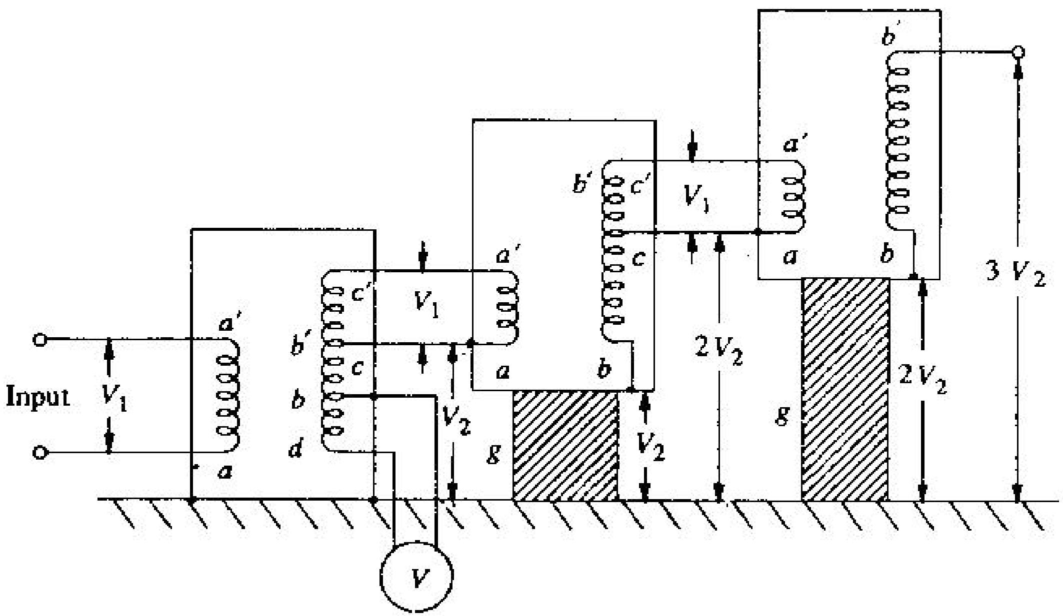
- When test voltage requirements are less than about 300 kV,a single transformer can be used.
- Each transformer unit consists of low,high and meter winding.
- Series connection of the several units of transformers used to produce very high voltage.

CASCADE TRANSFORMERS

- First transformer is at ground potential along with its tank.The 2nd transformer is kept on insulators and maintained at a potential of V_2.
- The high voltage winding of the 1st unit is connected to the tank of the 2nd unit,the low voltage winging of this unit is supplied from the excitation winding of the 1st transformer,which is in series with the high voltage winding of the 1st transformer at its high voltage end.
- The rating of the excitation winding is same as that of low voltage winding.3rd transformer is kept on insulator above the ground at a potential of $2V_2$.output of 3 stage is $3V_{2.}$
- The rating of the low voltage winding of 230 or 400 Vcan be used to produce 3.3 kV,6.6 kV or 11 kV.\

GENERATION OF HIGH AC VOLTAGE

CASCADE TRANSFORMER

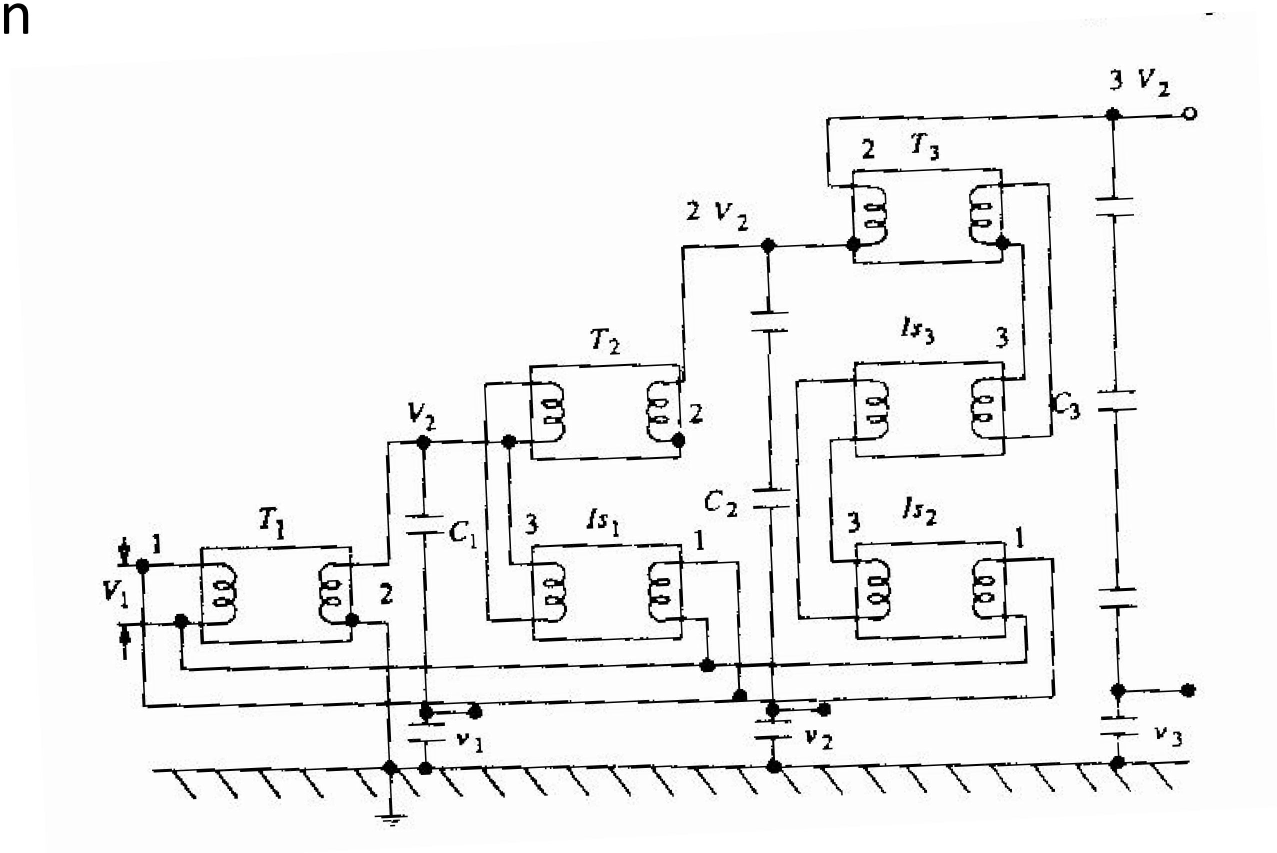


Cascade transformer connection (schematic)

V_1 — Input voltage
V_2 — Output voltage
aa' — L.V. primary winding
bb' — H.V. secondary winding
cc' — Excitation winding
bd — Meter winding (200 to 500 V)

GENERATION OF HIGH AC VOLTAGE

Cascade transformer with isolating transformer for excitation



GENERATION OF HIGH FREQUENCY A.C HIGH VOLTAGES

- High frequency high voltage damped oscillations are needed which need high voltage high frequency transformer which is a Tesla coil.
- Tesla coil is a doubly tuned resonant circuit,primary voltage rating is 10 kV and secondary voltage rated from 500 to 1000 kV.
- The primary is fed from DC or AC supply through C1.A spark gap G connected across the primary is triggered at V1 which induces a high self excitation in the secondary.The windings are tuned to a frequency of 10 to 100 kHz.

GENERATION OF IMPULSE VOLTAGES

STANDARD IMPULSE WAVESHAPE

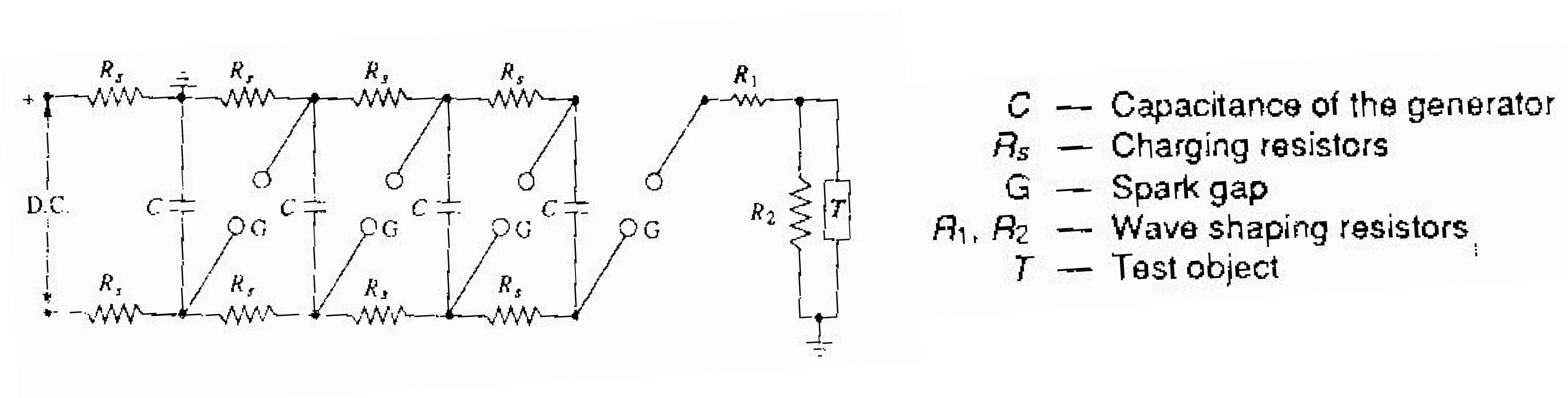
- It is specified by rise or front time,fall or tail time to 50% peak value and peak value.
- 1.2/50 μ s,1000 kV.

MARX CIRCUIT

- Charging resistance Rs is liming the charging current from 50 to 100 mA. CRs is about 10s to 1 min.
- The gap spacing G is grater than the charging voltage V.All the capacitance s are charged to the voltage V in 1 min.
- The spark gap G is made spark over, then all the capacitor C get connected in series and discharge into the load load
- In modified Marx circuit,R1is divided into n parts equal to R1/n and put in series with the gap G, R2is divided into n parts equal to R2/n and connected across each capacitor unit after the gap G.
- The nominal output is the number of stages multiplied by the charging voltage.

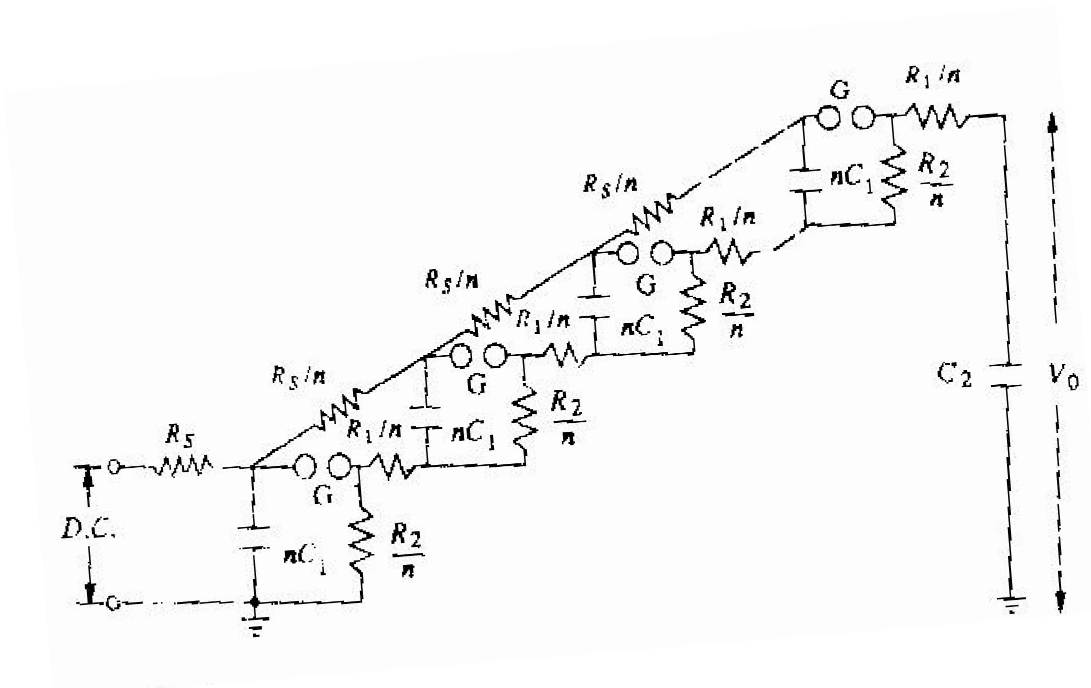
MULTISTAGE IMPULSE GENERATOR
MARX CIRCUIT

- A single capacitor C1 is to be charged first and then discharged into wave shaping circuits and it is limited to 200 kV
- For producing very high voltages a bank of capacitors are charged in parallel and then discharged in series.



MULTI STAGE IMPULSE GENERATORS

Modified Marx Circuit



COMPONENTS OF A MULTISTAGE IMPULSE GENERATOR

- DC Charging set
- Charging resistors
- Generator capacitors and spark gaps
- Wave shaping resistors and capacitors
- Triggering system
- Voltage dividers

GENERATION OF SWITCHING SURGES

- A switching surge is a short duration transient voltage produced in the system due to a sudden opening or closing of a switch or c.b or due to an arcing at a fault in the system.
- Impulse generator circuit is modified to give longer duration wave

  shape,100/1000 μs,R1 is increased to very high value and it is parallel to R2 in the discharge circuit.
- Power transformer excited by DC voltages giving oscillatory waves which produces unidirectional damped oscillations.Frequency of 1to 10 kHz
- Switching surges of very high peaks and long duration can be obtained by one circuit,In this circuit C1 charged to a low voltage d.c(20 to 25 kV) is discharged into the low voltage winding of a power transformer.The high voltage winding is connected inparallel to a load capacitance C2,potential divider R2,gap S and test object.

GENERATION OF IMPULSE CURRENTS

- For producing impulse currents of large value,a bank of capacitors connected in parallel are charged to a specified value and are discharged through a series R-Lcircuit.
- $I_m = V(\exp(-\alpha t))\sin(\omega t)/\omega L$

GENERATION OF HIGH IMPULSE CURRENTS

- For producing large values of impulse,a no.of capacitors are charged in parallel and discharged in parallel into the circuit.
- The essential parts of an impulse current generator are:
- (i) a.d.c. charging unit
- (ii) capacitors of high value (0.5 to 5 μF)
- (iii) an additional air cored inductor
- (iv) proper shunts and oscillograph for measurement purposes, and
- (v) a triggering unit and spark gap for the initiation of the current generator.

TRIPPING AND CONTROL OF IMPULSE GENERATORS

- In large impulse generators, the spark gaps are generally sphere gaps or gaps formed by hemispherical electrodes.
- The gaps are arranged such that sparking of one gap results in automatic sparking of other gaps as overvoltage is impressed on the other.
- A simple method of controlled tripping consists of making the first gap a three electrode gap and firing it from a controlled source.

TRIPPING AND CONTROL OF IMPULSE GENERATORS

- The first stage of the impulse generator is fitted with a three electrode gap, and the central electrode is maintained at a potential in between that of the top and the bottom electrodes with the resistors *R*1 and *RL*.
- The tripping is initiated by applying a pulse to the thyration G by closing the switch S.
- C produces an exponentially decaying pulse of positive polarity.
- The Thyraton conducts on receiving the pulse from the switch S and produces a negative pulse through the capacitance C1 at central electrode.
- Voltage between central electrode and the top electrode those above sparking potential and gap contacts.

TRIPPING CIRCUIT USING A TRIGATRON

- This requires much smaller voltage for operation compared to the three electrode gap.
- A trigatron gap consists of a high voltage spherical electrode, an earthed main electrode of spherical shape, and a trigger electrode through the main electrode.
- Tripping of the impulse generator is effected by a trip pulse which produces a spark between the trigger electrode and the earthed sphere.
- Due to space charge effects and distortion of the field in the main gap, spark over of the main gap occurs and it is polarity sensitive.

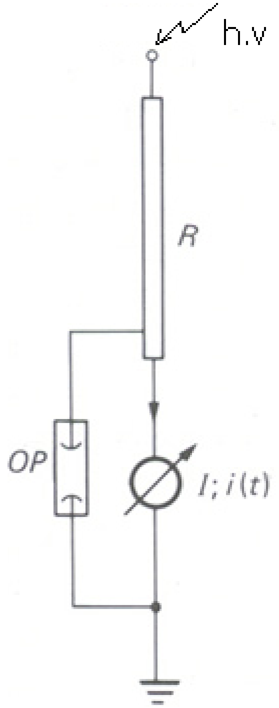
UNIT IV

MEASUREMENT OF HIGH VOLTAGES AND CURRENTS

MEASUREMENT OF HIGH DC VOLTAGE

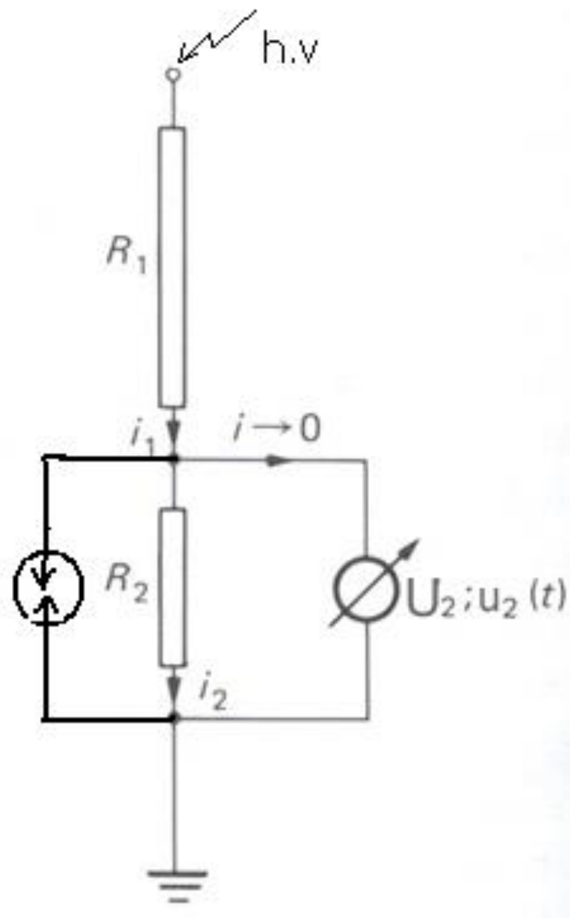
- Series resistance micrometer
- Resistance potential divider
- Generating voltmeter
- Sphere and other sphere gaps

SERIES RESISTANCE MICROMETER



- A very high resistance in series with a micrometer.
- V = IR
- The resistance is constructed from a large no. of wire wound resistors in series.

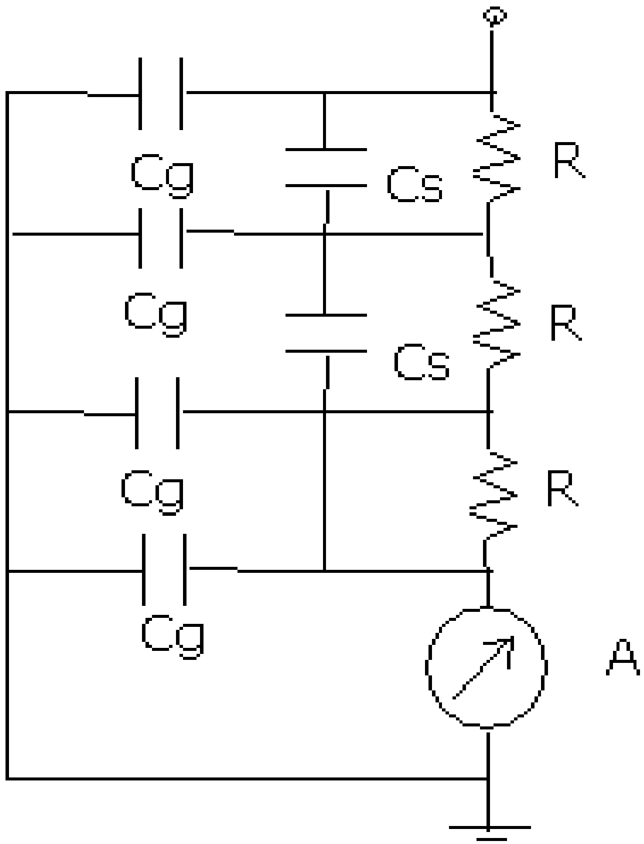
RESISTANCE POTENTIAL DIVIDER



MEASUREMENT OF HIGH AC VOLTAGE

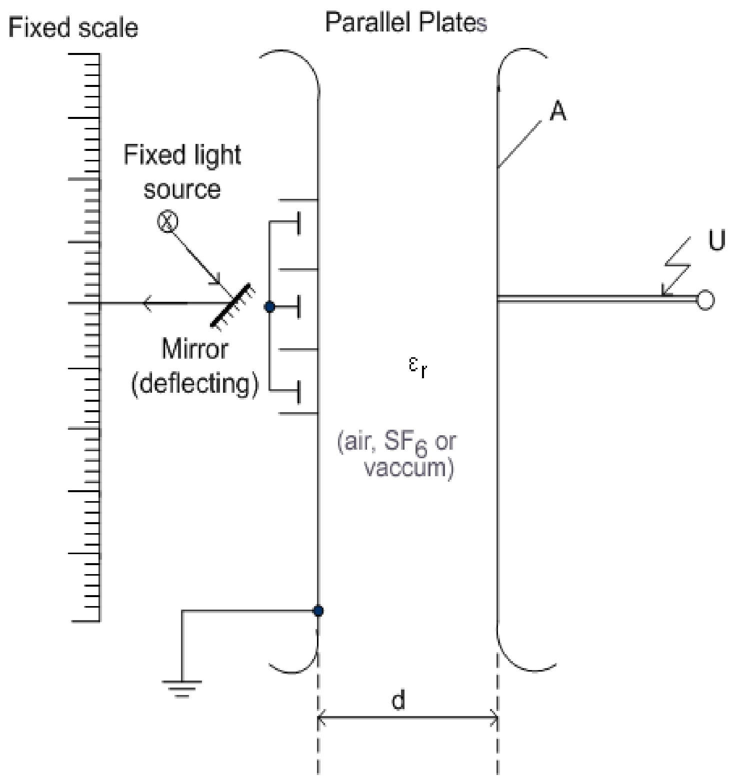
- Series impedance voltmeter
- Potential dividers
  (resistance or capacitance type)
- Potential transformers
  (Electromagnetic or CVT)
- Electrostatic voltmeter
- Sphere gaps

SERIES IMPEDANCE VOLTMETER



Extended series impedance with inductance neglected

ELECTROSTATIC VOLTMETER



$$F = -\frac{\partial W_{el}}{\partial d}$$

$$|F| = \frac{dW_{el}}{dd} = \frac{d}{dd}\left(\frac{1}{2}CU^2\right)$$

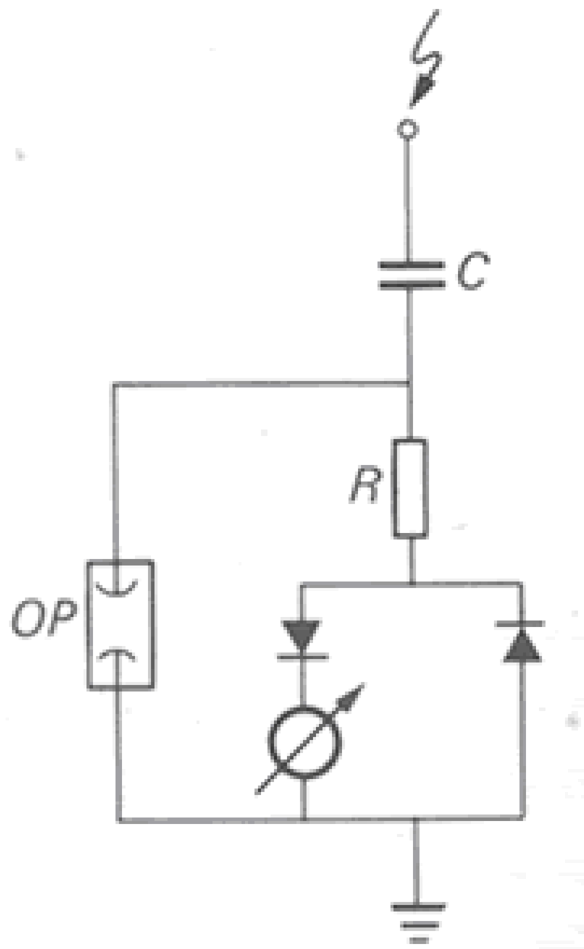
$$= \frac{1}{2}U^2\frac{dC}{dd} = \frac{1}{2}U^2\varepsilon_0\frac{d}{dd}\left(\frac{A}{d}\right) \quad (\text{since } \varepsilon_r = 1)$$

$$= \frac{1}{2}\varepsilon_0 U^2 \cdot \frac{A}{d^2}$$

$$|F| = \frac{1}{2}\varepsilon_0 AE^2$$

$$\frac{1}{T}\int_0^T F(t)\,dt = \frac{\varepsilon_0 A}{2d^2}\cdot\frac{1}{T}\int_0^T u^2(t)\,dt = \frac{\varepsilon_0 A}{2d^2}(U_{rms})^2$$

SERIES CAPACITOR PEAK VOLTMETER



C – capacitor

D_1,D_2 – Diodes

OP – Protective devices

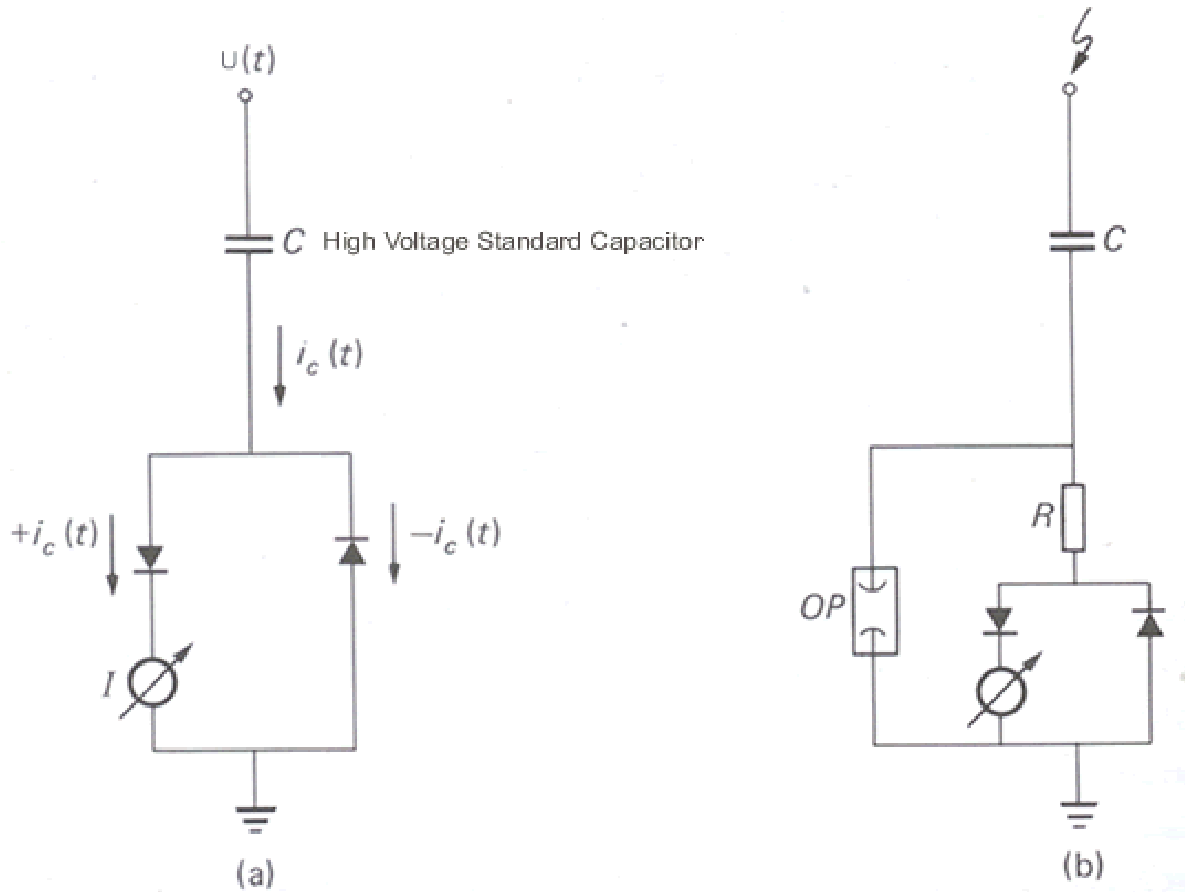
I – indicating meter

V(t) – voltage waveform

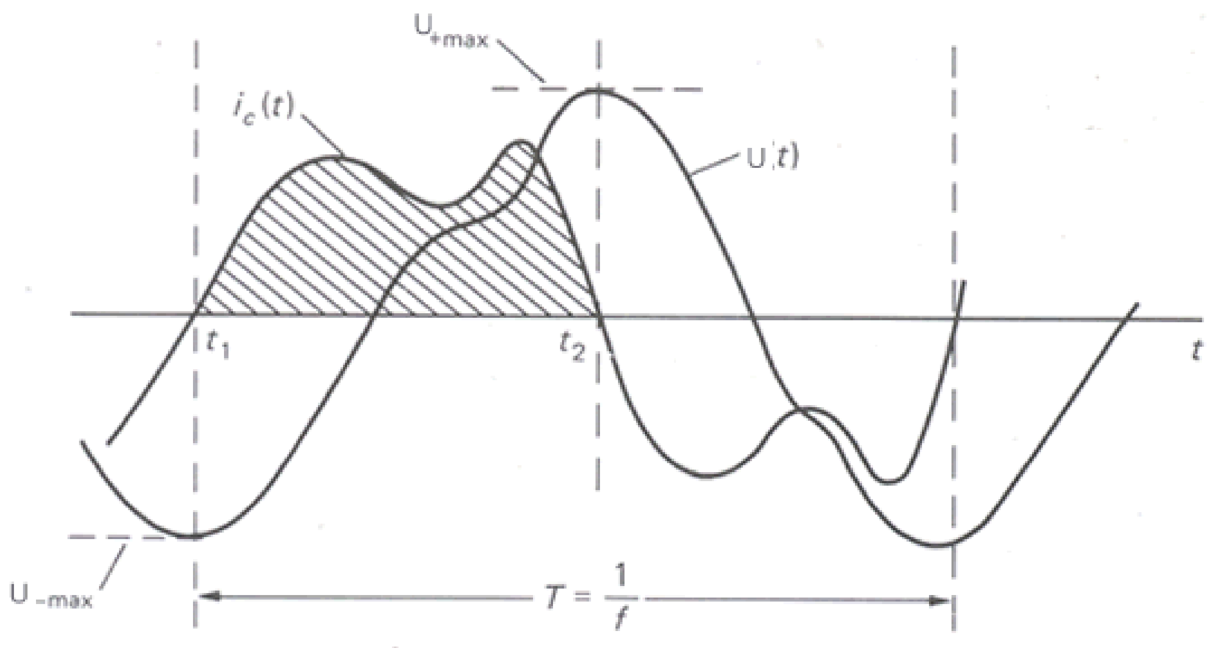
I_c(t) – capacitor current waveform

T – period

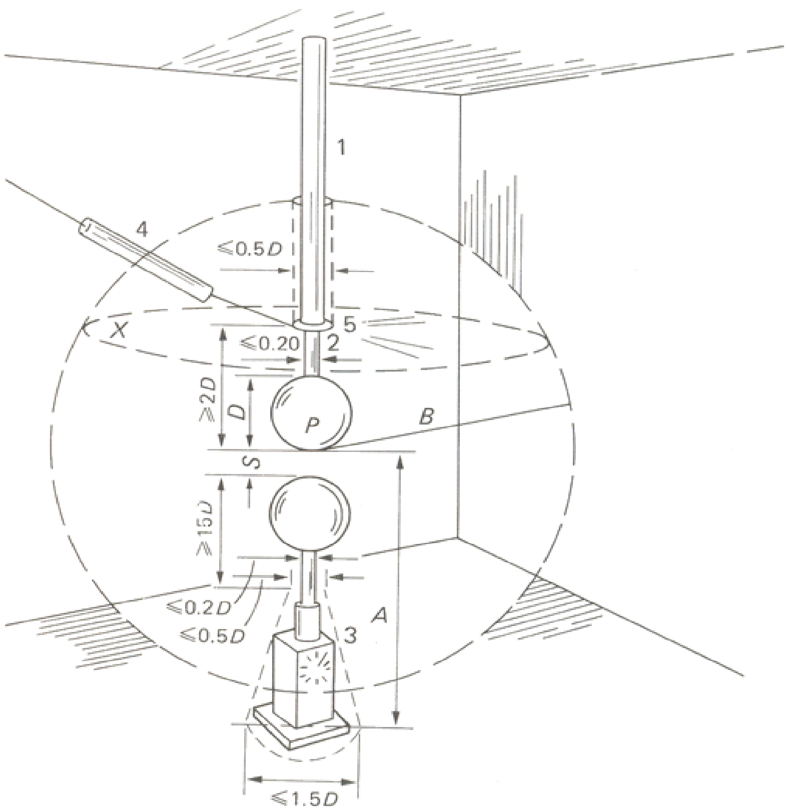
PEAK READING AC VOLTMETER



PEAK READING AC VOLTMETER



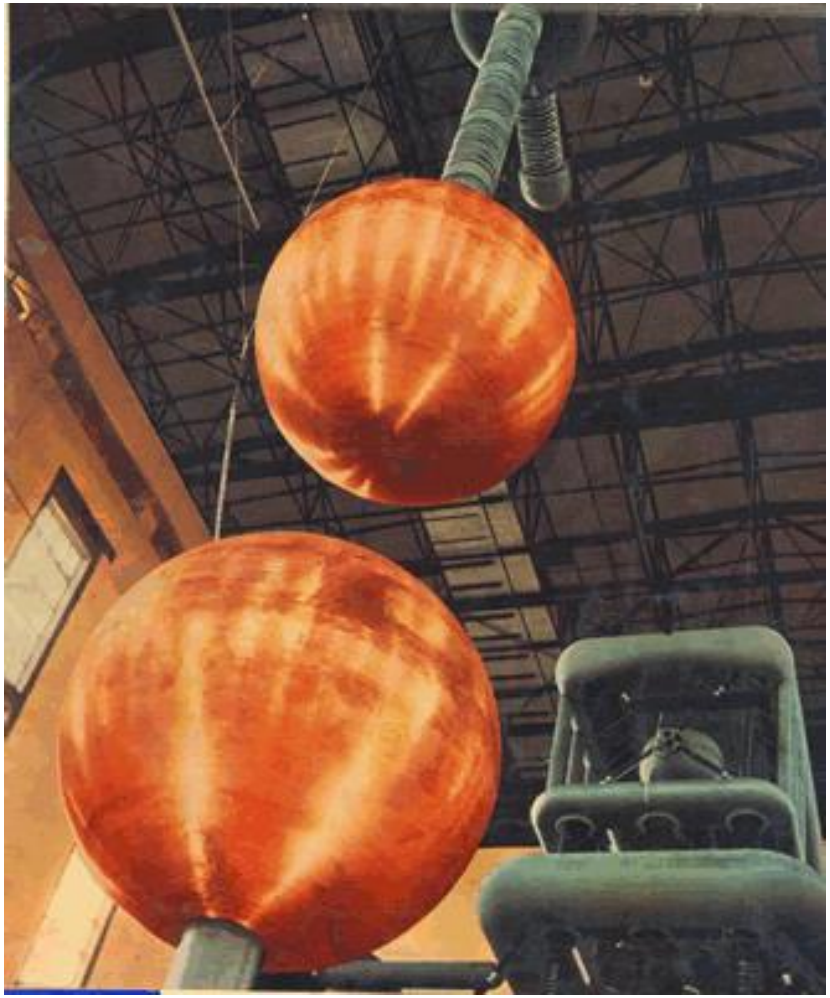
SPHERE GAPS MEASUREMENT



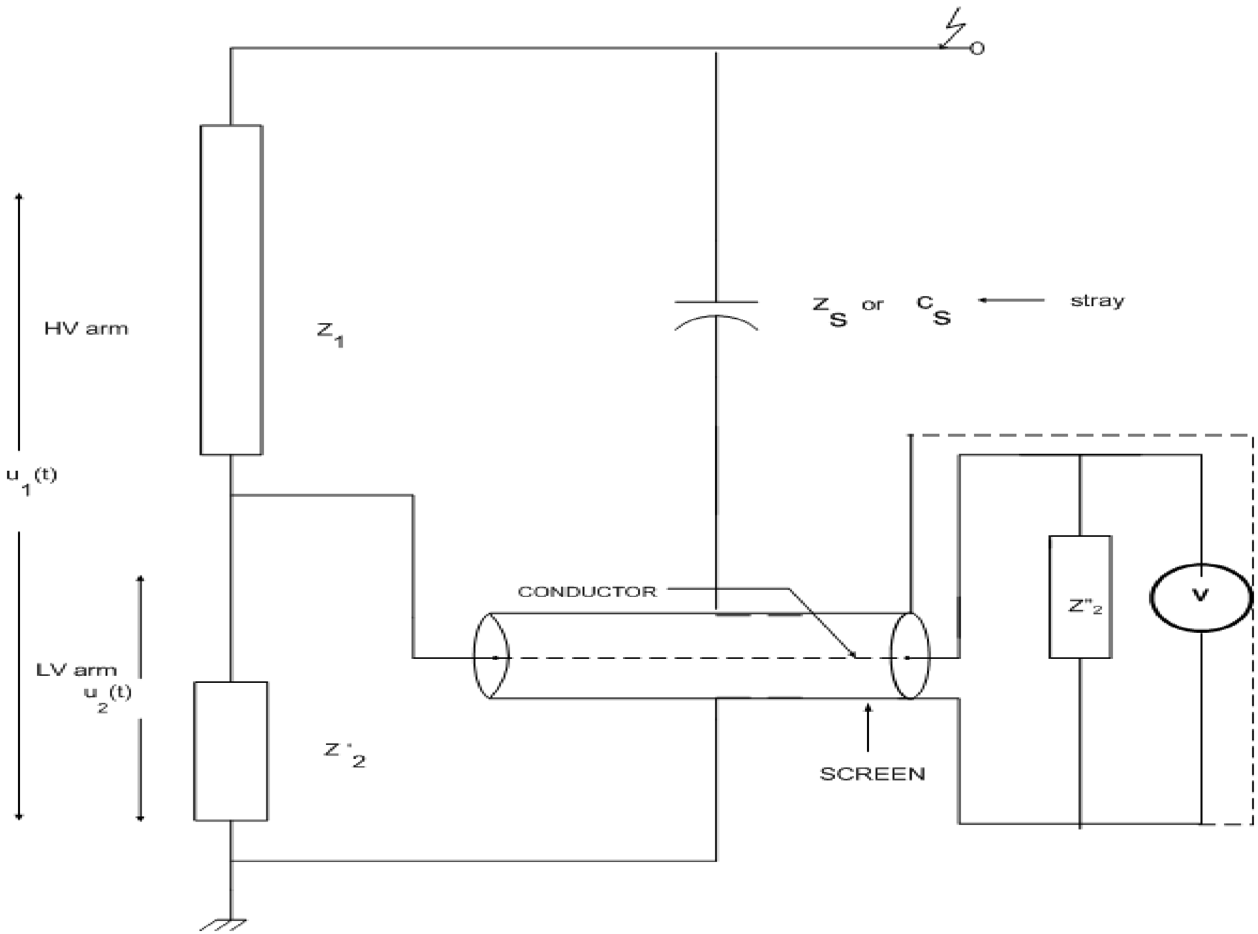
$$U_b = k_d \, U_{b0}$$

$$\delta = \frac{p}{p_0} \frac{273 + t_0}{273 + t} = \frac{p}{p_0} \cdot \frac{T_0}{T}$$

SPHERE GAPS



Potential divider for impulse voltage measurement



MEASUREMENT OF HIGH DIRECT CURRENTS

HALL GENERATORS FOR D.C CURRENT MEASUREMENTS

- Hall effect principle is used.If an electric current flows through a metal plate located in a magnetic field perpendicular to it,Lorenz forces will deflect the electrons in the metal structure in a direction normal to the direction of both the current and magnetic field.
- The charge displacement generates an emf in the normal direction (Hall voltage).
- $V_H=RB_i/d$
- $H=I/\delta$

MEASUREMENT OF HIGH POWER FREQUENCY ALTERNATING CURRENTS

- Current transformer is used.it uses electro optical technique.
- A voltage signal proportional to the measuring current is generated and it is transmitted to the ground side through electro optical device.
- Light pulses proportional to the voltage signal are transmitted by a glass optical fibre bundle to a photo detector and converted back into an analog voltage signal.

UNIT V

HIGH VOLTAGE TESTING OF ELECTRICAL APPARATUS

TESTS OF INSULATORS

- type test to check the design features
- routine test to check the quality of the individual test piece.
- High voltage tests include

(i) Power frequency tests

(ii) impulse tests

TESTS OF INSULATORS

POWER FREQUENCY TESTS

(a) Dry and wet flashover tests:

- a.c voltage of power frequency is applied across the insulator and increased at a uniform rate of 2% per second of 75%of ther estimated test voltage.
- If the test is conducted under normal conditions without any rain – dry flashover test.
- If the test is conducted under normal conditions of rain –wet flashover test

(b) Dry and wet withstand tests(one minute)

The test piece should withstand the specified voltage which is applied under dry or wet conditions.

IMPULSE TESTS ON INSULATORS

- Impulse withstand voltage test

  If the test object has withstood the subsequent applications of standard impulse voltage then it is passed the test
- Impulse flashover test

  The average value between 40% and 60% failure is taken,then the   insulator surface should not be damaged.
- Pollution Testing

  Pollution causes corrosion ,deterioration of the material,partial discharges and radio interference.Salt fog test is done.

TESTING OF BUSHINGS

Power frequency tests

(a) Power Factor-Voltage Test

Voltage is applied up to the line value in increasing steps and then reduced.The capacitance and power factor are recorded in each step.

(b) Internal or Partial discharge Test

This id done by using internal or partial discharge arrangement.

(c) Momentary Withstand Test at Power frequency

The bushing has to withstand the applied test voltage without flashover or puncture for 30 sec.

(d) One Minute withstand Test at Power Frequency

The bushing has to withstand the applied test voltage without flashover or puncture for 1min.

(d) Visible Discharge Test at Power Frequency

No discharge should be visible when standard voltage is applied.

IMPULSE VOLTAGE TESTS ON BUSHING

- Full wave Withstand Test

  The bushing is tested for either polarity voltages,5 consecutive full wave is applied, If the test object has withstood the subsequent applications of standard impulse voltage then it is passed the test.

- Chopped Wave Withstand and Switching Surge Tests

  It is same as full wave withstand test but it is done for high voltage bushings(220 kV and 400 kV)

IMPULSE VOLTAGE TESTS ON BUSHING

THERMAL TESTS ON BUSHING

Temperature Rise and Thermal Stability Tests

- Temperature rise test is done at temperature below 40^0C at a rated power frequency.The syteady temperature rise should not exceed 45^0C .
- Thermal st6ability tets is done for bushing rated for 132 kV above.

TESTING OF ISOLATORS AND CIRCUIT BREAKERS

Dielectric tests

Overvoltage withstand test of power frequency,lightning and switching impulse voltages.

The impulse test

impulse test and switching surge tests with switching over voltage are done.

Temperature and mechanical tests

tube tests s are done.

TESTING OF ISOLATORS AND CIRCUIT BREAKERS

Short circuit tests

(a) Direct tests

(b) using a short circuit generator as the source

(c) using the power utility system as the source.

SYNTHETIC TESTS
ON CIRCUIT BREAKER AND ISOLATOR

(a) Direct testing in the Networks or in the Fields

This is done during period of limited energy consumption or when the electrical energy is diverted to other sections of the network which are not connected to the circuit under the test.

(b) Direct Testing in short Circuit Test Laboratories

A make switch initiates the short circuit and the master c.b isolates the test device from the source at the end of predetermine time setnon a test controller.

SYNTHETIC TESTS ON CIRCUIT BREAKER AND ISOLATOR

(c) Synthetic Testing of Circuit Breakers

In the initial period of the short circuit test,a.c current source supplies the heavy current at a low voltage,and r5ecoveryvoltage is simulated by a source of high voltage of small current capadcity.

(d) Composite Testing

The C.B is tested first for its rated breaking capacity at a reduced voltageand afterwards for rated voltage at a low current.

(e) Unit Testing

When large C.B of very high voltage rating (220 kV and above) are to be tested and where more than one break is provided per pole,the breaker is tested for one break at its rated current and the estimated voltage.

SYNTHETIC TESTS
ON CIRCUIT BREAKER AND ISOLATOR

(f) Testing Procedure

The C.B are tested for their breaking capacity B and making capacity Mand it is tested for following duty cycle

(1) B-3-B-3-B at 10%of the rated symmetrical breaking capacity

(2) B-3-B-3-B at 30%of the rated symmetrical breaking capacity

(3) B-3-B-3-B at 60%of the rated symmetrical breaking capacity

(4) B-3-MB-3MB-MB0 at 10%of breaking capacity with the recovery voltage not less 95% of the rated service voltage

(g) Asymmetrical Tests

One test cycle is repeated for the asymmetrical breaking capacity in which the d.c component at the instant of contact separation is not less than 50% of the a.c component

TESTING OF 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

TETSING OF TRANSFORMERS

(a) Induced Over voltage Test

It is tested for overvoltages by exciting the secondary from a high frequency a.c source(100 to 400 Hz) to about twice the rated voltage.

(b) Partial Discharge Tests

It is done to assess the discharge magnitudes and radio interference levels.

TETSING OF TRANSFORMERS

IMPULSE TESTING OF TRANSFORMERS

(a) Procedure for Impulse Testing

- (i) applying impulse voltage of magnitude 75%of the BIL
- (ii) one full wave voltage of 100% BIL
- (iii) two chopped waves of 100% BIL
- (iv) one full wave voltage of 100% BIL
- (v) one full wave of 75% BIL

TETSING OF TRANSFORMERS

(b) Detection and Location of fault during impulse testing

The fault in a transformer insulation is located in impulse tests by any one of the following methods.

(i) General observations

(ii) Voltage oscillogram method

(iii) Neutral current method

(iv) Transferred surge current method

TESTING OF SURGE DIVERTERS

(i) Power frequency spark over test

It is a routine test. The test is conducted using a series resistance to limit the current in case a spark over occurs.It has to withstand 1.5 times the rated value of the voltage for 5 successive applications.

(ii) 100% standard impulse spark over test

This test is conducted to ensure that the diverter operates positively when over voltage of impulse nature occur.The test is done with both positive and negative polarity waveforms.The magnitude of the voltage at which 100% flashover occurs is the required spark over voltage.

TESTING OF SURGE DIVERTERS

(iii) Residual volatge test

This test is conducted on pro rated diverters of ratings in the range 3 to 12 kV only.standard impulse currents of the rated magnitudes are applied,voltage across it is recorded.

V1=rating of the complete unit

V2=rating of the prorated unit tested

V_{R1}=residual voltage of the complete unit

V_{R2}=residual voltage of the complete unit

$V1/V2 = V_{R1}/V_{R2}$

HIGH CURRENT IMPULSE TEST ON SURGE DIVERTERS

The unit is said to pass the test if

(i) the power frequency sparkover voltage before and after the test does not differ by more than 10%

(ii) The voltage and current waveforms of the diverter do not differ in the 2 applications

(iii) the non linear resistance elements do not show any puncture or flashover

HIGH CURRENT IMPULSE TEST ON SURGE DIVERTERS

(a) Long Duration Impulse Current Test

(b) Operating Duty Cycle Test

(c) Other tests are

(1) mechanical tests like porosity test,temperature cycle tests

(2) pressure relief test

(3) the voltage withstand test on the insulator housing of the insulator

(4) the switching surge flashover test

(5) the pollution test

INSULATION CO-ORDINATION

- A gradation of system insulation and protective device operation is to be followed.
- Substations contain transformers and switchgear with non-self restoring insulation should be protected against flashover
- For other apparatus which contain self restoring insulation may be allowed to flashover.
- Lightning impulse withstand level known as Basic Insulation Level(BIL).Various equipment and their component parts should have their BIL above the system protective level by a margin which is determined with respect to air insulation.

INSULATION CO-ORDINATION

- For higher system voltages,switching surges are of higher magnitude compared to the lightning over voltages.
- The flashover voltage of a protective device is chosen such that it will not operate for switching overvoltage and other power frequency and its harmonic overvoltages.BIL has to higher.
- For EHV systems,Switching Impulse Level(SIL) should be assigned to each protective device.

Thank You