ELECTRICAL MEASURING INSTRUMENTS AND INSTRUMENTATION List of Contents

Introduction

1.1 Measurement:
It is the act or result of quantitative comparison between a predefined standard and an unknown quantity.

Instrument:
It is a device or mechanism used to determine the present value of a quantity under observation.

1.2 Instruments can be classified as:
- Absolute instruments
- Secondary instruments

Absolute instruments:
- Absolute instruments indicate the value of the quantity being measured in terms of constant of instruments and its deflection.
- No comparison with standard instrument is necessary.
- Example: tangent galvanometer, Rayleigh current balance.

Secondary instruments:
- The secondary instruments need calibration with respect to the absolute instruments.
- The secondary instruments determine the value of the quantity being measured from the deflection of the instruments.
- Calibration is a must for secondary instrument, without calibration the deflection obtained is meaningless.
  Example: Ammeter, voltmeter, wattmeter etc.

1.3 Classification

Secondary instruments are further classified according to the nature of operation as :
1. Indicating
2. Recording
3. Integrating instruments.

- **Indicating instruments:** They uses scale and pointer to indicate the instantaneous value of quantity under measurement.
- **Recording instruments:** They use pen and graph to give a continuous record of variation of quantity being measured (such as voltage, frequency, power etc.). Recorders are commonly used in power plants, process industries.
- **An integrating instrument:** They uses dial and display is one which takes into consideration the period or the time over which the quantity is supplied. e.g. ampere-hour meter, energy meter.
- **Electrical instruments can also classified as:**

1. A.C. instruments
2. D.C. instruments
3. A.C./D.C. instruments

Some electrical instruments can measure only A.C. quantity, e.g. induction type instruments, some can measure only D.C. quantity, e.g. P.M.M.C. instruments. Some can work on both a.c. and d.c. e.g. moving iron instruments, dynamometer instruments etc.

Analog or Digital instruments: One more way of classifying instrument is:

1. Analog instruments
2. Digital instruments.

Analog information is continuous and step less function of time. Analog instruments are easy to understand, calibrate and maintain.
Digital information is in form of discrete pulses or steps. Digital instruments have higher resolution, high readability

For satisfactory operation of any indicating instrument, following three torques must act together appropriately:

1. Deflecting torque
2. Controlling torque
3. Damping torque

Deflecting Torque:

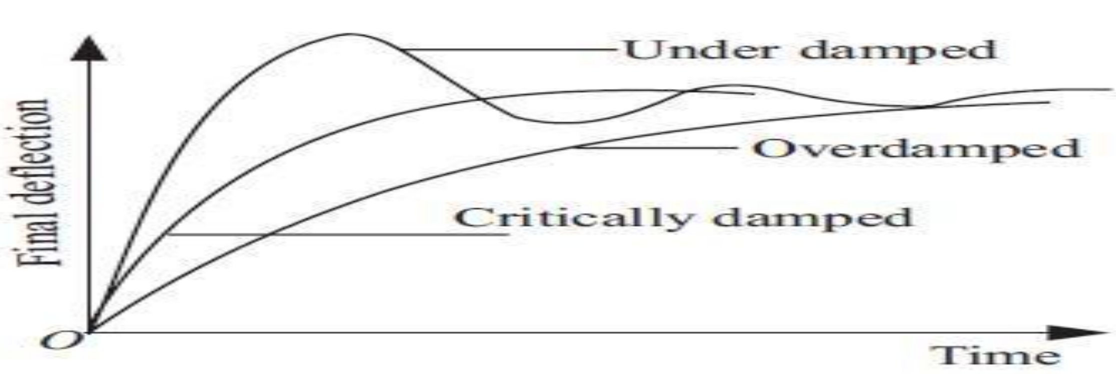
- It causes the moving system of the instrument to move from its initial position by means of operating quantities or measurand.
- Deflecting torque is produced by using any one of the following effects of electric current : Magnetic effect, Electromagnetic induction effect, Heating effect, Electrostatic effect .

Controlling Torque:

- It limits the movement of moving systems means used to bring back the pointer to its original position by means of spring and gravity control methods.
- Controlling torque acts in the opposite direction to that of the deflecting torque.
- At steady state, Deflecting torque = Controlling torque

Damping Torque:

- Due to deflecting torque, pointer moves in one direction while due to controlling torque pointer moves in opposite direction.
- Due to these opposite torques, the pointer may oscillate in the forward and backward direction if the damping torque is not present.
- Damping torque brings the moving system to rest quickly in its final position.
- Damping torque acts only when the moving system is actually moving. If moving system is at rest, damping torque is zero.
- Depending on the magnitude of torque, damping may be classified as under damped, over damped or critically damped. Effect of damping on the deflection of the instrument is shown in Fig. (1).
- If the instrument is under damped, the pointer will come to rest after some oscillations.
- If the instrument is overdamped, pointer takes considerable time to obtain its final deflected position. If the damping is critical, without oscillation and in short time the pointer reach its final steady position.



Multiple Choice Questions

Q1. The use of _____ instruments is merely confined within laboratories as standardizing Instruments.
(a) absolute
(b) indicating
(c) recording
(d) integrating
(e) None of the above Ans: a
Q2. Which of the following instruments indicate the instantaneous value of the electrical quantity being measured at the time at which it is being measured ?
(a) Absolute instruments
(b) Indicating instruments
(c) Recording instruments
(d) Integrating instruments Ans: b
Q3. _____ instruments are those which measure the total quantity of electricity delivered in a particular time.
(a) Absolute
(b) Indicating
(c) Recording
(d) Integrating Ans: d
Q4. Which of the following are integrating instruments?
(a) Ammeters
(b) Voltmeters
(c) Wattmeter
(d) Ampere-hour and watt-hour meters Ans: d
Q5. Resistances can be measured with the help of
(a) wattmeter
(b) voltmeters
(c) ammeters
(d) ohmmeters and resistance bridges
(e) all of the above Ans: d
Q6. According to application, instruments are classified as
(a) switch board
(b) portable
(c) both (a) and (b)
(d) moving coil
(e) Moving iron (f) both (d) and (e) Ans: c
Q7. Which of the following essential features is possessed by an indicating instrument?
(a) Deflecting device
(b) Controlling device
(c) Damping device
(d) All of the above Ans: d
Q8. A _____ device prevents the oscillation of the moving system and enables the latter to reach its final position quickly
(a) deflecting

(b) controlling
(c) damping
(d) Any of the above Ans: c

Q9. The spring material used in a spring control device should have the following property.
(a) Should be non-magnetic
(b) Most be of low temperature co-efficient
(c) Should have low specific resistance
(d) Should not be subjected to fatigue
(e) All of the above Ans: e

Q10. Which instrument uses scale and pointer?
(a) Indicating type
(b) Recording type
(c) Integrating type
(d) digital type

Short Answer Type Questions

Q1 What is measurement?
Q2 Define Errors.
Q3 Define Instrumentation.
Q4 Give types of measuring instruments.
Q5 Name different types of torque required for indicating instruments.

Long Answer Type Questions

Q1 Give classification of different types instruments as per their working principle.
Q2 Explain different types of torque required for indicating type instruments.

2 Ammeters and Voltmeters

Connection diagram of an Ammeter:

- Ammeter is used for the measurement of current.
- An ammeter is always connected in series with the load, the current through which is to be measured as shown in Fig. (2.1). Since the resistance offered by an ammeter is very small, its introduction in series with load.

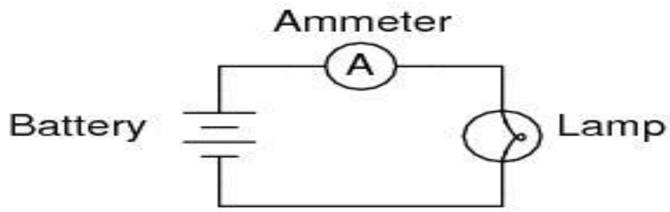


Fig 2.1

Connection diagram of a voltmeter:

- A voltmeter is used for the measurement of voltage (potential difference).
- So it is connected across the points between which the potential difference is to be measured.
- A voltmeter has a high resistance, so it draws very small current. The connection of a voltmeter is as shown in Fig.(2.2).

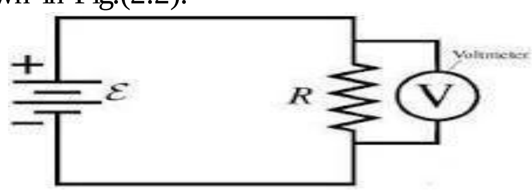


Fig. (2.2)

Comparison of Ammeter and Voltmeter

Sr. No	Ammeter	Voltmeter
1	It is used to measure Current in ampere	It is used to measure voltage in volt
2	Connected in series with load	Connected in parallel with load
3	Resistance are low	Resistance is high
4	To extend the range low resistance is connected	To extend the range high series resistance is connected (i.e. multiplier)

Instruments based on working Principle

- Permanent magnet moving coil (PMMC) type
- Moving iron (MI) type

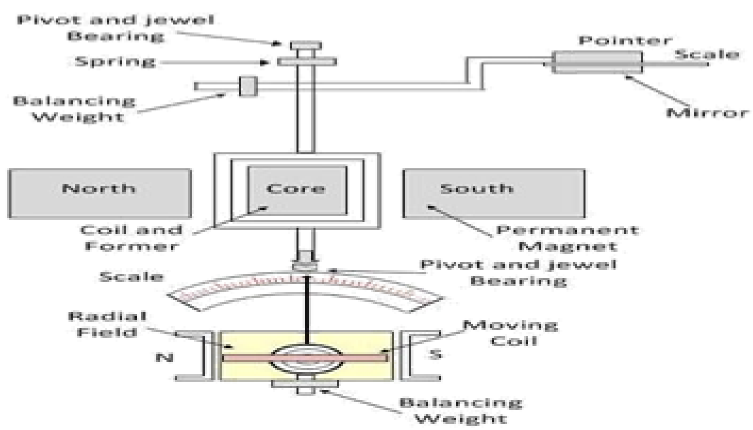
2.2.1 Moving Coil Instruments

- Moving coil instruments (ammeter and voltmeter) are of two types:
- Permanent magnet moving coil type (PMMC) used only for D.C.
- Dynamometer type can be used for AC as well DC.
- They are also known as d'Arsonval instruments.
- These instruments works on the electromagnetic effect of current.
- A permanent magnet used to produce magnetic flux and coil that carries the current to be
  measures moves in this field.

Working principle of PMMC - When a current carrying conductor is placed in a magnetic field, it experiences a force and tends to move in the direction as per Fleming's left-hand rule.

i.e. F = NBIL

where, Where F = Force in Newton, B = Flux density is tesla, I = Current is ampere, L = Length of conductor in meter, N= number of turn in coil



Permanent Magnet Moving Coil Instrument

Deflecting Torque:
It can be proved that the expression for the deflecting torque is given by,

Td = G x I where G = constant , I = Current through the moving coil

Controlling Torque:
The controlling torque is given by,

Tc = C. θ where C = Control spring constant in N-m/rad, θ = Deflection of coil from zero position

For steady state, the controlling torque is equal to the deflection torque

$\therefore$ Tc = Td , i.e. Cθ = GI , $\therefore \theta \propto I$

Thus deflection of the pointer is proportional to current passed through the coil.

Advantages of PMMC Instruments:
The PMMC consumes less power and has great accuracy.
It has uniformly divided scale and can cover arc of 270 degree.
The PMMC has a high torque to weight ratio.
It produces no losses due to hysteresis.

Disadvantages of PMMC Instruments:
The moving coil instrument can only be used on D.C supply as the reversal of current produces reversal of torque on the coil.

2.2.2 Types of moving iron instruments:

1. Attraction type
2. Repulsion type

2.2.2.1 Attraction type moving iron instrument:

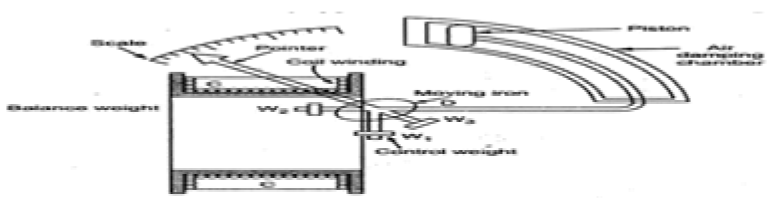


Fig .Moving iron instrument

Construction of the attraction type moving iron instrument is as shown in the given figure. The moving iron, i.e. the disc of soft iron, is eccentrically mounted. Coil is situated around the disc. When the coil is excited it produces magnetic field.
Due to magnetic field the moving iron moves from the weaker field outside the coil to the stronger field inside the coil. Thus moving iron gets attracted inwards and thus the name attraction type.
The controlling torque is provided by the balance weights attached to the moving iron. Spring also can be used to provide controlling torque.
Damping is provided by air friction in which aluminum piston is attached to the moving system and moves in a closed air damping chamber.

Working principle

In Moving Iron Instruments, a plate or van of soft iron or of high permeability steel forms the moving element of the system. The iron van is so situated that it can move in the magnetic field produced by a stationary coil
The stationary coil is excited by the current or voltage under measurement. When the coil is excited, it becomes an electromagnet and the iron van moves in direction of offering low reluctance path. Thus the force of attraction is always produced in a direction to increase the inductance of coil. Mind that as the van follows the low reluctance path, the net flux in air gap will increase which means increased flux linkage of coil and hence inductance of coil will increase. It shall also be noticed that, the inductance of coil is variable and depends on the position of iron van.
Deflecting torque in Moving iron Instruments is given as

$$Td = (1/2)I^2(dL/d\Theta)$$

In moving iron instruments, the controlling torque is provided by spring. Controlling torque due to spring is given as

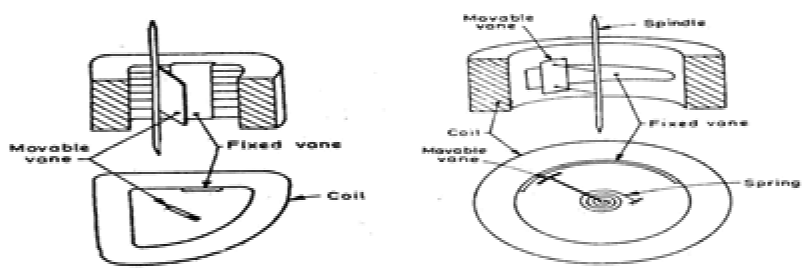
$Tc = K\Theta$

At steady state $T_c = T_d$ and $\Theta = (1/2)(I^2/K)(dL/d\Theta)$

We observe that the angular deflection of needle of moving iron instruments is square of rms current flowing through the coil. Therefore, the deflection of moving iron instruments is independent of direction of current.

2.2.3Repulsion Type

In the repulsion type, there are two vanes inside the coil one fixed and other movable. These are similarly magnetized when the current flows through the coil and there is a force of repulsion between the two vanes resulting in the movement of the moving vane. Two different nt designs are in common use (I) Radial Vane Type In this type, the vanes are radial strips of iron. The strips are placed within the coil



as shown in Fig. The fixed vane is attached to the coil and the movable one to the spindle of the instrument. (a) Radial vane type. (b) Co-axial vane type

(ii) *Co-axial Vane* Type In this type of instrument, the fixed and moving vanes are sections of co axial cylinders as shown in Fig. The controlling torque is provided by springs. Gravity control can also he used in vertically mounted instruments. The damping torque is produced by air friction as in attraction type instruments. The operating magnetic field in moving iron instruments is very weak and therefore eddy current damping is not used in them as introduction of a permanent magnet required for eddy current damping would destroy the operating magnetic
Field. It is clear that whatever may be the direction of the current in the coil of the instrument, the iron vanes are so magnetized that there is always a force of attraction in the attraction type and repulsion in the repulsion type of instruments. Thus moving iron instruments are unpolarised
Instruments i.e., they are independent of the direction in which the current passes. Therefore, these instruments can be used on both A.C. and D.C.

Comparison between Attraction and Repulsion Type of Instruments.
In general it may be said that attraction-type instruments possess the same advantages, and are subject to the limitations, described for the repulsion type.

• An attraction type instrument will usually have a lower inductance than the corresponding repulsion type instrument, and voltmeters will therefore be accurate over a wider range of
frequency and there is a greater possibility of using shunts with ammeters.
• On the other hand, repulsion instruments are more suitable for economical production in manufacture, and a nearly uniform scale is more easily obtained; they are, therefore, much more common than the attraction type.

2.4 Errors in Moving Iron Instruments

There are two types of errors, which occur in moving iron instruments — errors which occur with both a.c. and D.C. and the other which occur only with ac. only. Errors with both D.C. and A.C i) Hysteresis Error ii) Temperature error iii) Stray magnetic field Errors with only A.C Frequency errors
Advantages & Disadvantages 1) Universal use (2) Less Friction Errors (3) Cheapness (4) Robustness (5) Accuracy (6) Scale (7) Errors (8) Waveform errors.

Multiple choice questions
Q12. A moving-coil permanent- magnet instrument can be used as flux-meter
(a) by using a low resistance shunt
(b) by using a high series resistance
(c) by eliminating the control springs
(d) by making control springs of large moment of inertia
Ans: c
Q13. Which of the following devices may be used for extending the range of instruments?
(a) Shunts
(b) Multipliers
(c) Current transformers
(d) Potential transformers
(e) All of the above

(a) 10 A
(b) 30 A
(c) 60 A
(d) 100 A
Ans: d
Q15. For handling greater currents induction wattmeter are used in conjunction with
(a) potential transformers
(b) current transformers
(c) power transformers
(d) either of the above
(e) none of the above
Ans: b
Q16. Induction type single phase energy meters measure electric energy in
(a) kW

(b) Wh
(c) kWh
(d) VAR
(e) None of the
above Ans: c

Short Answer Type Questions

Q1 Give difference between ammeter and voltmeter.
Q2 Expand PMMC
Q3 Write types of moving iron instruments.

Long Answer Type Questions

Q1 Explain construction and working principle of moving coil instruments
Q2 Explain construction and working principle of moving iron instruments

3 Dynamometer Type Wattmeter

The **dynamometer type wattmeter** are very important because they are commonly employed for measuring power in AC circuits.

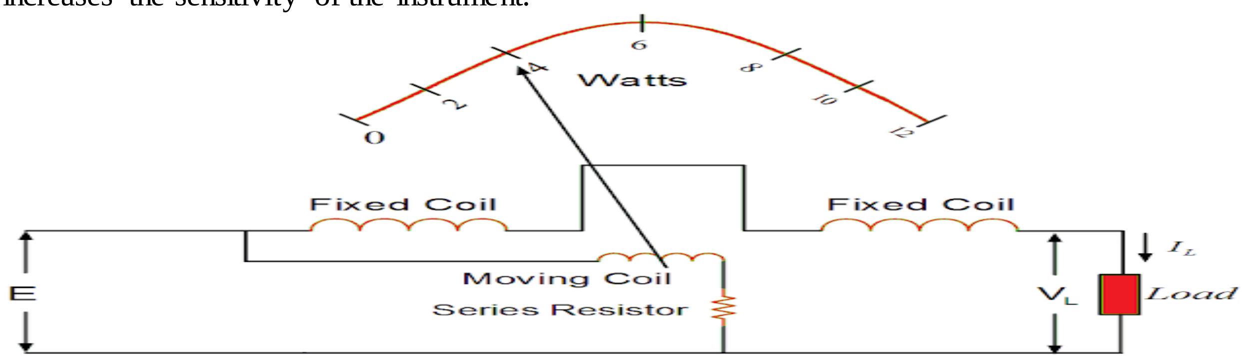
Construction of Dynamometer Type Wattmeter

A *dynamometer type wattmeter* essentially consists of two coils called fixed coil and moving coil. The fixed coil is splitted into two equal parts which are placed parallel to each other. The two fixed coils are air-cored to avoid hysteresis effects when used on AC.

A *dynamometer type wattmeter* essentially consists of two coils called fixed coil and moving coil. The fixed coil is splitted into two equal parts which are placed parallel to each other. The two fixed coils are air-cored to avoid hysteresis effects when used on AC.

The fixed coil is connected in series with the load and carries the circuit current. It is, therefore, called current coil. The moving coil is pivoted between the two parts of the fixed coil and is mounted on the spindle. A pointer is attached to the spindle which gives deflection. The moving coil is connected in parallel with the load and carries the current proportional to the voltage. It is, therefore, called potential coil.

Generally, a high resistance is connected in series with the moving coil to limit the current through it. By limiting the current, the moving coil is made of light weight which in turn increases the sensitivity of the instrument.



The controlling torque is provided by springs which also serve the additional purpose of leading current into and out of the moving coil. Air friction damping (not shown in fig.) is employed in such instruments.

Dynamometer Type Wattmeter Working

When power is to be measured in a circuit, the wattmeter is connected in the circuit. The current coil is connected in series with the load, carries the load current and the potential coil, connected in parallel with the load, carries the current proportional to the voltage across the load. The fixed coil produces a field F_m and moving coil produces a field F_r. The field F_r tries to come in line with the main field F_m, which produces a deflecting torque on the moving coil.

Advantages: It can be used both on AC and DC circuits. It has a uniform scale. High degree of accuracy can be obtained by careful design.

Disadvantages: At low power factors, the inductance of the potential coil causes serious errors. The reading of the instrument may be affected by stray fields acting on the moving coil.

In order to prevent it, magnetic shielding is provided by enclosing the instrument in an iron case.

4 Energymeter

Energy meters are the basic part to measure the power consumption. It is used everywhere, no matter how big or small consumption it is. It is also known as watt-hour meter. Here we discuss the construction and working principle of induction type energy meter.

To understand the structure of watt-hour meter, we must understand the four essential components of the meter. These components are as follows:

1. Driving system
2. Moving system
3. Braking system
4. Registering system

Now there are two types of induction meters and they are written as follows:

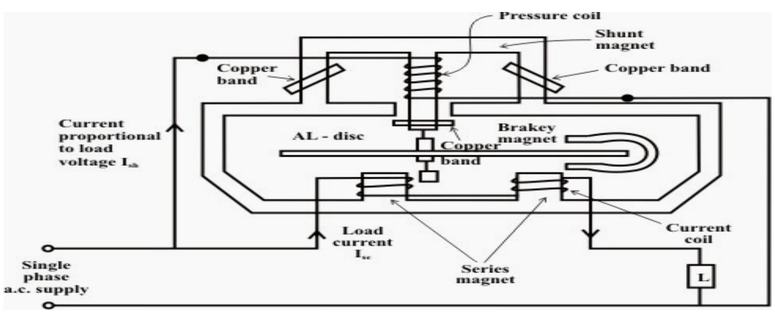
Single phase type

Three phase type induction meters.

Driving system

It consists of two electromagnets, called ***"shunt" magnet*** and ***"series" magnet***, of laminated construction. A coil having large number of turns of fine wire is wound on the middle limb of the shunt magnet.

This coil is known as "***pressure or voltage***" coil and is connected across the supply mains. This voltage coil has many turns and is arranged to be as highly inductive as possible. In other words, the voltage coil produces a high ratio of inductance to resistance.



Moving system

The moving system essentially consists of a light rotating aluminum disk mounted on a vertical spindle or shaft. The shaft that supports the aluminum disk is connected by a gear arrangement to the clock mechanism on the front of the meter to provide information that consumed energy by the load.

Braking system damping of the disk is provided by a ***small permanent magnet***, located diametrically opposite to the a.c magnets. The disk passes between the magnet gaps. The movement of rotating disc through the magnetic field crossing the air gap sets up eddy currents in the disc that reacts with the magnetic field and exerts a braking torque.

Phase and Speed Errors:

The phase errors is introduced because the shunt magnet flux does not leg behind the supply voltage by exactly 90 degree due to some resistance of the coil and iron losses. the angle less slightly less than 90 degree. Because this errors the torque is not zero at zero power factor of the load.

In order to remove this error, made supply voltage exact 90 degree . this is accomplished by

adjusting the position of copper shading band provided on central limb of the shunt magnet. an error on the fast under these condition can be eliminated by bringing the shading and near to the disc and vice-versa
Sometimes, the speed of the disc of energy meter is faster or slower , when tested on a load having power factor. there, energy meter register either more or less energy and errors is introduced.
In order to remove this error, the redial position of the braking magnet is adjusted. Movement of braking magnet, away from the centre of the disc increase the torque which decreases the speed of the Disc.

Frictional Error:
This error is introduced due to friction at the rotor bearing and the register mechanism. because this error is unwanted braking torque acts on the moving system and register less energy then the actual energy passing though it
This error is compensated by placing two short circuited bands on the outer limbs of the shunt magnet. These bands embrace the flux contain in two outer limbs of of the shunt magnet. An emf induces circulating current though them. This causes phase displacement between the enclose flux and main flux. As a result of this, a small driving torque is exerted on the disc solely by pressure coil which compensate the friction torque.

Creeping error:
The slow but continuous rotation of energy meter , which only pressure coil is excited but no current flow though the current coil is called creeping. This error may be due to excessive friction compensation, excessive voltage supply and stray magnetic field etc.
In order to prevent creeping on no load, two holes are drilled in the disc on the opposite side of the spindle at the same radius , this causes sufficient distortion of the field to prevent continuous rotation.

Temperature Error:
By changing the temperature, the parameter of the coils change slightly which introduce a small error in meter. However, this error negligible small and there is no need to prevent any means to eliminate the error.

Frequency Error:
Since the energy meter are used normally at fixed frequency, therefore , they are designed and adjusted to have minimum error declared supply frequency Which is normally 50 Hz in India.

Objective Questions

Q Creeping is avoided by __________
a) reversing the polarity of the voltage
b) drilling two diametrically opposite holes
c) holding the disc
d) increasing the friction

Q Energy meter creeps __________
a) due to change in supply
b) due to reversal in polarity of voltage
c) due to asymmetry in magnetic circuit
d) due to turns ratio of transformer

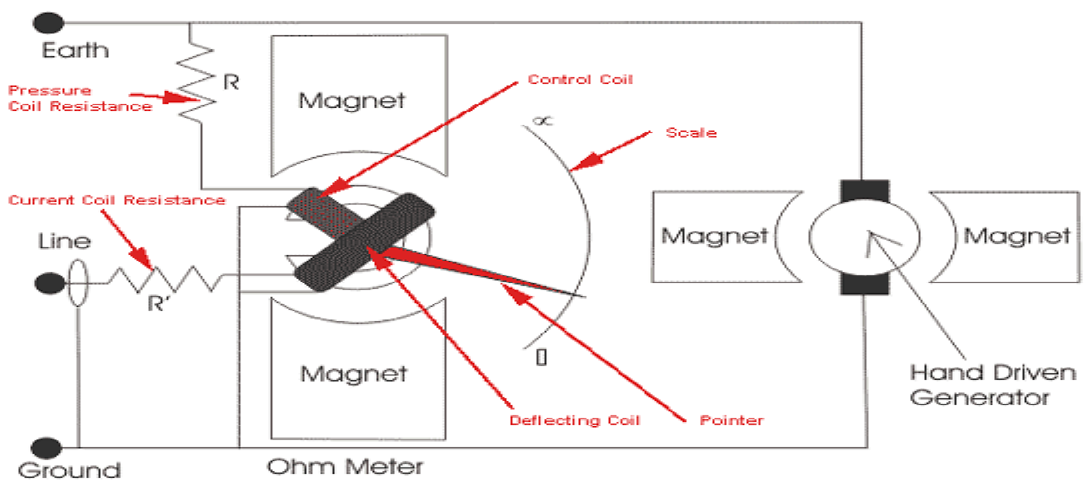
5 Miscellaneous Measuring Instruments:

5.1 Megger

Insulation resistance IR quality of an electrical system degrades with time, environment condition, i.e., temperature, humidity, moisture and dust particles. It also gets impacted negatively due to the presence of electrical and mechanical stress, so it's become very necessary to check the IR (Insulation resistance) of equipment at a constant regular interval to avoid any measure fatal or electrical shock.

The device enable us to measure electrical leakage in wire, results are very reliable as we shall be passing electric current through device while we are testing. The equipment basically uses for verifying the electrical insulation level of any device such as motors, cables, generators, windings, etc. This is a very popular test being carried out since very long back. Not necessary it shows us exact area of electrical puncture but shows the amount of leakage current and level of moisture within electrical equipment/winding/system.

Construction of Megger



Deflecting and Control coil : Connected parallel to the generator, mounted at right angle to each other and maintain polarities in such a way to produced torque in opposite direction.

1. Permanent Magnets : Produce magnetic field to deflect pointer with North-South pole magnet.
2. Pointer : One end of the pointer connected with coil another end deflects on scale from infinity to zero.
3. Scale : A scale is provided in front-top of the megger from range 'zero' to 'infinity', enable us to read the value.
4. D.C generator or Battery connection : Testing voltage is produced by hand operated DC generator for manual operated Megger. Battery / electronic voltage charger is provided for automatic type Megger for same purpose.
5. Pressure Coil Resistance and Current Coil Resistance : Protect instrument from any damage because of low external electrical resistance under test.

Working Principle of Megger

- Voltage for testing produced by hand operated megger by rotation of crank in case of hand operated type, a battery is used for electronic tester.

- 500 Volt DC is sufficient for performing test on equipment range up to 440 Volts.
- 1000 V to 5000 V is used for testing for high voltage electrical systems.
- Deflecting coil or current coil connected in series and allows flowing the electric current taken by the circuit being tested.
- The control coil also known as pressure coil is connected across the circuit.
- Current limiting resistor (CCR and PCR) connected in series with control and deflecting coil to protect damage in case of very low resistance in external circuit.
- In hand operated megger electromagnetic induction effect is used to produce the test voltage i.e. armature arranges to move in permanent magnetic field or vice versa.
- Where as in electronic type megger battery are used to produce the testing voltage.
- As the voltage increases in external circuit the deflection of pointer increases and deflection of pointer decreases with a increases of current.
- Hence, resultant torque is directly proportional to voltage and inversely proportional to current.
- When electrical circuit being tested is open, torque due to voltage coil will be maximum and pointer shows 'infinity' means no shorting throughout the circuit and has maximum resistance within the circuit under test.
- If there is short circuit pointer shows 'zero', which means 'NO' resistance within circuit being tested.

Earth Tester

Definition: The **instrument used for measuring the resistance of the earth is known as earth tester.** All the equipment of the power system is connected to the earth through the earth electrode. The earth protects the equipment and personnel from the fault current. The **resistance of the earth is very low**. The fault current through the earth electrode passes to the earth. Thus, protects the system from damage.

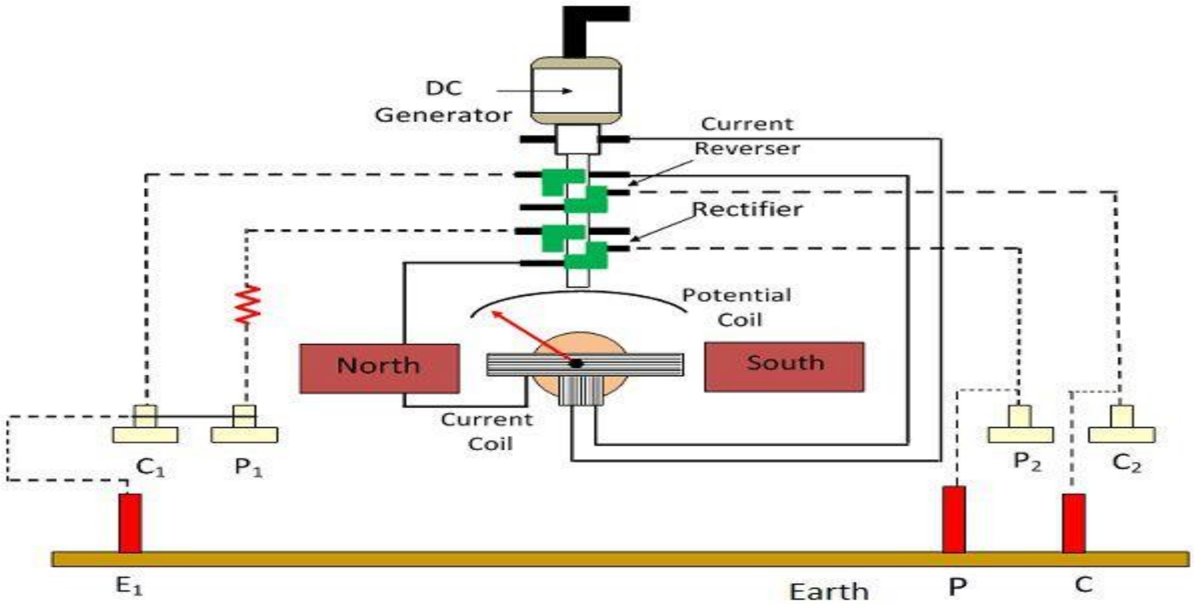
Construction of Earth Tester

The earth tester uses the hand driven generator. The **rotational current reverser and the rectifier are the two main parts of the earth tester**. The current reverser and the rectifier are mounted on the shaft of the DC generator. The earth tester works only on the DC because of the rectifier.

The tester has two commutators place along with the current reverser and rectifier. The each commutator consist four fixed brushes. The commutator is a device used for converting the direction of flows of current. It is connected in series with the armature of the generator. And the brushes are used for transferring the power from the stationary parts to the moving parts of the devices.

The **earth tester consists two pressures and the current coils.** The each coil has two terminals. The pair of the pressure coil and the current coil are placed across the permanent magnet. The one pair of current and pressure coil is short-circuited, and it is connected to the auxiliary electrodes.

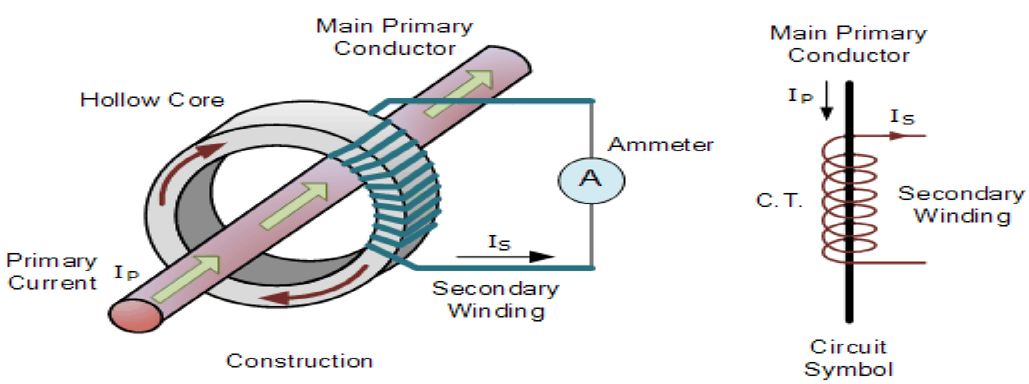
The earth tester consists the potential coil which is directly connected to the DC generator. The potential coil is placed between the permanent magnet. The coil is connected to the pointer, and the pointer is fixed on the calibrated scale. The pointer indicates the magnitude of the earth resistance. The **deflection of the pointer depends on the ratio of the voltage of pressure coil to the current of the current coil.**



5.2 Instrument transformers. These instruments transformers are of two types - (i) **Current Transformers (CT)** and (ii) **Potential Transformers (PT)**.

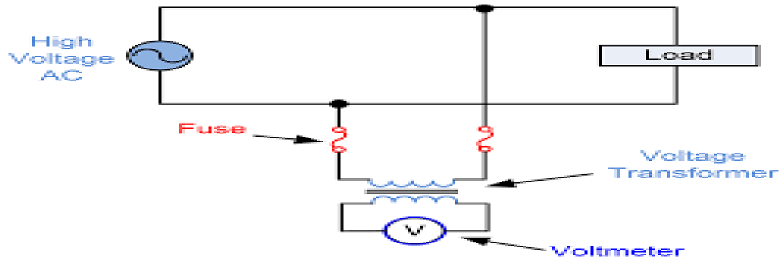
Current transformers are generally used to **measure currents of high magnitude**. These transformers step down the current to be measured, so that it can be measured with a normal range ammeter. A Current transformer has only one or very few number of primary turns. The primary winding may be just a conductor or a bus bar placed in a hollow core (as shown in the figure). The secondary winding has large number turns accurately wound for a specific turns ratio. Thus the current transformer steps up (increases) the voltage while stepping down (lowering) the current.

Now, the secondary current is measured with the help of an AC ammeter. The turns ratio of a transformer is $N_P / N_S = I_S / I_P$



Potential transformers are also known as **voltage transformers** and they are basically step down transformers with extremely accurate turns ratio. Potential transformers step down the voltage of high magnitude to a lower voltage which can be measured with standard measuring instrument. These transformers have large number of primary turns and smaller number of secondary turns.

A potential transformer is typically expressed in primary to secondary voltage ratio. For example, a 600:120 PT would mean the voltage across secondary is 120 volts when primary voltage is 600 volts.



Objective Questions

Q1 High resistances are of the order of __________

a) 0.1 MΩ

b) 10 mΩ

c) 1 kΩ

d) 10 GΩ

Q2 Megger is a ________

a) source of e.m.f

b) source to measure high resistance

c) type of a null detector

d) current carrier

Q3 Megger is also used for ________

a) providing additional e.m.f

b) bridge balance

c) testing insulation resistance

d) controlling the temperature

Q4 C.T. and P.T. are used for _________

a) measuring low current and voltages

b) measuring very low current and voltages

c) measuring high currentsand voltages

d) measuring intermediate currents and voltages

Q5 The primary winding of a C.T. has _________

a) a larger number of turns

b) no turns at all

c) intermediate number of turns

d) a few turns

Q6 The primary winding of a P.T. has _________

a) intermediate number of turns

b) no turns at all

c) a larger number of turns

d) a few turns

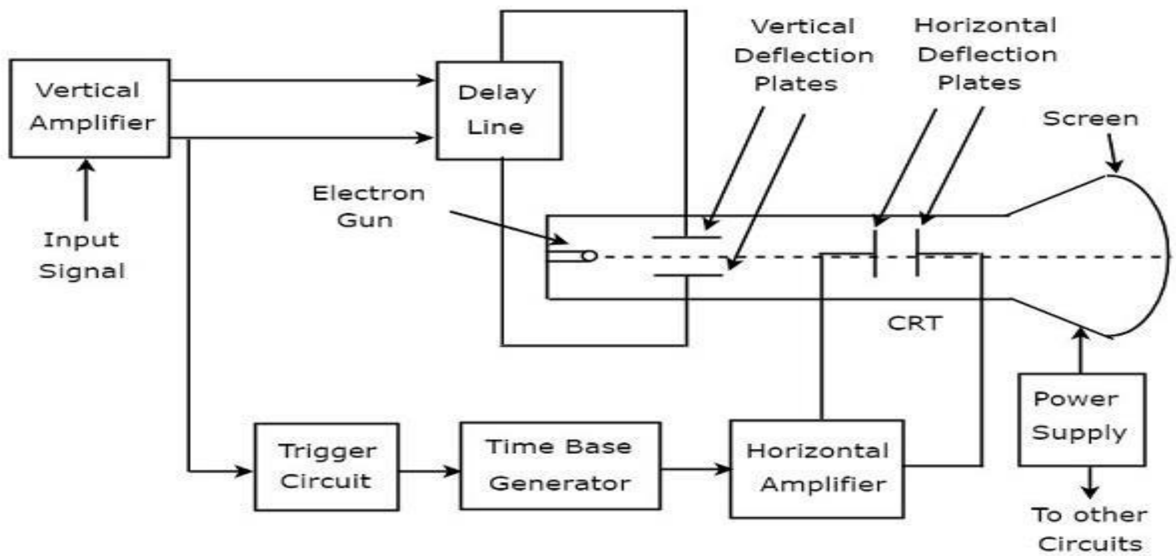
6 Cathode Ray Oscilloscope (CRO)

Oscilloscope is electronic equipment, which displays a voltage waveform. Among the oscilloscopes, Cathode Ray Oscilloscope (CRO) is the basic one and it displays a time varying signal or waveform.

In this chapter, let us discuss about the block diagram of CRO and measurements of some parameters by using CRO.

Block Diagram of CRO

Cathode Ray Oscilloscope (CRO) consists a set of blocks. Those are vertical amplifier, delay line, trigger circuit, time base generator, horizontal amplifier, Cathode Ray Tube (CRT) & power supply. The **block diagram** of CRO is shown in below figure.



The **function** of each block of CRO is mentioned below.

- **Vertical Amplifier** − It amplifies the input signal, which is to be displayed on the screen of CRT.
- **Delay Line** − It provides some amount of delay to the signal, which is obtained at the output of vertical amplifier. This delayed signal is then applied to vertical deflection plates of CRT.
- **Trigger Circuit** − It produces a triggering signal in order to synchronize both horizontal and vertical deflections of electron beam.
- **Time base Generator** − It produces a saw tooth signal, which is useful for horizontal deflection of electron beam.
- **Horizontal Amplifier** − It amplifies the saw tooth signal and then connects it to the horizontal deflection plates of CRT.

- **Power supply** − It produces both high and low voltages. The negative high voltage and positive low voltage are applied to CRT and other circuits respectively.
- **Cathode Ray Tube (CRT)** − It is the major important block of CRO and mainly consists of four parts. Those are electron gun, vertical deflection plates, horizontal deflection plates and fluorescent screen.

The electron beam, which is produced by an electron gun gets deflected in both vertical and horizontal directions by a pair of vertical deflection plates and a pair of horizontal deflection plates respectively. Finally, the deflected beam will appear as a spot on the fluorescent screen. In this way, CRO will display the applied input signal on the screen of CRT. So, we can analyse the signals in time domain by using CRO

Measurements by using CRO

We can do the following measurements by using CRO.

- Measurement of Amplitude
- Measurement of Time Period
- Measurement of Frequency

Now, let us discuss about these measurements one by one.

Measurement of Amplitude

CRO displays the voltage signal as a function of time on its screen. The **amplitude** of that voltage signal is constant, but we can vary the number of divisions that cover the voltage signal in vertical direction by varying **volt/division** knob on the CRO panel. Therefore, we will get the **amplitude** of the signal,

Measurement of Time Period

CRO displays the voltage signal as a function of time on its screen. The **Time period** of that periodic voltage signal is constant, but we can vary the number of divisions that cover one complete cycle of voltage signal in horizontal direction by varying **time/division** knob on the CRO panel.

Measurement of Frequency

The frequency, f of a periodic signal is the reciprocal of time period, T. **Mathematically**, it can be represented as

$f=1/T$

So, we can find the frequency, f of a periodic signal by following these two steps.

- **Step1** − Find the **Time period** of periodic signal
- **Step2** − Take **reciprocal** of Time period of periodic signal, which is obtained in Step1

Questions

Q Explain Block diagram of CRO in detail

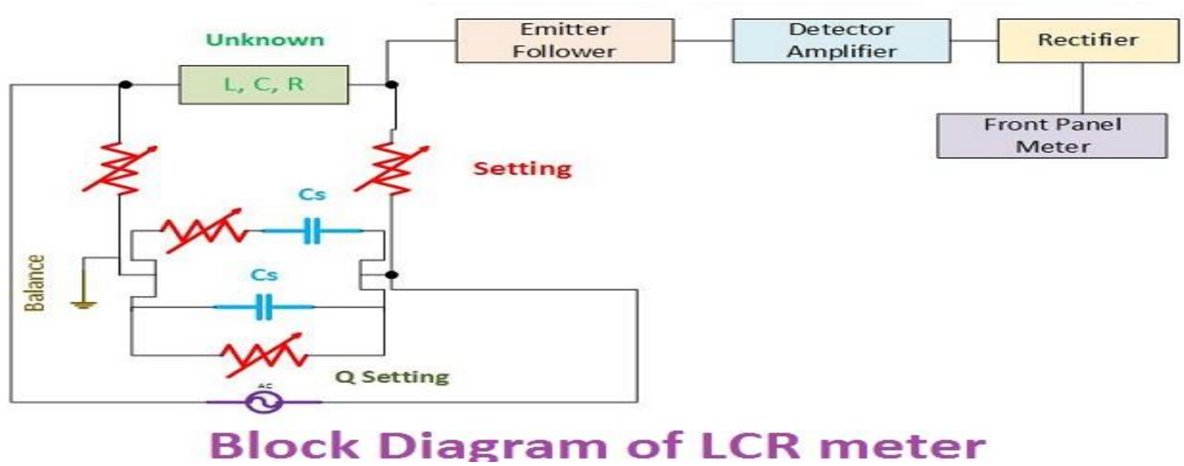
Q2 Oscilloscope is ___________

a) a ohmmeter

b) an ammeter c) a voltmeter d) a multimeter

7 LCR Meter

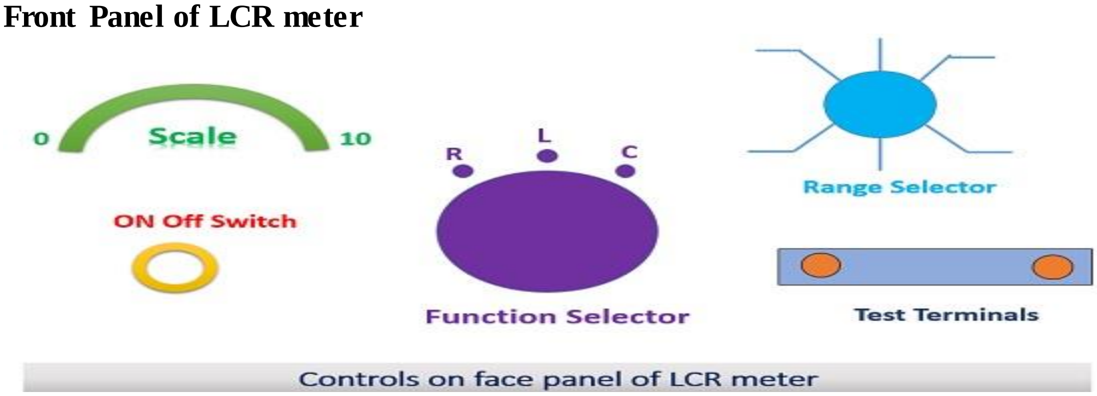
Definition: LCR meters can be understood as a multi meter, this is because it can measure **resistance, inductance, and capacitance** as per the requirement. Thus, it is termed as LCR meter. **L** in its name signifies inductance, **C** stands for capacitance and **R** denotes resistance. The significant component of LCR meter is the **Wheatstone bridge** and **RC ratio arm circuits.** The component whose value is to be measured is connected in one of the arms of the bridge. There are different provisions for the different type of measurements.



Working of LCR Meter

The bridge is adjusted in null position in order to balance it completely. Besides, the sensitivity of the meter should also be adjusted along with balancing of the bridge. The output from the bridge is fed to **emitter follower circuit.** The output from emitter follower circuit is given as an input to **detector amplifier.** The **rectifier** is used in the circuit to convert the AC signal into DC signal. When the bridge is provided with AC excitation then output end of the bridge the AC signal needs transformation into DC signal.

Front Panel of LCR meter



1. **ON/OFF Switch:** The ON/OFF switch can be used to turn on or off LCR meter. When the switch is positioned to ON state, the main supply is connected with LCR meter. After this, it is crucial to leave the meter for 15 minutes so that it can warm up. The indicator on the front panel will start glowing to indicate that the LCR meter is ON.

2. **Test Terminals:** The two points on the front panel are test terminals. The component which is to be measured is connected to these test terminals.
3. **Function Selector:** The function selector is used for setting the meter in the mode in order to measure the particular type of the component. If resistance is to be measured, then the function selector is to be set at **R mod**e, if inductance is to be measured it is to be adjusted to **L mode** and similarly in case of capacitance it is to be adjusted at **C mode**.
4. **Range Selector:** The range selector provides an extent of measuring range so that component of high magnitude or low magnitude values can be measured easily. The range selector should be adjusted properly in order to have correct measurement. For example: if a resistor of 10 mega ohms is under measurement and the range selector is in the range of ohms, then it will not show reliable and accurate results.

Questions

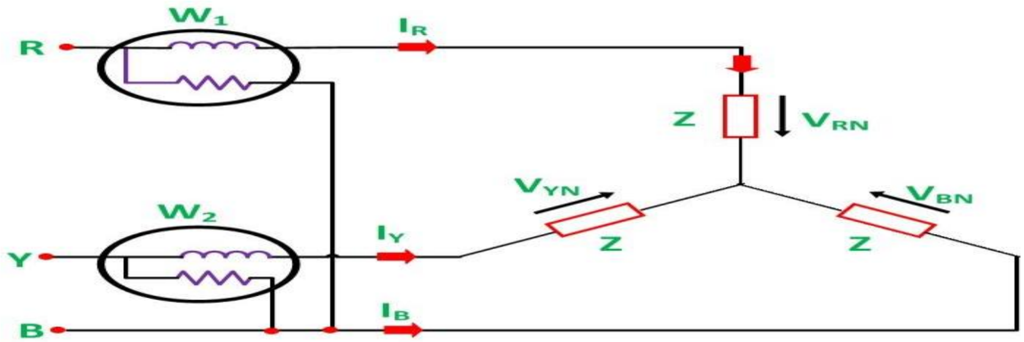
Q Where LCR meter is used?

LCR meters are used to measure the values of inductance (L), capacitance (C) and resistance (R) directly.

Q Explain working principle of LCR meter

8 Two Wattmeter Method

The **Two Wattmeter Method** is explained, taking an example of a balanced load. In this, we have to prove that the power measured by the Two Wattmeter i.e. the sum of the two wattmeter readings is equal to root 3 times of the phase voltage and line voltage ($\sqrt{3}V_L I_L \cos\phi$) which is the actual power consumed in a 3 phase balanced load.



Determination of Power Factor from Wattmeter Readings

As we know that,

$$W_1 + W_2 = \sqrt{3}\, V_L I_L \cos\varphi$$

Now,

$$W_1 - W_2 = V_L I_L\, [\cos(30^\circ - \varphi) - \cos(30^\circ + \varphi)] \quad \text{or}$$

$$W_1 - W_2 = V_L I_L\, [\cos 30^\circ \cos\varphi + \sin 30^\circ \sin\varphi - \cos 30^\circ \cos\varphi + \sin 30^\circ \sin\varphi\,] \text{ or}$$

$$W_1 - W_2 = 2\, V_L I_L \sin 30^\circ \sin\varphi$$

$$W_1 - W_2 = V_L I_L \sin\varphi$$

Dividing equation (3) by equation (2) we get,

$$\frac{W_1 - W_2}{W_1 + W_2} = \frac{V_L I_L \sin\varphi}{\sqrt{3}\, V_L I_L \cos\varphi} \quad \text{or}$$

$$\tan\varphi = \sqrt{3}\, \frac{W_1 - W_2}{W_1 + W_2}$$

Q 1 The input power to a 3-phase a.c. motor is measured as 5kW. If the voltage and current to the motor are 400V and 8.6A respectively, determine the power factor of the system?

Power P=5000W,

line voltage V_L = 400 V, line current, I_L = 8.6A and power, $P = \sqrt{3}\, V_L I_L \cos\varphi$ Hence

Power factor = cos φ = P √3 $V_L I_L$ = 5000 √3 (400) (8.6) = **0.839**

2. Two wattmeters are connected to measure the input power to a balanced 3-phase load by the two-wattmeter method. If the instrument readings are 8kW and 4kW, determine (a) the total power input and (b) the load power factor.

(a)Total input power, $P = P_1 + P_2$ =8+4=**12kW**

(b) tan φ =√3($P_1 - P_2$)/($P_1 + P_2$) =√3 (8 – 4) / (8 + 4) =√3 (4/12) =√3(1/3) = 1/ √3

Hence $\varphi = \tan^{-1} \frac{1}{\sqrt{3}} = 30^\circ$

Power factor= cos φ= cos 30◦ =**0.866**

1. In two wattmeters method of power measurement, one of the wattmeters will show negative reading when the load power factor angle is strictly

(a) than 30°

(b) less than 60°

(c) greater than 30°

(d) greater than 60°

2. Three identical impedances are connected in delta to a 3-phase supply of 400 V. The line-current is 34.65 A and the total power taken is 14.4 kW. The resistance of the load in each phase (in ohm) is

(a) 20
(b) 12
(c) 16
(d) 10

4. Which of the following statements associated with 3-phase delta connected circuits is *true?*

(a) Voltage is equal to phase voltage

(b) Line current is equal to phase current

(c) Line voltage is √3 time of phase voltage

(d) Line currents are 60° apart.

5. In a 3-phase supply, floating neutral is undesirable because it may result in …. across the load.

(a) line voltages

(b) high voltage

(c) low voltage

6. Phase reversal in a 4-wire unbalanced load supplied from a balanced 3-phase supply causes change in

(a) power consumed

(b) magnitude of phase currents

(c) only the magnitude of the neutral current

(d) magnitude as well as phase angle of the neutral current.

7. A 3-phase star connected symmetrical load consumes *P* watts of power from a balanced supply. If the same load is connected in delta to the same supply, the power consumption will be
(a) P
(b) √3P
(c) 3P
(d) not determined from the given data.
8. Three unequal impedances are connected in star to a 3-phase system. The sum of three line currents will be
(a) equal to the each line current
(b) Zero
(c) none of these
9. Three equal impedances are first connected in delta across a 3 – ϕ balanced supply. If the same impedances are connected in star across the same supply
(a) phase currents will be one-third
(b) line currents will be one-third
(c) power consumed will be one-third
(d) none of the above.
10. Which of the following is a four wire system?
(a) Delta
(b) Star
(c) Both delta and star
(d) Neither delta nor star.
11. In a 3-phase balanced star-connected load, neutral current is equal to
(a) zero
(b) I_P
(c) I_L
(d) unpredictable.
12. Which of the following equations is valid for a 3-phase 4-wire balanced star-connected load?
(a) $I_R + I_Y + I_R = I_N = O$
(b) $I_N + I_Y – I_B = I_N$
(c) $I_R – I_Y + I_B = I_N$
(d) $V_B + V_R + V_{Y\ /}\ Z = N$
13. Three unequal impedances are connected in delta to a 3-phase, 3-wire system.
a) The voltages across the three phases will be different
b) Both of the phase currents and line currents. will be unbalanced
c) Phase currents will be unbalanced but the line currents will be balanced
d) None of the above.
14. The relationship between the line and phase voltages of a delta-connected circuit is given by
a) $V_L = V_P$
b) $V_L = \sqrt{3}\ V_P$
c) $V_L = \frac{V_P}{\sqrt{2}}$
d) $V_L = \frac{2}{\pi} V_p$

15. In case of a delta connected load, if one resistor is removed, the power will become
a) Zero

b) one-third
c) two-third
d) none of the above.

16. Readings of 1154 and 577 watts are obtained when two wattmeters method was used on a balanced load. The delta connected load impedance for a system of 100 V will be
a) 15 ± 30°
b) 15 +*30*°
c) 15 –30°
d) 15 +90°.

17. Which of the following statements is true about two-wattmeters method for power measurement in 3-phase circuit?
a) Power can be measured using two wattmeters method only for star-connected 3-phase circuits
b) When two wattmeters show identical readings, the power factor is 0.5
c) When power factor is unity, one of the wattmeter reads zero
d) When the readings of the two wattmeters are equal but of opposite sign, the power factor is zero.

18. The minimum number of wattmeters to measure power in a 3-phase unbalanced star-connected load is
a) one
b) two
c) three
d) four.

19. While measuring power in a three phase load by two-wattmeters method, the readings of two wattmeters will be equal and opposite when
a) *pf* unity
b) load is balanced
c) phase angle is between 60° and 90°
d) the load is purely inductive.

20. In the measurement of 3-phase power by two-wattmeters method, if the two wattmeter will be equal the power factor of the circuit is
a) 0.8 lagging
b) 0.8 leading
c) Zero
d) unity

21. Which of the following are the necessary conditions for an entire 3-Φ system to be balanced?
1. The line voltages are equal in magnitude
2. The phase differences between successive line voltages are equal
3. The impedances in each of the phases are identical.

Select the correct answer using the codes given below:

Codes:

a) 1, 2 and 3

b) 1 and 3

c) 1 and 2

d) 2 and 3.

22. The power delivered to a 3-phase load can be measured by the use of 2 wattmeters only when the

a) load is balanced

b) load is unbalanced

c) 3-phase load is connected to the source through 3-wires

d) 3-phase load is connected to the source through 4-wires

23. The ratio of the readings of two wattmeters connected to measure power in a balanced 3-phase load is 5:3 and the load is inductive. The power factor of the load is'

a) 0.917 lead

b) 0.917 lag

c) 0.6lead

d) 0.6 lag.

24. In two phase system phase voltages differ by

a) 60°
b) 90°
c) 120°
d) 180°.

25. W_1 and W_2 are the readings of two wattmeters used to measure power of a 3-phase balanced load. The reactive power drawn by the load is

a) W_1+W_2
b) W_1-W_2
c) $\sqrt{3}(W_I + W_2)$
d) $(W_1 - W_2)$.

ANSWERS

1. *(d)* **2.** *(c)* **3.** *(b)* **4.** *(a)* **5.***(a)* **6.***(d)* **7.***(c)* **8.***(b)* **9.***(c)* **10.** *(b)* **11.** *(a)* **12.** *(a)* **13.** *(b)* **14.** *(a)* **15.** *(c)* **16.** *(b)* **17.** *(d)* **18.** *(b)* **19.** *(d)* **20.** *(d)* **21.** *(a)* **22.** *(c)* **23.** *(b)* **24.** *(b)* **25.** *(d)*

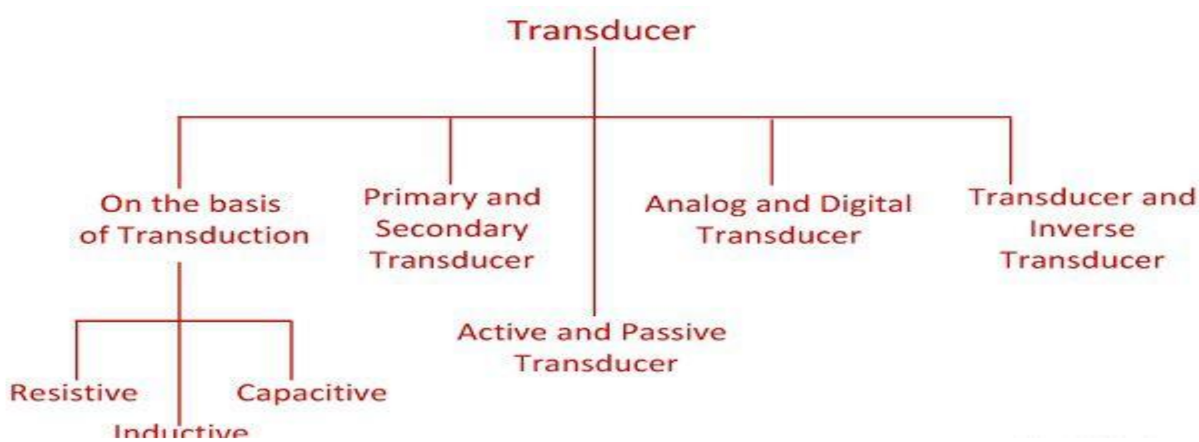
9 Transducers

The transducer changes the physical quantity into an electrical signal. It is an electronic device which has two main functions, i.e., sensing and transduction. It senses the physical quantity and then converts it into mechanical works or electrical signals.

The transducer is of many types, and they can be classified by the following criteria.

1. **By transduction used.**
2. **as a primary and secondary transducer**
3. **as a passive and active transducer**
4. **as analogue and digital transducer**
5. **as the transducer and inverse transducer**

The transducer receives the measured and gives a proportional amount of output signal. The output signal is sent to the conditioning device where the signal is attenuated, filtered, and modulated.

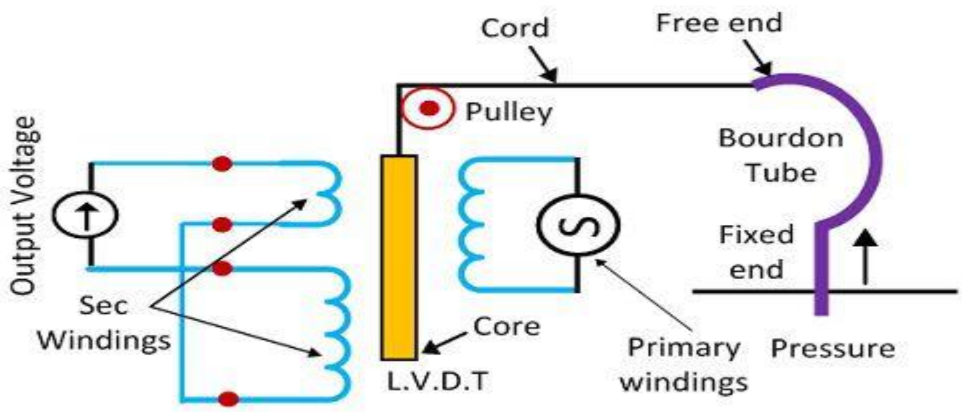


Primary Transducer – The transducer consists the mechanical as well as the electrical devices. The mechanical devices of the transducer change the physical input quantities into a mechanical signal. This mechanical device is known as the primary transducers.

Secondary Transducer – The secondary transducer converts the mechanical signal into an electrical signal. The magnitude of the output signal depends on the input mechanical signal.

Example of Primary and Secondary Transducer

Consider the Bourdon's Tube shown in the figure below. The tube act as a primary transducer. It detects the pressure and converts it into a displacement from its free end. The displacement of the free ends moves the core of the linear variable displacement transformer. The movement of the core induces the output voltage which is directly proportional to the displacement of the tube free end.



Passive Transducer – The transducer which requires the power from an external supply source is known as the passive transducer. They are also known as the external power transducer. The capacitive, resistive and inductive transducers are the example of the passive transducer.
Active Transducer – The transducer which does not require the external power source is known as the active transducer. Such type of transducer develops theirs owns voltage or current, hence known as a self-generating transducer. The output signal is obtained from the physical input quantity.
Transducer – The device which converts the non-electrical quantity into an electric quantity is known as the transducer.
Inverse Transducer – The transducer which converts the electric quantity into a physical quantity, such type of transducers is known as the inverse transducer. The transducer has high electrical input and low non-electrical
output.

Temperature Transducer
Definition: The temperature transducer converts the thermal energy into a physical quantity likes the displacement, pressure and electrical signal
Types of Temperature Transducer

The temperature transducer is mainly classified into two types.

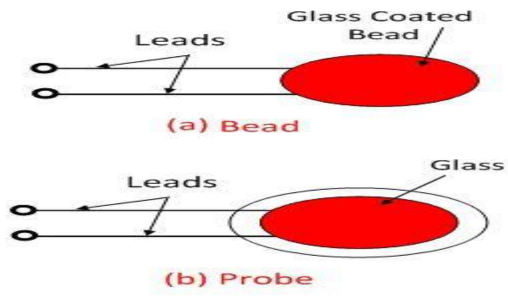
Contact Temperature Sensor Device

In such type of transducers, the sensing element is directly connecting to the thermal source. And the heat is transferred by the phenomenon of conduction. The conduction is the process through which the heat is transferred from one substance to another without the movement of the substance.

Non-contact Type Temperature Sensor Device

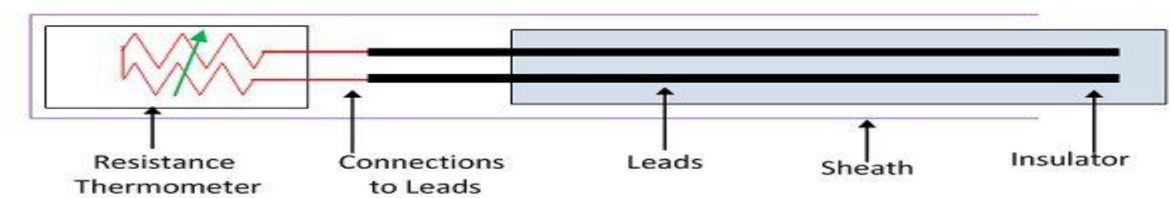
The sensing element is directly not contacting the thermal source. They use convection phenomenon for the transfer of heat. The convection is the process in which the heat is transfer by the movement of the substance. The non-contact type transducer is sub-categorised into the following categories.

Thermistor – The thermistor is a type of resistor whose resistance varies with the temperature. The resistance is measured by passing the small measured direct current, and this current causes the voltage drop across the resistance.



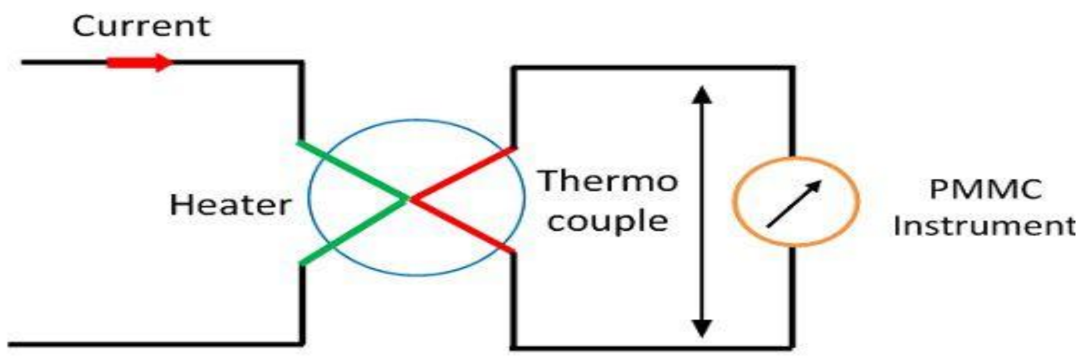
Thermistor

Resistance Thermometer – The resistance of metal varies with the temperature. And this property of the metal is used for measuring the temperature. The resistance thermometer uses the platinum as the sensing element and hence measures the surrounding temperature.



Resistance Thermometer

Thermocouples – The thermocouple converts the temperature into the electrical energy at the point of the contact. It works on the principle that the metals have different temperature coefficient and when these two metals join together then the voltage induces, and this voltage is directly proportional to the temperature.



· Thermocouple Instrument

Questions on Electrical Measurement

1Explain what is the difference between an ammeter and a voltmeter?
Ammeter is a low resistance indicating instrument while the voltmeter is a high resistance one.

2. Explain why an ammeter should be of very low resistance?
Ammeter, which is connected in series with the circuit carrying the current under measurement, must be over very low resistance so that the voltage drop across the ammeter and power absorbed from the circuit are as low as possible.

3. Explain why a voltmeter should be of very high resistance?
Voltmeter, which is connected in parallel with the circuit across which the voltage is to be measured, must be of very high resistance so that the current flowing through the voltmeter and the power absorbed from the circuit are minimum possible.

4. How an ammeter can be changed to a voltmeter?
An ammeter or low range can be converted into a voltmeter by connecting a high resistance in series with it provided the current through the series combination is within the range of the ammeter when connected across the voltage under measurement.

5. Explain what happens when an ammeter is connected across the circuit?
If an ammeter is connected in parallel to the circuit like a voltmeter, a very high current will flow through it which will produce such an excessive heat the insulation of the wire carrying the current will be destroyed. The wire may itself melt away. Thus the instrument will get damaged.

6. Explain what happens when a voltmeter is connected in series with the circuit?
If a voltmeter is connected in series with the circuit, the circuit resistance will become too large and consequently a very small current will flow through it. The instrument will, however, read almost the same emf acting on the circuit.

7. Explain what do you understand by ammeter shunt?
An ammeter shunt is merely a low resistance that is placed across the coil circuit of the instrument in order to measure fairly large currents.

8. Explain what do you understand by voltmeter multiplier?

Voltmeter multiplier is a high non-inductive resistance connected in series with the voltmeter coil and is used for increasing the range of a voltmeter.

9. Explain what is the advantage of using Ayrton or universal shunt in multi-range ammeters?

The advantage of using Ayrton or universal shunt is that it eliminates the possibility of the meter being in a circuit without a shunt.

10. Explain what is VOM?

The volt-ohm-milliammeter (VOM) is another name of multimeter. It is also called AVO meter.

11. Explain what is a multimeter?

The instrument, which contains a function switch to connect the appropriate circuits to the d'Arsonval movement, is often called a multimeter or ampere-volt-ohm (AVO) meter or volt-ohm-milliammeter (VOM).

12. Indicate the various quantities that can be measured with a multimeter.

Multimeteris used for measument of current (dc as well as ac), voltage (dc as well as ac) and resistance. With the external source, high resistance (exceeding 1MΩ),inductance and capacitance can be measured with this instrument.