

Ch-I

MEASURING INSTRUMENT

→ measure quantities (current, voltage, frequency etc) which do not varies with time is called static characteristics.

Accuracy:

→ closeness with which an instrument reading approaching the true value of the variable being measured.

Precision:

→ It is a measure of the degree to which successive measurement of differ from one another.

Sensitivity:

→ The ratio of the magnitude of the output signal to the input signal.

$$\text{Sensitivity} = \frac{\text{magnitude of output signal}}{\text{magnitude of input signal}}$$

Error:

→ variation from true value of the measured value.

$$\text{Resolution} = \frac{\text{Error}}{\text{true value - measured value}}$$

→ The smallest changes in measured variable to which

Tolerance :-
 → It is the difference of the maximum measured value to the actual measured value.

- ① Absolute Instrument
- ② Secondary Instrument

① Absolute Instrument :-

→ This instrument gives the magnitude of quantities under measurement in term of physical constants of the instrument and not measurable on a graduated scale.

→ These are generally used in research laboratory.

ex :- Absolute spectrometer
 Tarent galvanometer

② Secondary Instrument :-

→ These instruments are so constructed that the quantity being measured can only be measured by observing the output indicated by the instrument.

→ There are the instrument which do not give fully perfect value, it compare with absolute instrument.

→ Secondary instruments are

of 2 types

- ① Analog instrument
- ② Digital instrument

Again, Analog instrument are of 3 type - ① Indicating instrument
 ② Deflecting instrument
 ③ Integrating instrument

① Indicating instrument :-

→ These instruments are those who indicate the instantaneous value of electrical quantities being measured at the time of which it is being measured.

→ These indicators are given by pointers moving over calibrated scale.

eg :- Ammeter and voltmeter.

Essentials of Indicating Instrument

→ Indicating instrument fitted with a pointer which indicates on a scale the value of the quantity being measured.

→ The moving system of such instrument is usually carried by a spindle of hardie steel.

→ These instrument are of 3 essential features.

① Deflecting Torque:

→ The torque required to move the points of the instrument from it's zero position.

→ It is produced by mechanical force which is produce by electrical current, voltage or power.

→ This torque also can be produced by utilizing any one of the following effect like magnetic effect, electro-dynamic effect, electro-dynamic effect, induction effect, thermal effect

② Recording Instrument:

→ These instrument gives a continuous record of variation of an electrical quantity over a selected period of time.

→ ~~The~~ pointer in these type of instrument in an inked pen which leave a ~~trace~~ trace on a paper.

Eg: Radiating instrument for frequency power factor.

③ Integrating Instrument:

→ It is the instrument which measure the total quantity of electricity delivered in a particular time.

Eg: Ammeter hour meter, wattmeter, energy meter

chemical effect.

II Controlling Torque:

Controlling is essential to balance or oppose the deflecting torque, also this torque brings the pointer after, the measuring quantity withdrawn.

→ These torque can be provided by two method.

- ① Spring system
- ② Gravity system

① Spring system:

→ It is provided with the help of and spiral spring which is made up of phosphorus ~~and~~ brass.

② Gravity system:

Weights are controlled by a small weight which is called control weight which is attached to the moving system.

→ These torque produced to the ~~gravity~~ gravitational force acting on it.

(III) Damping torque:

→ The damping torque enables to prevent oscillation of the moving system and makes the pointer to reach its final position quickly.

→ The damping torque to an instrument can be provided by either of the following 3 method.

- ① Air friction damping
- ② Fluid friction damping
- ③ Eddy - current damping

Calibration of an instrument:

Natl - National Board of Accreditation for testing and calibration laboratory.

→ It is the instrument which measures the performance of an instrument by reference / master instrument.

OR

→ Performance of an instrument device is checked by comparing against a reference standard.

ANALOG AMMETER AND VOLT METER

AMMETER

→ measure the current.
→ it is used to measure the voltage.

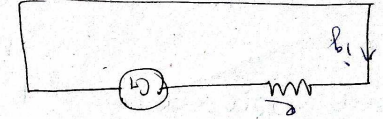
→ it is connected in series because it has low resistance.
→ it is connected in parallel because it has high resistance.

IMP for P.T

only low resistance is used. why with resistance is used because if we use high resistance some part of current is oppose by the instrument so path with out trouble we can't get accurate value.

IMP for P.T

How to convert galvanometer into voltmeter.

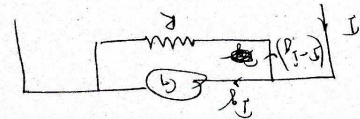


$$V = I_g R + I_g R_g \Rightarrow V = I_g (R + R_g)$$

→ we need to connect resistor in series.

IMP for P.T

How to convert galvanometer into ammeter.



$$I = \frac{V}{R} + \frac{V}{R_g}$$

$$\Rightarrow I = V \left(\frac{1}{R} + \frac{1}{R_g} \right)$$

→ we need to connect resistor in parallel.

VOLTMETER

→ it is used to measure potential difference between the two point of the circuit.
→ it is connected in parallel with circuit.

→ voltmeter is always designed with very high internal resistance.

AMMETER

→ it is used to measure the flow of current in a circuit.
→ so, it is connected with series.
→ its internal resistance is very low.

ERRORS IN AMMETER AND VOLTMETER

(i) FRICTIONAL ERROR

- The friction of pivot in the jewel produces frictional torque which opposes the deflection of moving element and as a result the point comes to rest at a short distance from its correct position this causes an error in the instrument.
- This error is more serious for sensitive instrument.
- In order to reduce effective frictional torque, the moving system must be made as small as possible compare with operating force.

(ii) TEMPERATURE ERROR

- It is produced heat generated in the instrument or by change in ambient temperature.
- The power loss in the instrument small.
- In order to eliminate temperature error the working coil is wound with copper wire and comparatively

low resistance.

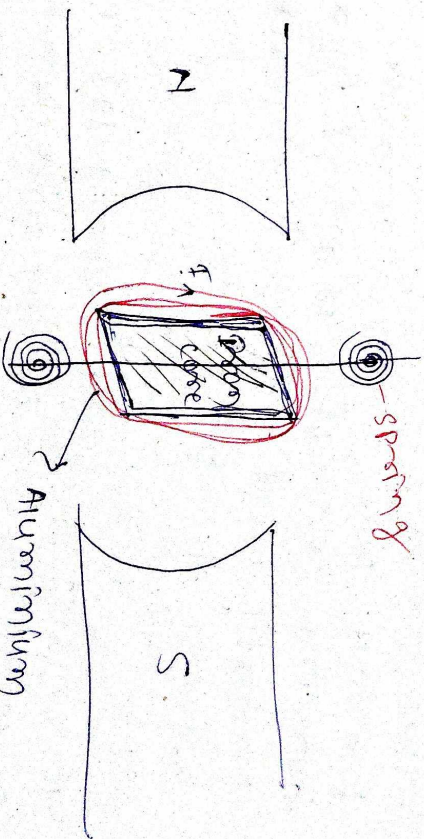
(iii) OBSERVATIONAL ERROR

- This error are due to mis-reading of the scale parallel in reading and error of estimation.
- Precision of reading becomes difficult if the pointer has a broader tip.

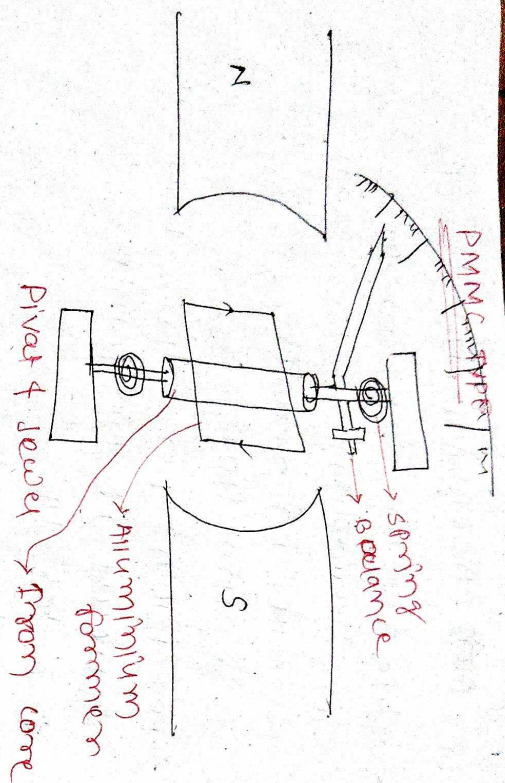
INDICATING TYPE OF INSTRUMENT

PMMC (Permanent magnet moving coil)

- It is used for measuring DC only.
- It can be used as a voltmeter as well as ammeter.



- Spring made up of Phosphor Bronze.



Statement:-

→ This instrument is either used as ammeter or voltmeter and suitable for DC work only.

Operating principle:-

→ This type of instrument is based on principle that when a current carrying conductor is placed in a magnetic field a mechanical force act on the conductor.

Construction:-

→ It consists of light rectangular coil of many turns having wire wound on a aluminium former inside which a soft iron core is present.

→ The coil is pivoted upon jewel bearing and is mounted between the core of a permanent magnet.

→ The spring also provide the controlling torque and damping torque. Damping torque is provided by eddy current induce in the aluminium former. As the coil moves from one coil to another.

Working:-

→ When the instrument is connected in the circuit to the measured voltage or current.

→ The operating current flow through the coil since the coil is carrying current and is placed in magnetic field of the permanent magnet a mechanical force is act on it.

→ As a result the pointer is attached to the moving system it moves in clockwise direction over the graduated scale to indicate the value of current or voltage.

→ The final position of the pointer is control by the controlling torque

which is provided by the too air spring attached to the spindle.

→ The aluminium former over which the coil wound provided the necessary damping torque by eddy current damping.

INDICATING TYPE OF INSTRUMENT

- ① M.C (moving coil) - only used for D.C.
- ② M.I (moving iron type) - It is used for both AC & DC.
- ③ HOT WIRE TYPE - it is used for both AC & DC.
- ④ Thermocoupled type - It is used for both AC & DC.
- ⑤ electrostatic type - It is used for both AC & DC.
- ⑥ Indicating type - It is used for only AC components.

DMP for P.F

→ if we need to increase the measuring capacity of a ammeter then we need to connect a resistance which parallel with the ammeter.

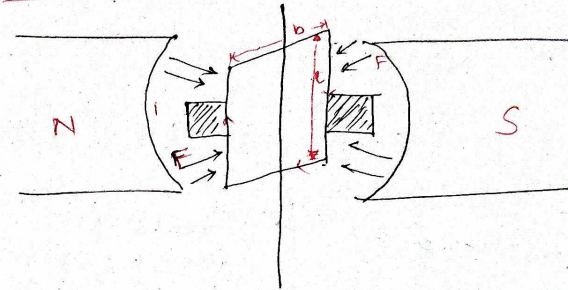
$$M = \frac{I}{I_m}$$

I = total current

I_m = meter current

M = multiplying factor

Torque equation in PMMC



→ Torque (T) = force × ⊥ distance

l = length of wire

N = No. of turns

B = flux intensity

$$F = B l I \sin \theta$$

$$\Rightarrow F = B l I \sin 90^\circ \quad [\theta = 90^\circ]$$

$$\Rightarrow F = B l I$$

$$\Rightarrow F = B I (l \times N)$$

$$\Rightarrow F = B I N A \quad (\text{Newton})$$

→ If I amp current passing through the coil, the magnitude of force (F) experience by each of its side is given by. $F = B I L$ (Newton)

where, B = flux density $\frac{Wb}{m^2}$
 l = length or depth of the coil in meter.

→ For 'N' turns the force is on each side of the coil is

$$F = NBIL \text{ (Newton)}$$

→ Deflecting torque (T_d) = force $\times$ distance

$$\begin{aligned} T_d &= NBIL \times b \\ &= NBIL(l \times b) \quad \left[\because \text{rectangle area} = l \times b \right] \\ &= NBIA \end{aligned}$$

$$\Rightarrow T_d = NBIA \text{ newton-meter}$$

where,

b = breadth of the coil in meter

A = Area of the coil.

→ if B is constant then

$$T_d \propto I.$$

$$T_d = KI$$

$$\Rightarrow K\theta = KI$$

$$\Rightarrow \theta = I$$

→ Since such instrument are in variable spring controlled the controlling torque (T_c) will be

directly proportional to θ .

$$T_c \propto \theta, \quad T_c = C\theta$$

C = constant given for spring

θ = Angular deflection

→ For steady deflection controlling torque (T_c) will be equal to deflecting torque (T_d)

$$T_c = T_d$$

$$\Rightarrow C\theta = KI$$

$$\Rightarrow \theta = \frac{K}{C} I$$

RANGES: (DC AMMETER)

(i) without shunt → 0 or 5 mA
 upto 0 or 30 mA

(ii) with shunt → upto 0 - 200 Amp

(iii) with external shunt → upto 0 - 500 Amp

DC VOLT METER:

(i) without series resistances →
 0 - 100 mV

(ii) with series resistance →
 upto 20000 or 30000 volts.

ERROR IN PMMC INSTRUMENT

(i) FRICTIONAL ERROR:

→ This can be avoided by winding of coil carefully.

(ii) TEMPERATURE ERROR:

→ It can be avoided by wound with copper wire which is low resistance.

(iii) ERROR DUE TO WEARING & PERMANENT MAGNET:

→ It can be eliminated completely in working of mechanical control and attaching a symmetrical iron or steel middle to the coil.

→ The magnetic middle is so arranged that magnetic control provided by it diminishes as the magnet becomes weaker.

(iv) STRAY MAGNETIC FIELD ERROR:

→ This error can be avoided by using an iron case for ordinary type instrument.

ADVANTAGES AND DISADVANTAGES OF VOLTMETER AND AMMETER:

ADVANTAGES:

- Low power consumption.
- The scales are uniform.
- ~~low~~ low hysteresis loss.
- High torque and weight ratio.
- They have very effective and efficient eddy current damping.
- Range ~~can~~ can be extended with shunt or multiplier.
- No effect of stray magnetic field as intence polarised or unidirection employed.

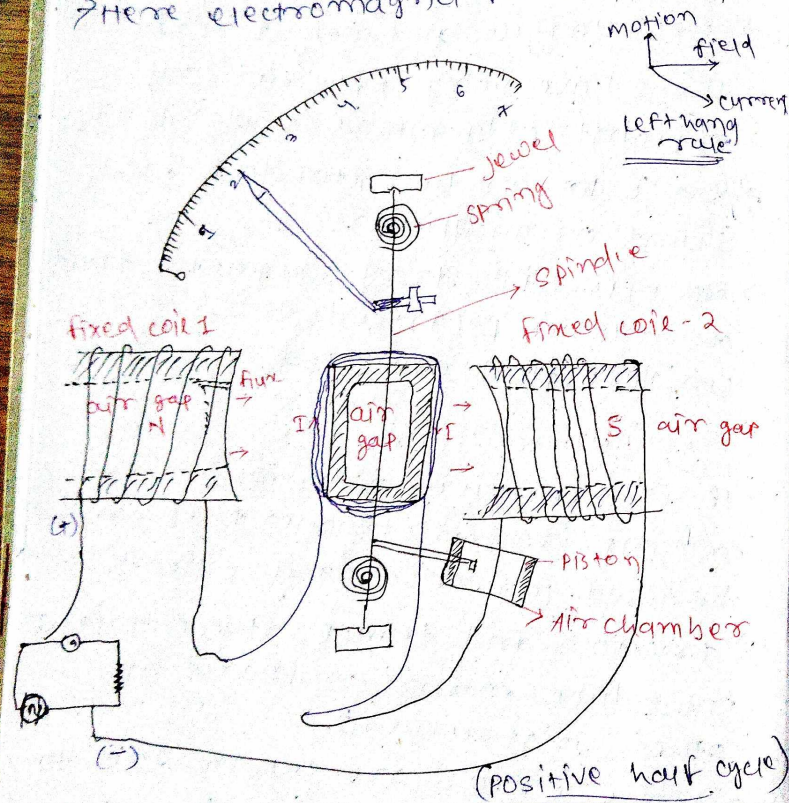
DISADVANTAGES:

- It is expensive as compare to moving iron instrument it can't be used for AC measurement.
- friction and temperature might introduce error as incase of other instrument.
- some error are set in due to the ageing of a controlling spring and permanent magnet.

① Electrodynamo meter type instrument or Dymmo meter type

- It will measure AC and DC.
- It can be used as voltmeter, ammeter and wattmeter.

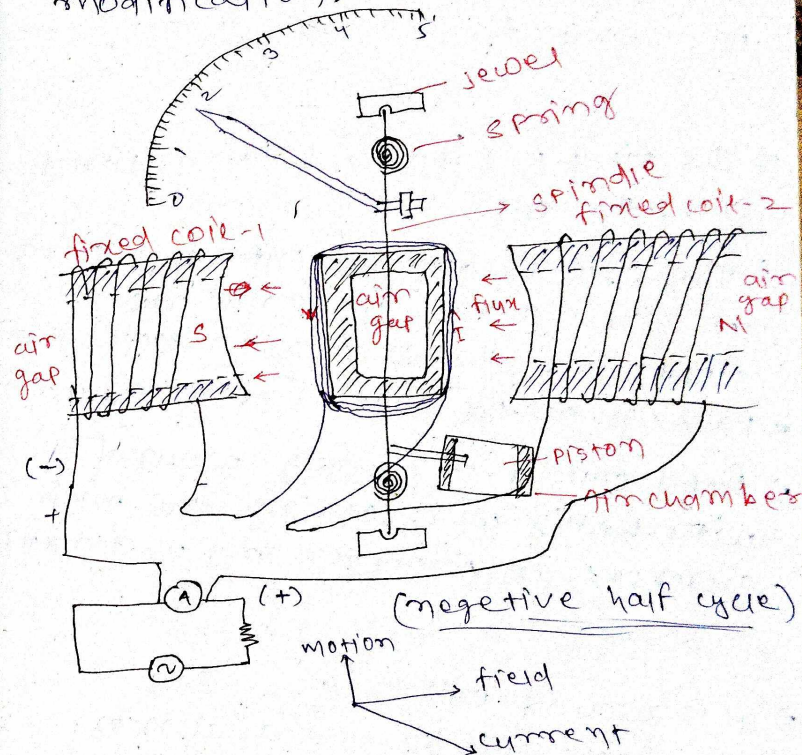
→ Here electromagnet pole and used.



→ This type of instrument operating field is produce by another fixed coil not by magnet (Permanent

magnet)

→ these instruments are capable of service as transfer instrument that is this may be calibrate with a DC source and than used as AC source without modification.



construction & working

- 1) main components are field system (fixed coil)
- 2) moving coil
- 3) control system (spring)

1) damping system (air friction damping)

⑤ swivling system

⑥ cases and scale

→ This is used for both AC & DC and it is also called as transferred instrument.

Fixed coil:-

→ The field is produced by a fixed coil. ~~the coil~~

→ The coil is divided into two sectors to give a more uniform ~~the~~ field near the center. to allow passage of the instrument shaft.

→ fixed coil are usually wound with heavy wire carrying the main current in ammeter and wattmeter

MOVING coil:-

→ It is wound either as a self sustaining coil or else as a non-magnetic former.

→ As metallic former can't be used as eddy current would be induced in it by the alternating field.

→ Here, Both fixed coil and moving coil are air core.

working principle:-

→ Air controlling torque is produced by two controlled spring. This controlled spring act as a lead to moving coil.

→ The moving coil is mounted on aluminium spindle.

→ The moving system also carrying the counter rate and truss type ~~the~~ pointer.

→ Air friction damping is employed for this instrument and it is provided by a pair of aluminium vanes attached to the spindle of the bottom.

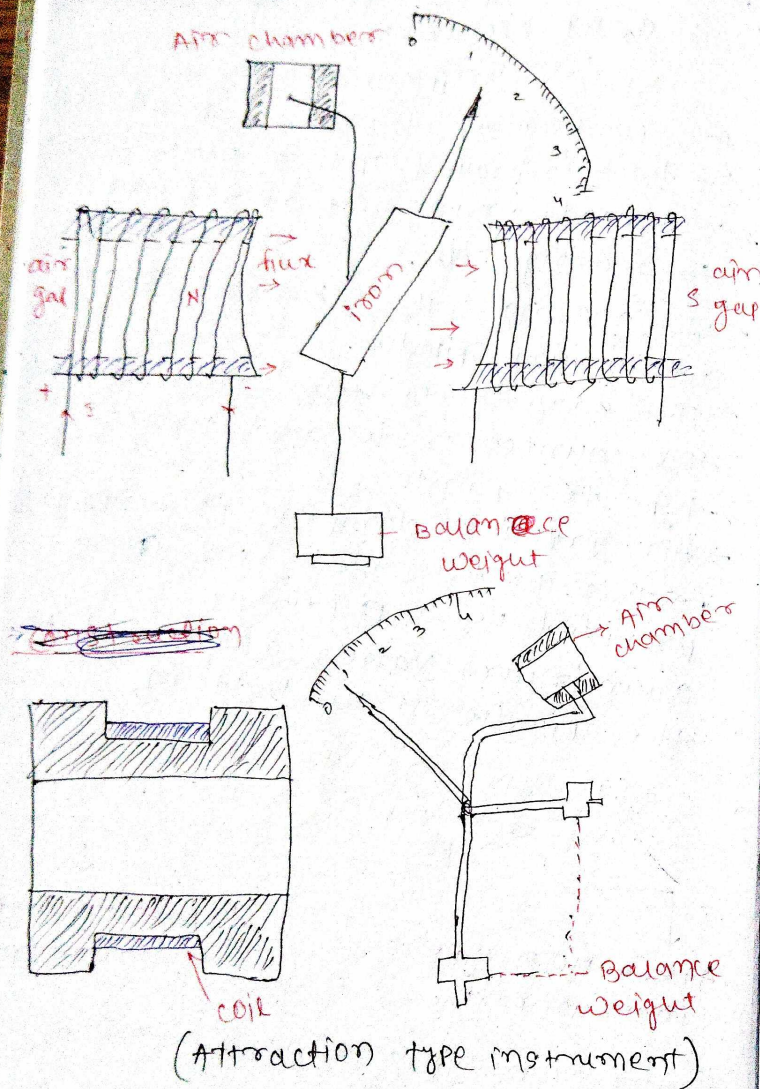
M.I type instrument
(moving iron type)

↓
Attraction type instrument

↓
Repulsion type instrument

① Attraction type instrument

→ This instrument used to measure both AC & DC



(Attraction type instrument)

Construction

- It consists a cylindrical coil which is kept fixed on over

shape soft iron this attached to the spindle in such way that it can move in and out of the coil.

- A pointer is attached to the spindle so that it is deflected with the motion of the soft iron
- The controlling torque is provided by an aluminium vane attached to the spindle which moves in a closed air chamber.

Working Principle

- When the instrument is connected in the circuit to measure the current and voltage the operating current flow through the coil and set of magnetic field or the coil behave like a magnet.
- This result that the pointer is attached to the moving system moves from zero position the pointer will come to rest at a position when the deflection torque is equal to the controlling torque.

$$T_d = T_c$$

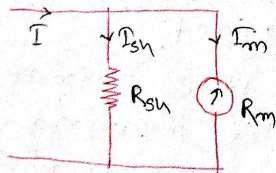
→ If the current in the coil is reversed the direction of deflecting torque remain unchanged so it is used for AC & DC.

Extension At Range:

DC Ammeter:

→ Since the coil and winding of a basic no movement of a DC ammeter is small and light.

→ It can carry only very small current when it is require to measure large current it is necessary to bypass the measure parts of current through a resistor called shunt resistance.



$$I = I_{sh} + I_m$$

$$I_{sh} = I - I_m$$

where,

R_m = Internal resistance of meter

R_{sh} = Shunt resistance

I_m = current through the meter

I_{sh} = shunt current

I = current of the circuit to be measure

DC Voltmeter:

→ By adding a series resistor or multiplier we can extend the voltmeter range.

I_m = full scale deflection current of the meter.

R_m = internal resistance of the meter.

R_s = multiplier resistance

V = voltage of the circuit to be measure.

$$V = I_m (R_m + R_s)$$

$$V = I_m (R_m + R_{se})$$

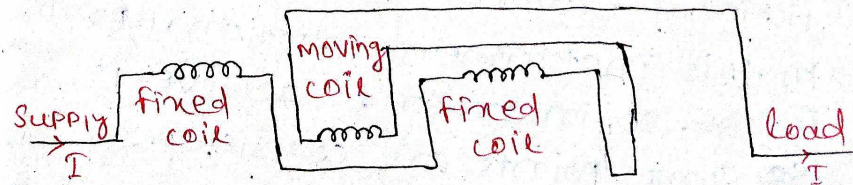
$$\Rightarrow V = I_m R_m + I_m R_{se}$$

$$\Rightarrow R_{se} = \frac{V - I_m R_m}{I_m}$$

$$\Rightarrow R_{se} = \frac{V}{I_m} - \frac{I_m R_m}{I_m}$$

$$\Rightarrow R_{se} = \frac{V}{I_m} - R_m$$

USE OF AN INSTRUMENT AS AN AMMETER:



* When the instrument used as an ammeter then same current passes through both moving coil.

$$I_1 = I_2 = I$$

$$\text{Hence deflection} \propto I \propto \sqrt{I}$$

→ In the case of heavy current a shunt resistance is used to limit current through the moving coil.



Range:

Ammeter:

- with fixed and moving coil: 0.01 A
- with moving coil shunt or parallel connection: $0 - 30 \text{ Amp}$

Voltmeter $\Rightarrow 0.750 \text{ V}$

ERROR IN DYNAMO TYPE INSTRUMENT:

(i) Fictional Error:

→ In this instrument frictional error is high. so in order to achieve it some points are consider.

* By a reasonable reduction in weight

* By proper selection of materials for bearing and spindle and adequate polishing if this part.

(ii) Temperature Error:

→ High currents are carried by coil which produce heat, self heating of coil produce error.

→ High accuracy instrument contain temp compensating resistors which tends to neutralize the effect of changes in temp.

(iii) Error Due to stray field:

→ In order to avoid the influence of stray field a good amount screening is necessary.

(iv) Error Due to the eddy current:

→ The eddy currents are induce in metal parts of instrument and developed a torque because of coupling between moving coil and near metal parts.

→ This error can be reduced by keeping the metal in the support of the coil and other structural part to the minimum possible.

Advantages of dynamo type instrument

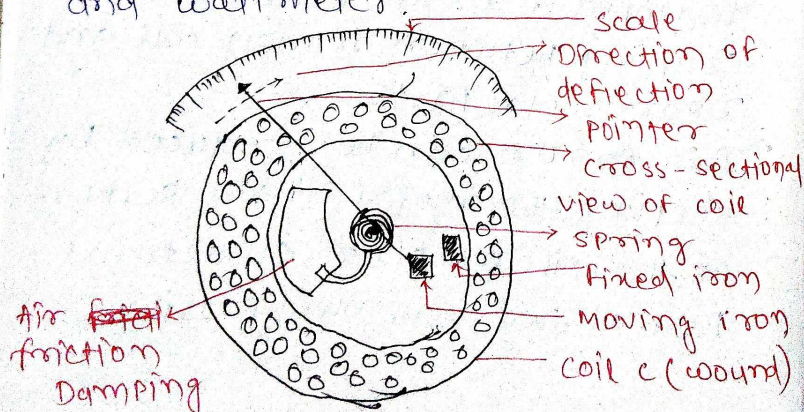
- It is used in both AC & DC.
- Easy in construction and light in weight.
- less power consumption
- Scale is uniform
- Range can be change

Disadvantages of dynamo type instrument

- low power factor
- low sensitivity
- frictional error
- High cost
- Effected by strong magnet.

(b) Repulsion type instrument

- It is used to measure AC and DC.
- It can be used as voltmeter, ammeter and wattmeter.



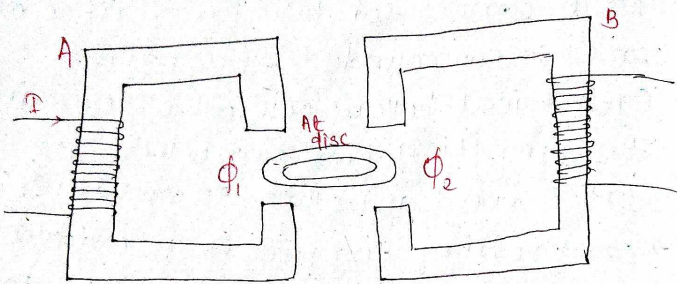
construction:

- It consist of two iron piece on vane ~~so~~ surrounded by a fixed cylindrical hollow coil which carries the operating current where ~~at~~ one is fixed and other is movable.
- controlling torque is provided by a spiral spring at the top of the instrument and damping is provided by air friction.

Working Principle:-

- When current to be measure through the coil the magnetic field is set up by the coil.
- This magnetic field is magnetized to vanes in the direction i.e same Polarity are developed at the same end of the vanes.
- Since the adjacent side vane are ~~are~~ same polarity (same terminal) the two vane are repel each other as a fixed vane can not move the movable vane deflect and causes the pointer to move from zero position.

Induction Type Instrument:



- It can be used only for AC measurement.
- It can be used as Ammeter, voltmeter, wattmeter and energy meter.

Construction:

- Two electromagnet and a magnetic Aluminium disc are the main part where metal disc is placed in between the electromagnet.
- The electromagnet produces flux Φ_1 and Φ_2 respectively in the metallic disc.
- Due to phase difference between the flux a deflecting torque is produced on the disc.

$$T_d \propto \Phi_1 \Phi_2 \sin \theta$$

where,

Φ_1 is the maximum flux

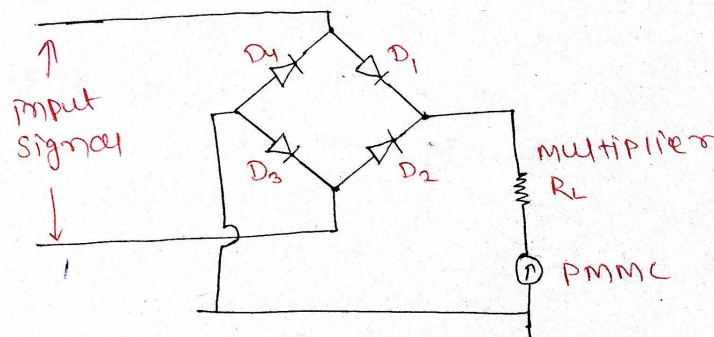
Generated by the electromagnet 'A'.

Φ_2 is the maximum flux generated by the electromagnet 'B'.

where θ is the phase difference between two flux.

- The maximum amount of deflection is produced when the phase difference is 90° .

Rectifier Type Instrument:



- These are used for measurement of AC voltage and current by using rectifier element which convert AC to DC and then using Ammeter to DC indicate the value of rectified A.C.

- The indicating instrument are PMMC instrument type.

→ The arrangement which employs a full wave rectifier circuit using 4 diode.

→ Rectifier type instrument are particularly suitable to measure the communication circuit and for all light, less current.

→ All light current work where the voltage is low and resistance is high.

§ In PMMC instrument which give full scale deflection at 50 mV potential difference and 10 mA current as

① Ammeter 0 to 10 A range

② Voltmeter 0 to 250 V range.

$$A \rightarrow R_m = \frac{V_m}{I_m}$$

$$\Rightarrow R_m = \frac{50 \times 10^{-3}}{10 \times 10^{-3}} = 5 \Omega$$

$$I_m R_m = (I - I_m) \times R_{sh}$$

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

$$\Rightarrow R_{sh} = \frac{10 \times 10^{-3} \times 5}{10 - 10 \times 10^{-3}} = 5.005 \times 10^{-3} \Omega$$

$$(ii) V = 250 V$$

$$V = I_m R_m + I_m R_s$$

$$\Rightarrow 250 = 10 \times 5 \times 10^{-3} + 10 \times 10^{-3} \times R_s$$

$$\Rightarrow 10^{-2} R_s = 250 - 0.05$$

$$\Rightarrow R_s = \frac{250 - 0.05}{10^{-2}} = 24995 \Omega$$

§ A millimeter with a resistance of 5 Ω is connected with a shunt of 0.005 Ω what will be the current flowing through the instrument to a circuit which a current of 10 A is flowing.

A → Given,

$$I = 10 A$$

$$R_m = 5 \Omega$$

$$R_{sh} = 5 \times 10^{-3} \Omega$$

$$I_m R_m = (I - I_m) \times R_{sh}$$

$$\Rightarrow I_m = \frac{(I - I_m) \times R_{sh}}{R_m}$$

$$\Rightarrow I_m = \frac{(10 - I_m) \times 5 \times 10^{-3}}{5}$$

$$\Rightarrow I_m = 10 \times 10^{-3} - 10^{-3} I_m$$

$$\Rightarrow I_m + 10^{-3} I_m = 10 \times 10^{-3}$$

$$\Rightarrow (1 + 10^{-3}) I_m = 10^{-2}$$

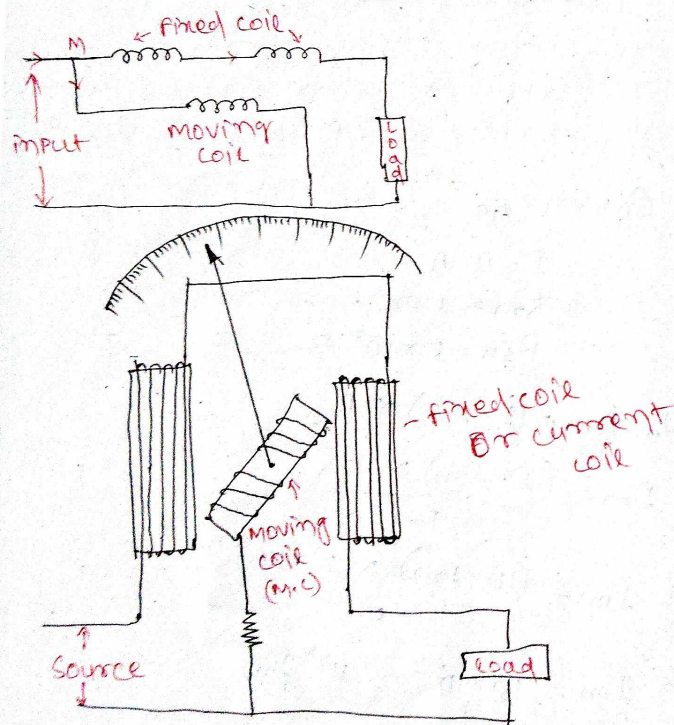
$$\Rightarrow I_m = \frac{10^{-2}}{(1+10^{-3})}$$

$$\Rightarrow I_m = 9.99 \times 10^{-3} \text{ A}$$

CH-3

WATTMETER AND MEASUREMENT OF POWER

@Dynamometer Type wattmeter :-



→ It measure power.

→ If the coil are connected so that the value of current proportional

to the load voltage flow in one and a value of current proportional to the load current flow in the other.

→ This type of wattmeter designed a simple which is used for measurement of voltage and current.

→ It consist of two coil one is fixed coil (current coil) another one is moving coil (pressure coil).

fixed coil :-

→ The fixed coil is connected in series with the load and carry the current coil of the wattmeter.

→ It is divided into two half. The wire present in this coil are laminated and are very heavy wire which can carry large amount of current.

moving coil :-

→ It is connected across the load so that the current proportional to the voltage drop which can flow through the coil since the current proportional to the voltage is flowing through it, so it is called as pressure coil.

Working:

- The moving coil is mounted on a spring so that it can move freely.
- The deflecting torque developed in the moving coil is proportional to the current flowing through the fixed coil and moving coil.

$$T_d \propto I_f \times I_m$$

$$\Rightarrow T_d \propto I_f \times \frac{V_m}{R}$$

$$\Rightarrow T_d \propto \frac{IV}{R}$$

$$\Rightarrow \boxed{T_d \propto P}$$

where,

I_f = current in fixed coil

- if ϕ is the angle between the voltage and current in the current coil then, we can say that current lags the voltage by an angle ϕ and

$$\boxed{T_d = \frac{VI_f}{R_m} \cos\phi \frac{dM}{d\phi}}$$

where,

dM = mutual inductance

- The pointer is connected to the spindle of the moving coil which

also get deflected due to the moving coil movement.

- Two springs are connected to the moving coil through spindle to provide the controlling torque.
- Air friction damping is used to absorb the oscillation of the instrument.

Low Power factor type dynamometer wattmeter:

- ordinary dynamometer wattmeter cannot measure the power in the circuit having low power factor without any error.

→ This happens due to deflecting torque in the moving system is small for low power factor and error introduced in the pressure coil is very large at lower power factor.

- So, some special features are included to make it low power factor type, that are

1) Pressure coil current :-

- In low power factor wattmeter is generally 10 times the value employed for high power factor wattmeter. So resistance of

of the pressure coil is decreased to allow the current flow through it.

→ If the pressure coil current will increase then more amount deflecting torque produced.

2) compensation of pressure current coil →

→ The power loss in the pressure coil is compensated by connecting a compensating winding with pressure coil in series.

compensation for inductances of pressure coil:

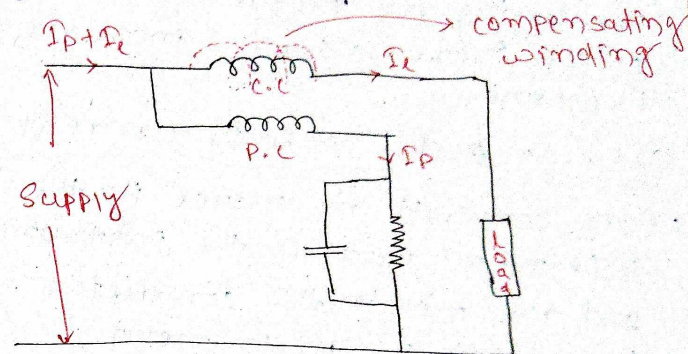
→ Due to lower power factor the value of phase angle ϕ is large and it give high error.

→ This error can be compensated by connecting a capacitor across a part of series resistance in pressure coil.

→ Low Power factor type wattmeter are designed with small controlling torque.

→ By introducing the above features the low power factor

(LPF) wattmeter can be represented as.



LOW POWER FACTOR TYPE DYNAMOMETER WATTMETER

ERROR IN DYNAMOMETER TYPE INSTRUMENT:

(A) ERROR DUE TO PRESSURE COIL INDUCTANCE:

→ Due to pressure coil inductance the wattmeter reading can vary when measuring LPF. (Low power factor).

→ The error can be compensated by means of connecting capacitor in parallel with a portion of pressure coil series resistance.

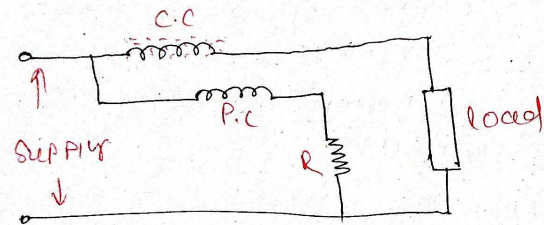
(B) Error due to Pressure coil capacitance:

→ The pressure coil circuit may possess capacitance which alter the wattmeter reading to some extent.

→ This effect is not present by measuring low frequency but its effect increases with increase in frequency.

(C) Error due to Eddy current :-

→ Eddy current are induce in the solid metal parts of the instrument and also with in the conductors present in the instrument.



→ This current is produce its own field and alter the magnitude and phase of the current coil and pressure coil which causes error in the instrument.

(D) Stray magnetic error :-

→ This wattmeter has a reliability magnetic field which is responsible which is for the generation of transmission.

→ This magnetic field is effect by the outside stray magnetic field

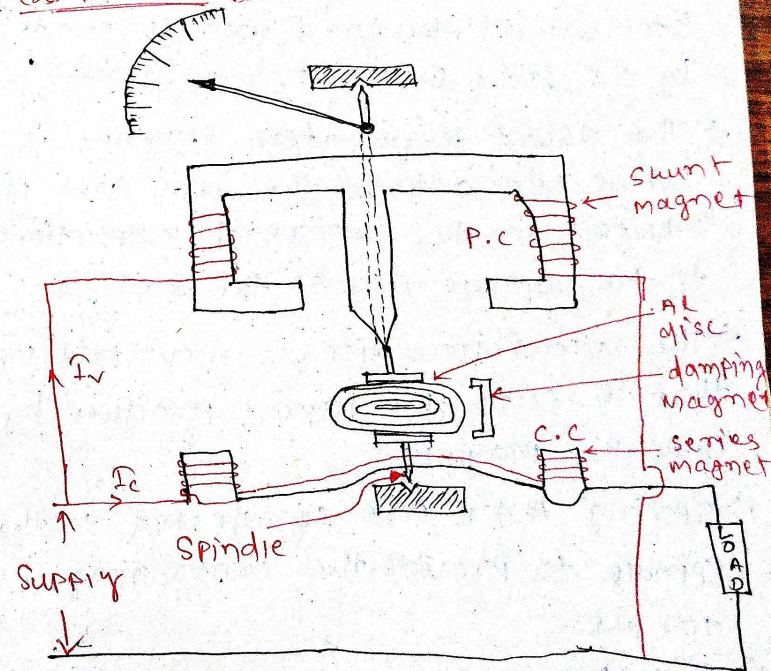
and causes error.

→ This error can be reduce by proper shielding of the instrument against the stray magnetic field.

→ The indication of the watt meter is effected by changes in room temperature.

→ This happen because any change in room temperature ($25^{\circ}-27^{\circ}$) it changes the length of the spring.

(2) INDUCTION TYPE WATTMETER :-



→ It can only measure A.C. current.

→ The induction type wattmeter is used to measure only AC power consumed by the load.

→ It works on the same principle of as a induction type voltmeter & ammeter type instrument.

CONSTRUCTION:

→ The induction type wattmeter is consist of two electromagnet i.e. shunt & series magnet.

→ The series magnet is connect in series with the load and is excited by the load current.

→ The shunt magnet is connected across the load and it excited by the current proportional to the voltage across the load.

→ The aluminium disc is mounted in that it cuts the fluxes produce by both the magnet.

→ Spring A & B are connected to the spindle to provide the controlling torque.

→ Damping magnet can be connected

to provide the damping torque.

WORKING PRINCIPLE:

→ The two flux generated by the electromagnet produce a eddy current in the aluminium disc.

→ Due to the intersection between the fluxes and the eddy current a deflecting torque is produce.

→ Due to the deflecting torque spindle also along with aluminium disc and move the pointer over the scale.

→ The deflecting torque produce

$$T_d \propto VI \cos \phi$$

where,

V = supply voltage

I = supply current

$\cos \phi$ = Power factor of the load

CHAPTER - 4

ENERGY METER

→ Energy is defined as power consumed by the load over a particular interval of time.

$$\text{Energy} = \text{Power} \times \text{Time}$$

$$E = \int_0^t p \, dt$$

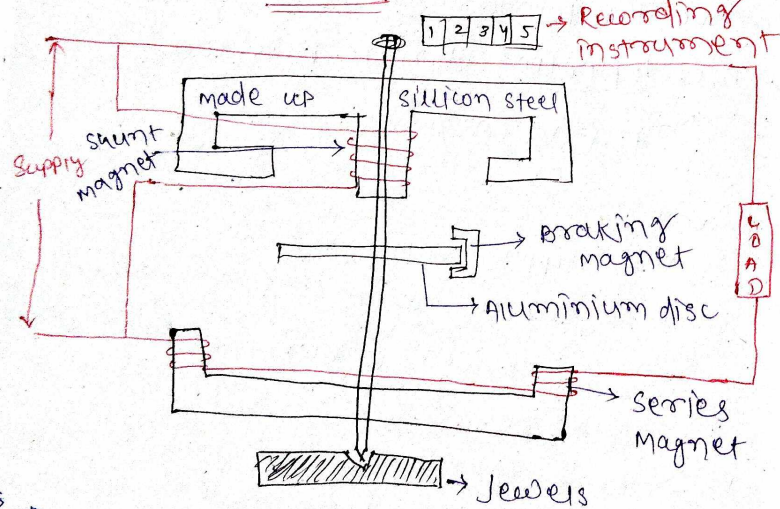
$$\Rightarrow E = \int_0^t VI \, dt$$

→ If the voltage is measured in Volt and current in Ampere and time in Second. then the energy consume can be expressed in watt Second.

→ If the time interval 'T' is in hour then the energy can be expressed as Watt-hour unit $\pm$ kWh also called as $\pm$ unit in domestic energy meter.

$$1 \text{ kWh} = 1 \text{ unit}$$

Single-Phase induction type energy meter



→ There are four main parts in the energy meter system which are

- ① driving system
- ② moving system
- ③ Breaking system
- ④ Recording or counting system

① driving system

→ It consists of two magnets one is excited by the load currents called current coil or series magnet another coil is excited by the current proportional to the voltage across the load.

→ The coil is connected across the load is known as pressure coil or shunt magnet.

→ Copper sliding may be provided to adjust the flux produce by the shunt magnet.

② Moving system:

→ It consists of aluminium disc mounted on a alloy shaft.

→ This disc is present with in the airgap betn the series and shunt magnet.

③ Breaking system:

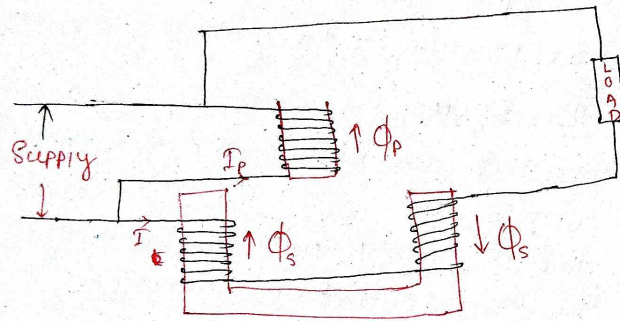
→ A Permanent magnet is position near the edge of the aluminium disc to provide the breaking system.

→ The breaking system is use to control the speed of moving system by adjusting the position of permanent magnet breaking torque can be adjusted.

④ Recording system :-

→ The function of this system is to record continuously a number which is proportional to the revolution of the moving system.

THEORY AND OPERATING PRINCIPLES SINGLE PHASE ENERGY METER:-



→ In the above diagram the supply voltage is applied across the pressure coil as the pressure which is highly inductive as it has very large no. of turns.

→ It is the current flow in the pressure coil which is proportional to the supply voltage and this current lags the voltage by few degree less than 90° .

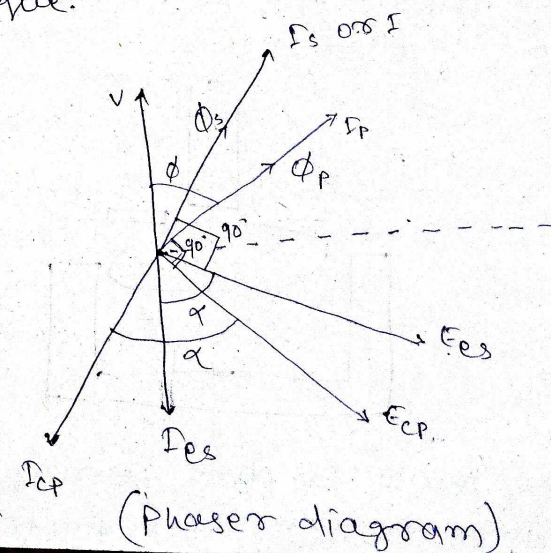
→ This I_p current produce a flux Φ_p which goes across the aluminium disc and responsible for the production of driving torque.

→ Φ_p in phase with I_p and the value is proportional to I_p .

→ The load current (I) flow the current coil and produce flux Φ_s this Φ_s flux is proportional to the load current I and is in phase with it.

→ Φ_p produce on eddy current I_{ep} and Φ_s produce on eddy current I_{es} in aluminium disc.

→ The net torque is the difference between the above the torque driving torque & moving torque.



where,

V = Supply voltage.

I = Load current

ϕ = Phase angle of load.

I_p = Current in pressure coil

Δ = Phase angle betⁿ supply voltage & I_p

f = frequency

Z = Impedence of eddy current path

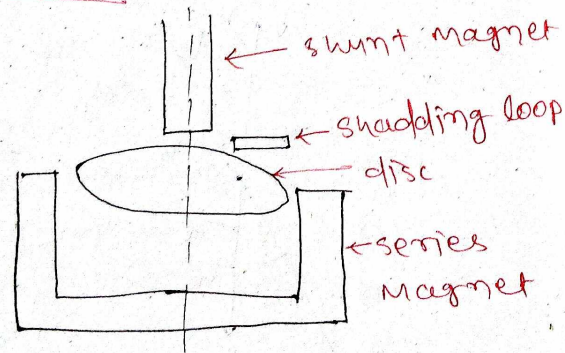
I_{ep} = eddy current due to ϕ_p

I_{es} = " " " " ϕ_s

E_{es} = EMF induced due to ϕ_s

E_{ep} = " " " " ϕ_p

COMPENSATION AND ADJUSTMENT LIGHT LOAD COMPENSATION:



→ The Jewel ~~for~~ pivot bearing for the spindle providing some friction to the

movement of aluminium disc.

→ During light load supply we need to generate an extra small torque to overcome from this friction.

→ This is because light load ~~lead~~ very small amount of driving torque is generated which is not sufficient to overcome the friction and move the ~~disc~~ aluminium etc.

→ To compensate this conditions a small shading pole or loop is added in between the center of the pole of the shunt magnet & disc.

① CREEPING & ERROR

→ In some meter a slow motion of the disc is often even when there is no currents flowing through the current coil, this is known as creeping.

→ In order to prevent this creeping two diametrically hole are drilled in the disc.

→ This disc comes to the rest when one of the hole is under the edge of the hole or breaking magnet.

② overload error

- During overload condition to compensate the driving and its proportional to breaking torque and extra magnetic shunt are used.
- The magnetic shunt saturate and divert the series magnetic flux to the disc air gap.
- Due to this action the driving torque during the overload condition can be controlled.

③ TEMPERATURE ERROR:-

- An increase in atmospheric temperature can increase the resistance of the copper and aluminium part present in the device.
- Due to this change to resistance the lag between the supply voltage and flux changes eddy current flowing in the aluminium disc also varies.
- In order to compensate the input of increase in temperature the meter should be installed with proper shielding.

TESTING OF ENERGY METER:-

- The term of testing include the checking of actual regulation of meter as well as the adjustment done to bring the error of the meter within the permissible limit.

A) AC ENERGY METER

- meter should be tested for following condition.
- (i) At 5% marked current with unity power factor.
- (ii) At 100% or 125% marked current with unity power factor.
- (iii) At marked current at 0.5 lagging power factor.

B) CREEPING TEST:-

- In some meter a slow motion of the disc is often even when there is no current flowing through the current coil, this is known as creeping.
- In order to prevent this creeping two diametrically hole are drilled in the disc.
- This disc comes to the rest when one ~~end~~ of the hole is under the edge of the hole

or breaking magnet.

IMP for I.E

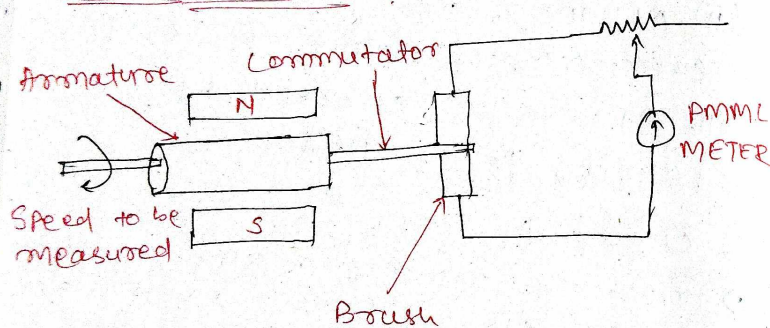
- ① frequency measure in
- cycloconverter
- ② direction of wind measure in
- Anemometer

CH-5

MEASUREMENT OF SPEED

FREQUENCY AND POWER FACTOR

① DC TACHOMETER:-



→ DC tachometer generator consist of a small armature which is connected to the machine whose speed is to be measure.

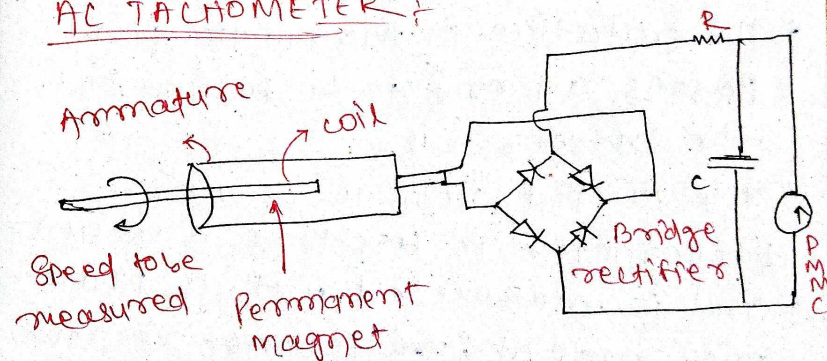
→ This armature coil revolves with in the permanent magnetic field due to the rotation of armature

with in the magnetic field and emf is induced in the armature coil.

→ this induced emf is proportional to flux & speed of rotation, since for this permanent magnet flux is constant so the generated voltage is proportional to the speed of rotation.

→ then induced emf can be collected by the help of commutator and brush arrangement this voltage can be measured by using a PMMC type meter. which can be calibrated w.r.t. speed.

AC TACHOMETER:-



→ In order to overcome some of the difficulties that is due to the maintenance problem of brush, Commutator contact DC commutator

is used.

→ It has rotating magnetic field which may be either a permanent magnet or an electromagnet.

→ But in AC tachometer we don't have brushes and commutator which is rugged and maintenance.

→ It has stationary armature and a rotating magnetic field.

→ The amplitude & frequency of this emf are both proportional to the speed of rotation, thus either amplitude or frequency of induced voltage is used as measure.

→ The rotation of magnetic field poses an emf to be induced in the starter coil.

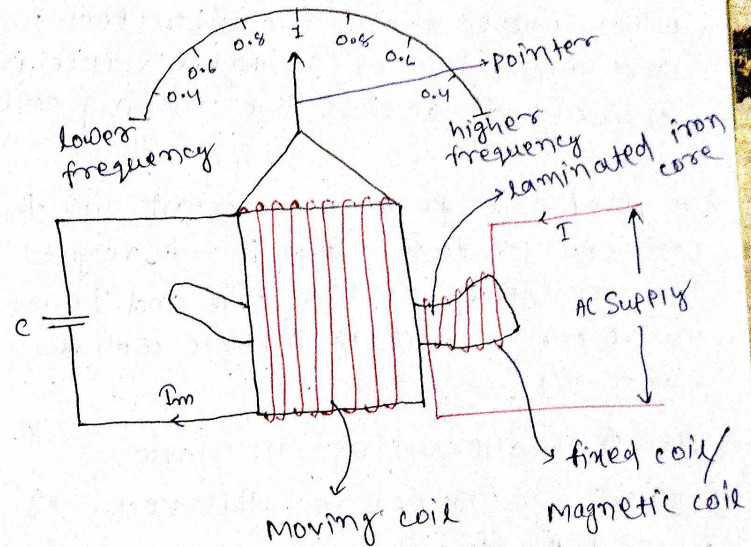
→ The output voltage of AC tachometer is used as a rectifier and is measured with a PMMC instrument, ~~resistance~~ resistor is used to manage voltage & current where capacitor filter is used to smooth the output and also smooth the ripple factor.

ELECTRICAL RESONANCE TYPE FREQUENCY METER

Ferrodynamic type frequency meter.

→ It consists of 2 fixed coils and 1 moving coil.

→ It is used to measure frequency.



WORKING PRINCIPLE :-

→ It works on the principle of R, L, C resonance ckt.

CONSTRUCTION :-

→ It consists of fixed coil which is connected across the supply to which the frequency is to be measured.

→ The coil is also called as magnetic

coil it is mounted on a iron core. the moving iron is attached to with a spindle which is fixed on the bearing which is allow to move freely.

→ The pointer is fixed with spindle which moves over a calibrated scale and capacitor of suitable value is connected across the moving coil.

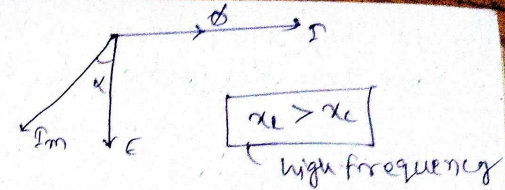
working:

→ A fixed coil draw a current and this current produce a flux if we neglect the resistivity of the coil and iron loss in the core flux ϕ is inphase with the current (I).

→ flux ϕ is alternating in nature induces an emf (E) and this emf lag behind the flux by 90° and this emf induces current I_m in the moving coil.

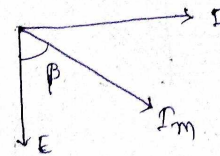
case-1

→ The circuit of the moving coil is assume to be inductive then the current I_m lags behind the emf by an angle " α " and the torque acting on the moving coil is $T_d \propto I_m \cos(90^\circ + \alpha)$.



case-2

The moving coil is assume to be purely capacitive then the current I_m leads the e.m.f by an angle " β " and the torque acting on the moving coil is $T_d \propto I_m \cos(90^\circ - \beta)$



case-3

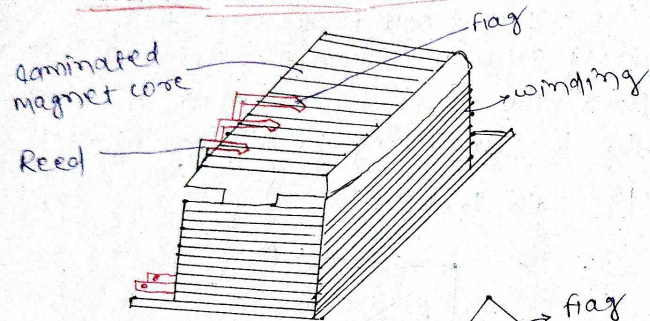
The inductive reactances is supposed to be equal to the capacitive reactance i.e. $X_L = X_C$ therefore the ckt is under resonance condition so, the moving coil ckt is purely resistive and I_m is inphase emf (E) and the deflecting torque (T_d)

$$T_d \propto I_m \cos 90^\circ = 0$$

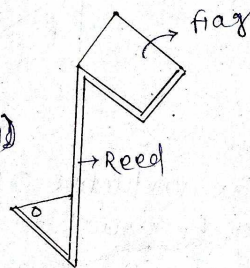
⇒ $T_d \propto I_m$ (so, the pointer does not move and act as equilibrium)

For high frequency $\omega > \omega_c$
for low frequency $\omega < \omega_c$

VIBRATING REED TYPES FREQUENCY METER MECHANICAL FREQUENCY RESONANCE METER



→ Reed made up of thin steel
 $4 \times 0.5 \text{ mm}$.



Construction:

- This frequency meter consists of no. of thin steel strips known as reeds.
- These reeds are placed in a row along the side of an electromagnet as shown in the fig.
- The electromagnet has a laminated iron core and its coil is connected across the supply whose frequency is to be measured.

→ The reeds are slidingly direction dimension and carry direction weight on their torque known as flag.

→ The natural frequency of the vibration of the reed depends on their width and dimension.

→ The reeds are approximately about 4 mm wide and 0.5 mm thick.

→ The reeds are not exactly similar to each other (variation in length)

→ The reeds are arranged in ascending order of their natural frequency with a direction between two adjacent reeds whose natural frequency of 0.5 Hz.

→ The reeds are fixed at bottom and free to move towards the top.

WORKING

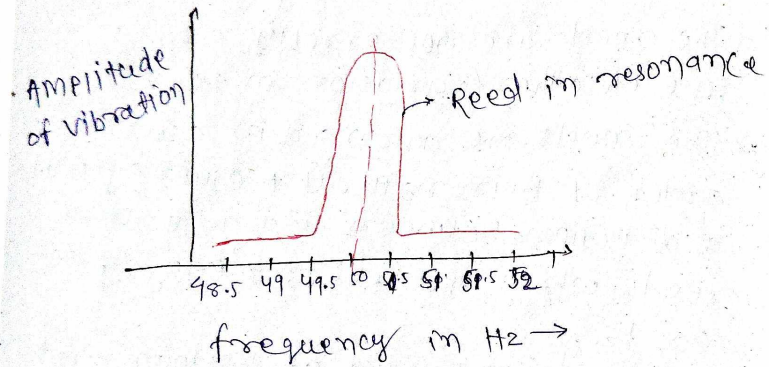
→ When the frequency meter is connected across the supplied coil, the coils of the electromagnet carries a current which alternates to the supply frequency.

→ The force, exerted as the reed, varies in every half cycle. So the reeds which have natural frequency ~~with~~ twice of the supplied frequency.

(The force of attraction between the reeds and the electromagnet is

Proportional to f^2 so the force vary twice the supply frequency.

→ All the reeds tends to vibrate due to the supply frequency but the reed which is resonance will vibrate the most and clearly visible.



ADVANTAGE:-

→ It independent of magnitude and wave form of supply voltage. so that it can work at low voltage also.

DISADVANTAGE

→ It can't be used to read small frictional frequency value between two adjacent reeds.
→ The reliability of the reading depends upon the accuracy with which reeds are tuned.

POWER FACTOR METER:-

→ $\cos \phi$ angle between voltage and current is known a power factor.

$$P = VI \rightarrow DC$$

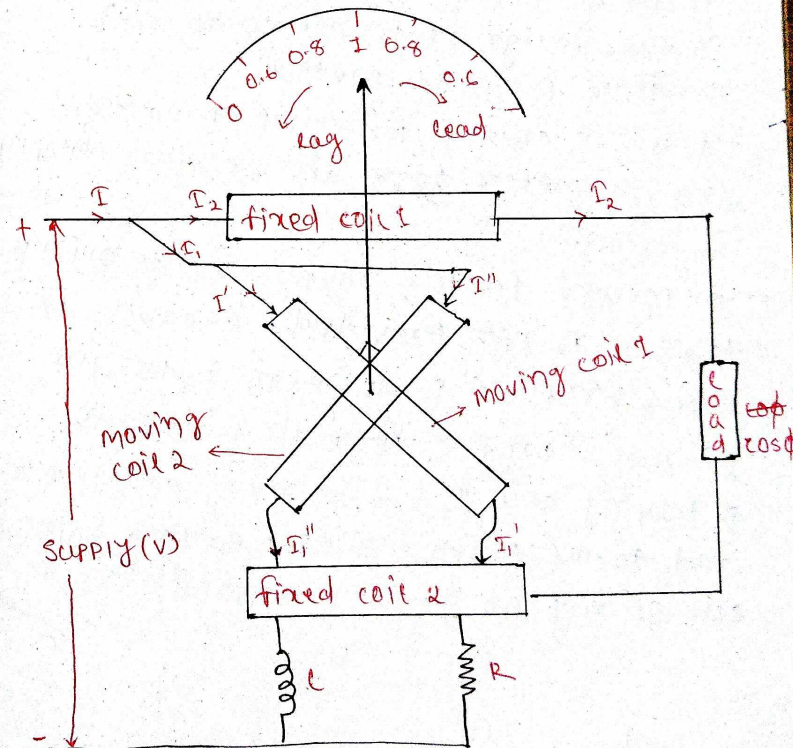
$$P = VI \cos \phi \rightarrow AC$$

$$P = 3 VI \cos \phi \rightarrow \text{for balanced load}$$

$$P = \sqrt{3} VI \cos \phi \rightarrow \text{for unbalanced load}$$

→ it ranges from 0 to 1.

→ 1- ϕ power factor meter consist of 2 fixed coil and 2 moving coil.



→ The instrument which indicate the power factor of a load ckt to which they're connected is called power factor meter.

$$\cos \phi = \frac{P}{VI}$$

where,

$\cos \phi$ = is known as power factor of the load.

→ So to measure the power factor, current, voltage is power consumed in an AC circuit may be calculated so the design of power factor is similar to watt meter.

→ It work on the principle of electro-dynamometer here air friction damping is used.

→ In power factor meter controlling torque is not provided. because in equilibrium the deflecting torque produced on the ~~deflecting torque~~ moving coil 1 & 2 balanced each other and so the pointer gives reading with out spring or gravity control.

WORKING OF SINGLE - PHASE POWER FACTOR METER

→ The current is in phase with the voltage when the load power factor is unity. ~~The current I_1 is in phase with the current I_1 is in phase with the~~ current I and the current I_2 lags behind by 90 degrees.

→ The torque act on coil C_1 and sets its plane perpendicular to the magnetic axis axes of the stationary coils SC_1 and SC_2 .

→ The torque does not act on the moving coil C_2 .

→ When the power factor is zero, the current lags with voltage by 90 degree.

→ The current I_2 is in phase with the current and the current I_1 will be 90 degree out of phase and there is no torque on the moving coil C_1 but it acts on C_2 . It will bring its plane perpendicular to the common magnetic axis of SC_1 and SC_2 .

→ This instrument must calibrated at the frequency of the supply on which it is operated for accurate readings.

→ If the frequency of the supply ~~on~~ changes its value continuously

then this power factor meter will cause serious errors.

CH-7

SENSOR & TRANSDUCER

TRANSDUCER:-

- Sensor is the device which convert the Physical signal to electrical signal.
- Transducer is a device which convert one of energy to another form.
or

→ transducer is a device which convert mechanical or non-mechanical energy to electrical energy.

Mechanical Energy → Pressure, humidity
nonmechanical Energy → light & heat, air

CLASSIFICATION OF TRANSDUCER:-

① On the basis of operation

(a) Resistive transducer

→ The output resistances changes w.r.t to input Parameter.

Ex:- Potentiometer, thermistor, resistance thermometer, strain gauge

(b) Inductive transducer

→ The output of inductances changes w.r.t. input Parameter.

Ex → LVDT - ~~Linear variable differential~~

② (c) Capacitive transducer:-

→ The output of capacitances changes w.r.t input Parameter.

Ex. → * variable Area type capacitive transducer

* variable Air gap type capacitive transducer.

② Primary and

② PRIMARY AND SECONDARY TRANSDUCER

→ The transducer which is directly connected to the Physical Parameter is known as P.T and the transducer which are connected to P.T are known as Secondary transducer.

③ ACTIVE AND PASSIVE TRANSDUCER:-

Active transducer:-

→ It generate electrical output in terms of voltage & current without any External Power Supply.

Ex :- thermocouple

Passive transducer

→ It require External power supply to generate output in terms of voltage & current

Ex - LVDT, Potentiometer, strain gauge

→ It produce output in terms of resistance inductance & capacitance with respect to

input parameter.

→ According to this it also 3 types:-

(i) resistive transducer:-

→ The output resistance changes w.r.t to input parameter.

Eg:- Potentiometer, thermistor, resistance thermometer, strain gauge.

(ii) Inductive transducer:-

→ The output of inductances changes w.r.t input parameter.

Ex - L.V.D.T.

(iii) capacitive transducer:-

→ The output of capacitances changes w.r.t. input parameter.

Ex - variable Area type capacitive transducer.

* variable Air gap type capacitive transducer.

POTENTIOMETER:-

→ It is a type of displacement sensor it also term as "POT".

→ POT meter consist of uniform resistive element and a sliding contact and the sliding contact is known as slider or wiper.

→ The motion of the sliding contact may be translational or rotational.

→ Depending upon movement of the slider the potentiometer are classified into 2 types.

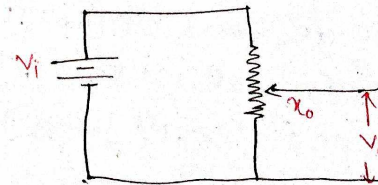
① Linear POT

② Angular POT

Linear POT

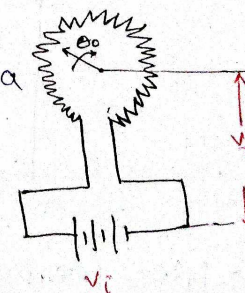
→ Here, the resistive element is linear in shape so it is called linear POT.

→ It is used to measure linear displacement.



ANGULAR POT

→ Here, the resistive element is present in a circular shape so, it is used to measure angular displacement.



THERMISTOR

→ Thermistor is a resistive transducer whose resistivity depends upon surrounding temperature.

→ For this reason it can be used as

temperature sensor.

→ The term thermistor, is a combination of thermal and resistor.

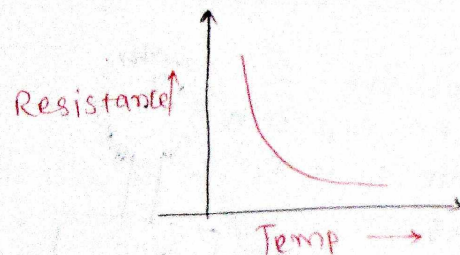
→ It is made up semiconductor material. This device generally made up oxides of certain metal like manganese, cobalt, nickel etc.

→ There are two types of thermistor.

① NTC

② PTC

→ ~~NTC~~ Negative temperature coefficient (NTC) when temperature increases resistance decreases similarly when temp. decrease resistance. This type of thermistor is used the most.



→ Positive temperature coefficient (PTC)
Here temperature increases or decreases simultaneously resistance is also increased or decreased.

WORKING PRINCIPLE:

→ As the temperature of the thermistor increases its resistance decreases exponentially so we can express by an equation.

$$R_1 = R_2 \exp \left[B \left(\frac{1}{T_1} - \frac{1}{T_2} \right) \right]$$

where,

R_1 = Resistance of the thermistor at the temp T_1 .

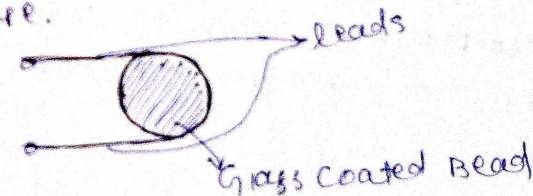
R_2 = Resistance of the thermistor at the temp T_2 .

B = constant whose value depends upon the material used.

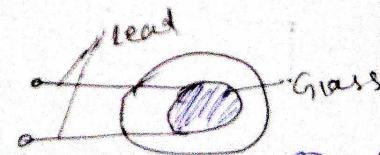
* Typically the value range varies from 3000 to 7500.

→ Thermistor can be of different size and shape.

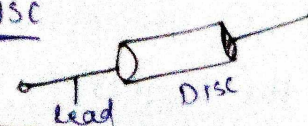
① Bead



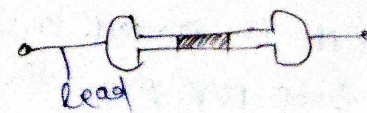
② Probe



③ Disc



④ Rod



Advantages

- They are compact and less expensive they have good stability and high sensitivity.
- The response is very fast they are not affected by stray magnetic and electric field.

RESISTANCE THERMOMETER (RTD)

- This is based under the principle of electrical resistance of the electrical wire, it is also known as RTD.
- It uses the resistance of electrical conductor for measuring temperature.

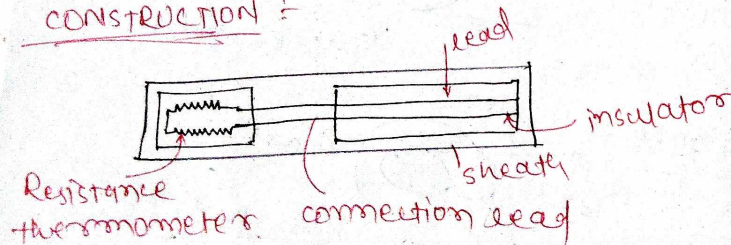
$$R_T = R_0 (1 + \alpha T)$$

where,

α = temp. coefficient of resistance of a particular material.

- This is made up extremely pure metal like platinum, nickel or copper.
- RTD is PTC type transducer.

CONSTRUCTION :



- It is placed inside the protective tube for providing the protection

against damage.

- The ~~resistance~~ resistive element is formed by placing the platinum wire on the ceramic bobbin.
- This resistance element is placed inside the tube which is made up of stainless steel or copper steel.
- The lead wire is used for connecting the resistance element with the external load.
- The lead wire is covered by the insulated tube which protects from short circuit.
- The ceramic material is used as an insulator for high temperature material and for low temperature materials, fibre or glass is used.

ADVANTAGES :-

- It provides highly accurate results.
- RTD provides a vast operating range.
- Due to its high accuracy, it is used in such applications where precise results are needed.

DISADVANTAGE :-

- The sensitivity of platinum RTD is very less.
- RTD possesses slower response time.

STRAIN GAUGE

- A strain gauge is a device that used to measure strain on a object.
- Resistances of the devices, varies w.r.t. applied force.
- It convert force, pressure, tension, weight etc into a change in electrical resistance when an external force is applied on an object due to which there is a deformation occurs in the shape of the object.
- This deformation is both compressive and tensile and is called strain and it is measured by strain gauge.

WORKING PRINCIPLE :-

- Resistances of any conductor wire is directly depends on the length and the cross-sectional area of the conductor, which is given by :-

$$R = \rho \frac{l}{A}$$

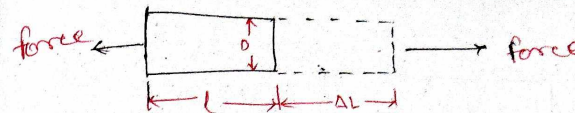
where,

R = Resistance of the material

ρ = resistivity of the material

l = length of the material

A = Area of the material



- If Δl is the change in length of the wire by the applied force of stress then,

$$\text{strain } (\epsilon) = \frac{\Delta l}{l}$$

- Sensitivity of the strain gauge is given by parameter known as gauge factor.

GAUGE FACTOR (G)

- It is defined as the ratio of fractional change in electrical resistance to the fractional change in length (strain).

$$G = \frac{\frac{\Delta R}{R}}{\frac{\Delta l}{l}}$$

$$\Rightarrow G = \frac{\Delta R / R}{\epsilon}$$

where,

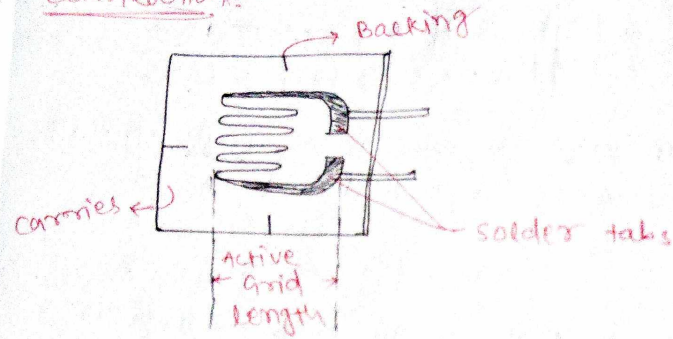
R = original resistance

ΔR = small change in resistance

Δl = small change in length

l = original length.

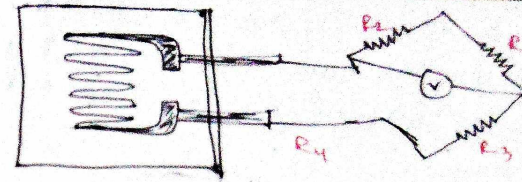
CONSTRUCTION:-



- It consists of a very fine wire or more commonly metallic foil arranged in a grid pattern.
- The grid is wound to a thin backing called the carrier which is attached directly to the test specimen, therefore, the strain experienced by the test object is transferred directly to the strain gauge and changes the resistance of the strain gauge.

MEASUREMENT BY USING BRIDGE CIRCUIT

- The change in resistance in the strain gauge can be measured in terms of change in voltage by connecting the strain gauge in a wheat stone bridge circuit.



→ In this ckt R_1 and R_3 are equal to each other and R_2 is the rheostat arm and its value is equal to the strain gauge initial resistance.

→ When no force is applied the gauge is unstrained and the bridge is balanced and voltmeter shows zero value at this condition.

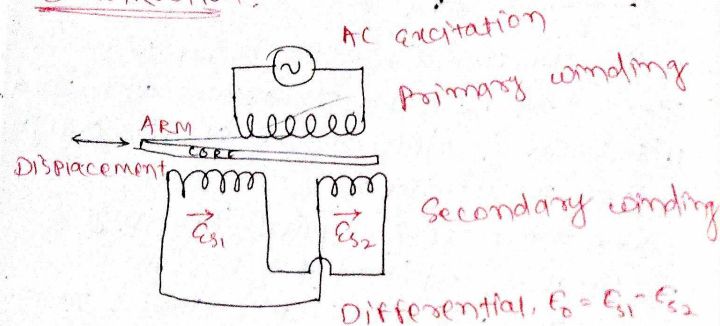
→ When force is applied on the strain gauge resistance of the gauge changes where the bridge gets unbalanced and produces a voltage indication of the voltmeter.

LVDt (Linear variable differential Transformer)

- It converts linear displacement into an electrical signal.
- It works on the principle of mutual inductances i.e. the ' ϕ ' flux of the primary winding is induced to the secondary winding.
- The output of the T/F is obtained.

because of the difference of the secondary voltage and hence it is called as differential transformer.

CONSTRUCTION :-



- It consists of primary winding and two secondary winding i.e. s_1 and s_2 .
- The secondary winding is wound in the cylindrical former.
- The secondary winding have an equal no. of turns, and placed identical to both the side of primary winding.
- The output voltage of secondary winding s_1 is E_{s1} and s_2 is E_{s2} .
- The secondary voltage signal is converted in a electrical signal by connecting the secondary winding in series operation.
- The output voltage of the transducer is determined by subtracting the voltage of the secondary winding.

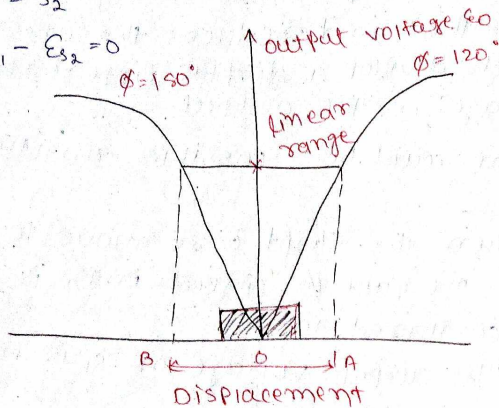
WORKING

- The change in output voltage is directly proportional to the displacement of the core.
- An displacement will increase the flux of the one of the secondary winding and other end reduces the other which develop a ~~diff~~ differential voltage in the output.
- There could be 3 possible condition i.e.
 - ① When the soft core move towards left the flux ' ϕ ' linked in s_1 is more as compared to s_2 .
The output voltage of s_1 is more than the s_2 .
→ Since $E_{s1} > E_{s2}$ so, E_o is positive and is inphase with the primary voltage.
 - ② When the soft iron core moves towards right the magnitude of flux ' ϕ ' linked in s_2 is more than s_1 .
→ The output voltage of s_1 is less than the s_2 .
→ Since, $E_{s1} < E_{s2}$ so, E_o is negative and it is 180° out of phase with the primary winding.

③ When the soft iron core is at the centre ~~the magnitude of flux~~ the S_1 and S_2 the flux ϕ linked in S_1 & S_2 are same.

→ The output voltage is equal to ~~$S_1 = S_2$~~

$$E_{S1} - E_{S2} = 0$$



→ The curve between the output voltage and displacement as shown in figure. The curve is linear.

USES

→ measuring the displacement having a range from few mm to cm.

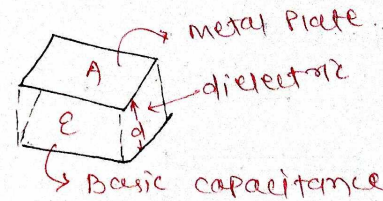
→ The LVDT directly convert the displacement into an electrical signal.

→ It is used as a device for measuring the force, weight and pressure

CAPACITIVE TRANSDUCER

→ The working principle of a capacitive transducer is variable capacitances.

→ It consists of two parallel metal plates which are separated by dielectric medium (such as Air)



The capacitances of the variable capacitor can be measure by

$$C = \frac{A \epsilon_0 \epsilon_r}{d} \quad \text{where,}$$

$$\Rightarrow C = \frac{A \epsilon}{d}$$

C = capacitance of the variable capacitor.

ϵ_0 = Permittivity of free space

ϵ_r = relative permittivity

A = overlapping area betⁿ the two plates

d = distance betⁿ the plates.

→ By varying the parameters like A, d, ϵ_r , so the capacitive transducers are of 3 types:

(i) variable are capacitive transducer

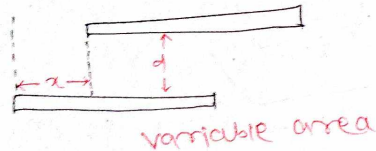
(ii) variable distance betⁿ two plates like ~~capacitor~~ capacitive transducer.

(iii) variable dielectric constant type capacitive transducer.

① VARIABLE AREA CAPACITIVE TRANSDUCER

→ Here the overlapping area. betⁿ the two plates changes due to the application of displacement force or pressure.

→ since 'A' changes the capacitances also changes as 'C' is directly proportional to 'A'.

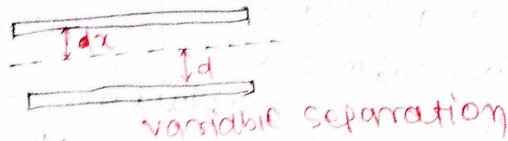


$$C = \frac{\epsilon(A - wx)}{d}$$

where, x = displacement of the plates
 w = width of the plates.

② VARIABLE DISTANCE BETWEEN TWO PLATES

→ Here the distance between the two plates changes due to application of displacement, force or pressure.



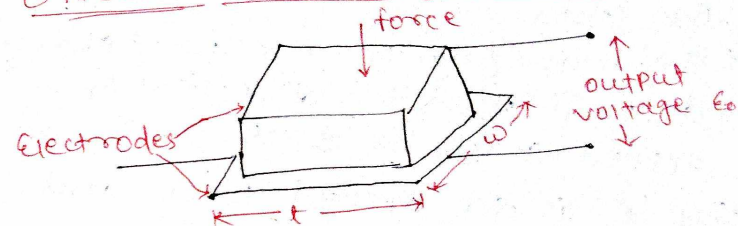
→ since 'd' changes the capacitances also changes as 'C' is inversely proportional to 'd'.

$$C = \frac{\epsilon A}{d + x}$$

where, x = displacement of plates.

ACTIVE TRANSDUCER

① PIEZOELECTRIC TRANSDUCER



→ It is a device which can convert mechanical energy like force or pressure into an electrical energy.

→ It uses piezo-electric effect for the generation of electric charge.

→ It is an active transducer.

CONSTRUCTION & WORKING :

* Piezoelectric material like quartz, Rochelle salt can be used to make the transducer.

→ The forces of piezoelectric material usually quartz is coated with a thin layer of conducting material such as silver known as electrode.

→ When stress is applied the ions (+ve & -ve) in the material moves

towards one of the conducting surface while moving away from the other ~~then~~ this results in generation of charge.

→ The charge is used to calibrate the stress.

→ The polarity of the produced charge depends upon the direction of applied stress or force.

→ If 'f' is the applied force and Q is the charge developed then,

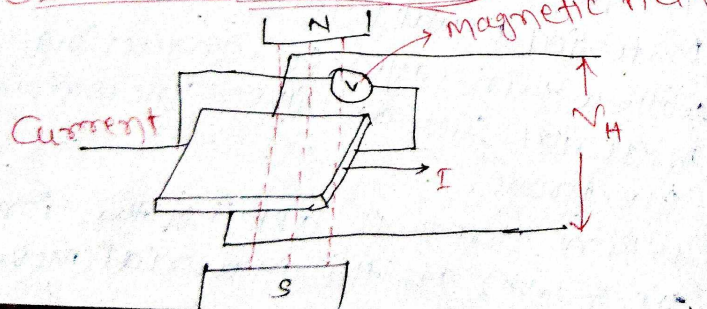
$$Q \propto f$$
$$\text{or } Q = df$$

where,

d = piezoelectric coefficient of the material.

→ Due to charge 'Q' potential difference P_0 developed between the electrodes which can be taken as output.

② HALLEFFECT TRANSDUCER :-



→ It varies its output voltage in respect to a magnetic field.

→ It works on the Principle of halleffect.

→ If a current carrying strip conductor placed in a transverse magnetic field then an emf is developed on the edge of conductor.

→ The magnitude of the developed voltage depends upon the density of flux, this property is known as halleffect.

$$V_H = K \frac{B \cdot I}{t} \quad \text{where,}$$

K = Halleffect coefficient

B = flux density

I = current

t = thickness of the conductor strip

(Hall element)

APPLICATION

① Magnetic to electric

→ It converts magnetic flux into ~~electro~~ electrical signal.

② Measurement of displacement

→ It measures the displacement of the structural element.

→ Consider the ferromagnetic structure which has a permanent magnet the halleffect transducer placed betⁿ the

Poles of the permanent magnet the magnetic field strength across the hall effect element changes by changing the position of the ferromagnetic field so, the output voltage of the transducer changes w.r.t input displacement.

(iii) Measurement of current :-

* The AC ~~or~~ or DC applied across the conductor for developing the magnetic field.

* The strength of the magnetic field is directly proportional to applied current which developed the EMF across the strip.

CHAPTER - 6

MEASUREMENT OF RESISTANCE

CLASSIFICATION OF RESISTOR :-

→ mainly there are 3 type of measurement of resistance.

- i) low resistance
- ii) High resistance
- iii) medium resistance.

(i) LOW RESISTANCE :-

→ All resistance of the order in 1Ω or less than 1Ω are classified as low resistance, armature resistance, series field resistance.

(ii) MEDIUM RESISTANCE :-

→ This class include resistance from 1Ω to $100\text{ k}\Omega$.

eg.:- Shunt field resistance, incandescence lamp.

(iii) HIGH RESISTANCE :-

→ Resistance of the order $100\text{ k}\Omega$ and upward as classified as high resistance.

eg.:- insulation resistance.

MEASUREMENT OF LOW RESISTANCE

POTENTIOMETER - METHOD

→ The current through the circuit a controlled by the rheostat.

→ A 2 pole double throw switch is used in the circuit, when the switch is put on position 1 and 1' it is connected to the unknown resistance to the potentiometer.

→ Suppose the reading of the potentiometer is $V = IR$

$$V_R = IR \quad \text{--- (i)}$$

$$\Rightarrow I = V_R / R \quad \text{--- (ii)}$$

> Now again the switch put in the position 2 and 2' and it connect standard resistance to the Potentiometer so the reading of the Potentiometer is

$$V_S = IS \quad \text{--- (iii)}$$

$$I = \frac{V_S}{S} \quad \text{--- (iv)}$$

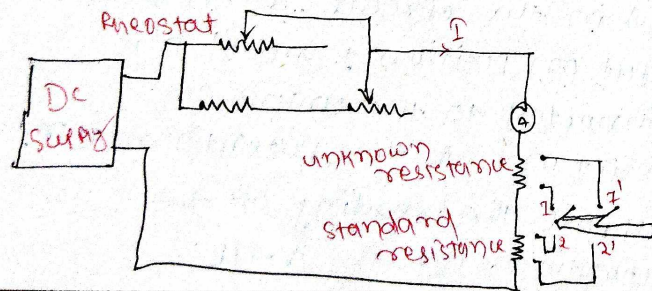
Comparing eqn (ii) & (iv)

$$\frac{V_R}{R} = \frac{V_S}{S}$$

$$\Rightarrow V_R = \frac{V_S R}{S}$$

$$\Rightarrow R = \frac{V_R}{V_S} \cdot S$$

> Since the value of standard resistance is known the value of V can also be known. This method is suitable for low resistance.

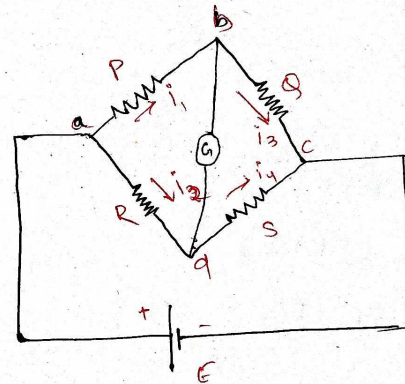


Potentiometer
DPDT

MEASUREMENT OF MEDIUM RESISTANCE BY WHEATSTONE BRIDGE METHOD

> A very important device used in the measurement of medium resistances is the ~~use~~ wheat stone bridge.

> A wheatstone bridge has been in use longer than almost any electrical measuring instrument.



> It has 4 resistive arms consisting of resistance P, Q, R and S together with a source of emf usually a galvanometer G or other sensitive current meter.

> for bridge balance

$$I_1 P = I_2 R \quad \text{--- (i)}$$

> for the galvanometer current to be zero the following condition also

exist.

$$I_1 = I_2 = \frac{E}{P+Q} \quad \text{--- (i)}$$

$$I_2 = I_3 = \frac{E}{R+S} \quad \text{--- (ii)}$$

where, E = emf of the battery
combining equation (i), (ii) + (iii)
simplifying we obtain.

$$\frac{E}{P+Q} \times P = \frac{E}{R+S} \times R$$

$$\Rightarrow \frac{P}{P+Q} = \frac{R}{R+S} \quad \text{--- (iv)}$$

$$\Rightarrow P(R+S) = R(P+Q)$$

$$\Rightarrow PR+PS = RP+RQ$$

$$\Rightarrow PS = RQ \quad \text{--- (v)}$$

$$R = \frac{1}{Q} \cdot S$$

→ eqn (v) is the well known expression for the balance of wheatstone bridge.

→ If 3 of the resistances are known the fourth may be determined from eqn (v) and we obtain

$$\text{i.e. } R = \frac{P}{Q} \cdot S$$

where,

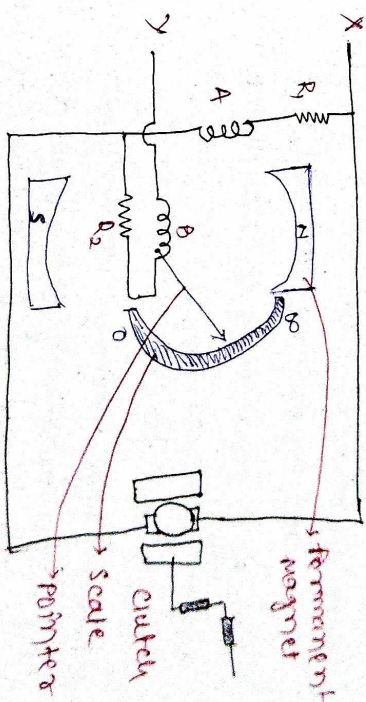
R = unknown resistance

S = standard arms of the bridge

and $P+Q$ = ratio arms

→ When the null detector has sufficient sensitivity to indicate the balance position of the bridge with the required degree of position, the measurement of the unknown resistance R is independent of the change of the null-deflecting galvanometer.

MAGGER



→ Megger is a instrument which is used to measure insulation resistance and very high resistance it is also called

as insulation tester.

→ It is a modified PMMC type ~~meter~~ instrument. It consists of a hand driven D.C. generator and an ohm meter.

→ The ohm meter consists of two coils A and B.

→ The pointer is attached to the spindle which moves over a calibrated scale. Let R_1 and R_2 be the two resistances of coil A and B.

→ The terminal X and Y are used to connect the resistances whose value is to be measured.

Operation:

→ To rotate a constant speed a clutch is attached to the d.c. generator, so that a constant output voltage can generate according to need.

→ coil A is connected to both the positive and negative of d.c. terminal, where in coil B, a terminals is open.

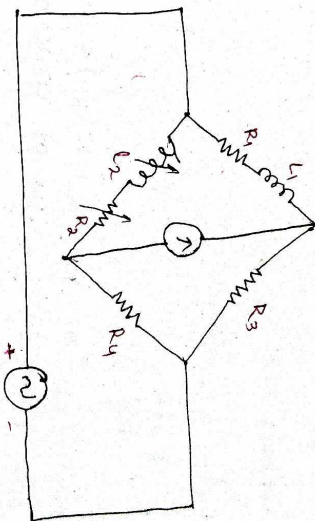
→ Due to high voltage from generator terminal earthing should be done in terminal wire to protect the device.

→ R_1 and R_2 are connected to limit the current flow through coil A and B.

→ When no insulation wire is connected it act as open circuit through coil A and pointer is in infinity (∞).

When a coil connected across the terminal it act as short circuit through B and pointer experience a force because of permanent magnet.

MAXWELL BRIDGE FOR INDUCTANCE MEASUREMENT



→ Maxwell bridge measures inductances by comparing with a variable standard inductances where,

L_1 = unknown inductance

L_2 = variable inductance

R_2 = variable resistance

R_1, R_3 & R_4 = known resistance.

The balance condition of bridge can be given by,

$$Z_1 Z_4 = Z_2 Z_3$$

$$\Rightarrow (R_1 + j\omega L_1) R_4 = (R_2 + j\omega L_2) R_3$$

$$\Rightarrow R_1 R_4 + j\omega L_1 R_4 = R_2 R_3 + j\omega L_2 R_3$$

$$\Rightarrow R_1 R_4 - R_2 R_3 = j\omega L_2 R_3 - j\omega L_1 R_4 \dots \text{--- (1)}$$

Equating the imaginary part we get the equation

$$j\omega R_2 L_2 - j\omega R_4 L_1 = 0 \dots \text{--- (2)}$$

~~Put eqn (2) in eqn (1)~~

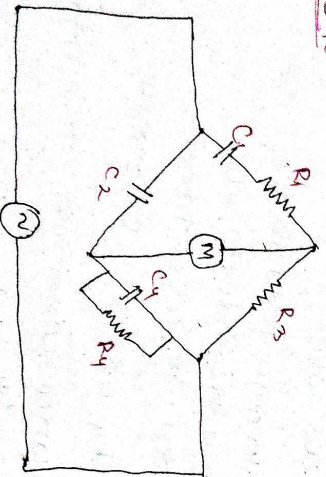
$$\Rightarrow R_1 R_4 - R_2 R_3 = 0$$

$$\Rightarrow j\omega R_2 L_2 = j\omega R_4 L_1$$

$$\Rightarrow L_1 = \frac{R_2 L_2}{R_4}$$

→ By knowing the value of L_2 , R_2 and R_4 we can find the value of unknown inductance ' L_1 '.

MEASUREMENT OF CAPACITANCE BY SCHERING BRIDGE



→ Schering bridge is used for measurement of unknown capacitance where,

C_1 = Capacitance to be measured.

R_1 = Series resistance representing losses in capacitance,

C_2 = standard capacitor

C_1 = variable capacitor

R_4 = variable resistor in parallel with C_1 .

R_3 = standard resistor

The balance condition of the bridge,

$$\Rightarrow Z_1 Z_4 = Z_2 Z_3$$

$$\Rightarrow \left(R_1 + \frac{1}{j\omega C_1} \right) \left(\frac{R_4}{1 + j\omega C_4 R_4} \right) = \frac{1}{j\omega C_2} \times R_3$$

$$\Rightarrow R_1 + \frac{1}{j\omega C_1} = \frac{R_3}{j\omega C_2} \times \frac{1 + j\omega C_4 R_4}{R_4}$$

$$\Rightarrow R_1 + \frac{1}{j\omega C_1} = \frac{R_3 R_4 + j\omega C_4 R_3 R_4}{j\omega R_4 C_2}$$

$$\Rightarrow R_1 + \frac{1}{j\omega C_1} = \frac{R_3}{j\omega R_4 C_2} + \frac{j\omega C_4 R_3 R_4}{j\omega R_4 C_2}$$

$$\Rightarrow \frac{j\omega C_1 R_1 + 1}{j\omega C_1} = \frac{R_3}{j\omega R_4 C_2} + \frac{C_4 R_3}{C_2}$$

$$\Rightarrow \frac{j\omega C_1 R_1 + 1}{j\omega C_1} = \frac{R_3 + j\omega R_4 C_4 R_3}{j\omega R_4 C_2}$$

$$\Rightarrow \frac{j\omega C_1 R_1 + 1}{j\omega C_1} = \frac{R_3 (1 + j\omega C_4 R_4)}{j\omega R_4 C_2}$$

$$\Rightarrow \frac{j\omega C_1 R_1 + 1}{C_1} = \frac{R_3 (1 + j\omega C_4 R_4)}{R_4 C_2}$$

$$\Rightarrow \frac{(j\omega C_1 R_1 + 1) R_4}{C_1} = \frac{C_1 R_3 (1 + j\omega C_4 R_4)}{C_2}$$

$$\Rightarrow R_4 + j\omega C_1 R_1 R_4 = \frac{C_1 R_3}{C_2} (1 + j\omega C_4 R_4)$$

$$\Rightarrow R_4 + j\omega C_1 R_1 R_4 = \frac{C_1 R_3}{C_2} + \frac{j\omega C_4 R_4 \cdot C_1 R_3}{C_2}$$

By equating Real Part:

$$\Rightarrow \boxed{R_4 = \frac{R_3 R_4}{C_2}} \quad \text{--- (1)}$$

By equating imaginary Part

$$j\omega C_1 R_1 R_4 = \frac{j\omega C_4 R_4 \cdot C_1 R_3}{C_2}$$

$$\Rightarrow \boxed{R_1 = \frac{C_4 R_3}{C_2}} \quad \text{--- (2)}$$

→ From the above equation capacitance C_1 can be determined by knowing value of C_2 , R_4 and R_3 .

→ The degradation factor can be given by:-

$$\tan \delta = \omega C_1 R_1$$

$$= \omega \frac{R_3 R_4}{C_2} \times \frac{C_4 R_3}{C_2}$$

$$\boxed{\tan \delta = \omega R_4 C_4}$$