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Electrical and Electronics engineering

IV YEAR/ VIIth Semester

EE8701 HIGH VOLTAGE ENGINEERING

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TOPIC NAME

UNIT 04 –MEASUREMENT OF HIGH VOLTAGES AND HIGH CURRENTS

"**Learning** is not attained by chance, it must be sought for with ardor and attended to with diligence."

—Abigail Adams

MEASUREMENT OF HIGH VOLTAGES AND HIGH CURRENTS

High Resistance with series ammeter–Dividers, Resistance, Capacitance and Mixed dividers- Peak Voltmeter, Generating Voltmeters-Capacitance Voltage Transformers, Electrostatic Voltmeters– Sphere Gaps- High current shunts- Digital techniques in high voltage measurement.

MEASUREMENT OF HIGH DC VOLTAGE

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

SERIES RESISTANCE MICROMETER

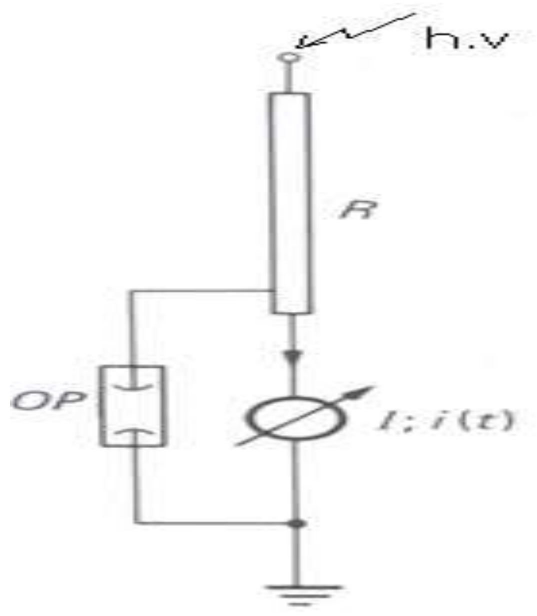
The voltage drop in the meter is negligible, as the impedance of the meter is only few ohms compared to few hundred megaohms of the series resistance *R*. A protective device like a paper gap, a neon glow tube, or a zener diode with a suitable series resistance is connected across the meter as a protection against high voltages in case the series resistance *R* fails or flashes over.

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.



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- The limitations in the series resistance design are

(i) power dissipation and source loading,

(ii) temperature effects and long time stability,

(iii) voltage dependence of resistive elements, and

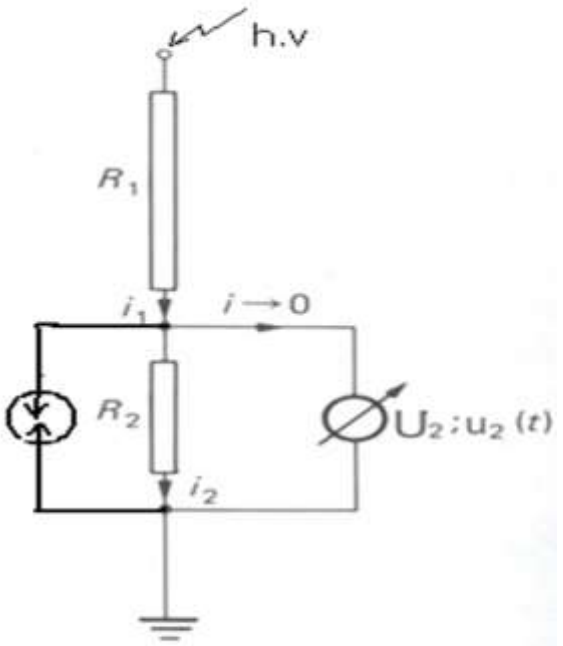
(iv) sensitivity to mechanical stresses.

Series resistance meters are built for 500 kV dc with an accuracy better than 0.2%.

RESISTANCE POTENTIAL DIVIDER

The influence of temperature and voltage on the elements is eliminated in the voltage divider arrangement. The high-voltage magnitude is given by [(R1 + R2)/R2] v2, where v2 is the dc voltage across the low-voltage arm R2. With sudden changes in voltage, such as switching operations, flashover of the test objects, or source short circuits, flashover or damage may occur to the divider elements due to the stray capacitance across the elements and due to ground capacitances.

RESISTANCE POTENTIAL DIVIDER



GENERATING VOLTMETERS

High-voltage measuring devices employ generating principle when source loading is prohibited (as with Van de Graaff generators, etc.) or when direct connection to the high-voltage source is to be avoided.

(a) Principle of Operation

The charge stored in a capacitor of capacitance C is given by q = CV. If the capacitance of the capacitor varies with time when connected to the source of voltage V, the current through the capacitor.

$$i = \frac{dq}{dt} = V\frac{dC}{dt} + C\frac{dV}{dt} \qquad (7.1)$$

For a constant angular frequency w, the current is proportional to the applied voltage V. More often, the generated current is rectified and measured by a moving coil meter. Generating voltmeter can be used for ac voltage measurements also provided the angular frequency ω is the same or equal to half that of the supply frequency.

(b)Advantages of Generating Voltmeters

(i) No source loading by the meter,

(ii) No direct connection to high voltage electrode,

(iii) Scale is linear and extension of range is easy, and

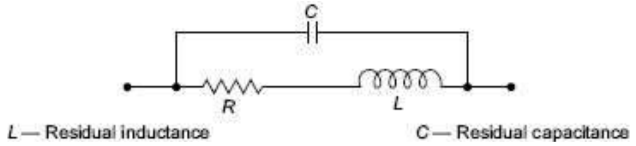
(iv) A very convenient instrument for electrostatic devices such as Van de Graaff generator and particle accelerators.

MEASUREMENT OF HIGH AC VOLTAGE

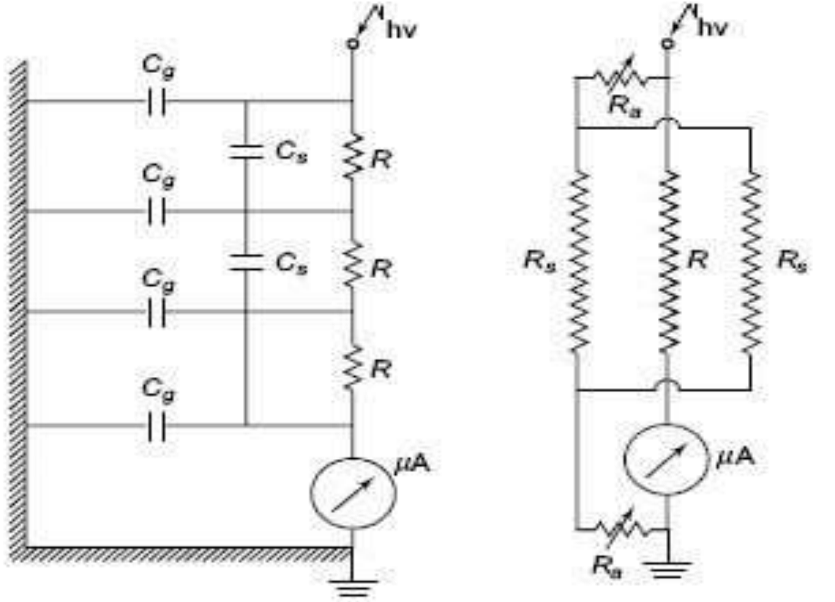
- Series impedance voltmeter
- Potential dividers (resistance or capacitance type)
- Potential transformers (Electromagnetic or CVT)
- Electrostatic voltmeter
- Sphere gaps

SERIES IMPEDANCE VOLTMETERS

For power frequency ac measurements the series impedance may be a pure resistance or a reactance. Since resistances involve power losses, often a capacitor is preferred as a series reactance. Moreover, for high resistances, the variation of resistance with temperature is a problem, and the residual inductance of the resistance gives rise to an impedance different from its ohmic resistance.



SERIES IMPEDANCE VOLTMETERS



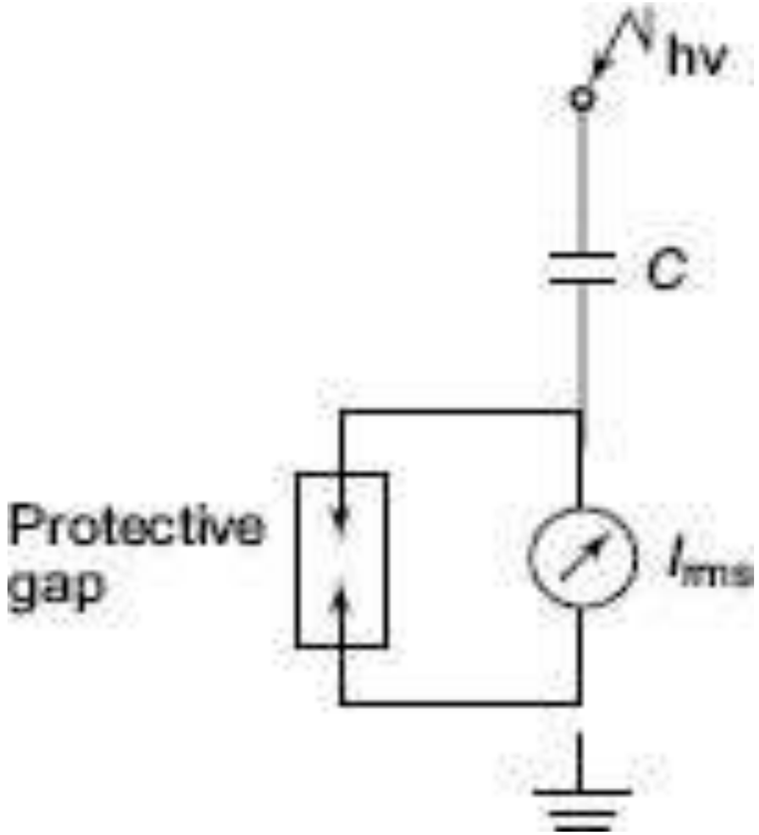
(a) Extended series resistance with inductance neglected

C_g — Stray capcitance to ground
C_s — Winding capacitance

(b) Series resistance with guard and tuning resistances

R — Series resistor
R_s — Guard resistor
R_a — Tuning resistor

SERIES CAPACITANCE VOLTMETER



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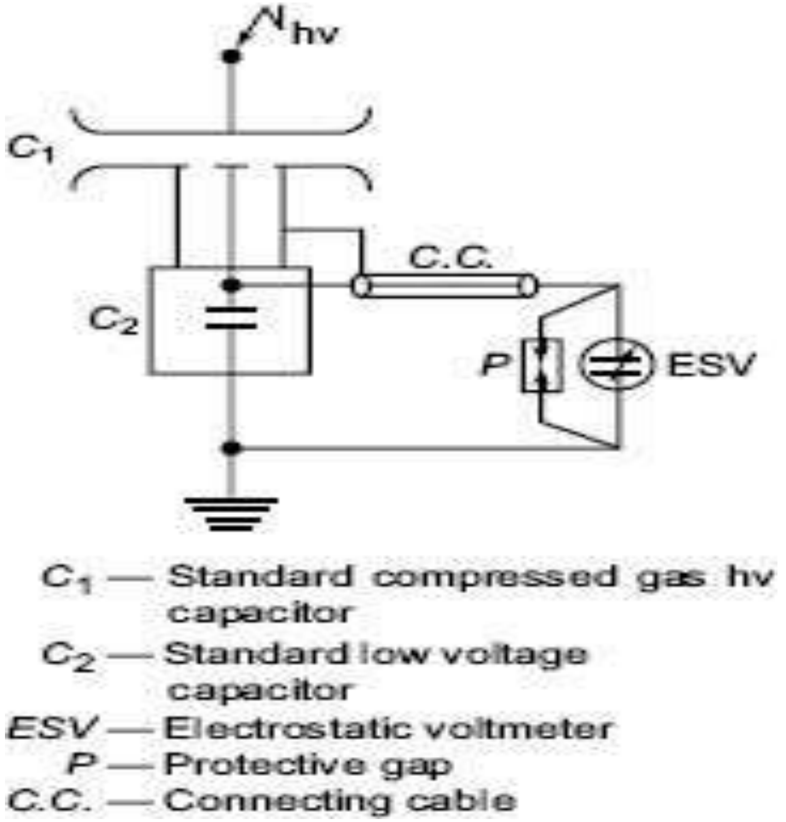
Series capacitance voltmeters were used with cascade transformers for measuring rms values up to 1000 kV. The series capacitance was formed as a parallel plate capacitor between the high voltage terminal of the transformer and a ground plate suspended above it. A rectifier ammeter was used as an indicating instrument and was directly calibrated in high voltage rms value. The meter was usually a 0-100 μα moving coil meter and the overall error was about 2%.

CAPACITANCE POTENTIAL DIVIDERS AND CAPACITANCE VOLTAGE TRANSFORMERS

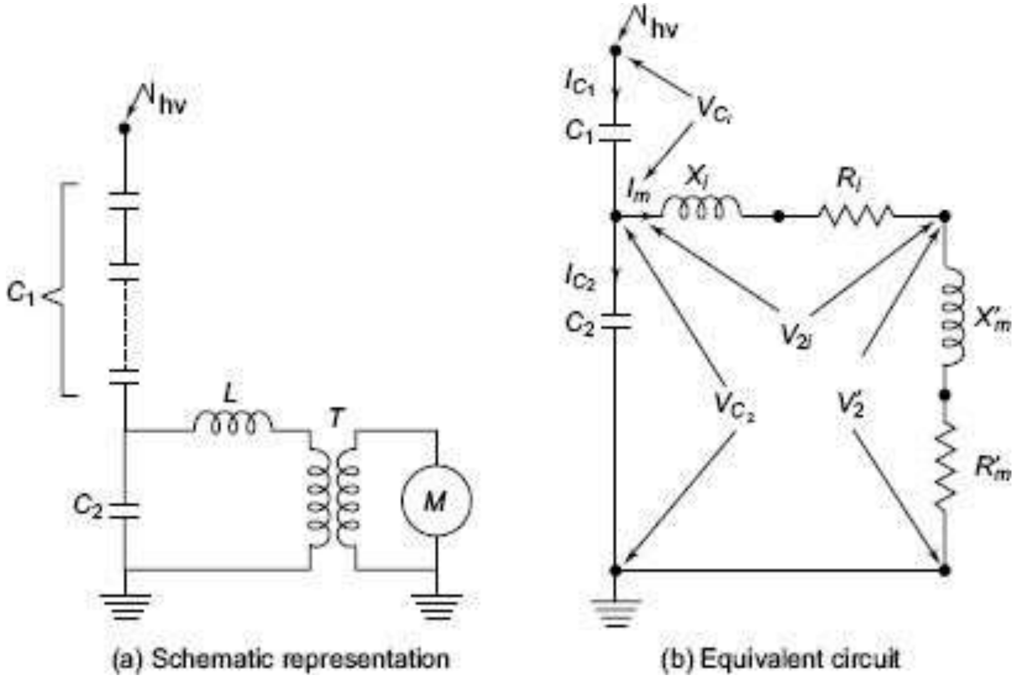
The errors due to harmonic voltages can be eliminated by the use of capacitive voltage dividers with an electrostatic voltmeter or a high impedance meter such as a TVM. If the meter is connected through a long cable, its capacitance has to be taken into account in calibration. Usually, a standard compressed air or gas capacitor is used as C1 ,and C2 may be any large capacitor (mica, paper, or any low loss capacitor. C1 is a three terminal capacitor and is connected to C2 through a shielded cable, and C2 is completely shielded in a box to avoid stray capacitances.



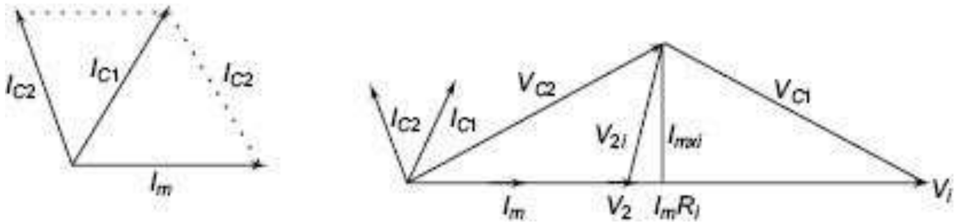
Capacitance potential divider

(a) Capacitance Voltage Transformer=CVT

Capacitance divider with a suitable matching or isolating potential transformer tuned for resonance condition is often used in power systems for voltage measurements. This is often referred to as CVT. In contrast to simple capacitance divider which requires a high impedance meter like a TVM or an electrostatic voltmeter, a CVT can be connected to a low impedance device like a wattmeter pressure coil or a relay coil.


hv
C_1
L
T
C_2
M
(a) Schematic representation
hv
I_{C_1}
C_1
V_{C_1}
I_m
X_l
R_l
I_{C_2}
C_2
V_{2i}
X'_m
V_{C_2}
V'_2
R'_m
(b) Equivalent circuit

The phasor diagram of the CVT under resonant conditions is shown in Fig. 7.13. The meter reactance, X_m is neglected and is taken as a resistance load R_m when the load is connected to the voltage divider side. The voltage across the potential transformer $V_2 = I_m R_m$ and the voltage across the capacitor $= V_2 + I_m (R_e + jX_e)$. The phasor diagram is written taking V_1 as the reference phasor. $V_1 = V_{C1} + V_{C2}$ and total current $= I_m + I_c$· It can be seen that with proper tuning V_2 will be in phase with V_1. The potential transformer resistance and reactance are not shown separately and are included in R_i and X_i, the resistance and reactance of tuning inductor L.



The advantages of a CVT are

(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.

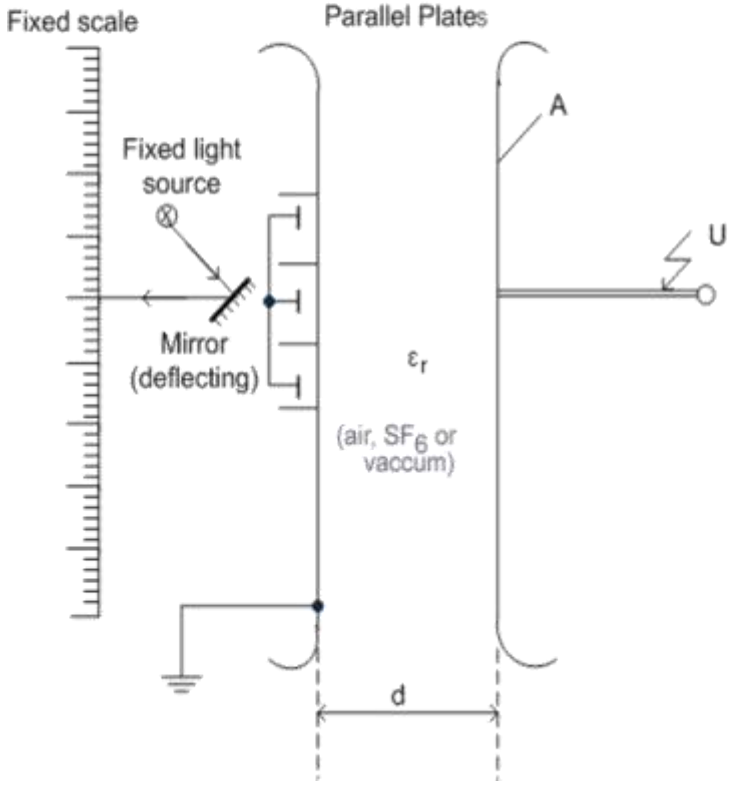
(iii) frequency independent voltage distribution along elements as against conventional magnetic potential transformers which require additional insulation design against surges, and

(iv) provides isolation between the high-voltage terminal and low-voltage metering

(b) Resistance Potential Dividers

Resistance potential dividers suffer from the same disadvantages as series resistance voltmeters for ac applications. Moreover, stray capacitances and inductances associated with the resistances make them inaccurate, and compensation has to be provided. Hence, they are not generally used.

ELECTROSTATIC VOLTMETER



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

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

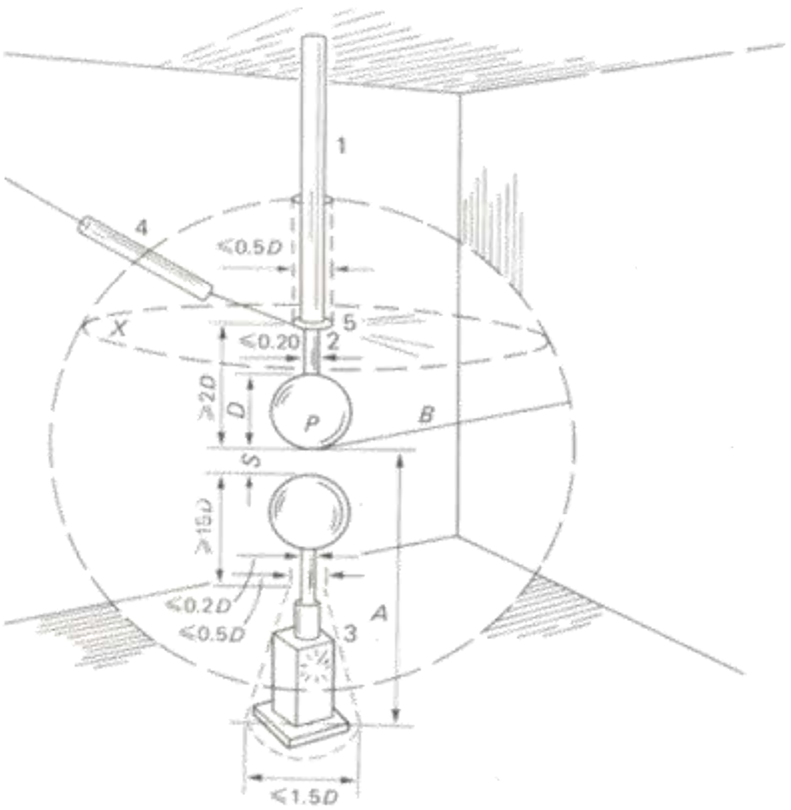
$$= \frac{1}{2}U^2\frac{dC}{dd} = \frac{1}{2}U^2\varepsilon_0\frac{d}{dd}\left(\frac{A}{d}\right) \quad (\text{since } \varepsilon_r = 1)$$

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

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

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

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

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.