CMR
INSTITUTE OF
TECHNOLOGY

USN

Internal Test3 –January 2023

Sub:	High Voltage Engineering							Code:	18EE56
Date:	19/01/2023	Duration:	90 mins	Max Marks:	50	Sem:	**V**	Branch:	EEE

Note: Answer any FIVE full questions with neat diagram wherever necessary.

		Marks	OBE CO	OBE RBT
1.	What are partial discharges? How are they detected using balance detection method?	[2+8]	CO6	L2

Earlier the testing of insulators and other equipment was based on the insulation resistance measurements, dissipation factor measurements and breakdown tests.

It was observed that the dissipation factor (tan δ) was voltage dependent and hence became a criterion for the monitoring of the high voltage insulation weak points in an insulation like voids, cracks, and other imperfections lead to internal or intermittent discharges in the insulation. These imperfections being small were not revealed in capacitance measurements but were revealed as power loss components in contributing for an increase in the dissipation factor. In modern terminology these are designated as "**partial discharges"** which in course of time reduce the strength of insulation leading to a total or **partial failure or breakdown of the insulation**

Balanced Detection Method

In the straight detection method, the external disturbances are not fully rejected.

The filter used to block the noise sources may not be effective.

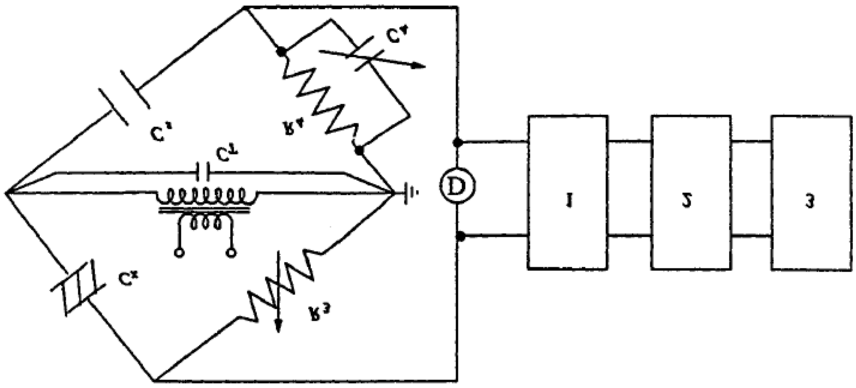
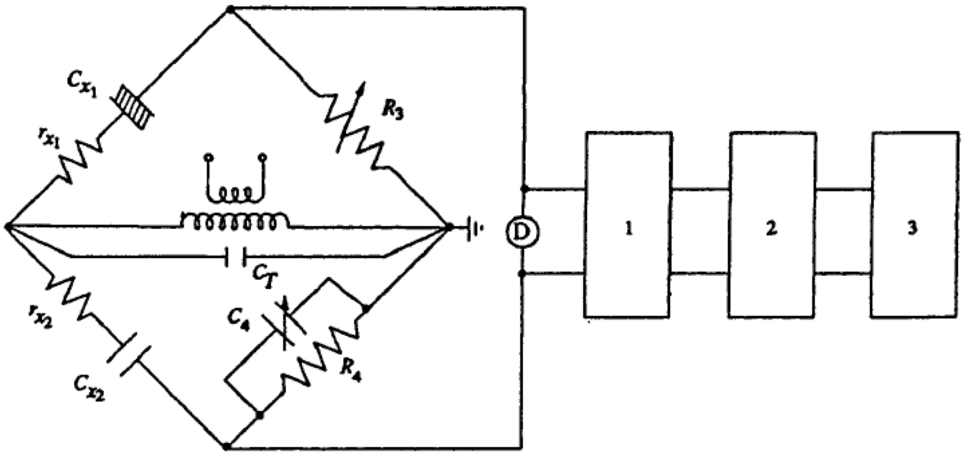
The Schering bridge employed for the tan δ measurement is sometimes used.

In this method, the test object is not grounded. A **modification** to the Schering bridge detector is **the differential discharge detector,** given by Kreuger. Both the schemes are given in Fig. 9.23. The bridges are tuned and balanced at 50 Hz.

A filter is used across the detector terminals to block the 50 Hz components present Signals in the range from 5 to 50 kHz are allowed to pass through the filter and amplified.

The CRO gives the display of the pulse pattern. Any external interference from outside is balanced out, and only internally (test piece) generated pulses are detected. In the modified scheme, another test sample called dummy sample is used in the place of the standard condenser. The capacitance and tan δ of the dummy sample are made approximately equal, but need not be equal. **The disadvantage is that if two discharges occur in both the samples simultaneously, they cancel out, but this is very rare.**

The main advantage of the second method is its capacity for better rejection of external noise and use of the wide frequency band with belter resolution of the individual pulses.

	D — Power frequency detector 1 — Filter (band pass) 2 — Amplifier 3 — Display unit — CRO or counter  (a) Balanced detector using Schering bridge  (b) Differential detector **Fig. 9.23** Balanced discharge detector schemes			
2.	What are the causes for power frequency over voltages? How are they controlled in power systems? **The power frequency overvoltages occur in large power systems and they are of much concern in EHV systems, i.e. systems of 400 kV and above. The main causes for power frequency and its harmonic overvoltages are** **(a) sudden loss of loads,** **(b) disconnection of inductive loads or connection of capacitive loads,** **(c) Ferranti effect, unsymmetrical faults, and** **(d) saturation in transformers, etc.** **Overvoltages of power frequency harmonics and voltages with frequencies nearer to the operating frequency are caused during tap changing operations, by magnetic or ferro-resonance phenomenon in large power transformers, and by resonating overvoltages due to series capacitors with shunt reactors or transformers.** **The duration of these overvoltages may be from one to two cycles to a few seconds**	[5+5]	CO5	L2

depending on the overvoltage protection employed.

(a) Sudden Load Rejection

Sudden load rejection on large power systems causes the speeding up of generator prime movers. The speed governors and automatic voltage regulators will intervene to restore normal conditions. But initially both the frequency and voltage increase.

The approximate voltage rise, neglecting losses, etc. may be taken as

$$v = \frac{f}{f_0} E' \left[\left(1 - \frac{f}{f_0} \right) \frac{x_s}{x_c} \right]$$

where xs is the reactance of the generator (« the sum of the transient reactances of the generator and the transformer), xc is the capacitive reactance of the line at open end at increased frequency, E' the voltage generated before the over-speeding and load rejection, f is the instantaneous increased frequency, and fo is the normal frequency.

(b) Ferranti Effect

Long uncompensated transmission lines exhibit voltage rise at the receiving end. The voltage rise at the receiving end V2 is approximately given by

$$V_2 = \frac{V_1}{\cos \beta l}$$

where, V_1 = sending end voltage,

l = length of the line,

β = phase constant of the line

$$\approx \left[\frac{(R + j\,\omega L)(G + j\,\omega C)}{LC} \right]^{1/2}$$

$\approx$ about 6° per 100 km line at 50 Hz frequency.

ω = angular frequency for a line

R — Resistance per unit length

L — Inductance per unit length

C — Capacitance per unit length

G — Leakage conductance per unit length

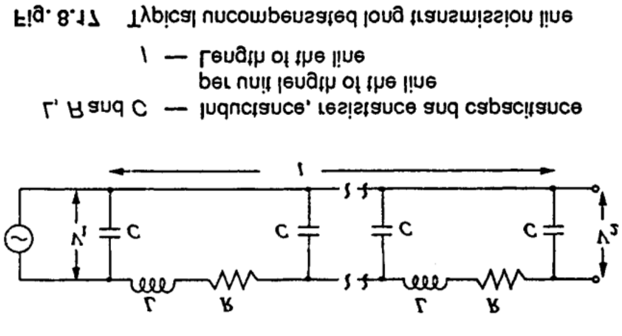


Fig. 8.17 Typical uncompensated long transmission line

L, R and C — inductance, resistance and capacitance per unit length of the line

l — length of the line

Ground Faults and Their Effects

Single line to ground faults cause rise in voltages in other healthy phases. Usually, with solidly grounded systems, the increases in voltage (phase to ground value) will be less than the line-to-line voltage. With effectively grounded systems, i.e. with

$$\frac{X_0}{X_1} \leq 3.0 \text{ and } \frac{R_0}{X_1} \leq 1.0$$

Saturation Effects

When voltages above the rated value are applied to transformers, their magnetizing currents (no load currents also) increase rapidly and may be about the full rated current for 50% overvoltage.

These magnetizing currents are not sinusoidal in nature but are of a peaky waveform.

The third, fifth, and seventh harmonic contents may be 65%, 35%, and 25% of the exciting current of the fundamental frequency corresponding to an overvoltage of 1.2 p.u.

For third and its multiple harmonics, zero sequence impedance values are effective, and delta connected windings suppress them.

But the shunt connected capacitors and line capacitances can form resonant circuits and cause high third harmonic overvoltages.

When such overvoltages are added, the voltage rise in the lines may be significant. For higher harmonics a series resonance between the transformer inductance and the line capacitance can occur which may produce even higher voltages.

Control of Overvoltages Due to Switching

The overvoltages due to switching and power frequency may be controlled by

(a) energization of transmission lines in one or more steps by inserting resistances and withdrawing them afterwards,

(b) phase controlled closing of circuit breakers,

(c) drainage of trapped charges before reclosing,

(d) use of shunt reactors, and

(e) limiting switching surges by suitable surge diverters

Insertion of Resistors

It is normal and a common practice to insert resistances in series with circuit breaker contacts when switching on but short circuiting them after a few cycles.

This will reduce the transients occurring due to switching.

The voltage step applied is first reduced to Z0/(R + Z0) per unit where Z0 is the surge impedance of the line.

It is reflected from the far end unchanged and again reflected back from the near end with reflection factor (R – Z0)/(R+ Z0) per unit.
If R = Z0, there is no reflection from the far end.
The applied step at the first instance is only 0.5 per unit.
When the resistor is short circuited, a voltage step equal to the instantaneous
voltage drop enters the line.
If the resistor is kept for a duration larger than 5ms (for 50 Hz sine wave = 1/4 cycle duration), it can be shown from successive reflections and transmissions, that the overvoltage may reach as high as 1.2 p.u. for a line length of 500 km.
But for conventional opening of the breaker, the resistors have too high an ohmic value to be effective for resistance closing.
Therefore, pre-insertion of suitable value resistors in practice is done to limit the overvoltage to less than 2.0 to 2.5 p.u.
Normal time of insertion is 6 to 10 m s.

Phase Controlled Switching
Overvoltages can be avoided by controlling the exact instances of the closing of the three phases separately.
But this necessitates the use of complicated controlling equipment and therefore is not adopted.

(c) Drainage of Trapped Charge
When lines are suddenly switching off, "electric charge" may be left on capacitors and line conductors. This charge will normally leak through the leakage path of the insulators, etc.
Conventional potential transformers (magnetic) may also help the drainage of the charge.
An effective way to reduce the trapped charges during the lead time before reclosing is by temporary insertion of resistors to ground or in series with shunt reactors and removing before the closure of the switches.

d)Shunt Reactors
Normally all EHV lines will have shunt reactors to limit the voltage rise due to the Ferranti effect.
They also help in reducing surges caused due to sudden energizing.
However, shunt reactors cannot drain the trapped charge but will give rise to oscillations with the capacitance of the system.
Since the compensation given by the reactors will be less than 100%, the frequency of oscillation will be less than the power frequency and overvoltages produced may be as high as 1.2 p.u.
Resistors in series with these reactors will suppress the oscillations and limit the over voltages.
Limiting the switching and power frequency over voltages by using surge diverters

3.	What is a surge diverter? Explain its function as a shunt protective device.	[3+7]	CO5	L2

Surge Diverters

These are non-linear resistors in series with spark gaps which act as fast switches. A typical surge diverter or lightning arrester is shown in Fig. 8.23 and its characteristics are given in Fig. 8.24. A number of non-linear resistor elements made of silicon carbide are stacked one over the other into two or three sections. They are usually separated by spark gaps (see Fig. 8.23). the entire assembly is housed in a porcelain water-tight housing. The volt-ampere characteristic of a resistance element is of the form

$$I = kV^{a}$$

where, I= discharge current,
V = applied voltage across the element, and
k and a are constants depending on the material and dimensions of the element.

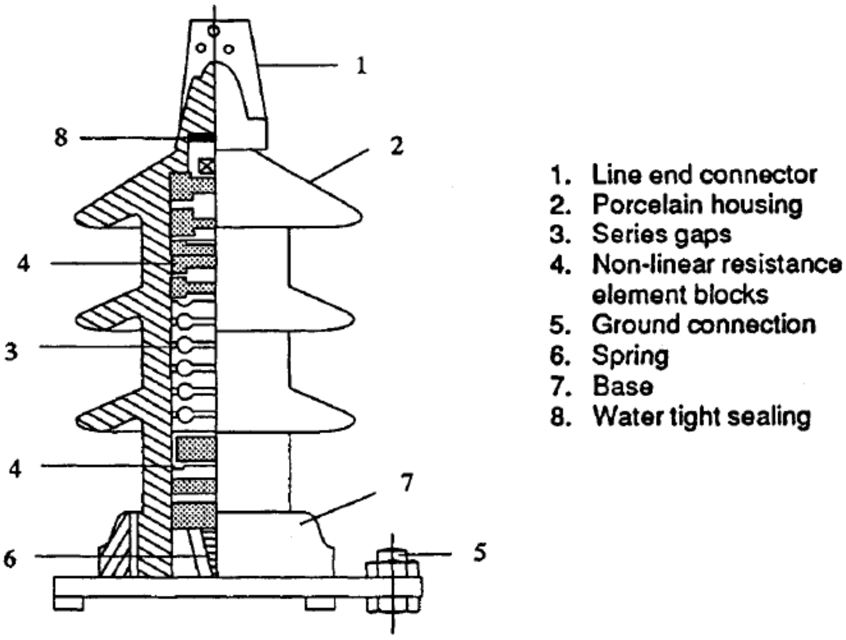


Fig. 8.23 Non-linear element surge diverter

When a surge voltage (Vi of Fig. 8.24b) is applied to the surge diverter, it breaks down giving the discharge current id and maintains a voltage Vd across it Thus, it provides a protection to the apparatus to be protected above the protective level Vp
The lighter designs operate for smaller duration of currents, while the heavy duty surge diverters with assisted or active gaps are designed for high currents and long duration surges.
The lighter design arresters can interrupt 100 to 300 A of power frequency follow-on current and about 5000 A of surge currents.
If the current is to be more and has to be exceeded, the number of series elements has to be increased or some other method to limit the current has to be used. In heavy duty arresters, the gaps are so arranged that the arc burns in the magnetic field of the coils excited by power
frequency follow-on currents.
During lightning discharges, a high voltage is induced in the coil by the steep front of the surge, and sparking occurs in an auxiliary gap.
For power frequency follow-on currents, the auxiliary gap is extinguished, as sufficient voltage will not be present across the auxiliary gap to maintain an arc.
The main gap arcs occur in the magnetic field of the coils.

The magnetic field, aided by the born shaped main gap electrodes, elongates the arc and quenches it rapidly.

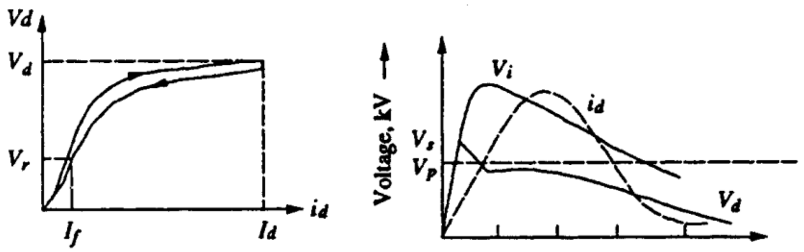
The follow-on current is limited by the voltage drop across the arc and the resistance element.

During surge discharge the lightning protective level becomes low.

Sometimes, it is possible to limit the power frequency and other overvoltages after a certain number of cycles using surge diverters.

The permissible voltage and duration depend on the thermal capacity of the diverter.

The rated diverter voltage is normally chosen so that it is not less than the power frequency overvoltage expected (line to ground) at the point of installation, under any faulty or abnormal operating condition.



(a) Volt-ampere characteristic of a non-linear resistor block

(b) Surge diverter operation

I_f — Power frequency follow-on current at system voltage V_r

V_d — Max. voltage across the diverter during discharge of surge current with peak value I_d

V_s — Sparkover voltage

V_p — Protective level

V_i — Surge voltage

i_d — Discharge current

V_d — Voltage across the diverter when discharging the current i_d

Fig. 8.24 Characteristics of a surge diverter

---

4. A transmission line has the following line constants R = 0.1 ohm/km, L = 1.26 mH/km, C = 0.009 |μF/km, and G=0. If the line is a 3-phase line and is charged from one end at a line voltage of 230 kV, find the rise in voltage at the other end, if the line length is 400 km. [10] CO5 L3

Solution: ***Method I***: Neglecting the resistance of the line,

$$V_2 = V_1\left(1 - \frac{X_L}{2X_C}\right)$$

$$X_L = j\omega L = j(314)\,(1.26\times 10^{-3}\ \times 400) = j\,158.26\,\Omega$$

$$X_C = -j/\omega C = -j\,(10^6/314\times 0{:}009\times 400) = -j\,884.6\,\Omega$$

$$\therefore \quad V_2 = V_1\left[1 - \frac{j\,158.26}{2(-j\,884.6)}\right]$$

$$= V_1\,(1 + 0.0896)$$

The given line voltage = 230 kV

$$\therefore \quad \text{phase voltage} = \frac{230}{\sqrt{3}} = 132.8\text{ kV}$$

Hence, the rise in voltage $= 0.0896\times 132.8$ kV

$= 11.9$ kV

---

5. Explain the working principle and construction of Electrostatic Voltmeter with a neat diagram. Mention advantages. [4+4+2] CO4 L2

ELECTROSTATIC VOLTMETER

D–Metal Dome

M-mounting Plate

G –guard plate

P –Fixed Plate

H- Guard loop or ring

B-Balance

C-Capacitance Divider

W Balancing Weight

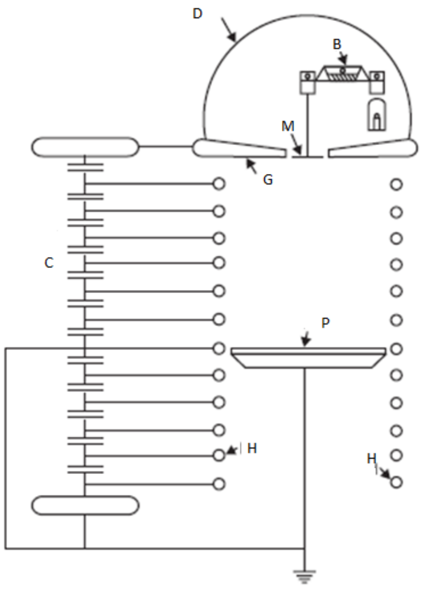


Fig. 4.7 Schematic diagram of electrostatic voltmeter

Fig. shows a schematic diagram of an absolute electrostatic voltmeter.

The hemispherical metal dome D encloses a sensitive balance B which measures the force of attraction between the movable disc which hangs from one of its arms and the lower plate P.

The movable electrode M hangs with a clearance of above 0.01 cm, in a central opening in the upper plate which serves as a guard ring.

The diameter of each of the plates is 1 metre.

Light reflected from a mirror carried by the balance beam serves to magnify its motion and to indicate to the operator at a safe distance when a condition of equilibrium is reached.

As the spacing between the two electrodes is large (about 100 cms for a voltage of about 300 kV), the uniformity of the electric field is maintained by the guard rings G which surround the space between the discs M and P.

The guard rings G are maintained at a constant potential in space by a capacitance divider ensuring a uniform spatial potential distribution.

When voltages in the range 10 to 100 kV are measured, the accuracy is of the order of 0.01 per cent.

rinciple: The electric field according to Coulomb is the field of forces. The electric field is produced by voltage and, therefore, if the field force could be measured, the voltage can also be measured.

The voltmeters are used for the measurement of high a.c. and d.c. voltages. The measurement of voltages lower than about 50 volt is, however, not possible, as the forces become too small.

When a voltage is applied to a parallel plate electrode arrangement, an electric field is set up between the plates.

It is possible to have uniform electric field between the plates with suitable arrangement of the plates.

The field is uniform, normal to the two plates and directed towards the negative plate.

If A is the area of the plate and E is the electric field intensity between the plates ε the permittivity of the medium between the plates, we know that the energy density of the electric field between the plates is given as,

$$W_d = \frac{1}{2}\varepsilon E^2$$

Consider a differential volume between the plates and parallel to the plates with area A and thickness dx, the energy content in this differential volume Adx is

$$dW = W_d A dx = \frac{1}{2}\varepsilon E^2 A dx$$

Now force F between the plates is defined as the derivative of stored electric energy along the field direction i.e.,

$$F = \frac{dW}{dx} = \frac{1}{2}\varepsilon E^2 A$$

Now E = V/d where V is the voltage to be measured and d the distance of separation between the plates. Therefore, the expression for force

$$F = \frac{1}{2}\varepsilon \frac{V^2 A}{d^2}$$

Since the two plates are oppositely charged, there is always force of attraction between the plates.

If the voltage is time dependant, the force developed is also time dependant. In such a case the mean value of force is used to measure the voltage. Thus

$$F = \frac{1}{T}\int_0^T F(t)dt = \frac{1}{T}\int \frac{1}{2}\,\varepsilon\,\frac{V^2(t)}{d^2}\,A\,dt = \frac{1}{2}\frac{\varepsilon A}{d^2}\cdot\frac{1}{T}\int V^2(t)dt = \frac{1}{2}\,\varepsilon A\,\frac{V_{rms}^2}{d^2}$$

Electrostatic voltmeters measure the force based on the above equations and are arranged such that one of the plates is rigidly fixed whereas the other is allowed to move.

With this the electric field gets disturbed.

For this reason, the movable electrode is allowed to move by not more than a fraction of a millimetre to a few millimetres even for high voltages so that the change in electric field is negligibly small.

As the force is proportional to square of Vrms, the meter can be used both for a.c. and d.c. voltage measurement

advantage of the electrostatic voltmeter is its extremely low loading effect as only electric fields are required to be set up.

Because of high resistance of the medium between the plates, the active power loss is negligibly small.

The voltage source loading is, therefore, limited only to the reactive power required to charge the instrument capacitance which can be as low as a few picofarads for low voltage voltmeters.

The measuring system as such does not put any upper limit on the frequency of supply to be measured. However, as the load inductance and the measuring system capacitance form a series resonance circuit, a limit is imposed on the frequency range.

For low range voltmeters, the upper frequency is generally limited to a few MHz

6 Write short notes on a. Transformer Ratio Arm Bridge, b. Chubb Fortescue method [5+5] CO4 L2

Transformer Ratio Arm Bridges

- It is a common practice to use the four arm Wheatstone bridge network for a.c. measurements.
- In high frequency measurements, the arms with high values of resistances lead to difficulties due to their residual inductances, capacitances, and skin effect.
- shielding and grounding becomes difficult in large arms.
- at high frequencies the transformer ratio arm bridges which eliminate at least two arms are preferred.
- These bridges are also **useful for the measurement of low value of capacitances** accurately.
- The ratio arm bridges can be either **voltage ratio type** or **current ratio type**;
- the former being used for high frequency low voltage applications.
- The schematic diagram of a ratio arm bridge (voltage ratio) is given in Fig. 9.18.

- Assuming ideal transformer conditions, for a null indication of the detector

$$\frac{V_s}{V_x}=\frac{N_s}{N_x}=\frac{C_x}{C_s};\ \text{and}\ \frac{R_x}{R_a}=\frac{N_x}{N_a}$$

- In practical transformers, the voltage ratio slightly differs from the turns ratio due to the no load magnetizing current and is also affected by the load current
- the balance conditions shown above involve errors.
- The errors are classified as the ratio and loading errors and are determined separately and compensated for in the construction.

For high voltage applications where sensitive measurements at fixed frequency (at 50 Hz) are required, the current comparator or the current ratio method (Fig. 9.19a) is used.

This bridge has the advantage that full voltage is applied across the test capacitor but also has the drawback that a standard conductance has to be built for high voltages.

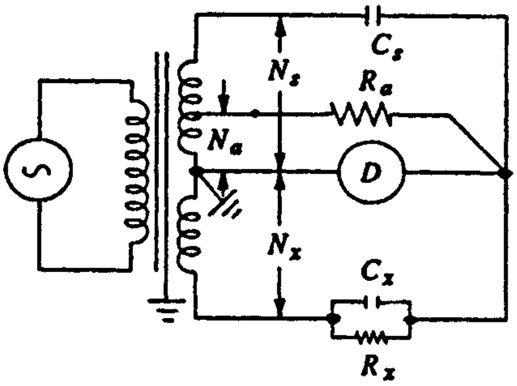
It is difficult to construct a precision conductance suitable for high voltage operation.

This disadvantage is overcome by generating a low voltage signal Ef proportional to and in phase with the supply voltage as shown in the modified Fig. 9.19b

where Cx and CSare unknown and standard capacitances respectively,

Rx and Ra are unknown and standard resistances,

Nx, Na and Ns are the corresponding turns of the transformer ratio windings



THE CHUBB-FORTESCUE METHOD

Chubb and Fortescue suggested a simple and accurate method of measuring **peak value of a.c. voltages.**

The basic circuit consists of a standard capacitor, two diodes and a current integrating ammeter (MC ammeter) as shown in Fig. 4.11 (a).

The displacement current ic(t), Fig. 4.12 is given by the rate of change of the charge and hence the voltage V(t) to be measured flows through the high voltage capacitor C and is subdivided into positive and negative components by the back to back connected diodes.

- The voltage drop across these diodes can be neglected (1 V for Si Diodes) as compared with the voltage to be measured.
- The measuring instrument (M.C. ammeter) is included in one of the branches.
- The ammeter reads the mean value of the current.

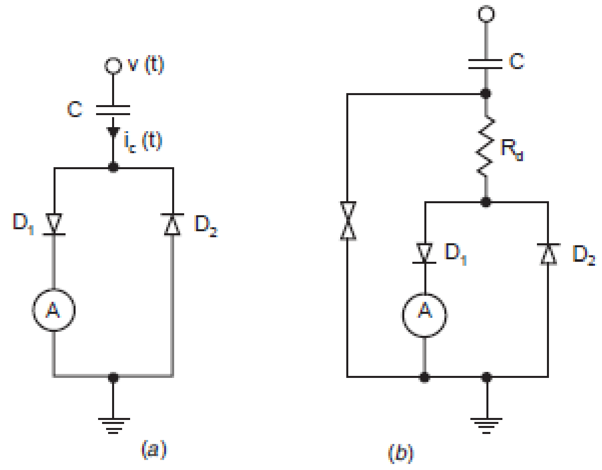
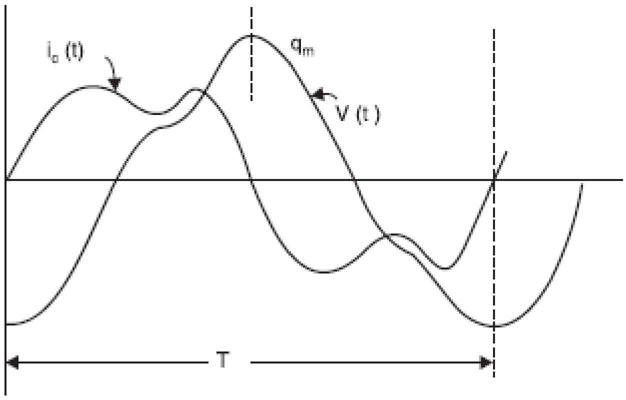


Fig. 4.11 (*a*) Basic circuit (*b*) Modified circuit

$$I = \frac{1}{T}\int_{t_1}^{t_2} C\,\frac{dv(t)}{dt}\,.\,dt = \frac{C}{T}\,.\,2V_m = 2V_m fC \text{ or } V_m = \frac{I}{2fC}$$



7 Explain with a neat diagram sphere gap method for measuring high voltage. Explain briefly the factors affecting the measurement. [10] CO4 L2

MEASUREMENT OF HVAC AND HVDC AND IMPULSE VOLTAGE USING SPHERE GAP

- Sphere gap is by now considered as one of the standard methods for the measurement of peak value of **d.c, a.c and impulse voltages** and is used for checking **the voltmeters and other voltage measuring devices** used in high voltage test circuits.

- Two identical metallic spheres separated by certain distance form a sphere gap.

- The sphere gap can be used for measurement of impulse voltage of either polarity provided that the impulse is of a standard wave form and has wave front time at least 1 micro sec. and wave tail time of 5 micro sec.
- **the gap length between the sphere should not exceed a sphere radius**.
- If these conditions are satisfied and the specifications regarding the shape, mounting, clearances of the spheres are met, the results obtained by the use of sphere gaps are reliable to within ±3%.
- in standard specification that in places where the availability of ultraviolet radiation is low, irradiation of the gap by radioactive or other ionizing media should be used when voltages of magnitude less than 50 kV are being measured or where higher voltages with accurate results are to be obtained

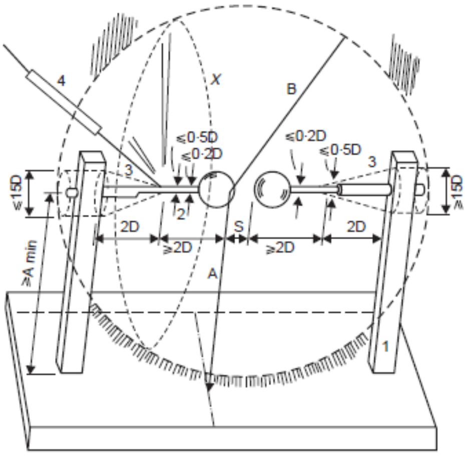


Fig. 4.1

- For the **measurement of a.c. or d.c. voltage, a reduced voltage is applied** to begin with so that the **switching transient does not flash over the sphere gap** and then the voltage is **increased gradually till the gap breaks down**.
- **Alternatively** the **voltage is applied across a relatively large gap** and the **spacing** is then **gradually decreased** till the gap breaks down. Corresponding to this gap the value of peak voltage can be read out from the calibration tables.
- The calibration tables values correspond to 760 mm Hg pressure and 20°C temperature.
- Any deviation from the value, a correction factor will have to be used to get the correct value of the voltage being measured.

The breakdown voltage of a sphere gap increases with increase in pressure and decreases with increase in temperature.

.

For small variation in temperatures and pressures, the disruptive voltage

is closely proportional to the relative air density. The relative air density δ is given by

$$\delta = \frac{293b}{760\,(273+t)}$$

Various factors that affect the sparkover voltage of a sphere gap are:

(i) nearby earthed objects,

(ii) atmospheric conditions and humidity,

(iii) irradiation, and

(i v) polarity and rise time of voltage waveforms.

Effect of nearby earthed objects

The effect of nearby earthed objects was investigated by Kuffel by enclosing the earthed sphere inside an earthed cylinder.

It was observed that the sparkover voltage is reduced.

The reduction was observed to be

$$\Delta V = m \log (B/D) + C$$

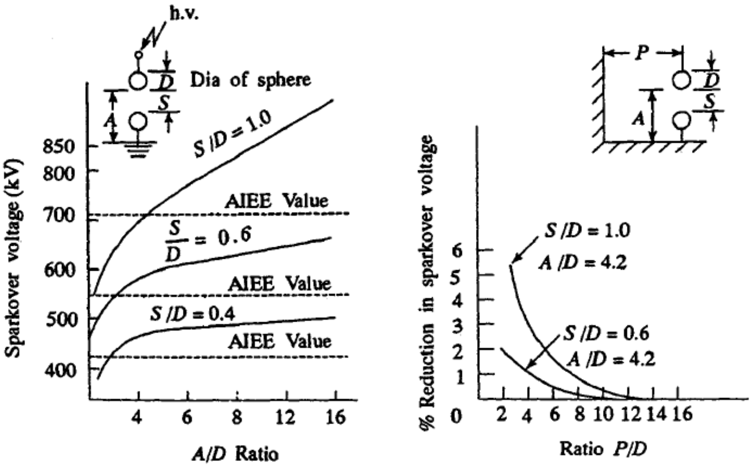
where,

$\Delta V =$ percentage reduction,

$B =$ diameter of earthed enclosing cylinder,

$D =$ diameter of the spheres,

$S =$ spacing, and m and C are constants.



(a) (b)

(ii) Effect of atmospheric conditions

he sparkover voltage of a spark gap depends on the air density which varies with the changes in both temperature and pressure.

Let sparkover voltage = V under test conditions of temperature T and pressure p torr sparkover voltage =V0 under standard conditions of temperature T = 2O°C and pressure p = 760 torr, then V=kV0

where k is a function of the air density factor d, given by

$$d = \frac{p}{760}\left(\frac{293}{273+T}\right)$$

Influence of Humidity

Kuffel has studied the effect of the humidity on the breakdown voltage by using spheres of 2 cms to 25 cms diameters and uniform field electrodes.

The effect was found to be maximum in the region 0.4 mm Hg. and thereafter the change was decreased.

Between 4–17 mm Hg. the relation between breakdown voltage and humidity was practically linear for spacing less than that which gave the maximum humidity effect.

Fig. 4.4 shows the effect of humidity on the breakdown voltage of a 25 cm diameter sphere with spacing of 1 cm when a.c. and d.c voltages are applied.

It can be seen that

(i) The a.c. breakdown voltage is slightly less than d.c. voltage.

(ii) The breakdown voltage increases with the partial pressure of water vapour.

It has also been observed that

(i) The humidity effect increases with the size of spheres and is largest for uniform field electrodes.

(ii) The voltage change for a given humidity change increase with gap length.

The increase in breakdown voltage with increase in partial pressure of water vapour and this increase in voltage with increase in gap length is due to the relative values of ionisation and attachment coefficients in air.

The water particles readily attach free electrons, forming negative ions.

The molecules under field conditions in which electrons will readily ionise.

It has been seen ions therefore slow down and are unable to ionise neutral observed that within the humidity range of 4 to 17 g/m3 (relative humidity of 25 to 95% for 20°C temperature) the relative increase of breakdown voltage is found to be between 0.2 to 0.35% per gm/m3 for the largest sphere of diameter 100 cms and gap length upto 50 cms.

Influence of Dust Particles

When a dust particle is floating between the gap this results into erratic breakdown in homogeneous or slightly in homogenous electrode configurations.

When the dust particle comes in contact with one electrode under the application of d.c. voltage, it gets charged to the polarity of the electrode and gets attracted by the opposite electrode due to the field forces and the breakdown is triggered shortly before arrival.

Gaps subjected to a.c. voltages are also sensitive to dust particles but the probability of erratic breakdown is less.

Under d.c. voltages erratic breakdowns occur within a few minutes even for voltages as low as 80% of the nominal breakdown voltages.

This is a major problem, with high d.c. voltage measurements with sphere gaps.

Effect of Irradiation

Illumination of sphere gaps with ultra-violet or x-rays aids easy ionization in gaps.

The effect of irradiation is pronounced for small gap spacings.

A reduction of about 20% in sparkover voltage was observed for spacings of 0.1 D to 0.3 D for a 1.3 cm sphere gap with d.c. voltages.

The reduction in sparkover voltage is less than 5% for gap spacings more than 1 cm, and for gap spacings of 2 cm or more it is about 1.5%.

Hence, irradiation is necessary for smaller sphere gaps of gap spacing less than 1 cm for obtaining consistent values.

Effect of polarity and waveform

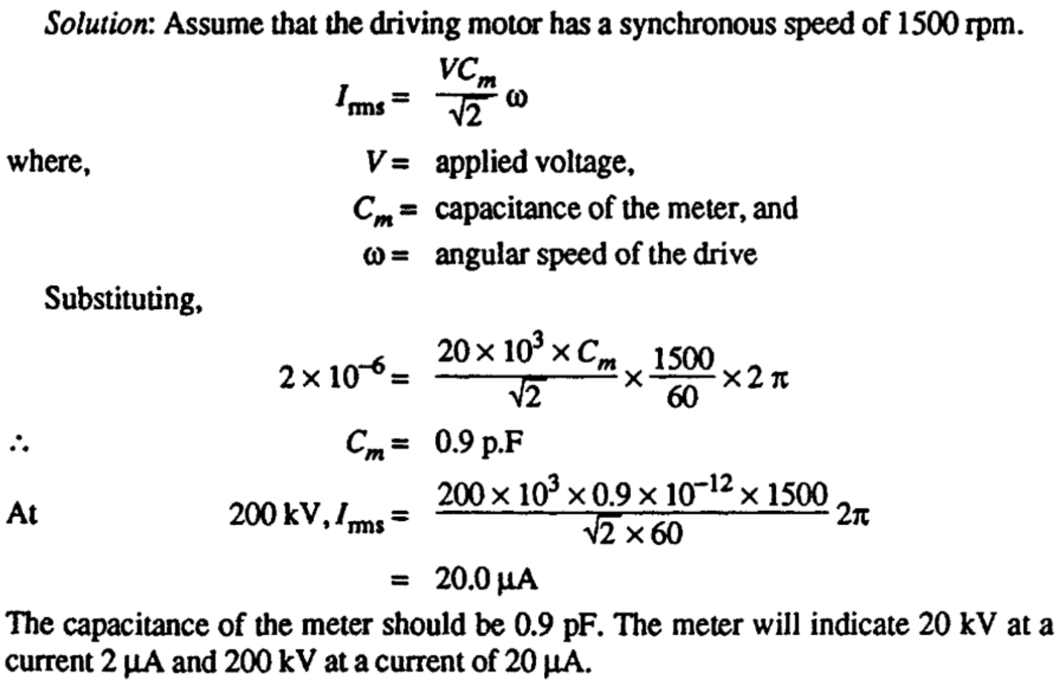
It has been observed that the sparkover voltages for positive and negative polarity impulses are different.

Experimental investigation showed that for sphere gaps of 6.25 to 25 cm diameter, the difference between positive and negative d.c. voltages is not more than 1%.

For smaller sphere gaps (2 cm diameter and less) the difference was about 8% between negative and positive impulses of 1/50 μs waveform.

the wave front and wave tail durations also influence the breakdown voltage.

For wave fronts of less than 0.5 μs and wave tails less than 5 μs the breakdown voltages are not consistent and hence the use of sphere gap is not recommended for voltage measurement in such cases.

8	A generating voltmeter has to be designed so that it can have a range from 20 to 200 kV d.c. If the indicating meter reads a minimum current of 2 µA and maximum current of 25 µA, what should the capacitance of the generating voltmeter be?  *Solution*: Assume that the driving motor has a synchronous speed of 1500 rpm. $I_{rms} = \frac{VC_m}{\sqrt{2}} \omega$ where, $V =$ applied voltage, $C_m =$ capacitance of the meter, and $\omega =$ angular speed of the drive Substituting, $2 \times 10^{-6} = \frac{20 \times 10^3 \times C_m}{\sqrt{2}} \times \frac{1500}{60} \times 2\pi$ ∴ $C_m =$ 0.9 p.F At 200 kV, $I_{rms} = \frac{200 \times 10^3 \times 0.9 \times 10^{-12} \times 1500}{\sqrt{2} \times 60} 2\pi$ = 20.0 µA The capacitance of the meter should be 0.9 pF. The meter will indicate 20 kV at a current 2 µA and 200 kV at a current of 20 µA.	[10]	CO4	L3