Salahaddin University – Erbil
College of Engineering
Department of Electrical Engineering
Instrumentation & Measurement

Instrumentation & Measurements

4^{nd} Stage Lecture 3
Fall Semester
2024-2025

Suzan Fouad Wahhab
suzan.wahhab@su.edu.krd

LECTURE 3

Permanent Magnet Moving Coil (PMMC) instrument

OUTLINES

- An overview of a PMMC instrument, definition, diagram, construction, working, type, advantages, disadvantages, and applications.

Electrical measurement:

The following instruments are used for measuring current, voltage, Power, and Energy.

1. Permanent Magnet Moving Coil (PMMC) instrument
2. Moving Iron (MI) instrument
3. Dynamometer (or) Electromagnetic moving coil instrument (EMMC)
4. Electrostatic instrument
5. Induction- type instrument

Permanent Magnet Moving Coil (PMMC) instrument

PMMC is one of the most accurate instrument types used for D.C. current and voltage measurements.

Definition: The instruments that use the permanent magnet for creating the stationary magnetic field between which the coil moves is known as the permanent magnet moving coil or PMMC instrument. It operates on the principle that the torque is exerted on the moving coil placed in the field of the permanent magnet. The PMMC meter or (D'Arsonval) meter or galvanometer all are the same instrument.

Construction of PMMC Instrument

The moving coil and permanent magnet are the main part of the PMMC instrument. The parts of the PMMC instruments are explained below in detail.

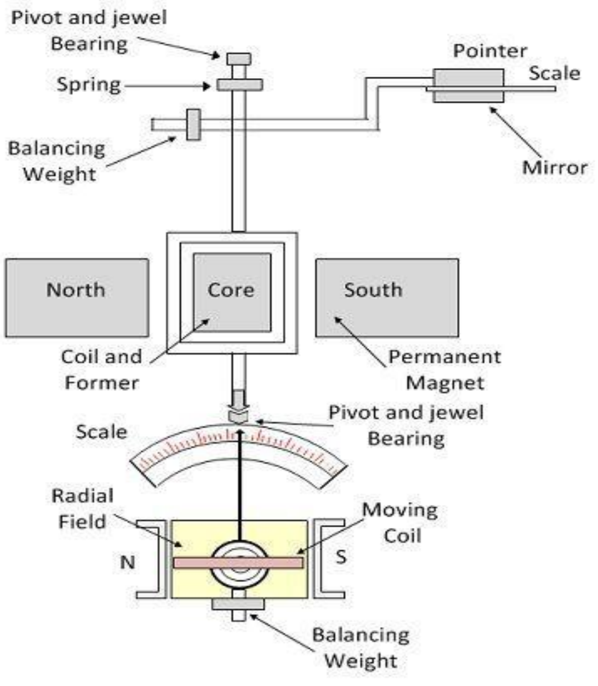
Moving Coil

The coil is the current-carrying part of the instruments which is freely moved between the stationary field of the permanent magnet. The current passes through the coil and deflects it due to which the magnitude of the current or voltage is determined. The coil is mounted on the rectangular former which is made up of aluminum. The former increases the radial and uniform magnetic field between the air gap of the poles.

The coil is wound with the cover copper wire between the poles of a magnet.

Magnet System

The PMMC instrument uses a permanent magnet for creating stationary magnets. The Alcomax and Alnico material is used to create the permanent magnet because this magnet has a high coercive force (The coercive force changes the magnetization). Also, the magnet has high field intensities.



Permanent Magnet Moving Coil Instrument

Control

In the PMMC device, the torque can be controlled due to the springs which are fabricated with phosphorous bronze. These springs are arranged among the two jewel bearings. The spring provides the lane to the lead current to supply in & out of the moving coil. The torque can be controlled mainly due to the delay of the ribbon.

Damping

The damping torque is used to keep the movement of the coil at rest. This damping torque is induced because of the movement of the aluminum core which is moving between the poles of the permanent magnet.

Pointer and Scale

In this instrument, the connection of the pointer can be done through the moving coil. It notices the moving coil’s deflection. The magnitude of their derivation can be displayed on the scale. The pointer within the instrument can be designed with lightweight material. Thus, it can be simply deflected through the coil’s movement.

PMMC Instrument Working

The PMMC instrument working is similar to the motor working. The current through the coil when the instrument is connected to the circuit. When the current-carrying coil is placed in the magnetic field produced by a permanent magnet, then a mechanical torque acts on the coil and starts moving.

Therefore the pointer of the instrument attached to the moving coil moves gradually in a clockwise direction, which indicates the measured value of current in the circuit. The deflecting torque due to the mechanical torque is proportional to the magnetic flux density and length of the moving coil. The pointer deflection is directly proportional to the current flowing through the moving coil.

The action of the spring produces the controlling torque, which opposes the deflecting torque, and the pointer of the instrument starts deflecting in an anticlockwise direction as the current in the coil is reduced. At steady-state conditions of the PMMC instrument, the controlling torque and the deflecting torque are equal. The angle of deflection is directly proportional to the controlling torque.

At the steady-state position of the pointer, the damping torque is produced due to the eddy current. The eddy current setup on the aluminum former opposes the movement of the coil, which deflects the pointer and comes to a rest position. The pointer of the instrument indicates the magnitude of the measured current.

Deflecting Torque

When the current is passed through the coil, the forces are set up on both sides which produce deflection torque. If the current is measured in ampere (I) the current passes through the coil.

The Magnitude of the force (F) experienced by both sides of the coil is given by,

$$\mathbf{F = BIL\ Newton}$$

where,

B – flux density wb/m

L – length of the coil in meters.

for N – turns the equation can be written as,

F = N BIL Newten

Deflecting torque (Td) = Force x perpendicular distance.

Td = N BIL x d

Td = NBI (l x d)

Deflecting torque (Td) = NBI A

If B is constant

$$\text{Deflecting torque } (T_d) = GI$$

G is constant for the given instrument

where,

I- length of the coil in meter

d- Face area of the coil.

Controlling Torque

Controlling torque of the spring (Tc) ∝ Angular deflection θ

$$T_c \propto \theta$$

$$T_c = K \times \theta$$

Here, K is the constant of the spiral spring.

For steady-state deflection,

$$Tc = Td$$

We know that Td = GI

$$K \times \theta = G\,I$$

$$\text{angular deflection, } \theta = GI/K = \frac{G}{K}\,I \qquad \therefore \theta \propto I$$

∴ Deflection is linearly proportional to the current so the instrument's scale is uniform.

What are the different reasons for an error in PMMC?

In a PMMC instrument, different errors can occur due to the temperature effects as well as getting:

older of the instruments. The errors can be caused by the main parts of the instrument like the magnet, the effect of temperature, the moving coil, and the spring.

So, these errors can be reduced when the swamping resistance is connected in series using the moving coil. Here, the swamping resistance which includes less temperature coefficient. This resistance can reduce the temperature effect on the moving coil.

Extension of range of PMMC instrument

Case-I: Shunt

A low shunt resistance is connected in parallel with the ammeter to extend the range of current. Large current can be measured using a shunt and a low current-rated ammeter.

Let

R_m = Resistance of meter

R_{sh} = Resistance of shunt

I_m = Current through a meter

I_{sh} = Current through shunt

I= Current to be measure

$$\therefore V_m = V_{sh}$$

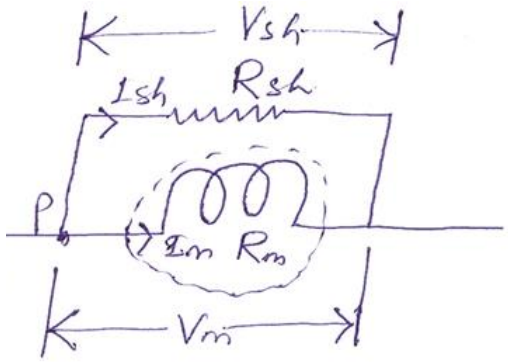
$$I_m R_m = I_{sh} R_{sh}$$

$$\frac{I_m}{I_{sh}} = \frac{R_{sh}}{R_m}$$

Apply KCL at 'P' $I = I_m + I_{sh}$

Eq^n (1.12) ÷ by I_m

$$\frac{I}{I_m} = 1 + \frac{I_{sh}}{I_m}$$



$$\frac{I}{I_m} = 1 + \frac{R_m}{R_{sh}}$$

$$\therefore I = I_m\left(1 + \frac{R_m}{R_{sh}}\right)$$

$\left(1 + \frac{R_m}{R_{sh}}\right)$ is called multiplication factor

Shunt resistance is made of manganin. This has the least thermoelectric emf. The change in resistance, due to temperature change is negligible.

Case (II): Multiplier

A large resistance is connected in series with a voltmeter is called a multiplier. A large voltage can be measured using a voltmeter of a small rating with a multiplier.

Let

R_m =resistance of the meter

R_{se} =resistance of multiplier

V_m =Voltage across the meter

V_{se} = Voltage across the series resistance

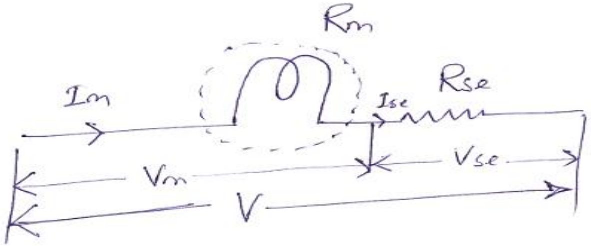
V= voltage to be measured

ltage to be measured

$$I_m = I_{se}$$

$$\frac{V_m}{R_m} = \frac{V_{se}}{R_{se}}$$

$$\therefore \frac{V_{se}}{V_m} = \frac{R_{se}}{R_m}$$



Apply KVL, $V = V_m + V_{se}$

Equation above divided to V_m

$$\frac{V}{V_m} = 1 + \frac{V_{se}}{V_m} = \left(1 + \frac{R_{se}}{R_m}\right)$$

$$\therefore V = V_m\left(1 + \frac{R_{se}}{R_m}\right)$$

$$\left(1 + \frac{R_{se}}{R_m}\right) \rightarrow \text{Multiplication factor}$$

Advantages of PMMC Instrument

- ✓ The scale of the PMMC instruments is correctly divided.
- ✓ The power consumption of the devices is very less.
- ✓ This instrument can measure the voltage & current with different ranges.
- ✓ The PMMC instruments have high accuracy because of the high torque-weight ratio.

Disadvantages of PMMC Instruments

- ✓ The PMMC instruments are only used for the direct current. The alternating current varies with the time. The rapid variation of the current varies the torque of the coil. However, the pointer can not follow the fast reversal and the deflection of the torque. Thus, it cannot be used for AC.

- ✓ The cost of the PPMC instruments is much higher as compared to the moving coil instruments.

- ✓ Friction and temperature errors are present.

Applications

The applications of PMMC Instrument are given below,

- ✓ It is used to measure the change in magnetic flux linkage in Ballistic galvanometers.
- ✓ It is used as an Ammeter.

- ✓ It is used as a Voltmeter.
- ✓ It is used as an Ohm meter.
- ✓ It is used as a Galvanometer.
- ✓ At low frequencies, the PMMC instrument along with the rectifier is used to measure AC by converting into DC (<1mA).

Example 1:

A PMMC ammeter has the following specification Coil dimensions are 1cm×1cm. The spring constant is 0.15 x10^{-6} $N-m/rad$, Flux density is $1.5x10^{-3}$ wb/m^2. Determine the no. of turns required to produce a deflection of 90° when a current of 2mA flows through the coil.

Solution:

At steady state **condition** $T_d = T_C$

$BANI = K\theta$

$\Rightarrow N = \dfrac{K\theta}{BAI}$

$A = 1\times10^{-4} m^2$

$K = 0.15\times10^{-6} \dfrac{N-m}{rad}$

$B = 1.5\times10^{-3} wb/m^2$

$I = 2\times10^{-3} A$

$\theta = 90^\circ = \dfrac{\Pi}{2} rad$

N=785 ans.

Example 2:

The pointer of a moving coil instrument gives a full-scale deflection of 20mA in the PMMC instrument. The potential difference across the meter when carrying 20mA is 400mV. The instrument to be used is 200A. for full-scale deflection. Find the shunt resistance required to achieve this, if the instrument is to be used as a voltmeter for full-scale reading with 1000V. Find the series resistance to be connected to it.

Solution:

Case-1

V_m =400mV

$I_m = 20mA$

I=200A

$$R_m = \frac{V_m}{I_m} = \frac{400}{20} = 20\Omega$$

$$I = I_m\left(1 + \frac{R_m}{R_{sh}}\right)$$

$$200 = 20\times10^{-3}\left[1 + \frac{20}{R_{sh}}\right]$$

$$R_{sh} = 2\times10^{-3}\Omega$$

Case-II

V=1000V

$$V = V_m\left(1 + \frac{R_{se}}{R_m}\right)$$

$$4000 = 400\times10^{-3}\left(1 + \frac{R_{se}}{20}\right)$$

$$R_{se} = 49.98k\Omega$$

Example 3:

A 150 v moving iron voltmeter is intended for 50HZ and has a resistance of 3kΩ. Find the series resistance required to extend the range of the instrument to 300v. If the 300V PMMC instrument is used to measure a d.c. voltage of 200V. Find the voltage across the meter.

Solution:

Case- I

$$R_m = 3k\Omega, V_m = 150V, V = 300V$$

$$V = V_m\left(1+\frac{R_{se}}{R_m}\right)$$

$$300 = 150\left(1+\frac{R_{se}}{3}\right) \Rightarrow R_{se} = 3k\Omega$$

Case-II $\quad V = V_m\left(1+\frac{R_{se}}{R_m}\right)$

$$200 = V_m\left(1+\frac{3}{3}\right)$$

$$\therefore V_m = 100V$$ Ans


Thank you