CHAPTER

15 Electrical Instruments

Introduction: The instruments which are used to measure the electrical values such as voltage, current, power and frequency etc. are called electrical instruments. For example, Ampere meter for current, Volt meter for voltage and Frequency meter for frequency etc.

Main Types of Electrical Measuring Instruments:

There are three main types of electrical measuring instrument:

1. Indicating Type Instrument 2. Recording Type Instrument 3. Integrating Type Instrument

1. Indicating Type Instrument: The instruments which indicate the value by pointer and scale are called indicating type or deflecting type instruments, *viz.* ampere meter, volt meter, power factor meter etc.

2. Recording Type Instrument: The instruments which indicate the value by pen and graph-paper or sheet instead of pointer and scale, are called recording type instruments. These instruments are mostly used in power houses.

3. Integrating Type Instrument: The instruments which record the total quantity with respect to time are called integrating type instruments such as energy meter and ampere hour meter etc.

Types of Forces or Torque Employed in the Instruments:

For proper functioning of an instrument the following forces are employed:

1. Deflecting Torque (Deflecting Force): The force or torque which brings the needle (pointer) in motion is called deflecting force or deflecting torque. This force is obtained by magnetic effect or heating effect of electricity etc. but mostly magnetic effect is utilized.

2. Controlling Torque (Controlling Force): The force or torque which controls the movement of pointer caused by deflecting force and brings the pointer at its original position when there is no deflecting force, is called controlling force or controlling torque.

There are two ways for producing controlling force:

(*a*) Spring Control, (*b*) Gravity Control.

(*a*) Spring Control: In this type of controlling force a special type of spring made of phosphor bronze are used. These springs have properties of low specific resistance, non-magnetic and low temperature co-efficient etc. Mostly two springs attached with lower and upper portion of the spindle are used.

The function of spring is to provide controlling force due to spring action and supply electricity to the moving coil instruments.

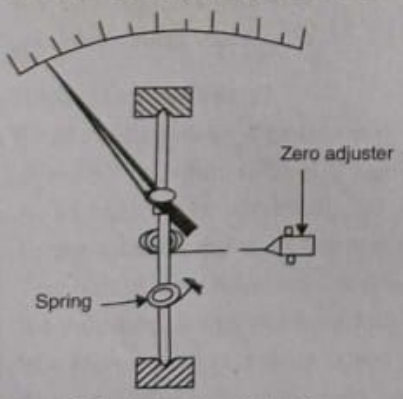

Fig. 1. Spring Control

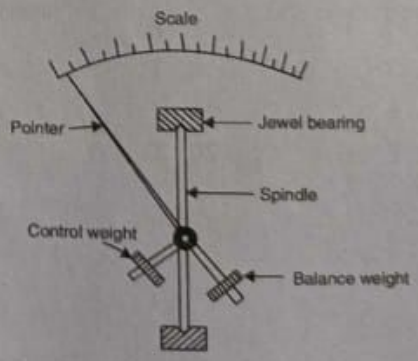

Fig. 2. Gravity Control

(b) Gravity Control: In this type of controlling force a small calculated weight is attached to one end of the spindle which works on the principle of gravitational force, so it is called gravity control.

Note: The direction of controlling force is always opposite to deflecting force.

3. Damping Torque or Force: The force or torque which brings the needle in its proper position very quickly *e.g.*, minimize the accelating effect (vibration effect) is called force. There are three methods to obtain this force.

(*a*) Air Damping Method (*b*) Eddy Current Damping Method (*c*) Fluid Friction Damping Method

(a) Air Damping: A small-light weight piece of aluminium attached to pointer is placed in a fixed closed chamber. This piece of metal moves in the chamber as pointer deflects and due to air resistance, it brings the needle in its proper position. The damping is produced due to friction of air, so it is called air damping.

(b) Eddy Current Damping: A small light weight disc normally made of aluminium attached to spindle is rotated in between poles of permanent magnet and produces eddy current in disc. We know, as per Lenz's law, the direction of an induced eddy current force is always opposite to the cause. This opposition acts as an eddy current damping force. This is most effective and popular method used as damping force in the instruments.

(c) Fluid Friction Damping: In this system, in place of air some liquid is used in which small metal piece or disc attached to one end of the spindle is placed in fluid. Due to friction of fluid, a force is produced which minimizes the vibration effect. This force is called Fluid friction damping force.

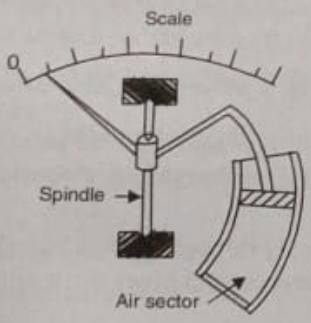

Fig. 3. Air Damping

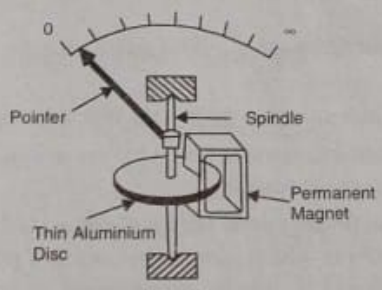

Fig. 4. Eddy Current Damping

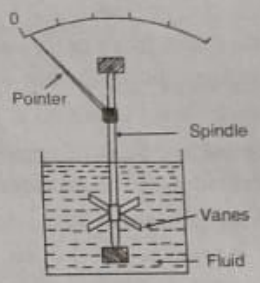

Fig. 5. Fluid Friction Damping

Electrical Measuring Instruments Symbols

Type of Instrument	Symbol	Type of Instrument	Symbol
Moving coil Instruments for D.C. voltmeters, ammeters, milli ammeters, galvano-meter, milli voltmeters.		Electro dynamic instruments, power factor meters for measuring power factor and wattmeter for measuring power.	
Moving coil Instruments with rectifiers for A.C. measurements.		Electrostatic instruments for A.C. and D.C.	
Moving coil instruments with thermocouple for measuring high frequencies.		Frequency meters reed type.	
Moving iron instruments for A.C. voltmeters and ammeters.		Hot wire instruments.	

Classification of the Electrical Instruments:

There are following types of electrical instruments:

1. Moving Coil Instrument
2. Moving Iron Instrument
3. Dynamo Meter Type Instrument
4. Hot Wire Instrument
5. Induction Type Instrument
6. Electro Static Instrument

Moving Coil Instrument:

The deflection is due to movement of a coil so it is called moving coil instrument.

Construction: It consists of following main parts:

1. Permanent Magnet: It is a horse-shoe permanent magnet which provide magnetic flux. The soft iron pole pieces are used to get uniform flux.

2. Moving coil: It is a movable coil made of thin winding wire, having a few number of turns placed on rectangular aluminium frame. This frame along with coil is attached to spindle (axel).

3. Spring: Two flat spiral springs of phosphor bronze are attached to both sides of spindle. The function of spring is to provide controlling force and supply the current to moving coil.

4. Iron Core: It is a soft iron core placed in the magnetic field and its function is to minimize the reluctance effect.

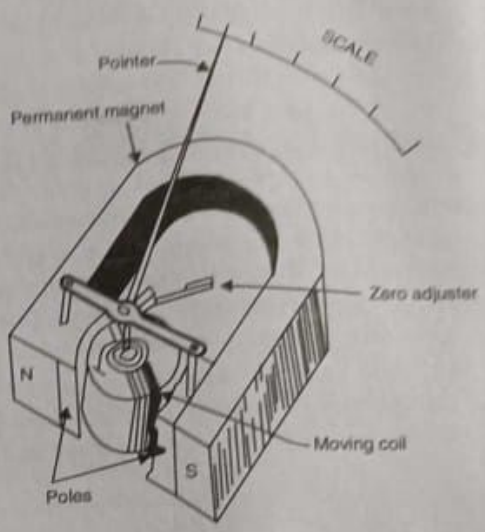

Fig. 6. Moving Coil Instrument

5. Jewel: Jewel is placed at each side of the spindle which acts like a bearing to minimize the friction effect.

6. Pointer and Scale: Light pointer is attached to spindle which moves over the scale and gives the reading. Sometimes mirror is also provided in the instrument dial for accurate reading.

Working Principle: When coil is placed in the magnetic field and connected to D.C. supply through springs like D.C. meter, a torque is produced in it called deflecting torque which moves the coil in a particular direction and gives the reading. As the magnetic field is constant so the torque produced is directly proportional to current.

$$\text{Deflecting Torque} = \text{Flux} \times \text{Current}$$

$$T_d = \phi \times I \ (\phi \text{ is constant})$$

$$T_d \propto I$$

Due to this, the scale of moving coil instrument is always uniform. Controlling force is produced by spring control and Damping force is produced by Eddy current damping.

Applications: Moving coil instrument is used only in D.C. supply as in the case of A.C. supply, the torque produced shifts the pointer on both sides during each half cycle with the result net torque is zero thus, there is no reading but produces vibration only. This meter is used to measure current or voltage by using shunt or multiplier.

Merits:

1. Its scale has uniform marking.
2. Damping force is very effective.
3. There is no hysteresis loss.
4. Its range can be changed by changing shunt or multiplier.

Demerits:

1. It can be used on D.C. supply only.
2. It is costly.

Permanent Magnet Moving Coil (PM MC) Instrument: When any current carrying coil is placed in the permanent magnet, a force (torque) is produced which moves the coil. It is used to measure D.C. voltage and current.

Moving Iron Instrument: This meter works on attraction or repulsion of iron piece, so it is called moving iron instrument. There are two types of moving iron instrument.

(*i*) Attraction type moving iron instrument. (*ii*) Repulsion type moving iron instrument.

(*i*) Attraction Type Moving Iron Instrument: There is a fixed coil wound over the bobbin and its construction depends upon its working like for ampere meter it is of thick wire with less number of turns and for volt meter thin wire with more number of turns. A soft iron oval shape rod or disc is placed near the coil with the help of spindle and jewels. A pointer is fitted with one side of the spindle. Controlling torque is obtained either by spring or gravity control method and damping torque is produced by air damping.

Working Principle: When coil is connected with supply, the magnetic field is produced around that coil which attracts the iron disc towards coil, thus, deflecting force is produced due to attraction of iron disc which moves the pointer in a particular direction. The induced torque is proportional to the current and magnetic field.

$$\text{Torque} = \text{Current} \times \text{Flux}$$
$$T = \phi \times I \quad (\phi \propto I)$$
$$T \propto I^2$$

As the torque is proportional to I^2 so the scale of instrument is not uniform *e.g.*, narrow at starting and end whereas wide in middle.

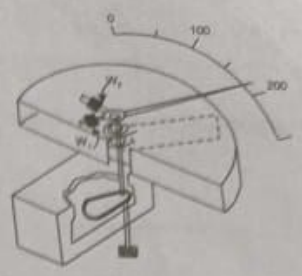

Fig. 7. Attraction Type M.I. Instrument

***(ii)* Repulsion Type Moving Iron Instrument:** The construction of this type of an instrument is almost same except an iron piece. In this, two soft iron pieces are placed inside the coil, one is called fixed iron piece and another is called moving iron piece which is attached to spindle and jewels.

Working Principle: When supply is given to fixed coil, both the iron pieces will be magnetised and have same magnetic poles. Due to this force of repulsion will be produced which will move the moving iron piece in a particular direction. This force is known as deflecting force.

Controlling and damping force is the same as in attraction type moving iron instrument.

This meter can be connected with A.C. and D.C. both as coil is magnetised in both the conditions and produce deflecting force.

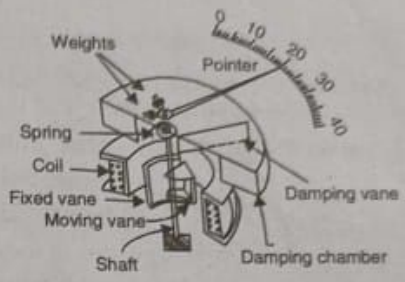

Fig. 8. Repulsion Type M.I. Instrument

Merits:

1. It is cheaper.
2. It can be used on A.C. and D.C. supply.
3. It is simple in construction.
4. It has more deflecting torque. ($T \propto I^2$)

Demerits:

1. Its scale is not uniform.
2. It consumes more power.
3. Stray losses affect its reading.

Comparison between M.C. and M.I. Meter

S. No.	Moving Coil	Moving Iron
1.	It is used on D.C. supply only.	1. It can be used on A.C. and D.C.both.
2.	Its scale is uniform.	2. Its scale is not uniform (uneven).
3.	It is costly.	3. It is cheap.
4.	It is not simple in construction.	4. It is simple in construction.
5.	Eddy current damping is used.	5. Air damping is used.
6.	Its coil is always made of thin wire with a few turns.	6. Its coil is made according to value of current or voltage.
7.	Deflecting force is produced due to moving coil.	7. Deflecting force is produced due to moving iron piece.
8.	Permanent magnet is used.	8. Electromagnet is used.
9.	It is more sensitive.	9. It is less sensitive.
10.	It consumes less power.	10. It consumes more power.
11.	It is more accurate.	11. It is less accurate.
12.	Controlling force is produced by spring control.	12. Controlling force is produced either by spring control or by gravity control.