High Voltage Engineering – BEE515A

Module-3

Prepared By,

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Course Outline

Course Code	Course Title	Core/Elective	Prerequisite	Contact Hours			Total Hrs/ Sessions
				L	T	P	
18EE56	High Voltage	Core	-	3	-	-	40

Course Module Details

Module-3

Measurement of High Voltages and Currents:

Measurement of High Direct Current Voltages, Measurement of High AC and Impulse Voltages, Measurement of High Currents – Direct, Alternating and Impulse, Cathode Ray Oscillographs for Impulse Voltage and Current Measurements

Objectives of Today's Session

Measurement of High Voltages and Current

1. Generating Voltmeters

2. Measurement of High AC and Impulse Voltages

- Series Impedance Voltameter
- Series Capacitance Voltmeter
- Potential Transformer
- Electrostatic Voltmeter

Generating Voltmeters

1. High voltage measuring device employs Generating principle

- When source loading is prohibited
- When direct connection to the HV source is to be avoided

2. Generating Voltmeter is a variable capacitor electrostatic voltage generator that generates current proportional to the applied external voltage

3. It is driven by a synchronous or constant speed motor

Generating Voltmeters: Principle of Operation

- Charge stored in a capacitor of Capacitance "C" is given by

$Q= CV$ ----(1)

If the Capacitance 'C' varies with time when connected to source voltage 'V' then,

$i = dq/dt$

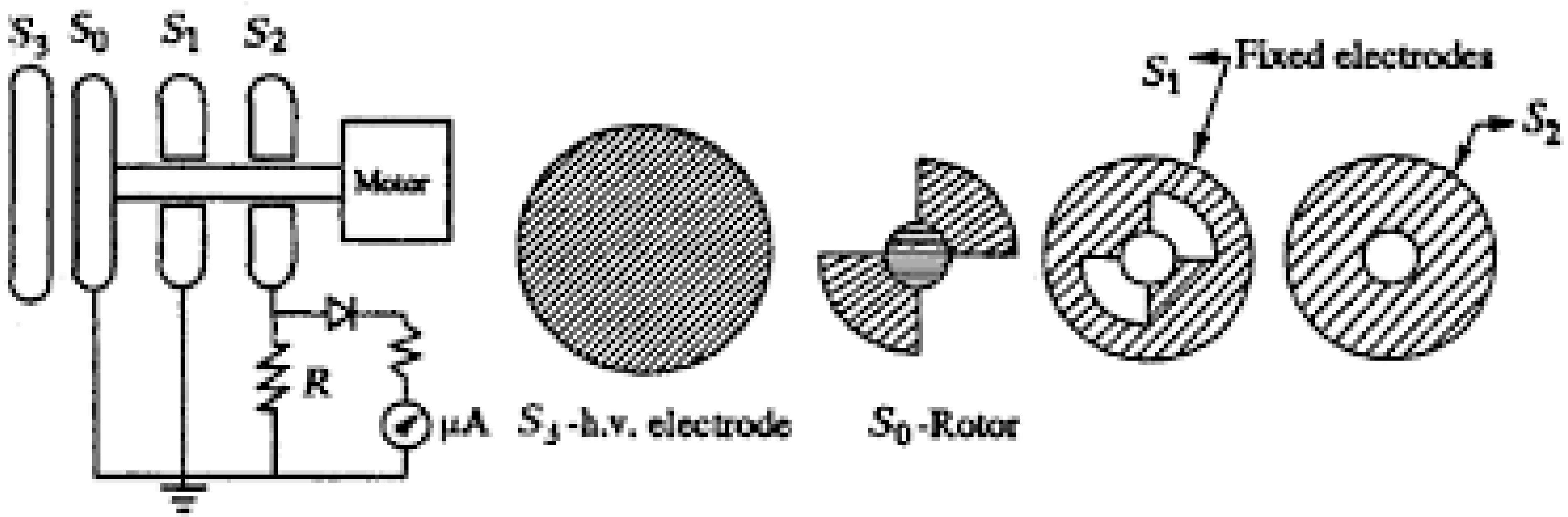
$i = V\,dC/dt$ ---- (2)

If the 'C' varies within the limit C_0 and $C_0{}^+ C_m$

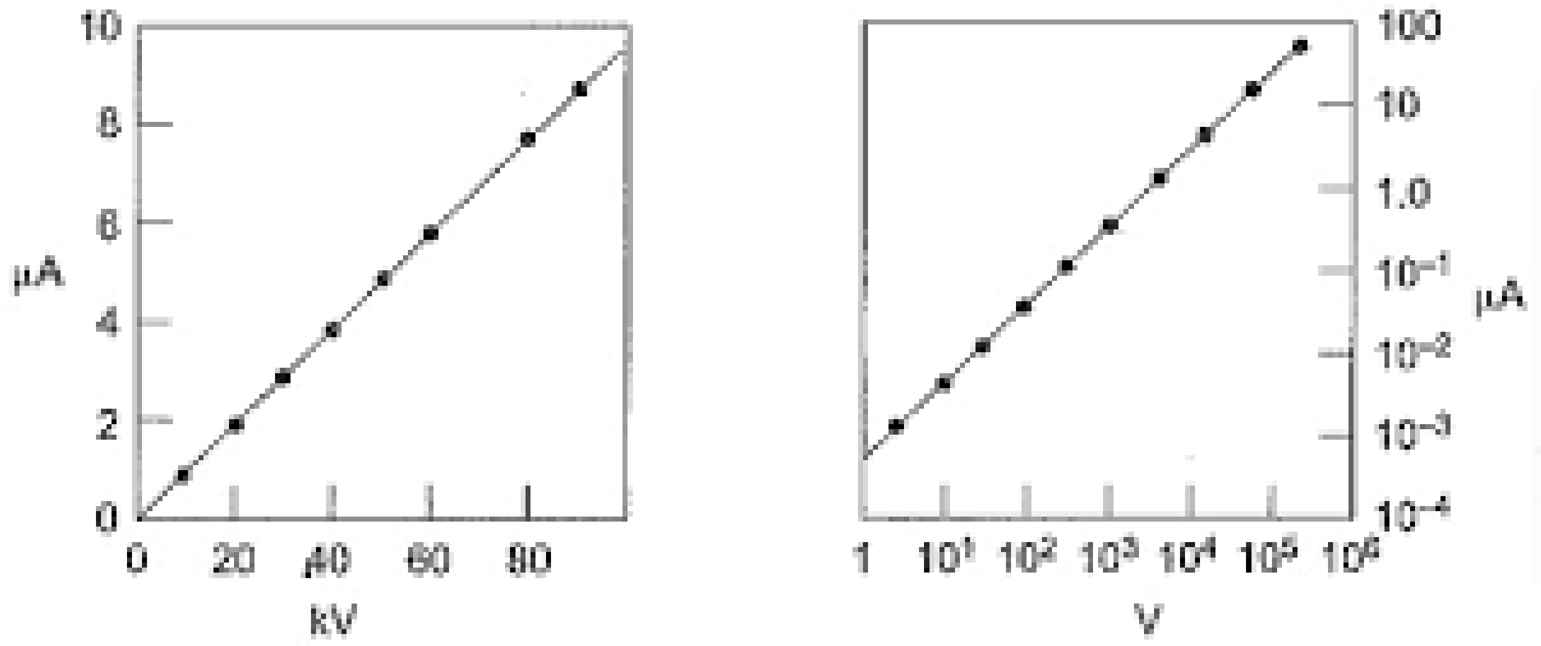
- For a constant frequency **'ω'**, the current is proportional to the applied voltage
- The generated current is rectified and measured using moving coil meter.
- Generating Voltmeters can be used for a measurement of a.c voltage measurements

Generating Voltmeters: Principle of Operation

- It has a rotating cylinder consists of two exciting field electrodes S_1 and S_2 and a rotating two pole armature driven by a synchronous motor at a constant speed ‘n”.



Generating Voltmeters: Calibration Curves



(a) Rotating cylinder type

(b) Rotating vane type

Generating Voltmeters: Principle of Operation

- AC voltages can be measured if the speed of the driving motor is half the frequency of the voltage to be measured.
- Synchronous motor with 1500 rpm is suitable for 50Hz
- For peak value measurements, Phase angle must be adjusted such that C_{max} and the crest value occur at the same instant.

Note: Crest is the ratio of I_m / I_{rms} value ranging bet 1.5 to 2

Generating Voltmeters: Principle of Operation

- High voltage source is connected to a disc electrode S_3
- S_3 is placed at fixed distance on the axis of the low voltage electrodes S_0, S_1 and S_2
- S_0 is driven at a constant speed by a synchronous motor at suitable speed i.e 1500, 3000 or 3600 rpm
- S_0, S_1 are deigned to produce sinusoidal variations in the Capacitance
- Generated AC current through resistance "R" is rectified and measured through moving coil meter.
- The meter scale is linear and can be extended by extrapolation

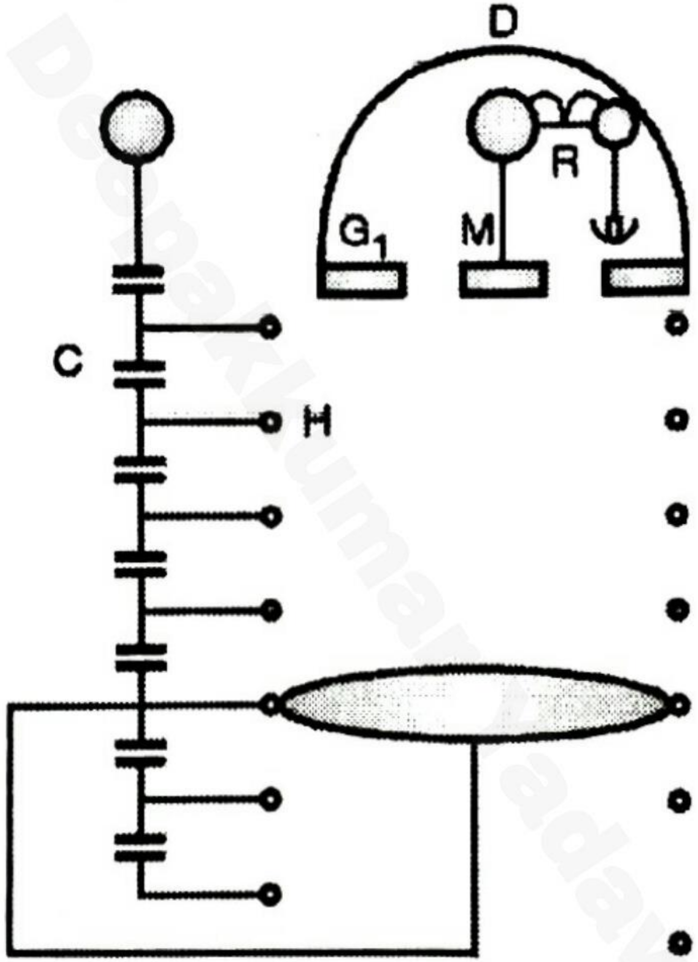
Generating Voltmeters: Advantages

- No source loading by the meter
- No direct connection with the HV Electrode
- Linear Scale and Extension of Range is easy

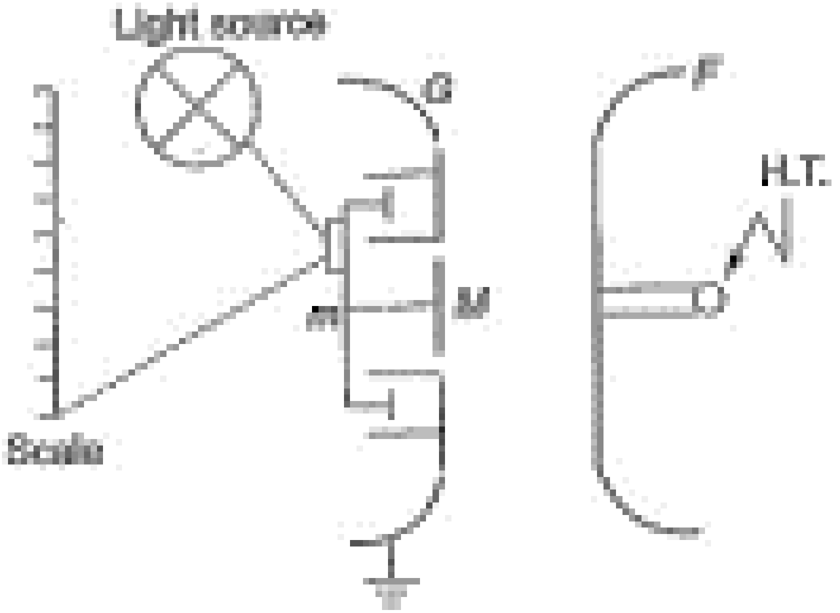
Disadvantages

- Complexity in construction
- Size is large, Requires additional auxiliary drive motor
- Complexity in Calibration due to disturbance in position and mounting of electrodes

Electrostatic Voltmeter



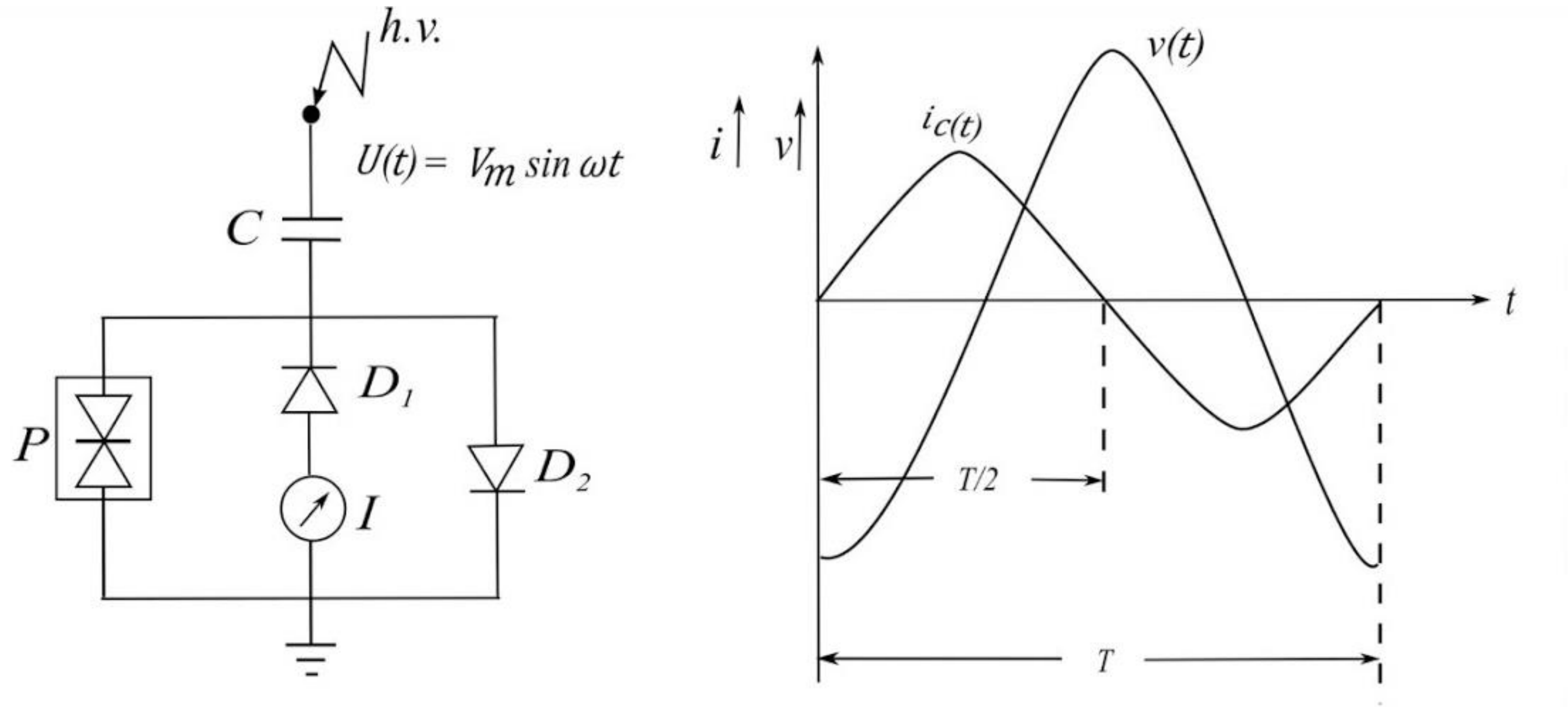
Electrostatic Voltmeter



Working

- C – 5 to 50 pF and R is in 10^13 Ohms
- Control torque is provided by a balancing weight
- Moving disc ‘M’ forms central core
- Due to large space Gap, Uniformity of the electric field is maintained by Guard rings H
- H are maintained at constant potential in space by a capacitance divider.
- Safe Working stress in air : 5 kV/cm or less
- Safe Working stress in vacuum: 100 kV/cm

Peak Reading ac Voltmeter: **Chubb- Fortscue Method**



Peak Reading ac Voltmeter: Digital Peak Voltmeter

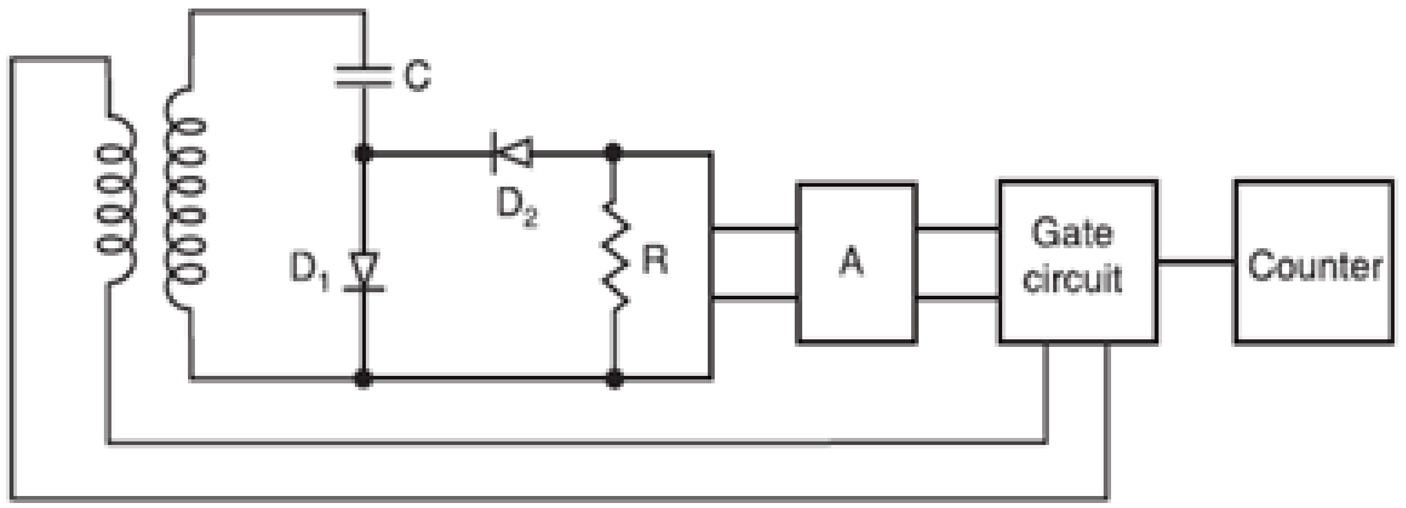


Fig: Digital Peak voltmeter

Factors influencing the Spark over voltage of Sphere Gap

1. Nearby Earthed Objects
2. Atmospheric conditions and Humidity
3. Irradiation
4. Polarity and Rise Time of voltage waveforms

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Factors influencing the Spark over voltage of Sphere Gap

1. Nearby Earthed Objects

- Investigated by Kuffel
- By enclosing the earthed sphere inside an earthed cylinder
- Observations:
- Spark Over Voltage is been reduced
- Reduction found to be $\Delta V = m \log\left(\frac{B}{D}\right) + C$
- ΔV – Percentage Reduction
- B – Diameter of the earthed enclosing cylinder
- D – Diameter of the Spheres
- m, C are constants

Factors influencing the Spark over voltage of Sphere Gap

1. Nearby Earthed Objects

- $\Delta V = m \log\left(\frac{B}{D}\right) + C$
- Reduction of less than 2% for S/D $\leq$ 0.5 and B/D $\geq$ 0.8
- Reduction of up to 3% for S/D $\approx$1.0 and B/D $\geq$ 1.0
- It is observed, The reduction in voltage is within the limits if S/D is $\leq$ 0.6 A.
- A – Spacing b/w Sparking point to horizontal ground plane

Factors influencing the Spark over voltage of Sphere Gap

2. Effects of Atmospheric conditions

- Spark over voltages of a spark gap depends on the air density
- Varies with the changes in the Temperature and Pressure

$$V = kV_0 \text{ ----- } (1)$$

V – Spark Over voltage under test condition of temp ‘T’ and pressure ‘P’ torr

V_0 – Spark Over voltage under Standard conditions of temp T = 20^0C p = 760 torr

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

$$d = \frac{p}{760}\left(\frac{293}{273+T}\right) \text{ ----- } (2)$$

- Spark over voltages increase with humidity.
- 2% to 3% increase with humidity range of 8 g/m^3 to 15 g/m^3

Factors influencing the Spark over voltage of Sphere Gap

3. Effect of Irradiation

- Illumination with UV rays and X-rays helps for easy Ionization in gaps
- Reduction of 20% in spark over voltage is observed for spacings of 0.1D to 0.3 D for a 1.3 cm sphere gap
- Irradiation is necessary for smaller gaps of Gap space < 1 cm to obtain consistent values

4. Effect of Polarity and Waveform:

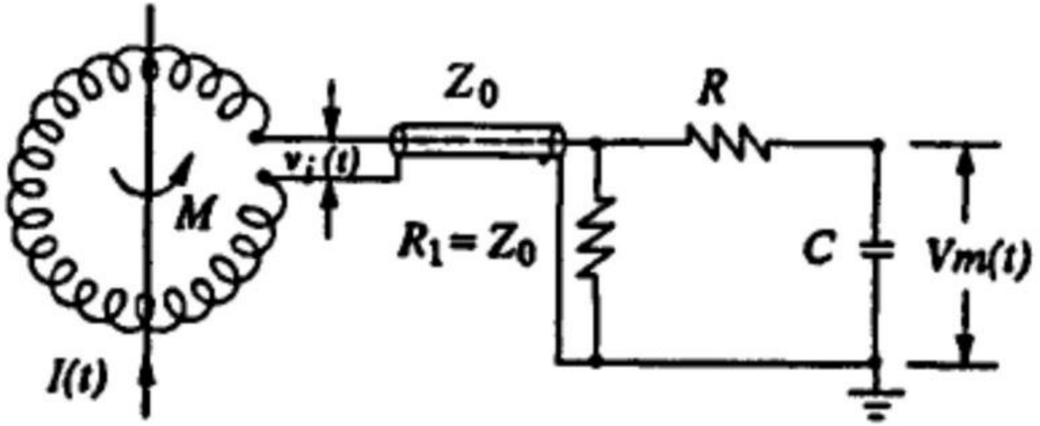
- Spark over voltages for Positive and –Ve polarity impulses are different
- The wave front and wave tail durations also influence the breakdown voltage

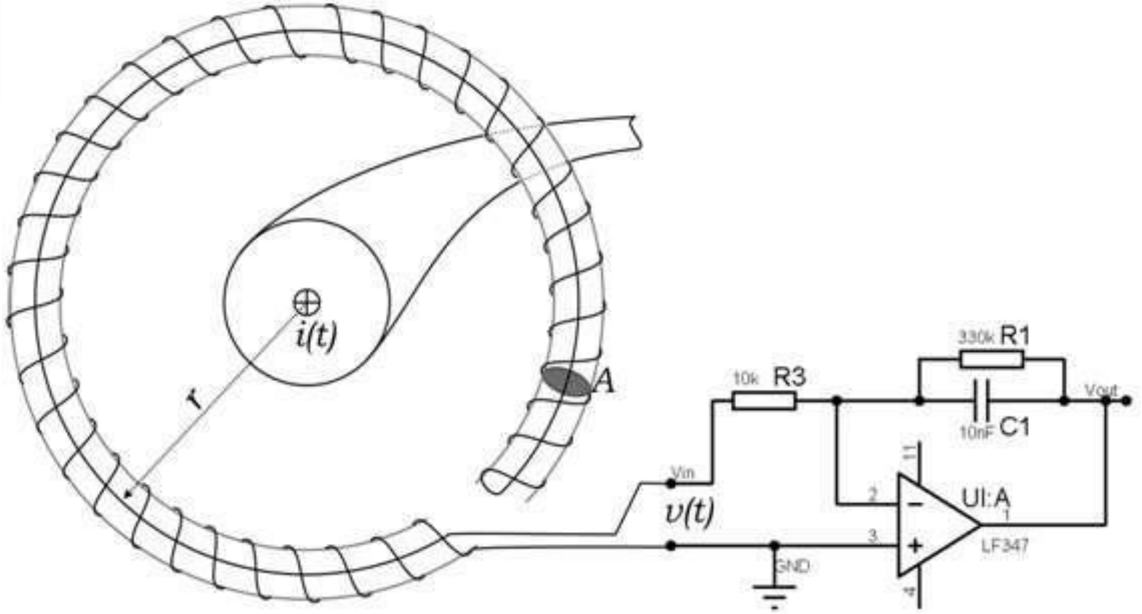
Measurement of High Impulse Currents: Rogowski Coils CTs & Magnetic Links

- It is an electrical device for measuring Alternating Current(AC) or high speed current pulses.
- It consists of a helical coil of wire with the lead from one end returning through the centre of the coil to the other end, so that both terminals are at the same end of the coil.
- The whole assembly is then wrapped around the straight conductor whose current is to be measured.
- The voltage induced in the coil is proportional to the rate of change of current in the straight conductor.
- There is no metal (iron) core.

Measurement of High Impulse Current: Rogowski Coils CTs & Magnetic Links

- The output of the Rogowski coil is an integrator circuit to provide an output signal that is proportional to the current





Measurement of High Impulse Currents: Rogowski Coils CTs & Magnetic Links

- The output of the Rogowski coil is an integrator circuit to provide an output signal that is proportional to the current
- If a coil is placed surrounding a current carrying conductor, the voltage signal induced in the coil is $v_i(t) = M dI(t)/dt$
- The output voltage is given by : $V_m(t) = \frac{1}{CR}\int_0^t v_i(t) = \frac{M}{CR} I(t)$

Measurement of High Impulse Currents: Rogowski Coils CTs & Magnetic Links

- Magnetic links can be used for measurement of peak value of impulse currents.
- Magnetic links are highly retentive steel strips arranged on a circular wheel or drum
- The strips will be kept at a known distance from the current carrying conductor and parallel to it.
- The Remanent magnetism (Residual magnetism) is then measured in the laboratory from which the peak value of the current can be estimated.
- These are useful for field measurements, mainly for estimating the lightning currents on the transmission lines and towers.

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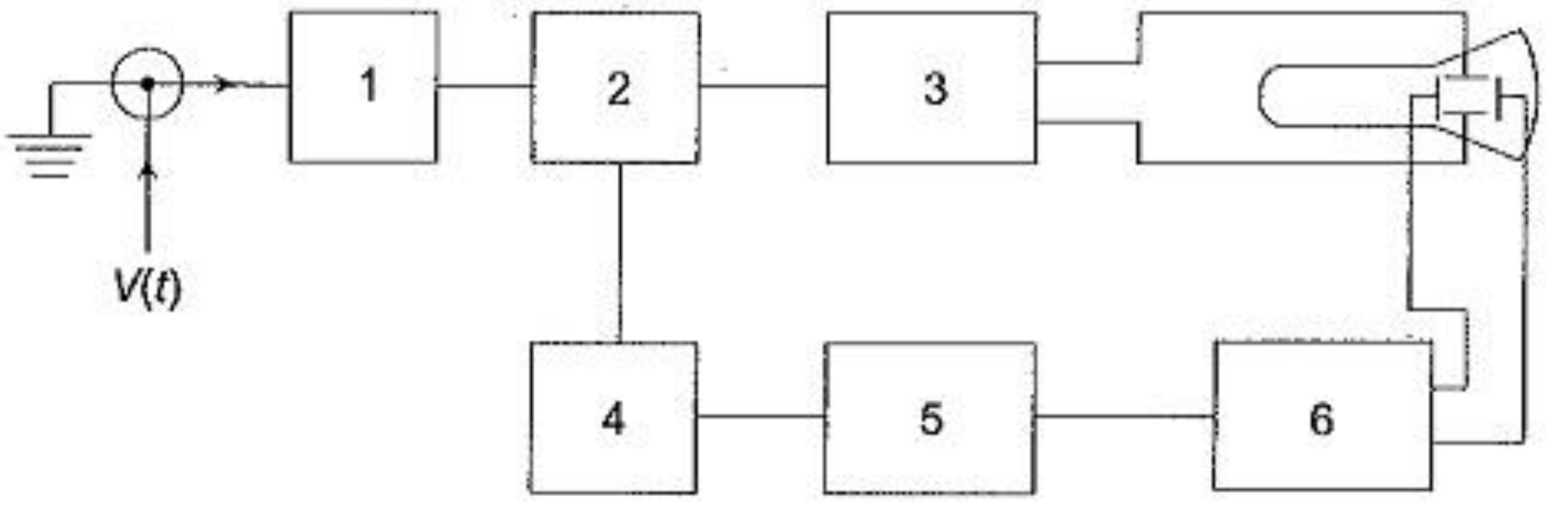
Cathode Ray Oscillographs for Impulse Voltage & Current Measurements



1. *Plug-in amplifier* 2. *Y amplifier* 3. *Internal delay line*
4. *Trigger amplifier* 5. *Sweep generator* 6. *X amplifier*

Cathode Ray Oscillographs for Impulse Voltage & Current Measurements

- A long interconnecting coaxial cable 20 to 50 in long. The required triggering is obtained from an antenna whose induced voltage is applied to the external trigger terminal.
- The measuring signal is transmitted to the CRO by a normal coaxial cable. The delay is obtained by an externally connected coaxial long cable to give the necessary delay.
- The impulse generator and the time base of the CRO are triggered from an electronic tripping device. A first pulse from the device starts the CRO time base and after a predetermined time a second pulse triggers the impulse generator

THANK YOU