MOVING IRON INSTRUMENTS

The instrument in which the moving iron is used for measuring the flow of current or voltage is known as the moving iron instrument. It works on the principle that the iron place near the magnet attracts towards it. The force of attraction depends on the strength of the magnet field. The magnetic field induces by the electromagnet whose strength depends on the magnitude of the current passes through it.

Moving iron instrument is used for both AC and DC because the deflecting torque produced by the magnetic field is independent of the direction of the current. Which allows the pointer to move for any direction of current (whether constant DC supply or +ve and -ve AC supply).

Moving Iron instruments are most commonly used laboratory instruments because of its advantages like low cost, high accuracy and ruggedness. Two basic classification of MI instruments are,

i) Moving Iron attraction type instruments and

ii) Moving Iron repulsion type instruments

i) Moving Iron attraction type instruments

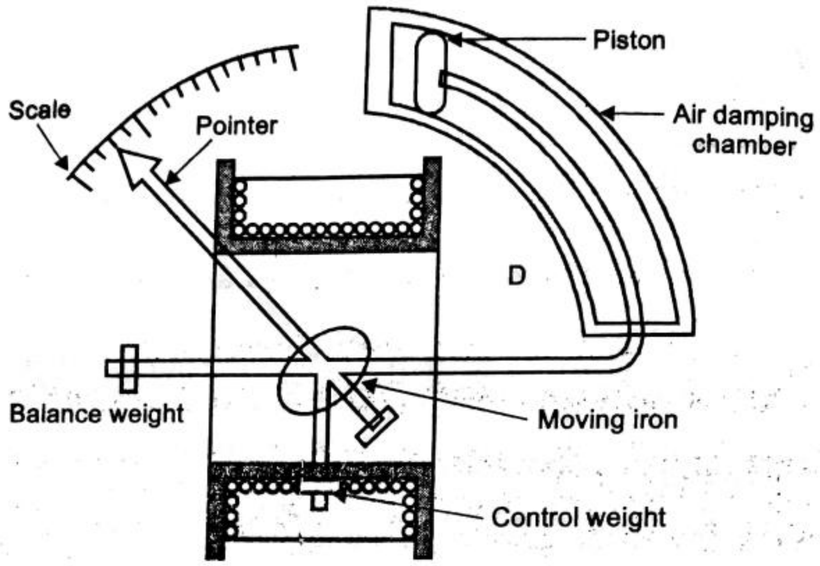


Figure 5.43 Attraction type MI instrument

Figure 5.43 shows the attraction type moving iron instrument, which has a flat coil and a narrow slot like opening.

The moving iron is a flat disc which is eccentrically mounted. When the current to be measured flows through the coil, magnetic field is produced which attracts the moving iron towards it, this makes the pointer to move. Controlling torque is provided by springs.

However, gravity control can be used for panel type of instruments which are vertically mounted.

Air friction damping is provided with the help of light aluminium piston attached to the moving system.

ii) Moving Iron repulsion type instruments

Moving iron repulsion type instrument consists of two vanes inside the coil. Among the two vanes, one is fixed and the other is movable.

When the current to be measured flows through the coil, both the vanes get magnetised in a similar way and hence, a force of repulsion exists between the two vanes which results in the movement of the moving vane and thus the movement of the pointer.

Hence, the current to be measured is proportional to the movement of the pointer.

Commonly used two different designs of repulsion type MI instruments are

i) Radial vane type

Figure 5.44 shows the radial vane repulsion type MI instrument which consists of two vanes that are radial strips of iron.

The strips are placed within the coil.

The fixed vane is attached to the coil and the movable vane is attached to the spindle of the instrument which inturn is attached to the pointer.

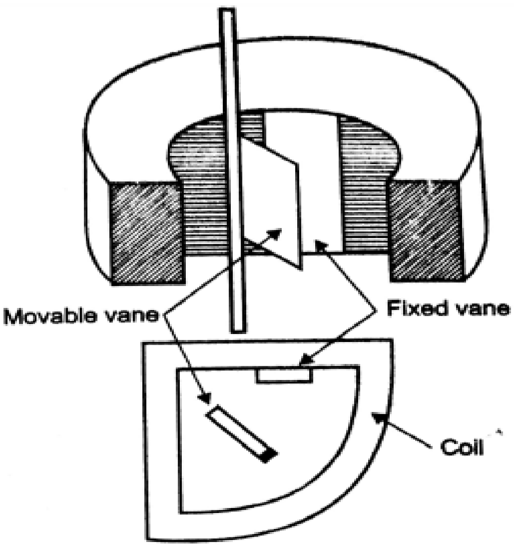


Figure 5.44 Radial vane repulsion type MI instrument

ii) Coaxial vane type

In this type of instrument, the fixed and moving vanes are sections of coaxial cylinder as shown in figure 5.45. Generally, controlling torque is provided by springs.

However, gravity control can also be used in vertically mounted instruments. Damping torque is provided by air friction damping.

Eddy current damping cannot be used in moving iron type instruments, because introduction of permanent magnet required for eddy current damping would distort the operating magnetic field of MI instruments which is very weak.

Moving Iron type of instruments can be used for both AC and DC measurement because, whatever may be the direction of the current through the coil in the instrument, the iron vanes get magnetised and there will be a force of attraction in the attraction type instrument and there will be a force of repulsion in the repulsion type instrument.

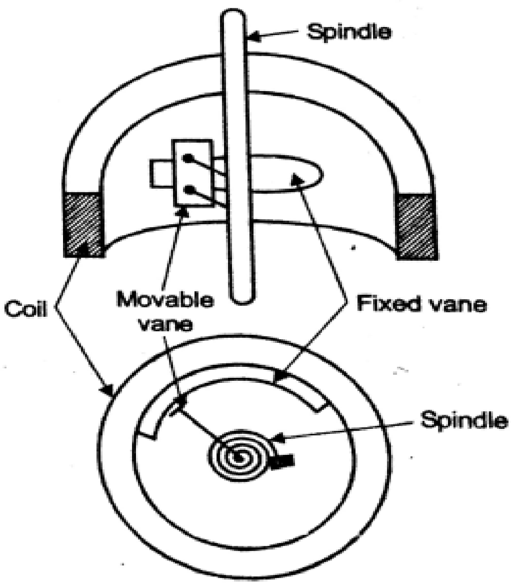


Figure 5.45 Coaxial vane repulsion type MI instrument

Advantages of moving iron instruments

The various advantages of moving iron instruments are,

- The same instrument can be universally used for both AC and DC measurements.
- $\frac{\text{Torque}}{\text{Weight}}$ ratio is very high and hence error due to friction is vey small.
- As the single moving system can be used for wide range of measurement, these instruments are cheaper than other types of instruments.
- These instruments are robust and simple in construction as there is no current carrying moving parts.
- These instruments are highly accurate.
- Moving iron instruments are available with 240° circular scales.

Disadvantages of moving iron instruments

The various disadvantages of moving iron instruments are,

- The scale of the moving iron instruments is not uniform and is cramped at the lower end and therefore accurate readings are not possible at this end.
- These instruments are subjected to serious errors due to hysteresis, change in frequency and stray magnetic fields.
- The non-linearity of B-H curve of iron leads to the fact that the deflection torque is not exactly proportional to the square of the current.
- Difference between DC and AC calibrations occurs on an account of effect of inductance of the meter and the eddy currents when the meter is used on AC. Hence, the meter should be calibrated for frequencies at which they are used.

PERMANENT MAGNET MOVING COIL (PMMC) INSTRUMENTS

The permanent magnet moving coil instruments are used to give accurate reading in DC measurements.

Basic Principle

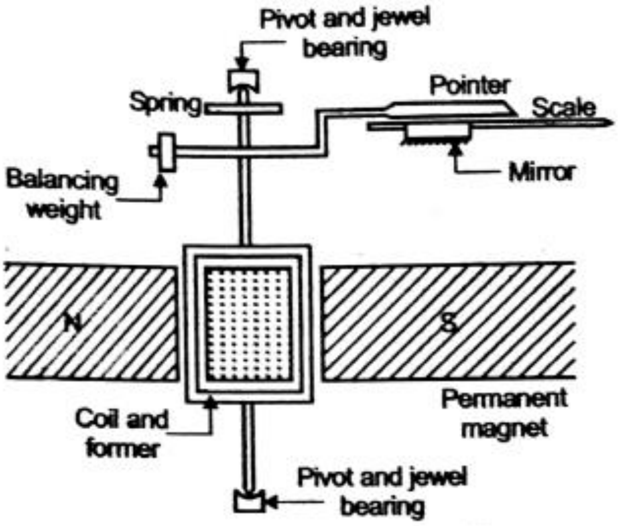
PMMC instruments mainly works on motoring principle. When a current carrying conductor is placed in a magnetic field produced by a permanent magnet, the coil experiences a force and hence moves. As the coil is moving and the magnet is permanent, this instrument is called permanent magnet moving coil instrument. This basic principle is called D'Arsonval principle which is the main principle of operation of Galvanometer. The amount of force experienced by the coil is proportional to the current passing through the coil.

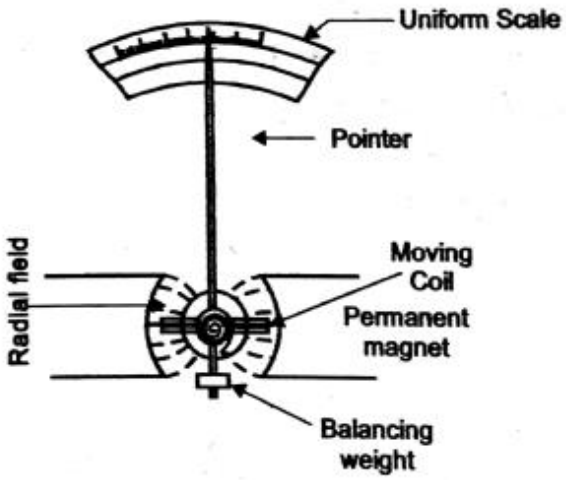
Constructional Details

Figure 5.42 shows the constructional diagram of the PMMC instrument. It consists of a moving coil which is either rectangular or circular in shape, which has number of turns of fine wire. The coil is suspended so that it is free to turn about its vertical axis.

The coil is placed in uniform, horizontal and radial magnetic field of a permanent magnet in the shape of a horse-shoe. The iron core is spherical if the coil is circular and is cylindrical if the coil is rectangular. Due to iron core, the deflection torque increases, which inturn increases the sensitivity of the instrument.

Controlling torque is provided by the method of spring control with the help of two phosphor bronze hair springs. Damping torque is provided by the movement of the aluminium former in the magnetic field produced by the permanent magnet.





The pointer is connected to the spindle and it moves over a uniformly graduated scale. The pointer is a light weight one and hence it deflects rapidly. The mirror is placed below the pointer to get an accurate reading without parallax error. The total weight of the instrument is normally counter balanced by balancing weight. In PMMC instrument, the deflection of the pointer is directly proportional to the current passing through the coil, which is the quantity to be measured in case of ammeter and it is proportional to the voltage to be measured in case of voltmeter. Hence a linear scale is used in 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 deflecting torque of a moving coil instrument can be derived from the basic equation of the electromagnetic torque.

Deflecting torque, $T_d = NBAI$ ...(1)

where T_d = Deflecting torque in N-m

N = Number of turns of the coil

A = Effective coil area in m^2

I = Current passing through the moving coil in ampere

B = Flux density in air gap in Wb/m^2

Let $G = NBA$ = constant

Errors in PMMC instruments

The main sources of error in PMMC instruments are due to,

- Weakening of permanent magnets due to ageing and temperature effects.
- Weakening of springs due to ageing and temperature effects.
- Change of resistance of moving coil with respect to temperature.

Advantages of PMMC instruments

The main advantages of PMMC instruments are,

- Uniform scale.
- Low power consumption in the order of 25 uW to 200 μW.
- High $\frac{\text{torque}}{\text{weight}}$ ratio which inturn gives high accuracy.
- Extension of instrument range is possible with the help of different values of shunts and multipliers.
- Operating forces are large which lead to large flux density in the order of 0.5 Wb/m^2.
- Not affected by external magnetic fields called stray magnetic fields because of high flux density.
- Sensitivity is high sensitivity.
- Instrument is free from hysteresis error.
- Effective damping is provided because of eddy current.

Disadvantages of PMMC instruments

The main disadvantages of PMMC instruments are,

- It can be used only for DC measurement.

The torque reverses if the current reverses. Hence, if the instrument is connected to AC, the pointer cannot follow the rapid reversals and hence the deflection corresponds to mean torque which is zero. Hence, PMMC instruments cannot be used for AC.

- Cost of PMMC instrument is higher than that of moving iron instrument.

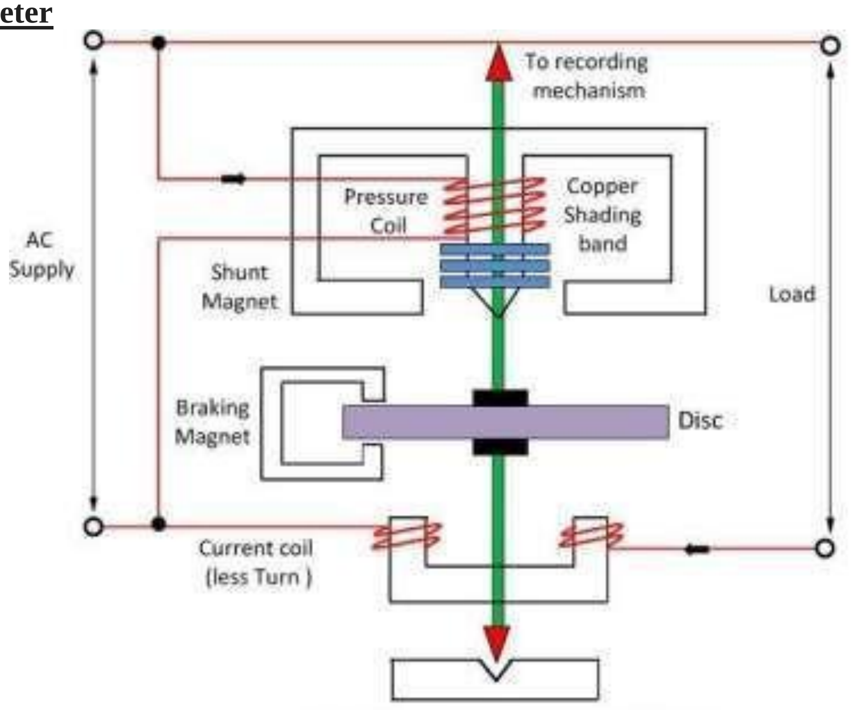
The applications are

- ✓ Ammeter
- ✓ Galvanometer
- ✓ Ohmmeter
- ✓ Voltmeter

ENERGYMETER

Definition: The meter which is used for measuring the energy utilises by the electric load is known as the energy meter. The energy is the total power consumed and utilised by the load at a particular interval of time. It is used in domestic and industrial AC circuit for measuring the power consumption. The meter is less expensive and accurate.

Construction of Energy Meter



Induction Type Energy Meter

The energy meter has four main parts. They are the

- Driving System
- Moving System
- Braking System
- Registering System

1. **Driving System** – The electromagnet is the main component of the driving system. It is the temporary magnet which is excited by the current flow through their coil. The core of

the electromagnet is made up of silicon steel lamination. The driving system has two electromagnets. The upper one is called the shunt electromagnet, and the lower one is called series electromagnet.

The series electromagnet is excited by the load current flow through the current coil. The coil of the shunt electromagnet is directly connected with the supply and hence carry the current proportional to the shunt voltage. This coil is called the pressure coil.

The centre limb of the magnet has the copper band. These bands are adjustable. The main function of the copper band is to align the flux produced by the shunt magnet in such a way that it is exactly perpendicular to the supplied voltage.

2. **Moving System** – The moving system is the aluminium disc mounted on the shaft of the alloy. The disc is placed in the air gap of the two electromagnets. The eddy current is induced in the disc because of the change of the magnetic field. This eddy current is cut by the magnetic flux. The interaction of the flux and the disc induces the deflecting torque. When the devices consume power, the aluminium disc starts rotating, and after some number of rotations, the disc displays the unit used by the load. The number of rotations of the disc is counted at particular interval of time. The disc measured the power consumption in kilowatt hours.

3. **Braking system** – The permanent magnet is used for reducing the rotation of the aluminium disc. The aluminium disc induces the eddy current because of their rotation. The eddy current cut the magnetic flux of the permanent magnet and hence produces the braking torque.This braking torque opposes the movement of the disc, thus reduces their speed. The permanent magnet is adjustable due to which the braking torque is also adjusted by shifting the magnet to the other radial position.

4. **Registration** (**Counting Mechanism**) – The main function of the registration or counting mechanism is to record the number of rotations of the aluminium disc. Their rotation is directly proportional to the energy consumed by the loads in the kilowatt hour. The rotation of the disc is transmitted to the pointers of the different dial for recording the different readings. The reading in kWh is obtained by multiply the number of rotations of the disc with the meter constant. The figure of the dial is shown below.

Working of the Energy Meter

The energy meter has the aluminium disc whose rotation determines the power consumption of the load. The disc is placed between the air gap of the series and shunt electromagnet. The shunt magnet has the pressure coil, and the series magnet has the current coil.The pressure coil creates the magnetic field because of the supply voltage, and the current coil produces it because of the current.

The field induces by the voltage coil is lagging by 90º on the magnetic field of the current coil because of which eddy current induced in the disc. The interaction of the eddy current and the magnetic field causes torque, which exerts a force on the disc. Thus, the disc starts rotating.

The force on the disc is proportional to the current and voltage of the coil. The permanent magnet controls Their rotation. The permanent magnet opposes the movement of the disc and equalises it on the power consumption. The cyclometer counts the rotation of the disc. Theory of Energy Meter

The pressure coil has the number of turns which makes it more inductive. The reluctance path of their magnetic circuit is very less because of the small length air gap. The current I_p flows through the pressure coil because of the supply voltage, and it lags by 90º.