I. INTRODUCTION TO ELECTRICAL MEASURING INSTRUMENTS:

1.1 Concept of measurement and instruments:-

What is Electrical Measurement & Instrument?

Definition: In electrical, the instruments used to measure the resistance or current, voltage, frequency, flux, power factor, etc. are called **'Electrical measuring instruments'**.
These instruments are known as the ohmmeter, ammeter, voltmeter, frequency meter, flux meter, power factor meter, etc.

Electrical Parameter	**Meter Type**
Resistance	Ohmmeter
Current	Ammeter
Voltage	Voltmeter
Frequency	Frequency Meter
Flux	Flux Meter
Power Factor	Power Factor Meter

In simple words, sometimes, the measuring instrument called as **'Meter'**.

Block Diagram of Measuring Instruments

Practically, the electrical measurement is a comparison between the actual measurement value and the standard value. The standard value is also called as 'True value'.
After comparing, there can be some deviation called 'error'.
The error is the deviation of the measurement value to the standard value. It is denoted by ' δ'.

Mathematically represent as,

$$Error = \delta = [(A_m) - (A_t)]$$

Where,

'Am' is the measured value.

'At' is the standard value.

Note: When Am > At, the positive error occurs. And when Am<At, a negative error occurs.
These measurement values are measured in terms of numerical values.

There are different electrical companies manufacturing these electrical instruments.

Classification of Electrical Measuring Instruments:

In electrical and electronic technologies, multiple types of instruments are used based on the studies, use cases, and the requirements.

The classification is based on the electrical quantities of parts, the nature of the operations, its purposes, its electrical supply, occurring effects, uses and many other terms.

Multimeters are a popular type of electrical measuring instrument. Like its name, it works like an ammeter, ohmmeter, and voltmeter to measure current, voltage, and resistance, respectively. With this single device, you can measure multiple units.
Multimeters are available into two forms.

- Analog type Multimeter
- Digital type Multimeter

In this advanced technology, both meters are used.

The analog type of multimeter shows the continuous signal. Whereas, digital type of multimeter shows the discrete signal.

Digital meter is also called as 'Smart Meters' or 'Advance Meters'. It gives a more accurate, fast response and also displays the measuring units.
For more detail, I have classified the list of different types of electrical measuring instruments in another article. This covers all the classification with an explanation.

Necessity or Uses of Electrical Measuring Instruments:

These measuring instruments are helping to determine the electrical quantities Or the numerical values for the electrical appliances.

In the daily routine, instruments used in the lab, commercial, industrial, many more places.

In Generating Station and Substation, the most important purpose of the instruments is the data recording.

Apart from that, the following are some of the major use cases of electrical measuring instruments.

- To find out the unknown numerical values of the electrical quantities and for comparison with the standard values.
- To find out the error in the measuring values in the circuit or system.
- It helps to find out fault conditions and to protect the electrical appliances.
- Measuring instruments are used for recording the data with respect to the time.
- It is essential for displaying numerical values of the electrical quantities as per the time.
- Electrical measuring instruments give an accurate and efficient reading for electrical equipment. Mostly, the digital meter is used for an accurate reading.

- It is also used for safety purpose while electrical circuit development and testing in the lab.

1.2 CONCEPT OF MEASUREMENT OF ELECTRICAL QUANTITIES AND INSTRUMENTS FOR THEIR MEASUREMENTS, SOURCES OF ERROR.

Measurements and Error Analysis

"It is better to be roughly right than precisely wrong." — Alan Greenspan

THE UNCERTAINTY OF MEASUREMENTS

Some numerical statements are exact: Mary has 3 brothers, and 2 + 2 = 4. However, all **measurements** have some degree of uncertainty that may come from a variety of sources. The process of evaluating the uncertainty associated with a measurement result is often called **uncertainty analysis** or **error analysis**.The complete statement of a measured value should include an estimate of the level of confidence associated with the value. Properly reporting an experimental result along with its uncertainty allows other people to make judgments about the quality of the experiment, and it facilitates meaningful comparisons with other similar values or a theoretical prediction. Without an uncertainty estimate, it is impossible to answer the basic scientific question: "Does my result agree with a theoretical prediction or results from other experiments?" This question is fundamental for deciding if a scientific hypothesis is confirmed or refuted.When we make a measurement, we generally assume that some exact or true value exists based on how we define what is being measured. While we may never know this true value exactly, we attempt to find this ideal quantity to the best of our ability with the time and resources available. As we make measurements by different methods, or even when making multiple measurements using the same method, we may obtain slightly different results. So how do we report our findings for our best estimate of this elusive **true value**? The most common way to show the range of values that we believe includes the true value is:

(1)

measurement = (best estimate ± uncertainty) units

Let's take an example. Suppose you want to find the mass of a gold ring that you would like to sell to a friend. You do not want to jeopardize your friendship, so you want to get an accurate mass of the ring in order to charge a fair market price. You estimate the mass to be between 10 and 20 grams from how heavy it feels in your hand, but this is not a very precise estimate. After some searching, you find an electronic balance that gives a mass reading of 17.43 grams. While this measurement is much more **precise** than the original estimate, how do you know that it is **accurate**, and how confident are you that this measurement represents the true value of the ring's mass? Since the digital display of the balance is limited to 2 decimal places, you could report the mass as

$m = 17.43 \pm 0.01$ g.

Suppose you use the same electronic balance and obtain several more readings: 17.46 g, 17.42 g, 17.44 g, so that the average mass appears to be in the range of

17.44 ± 0.02 g.

By now you may feel confident that you know the mass of this ring to the nearest hundredth of a gram, but how do you know that the true value definitely lies between 17.43 g and 17.45 g? Since you want to be honest, you decide to use another balance that gives a reading of 17.22 g. This value is clearly below the range of values found on the first balance, and under normal circumstances, you might not care, but you want to be fair to your friend. So what do you do now? The answer lies in knowing something about the accuracy of each instrument.To help answer these questions, we should first define the terms **accuracy** and **precision**:

Accuracy is the closeness of agreement between a measured value and a true or accepted value. Measurement **error** is the amount of inaccuracy.

Precision is a measure of how well a result can be determined (without reference to a theoretical or true value). It is the degree of consistency and agreement among independent measurements of the same quantity; also the reliability or reproducibility of the result.

The **uncertainty** estimate associated with a measurement should account for both the accuracy and precision of the measurement.

Note: Unfortunately the terms **error** and **uncertainty** are often used interchangeably to describe both imprecision and inaccuracy. This usage is so common that it is impossible to avoid entirely. Whenever you encounter these terms, make sure you understand whether they refer to accuracy or precision, or both.Notice that in order to determine the **accuracy** of a particular measurement, we have to know the ideal, true value. Sometimes we have a "textbook" measured value, which is well known, and we assume that this is our "ideal" value, and use it to estimate the **accuracy** of our result. Other times we know a theoretical value, which is calculated from basic principles, and this also may be taken as an "ideal" value. But physics is an empirical science, which means that the theory must be validated by experiment, and not the other way around. We can escape these difficulties and retain a useful definition of **accuracy** by assuming that, even when we do not know the true value, we can rely on the best available **accepted** value with which to compare our experimental value.For our example with the gold ring, there is no accepted value with which to compare, and both measured values have the same precision, so we have no reason to believe one more than the other. We could look up the accuracy specifications for each balance as provided by the manufacturer (the Appendix at the end of this lab manual contains accuracy data for most instruments you will use), but the best way to assess the accuracy of a measurement is to compare with a known **standard**. For this situation, it may be possible to calibrate the balances with a standard mass that is accurate within a narrow tolerance and is traceable to a **primary mass standard** at the National Institute of Standards and Technology (NIST). Calibrating the balances should eliminate the discrepancy between the readings and provide a more **accurate** mass measurement.Precision is often reported quantitatively by using **relative** or **fractional uncertainty**:

(2)

Relative Uncertainty =

$$\left|\frac{\text{uncertainty}}{\text{measured quantity}}\right|$$

Example:

$m = 75.5 \pm 0.5$ g

has a fractional uncertainty of:

$$\frac{0.5\ g}{75.5\ g} = 0.006 = 0.7\%.$$

Accuracy is often reported quantitatively by using **relative error**:

(3)

Relative Error =

$$\frac{\text{measured value} - \text{expected value}}{\text{expected value}}$$

If the expected value for m is 80.0 g, then the relative error is:

75.5 − 80.0

80.0

= −0.056 = −5.6%

Note: The minus sign indicates that the measured value is **less** than the expected value.When analyzing experimental data, it is important that you understand the difference between precision and accuracy. **Precision** indicates the quality of the measurement, without any guarantee that the measurement is "correct." **Accuracy**, on the other hand, assumes that there is an ideal value, and tells how far your answer is from that ideal, "right" answer. These concepts are directly related to **random** and **systematic** measurement errors.

TYPES OF ERRORS

Measurement errors may be classified as either **random** or **systematic**, depending on how the measurement was obtained (an instrument could cause a random error in one situation and a systematic error in another).

Random errors are statistical fluctuations (in either direction) in the measured data due to the precision limitations of the measurement device. Random errors can be evaluated through statistical analysis and can be reduced by averaging over a large number of observations (see standard error).

Systematic errors are reproducible inaccuracies that are consistently in the same direction. These errors are difficult to detect and cannot be analyzed statistically. If a systematic error is identified when calibrating against a standard, applying a correction or correction factor to compensate for the effect can reduce the bias. Unlike random errors, systematic errors cannot be detected or reduced by increasing the number of observations.

When making careful measurements, our goal is to reduce as many sources of error as possible and to keep track of those errors that we can not eliminate. It is useful to know the types of errors that may occur, so that we may recognize them when they arise. Common sources of error in physics laboratory experiments:

Incomplete definition (may be systematic or random) — One reason that it is impossible to make exact measurements is that the measurement is not always clearly defined. For example, if two different people measure the length of the same string, they would probably get different results because each person may stretch the string with a different tension. The best way to minimize definition errors is to carefully consider and specify the conditions that could affect the measurement.**Failure to account for a factor** (usually systematic) — The most challenging part of designing an experiment is trying to control or account for all possible factors except the one independent variable that is being analyzed. For instance, you may inadvertently ignore air resistance when measuring free-fall acceleration, or you may fail to account for the effect of the Earth's magnetic field when measuring the field near a small magnet. The best way to account for these sources of error is to brainstorm with your peers about all the factors that could possibly affect your result. This brainstorm should be done **before** beginning the experiment in order to plan and account for the confounding factors before taking data. Sometimes a **correction** can be applied to a result **after** taking data to account for an error that was not detected earlier.**Environmental factors** (systematic or random) — Be aware of errors introduced by your immediate working environment. You may need to take account for or protect your experiment from vibrations, drafts, changes in temperature, and electronic noise or other effects from nearby apparatus.**Instrument resolution** (random) — All instruments have finite precision that limits the ability to resolve small measurement differences. For instance, a meter stick cannot be used to distinguish distances to a precision much better than about half of its smallest scale division (0.5 mm in this case). One of the best ways to obtain more precise measurements is to use a **null difference** method instead of measuring a quantity directly. **Null** or **balance** methods involve using instrumentation to measure the difference between two similar quantities, one of which is known very accurately and is adjustable. The adjustable reference quantity is varied until the difference is reduced to zero. The two quantities are then balanced and the magnitude of the unknown quantity can be found by comparison with a measurement standard. With this method, problems of source instability are eliminated, and the measuring instrument can be very sensitive and does not even need a scale.**Calibration** (systematic) — Whenever possible, the calibration of an instrument should be checked before taking data. If a calibration standard is not available, the accuracy of the instrument should be checked by comparing with another instrument that is at least as precise, or by consulting the technical data provided by the manufacturer. Calibration errors are usually linear (measured as a fraction of the full scale reading), so that larger values result in greater absolute errors.**Zero offset** (systematic) — When making a measurement with a micrometer caliper, electronic balance, or electrical meter, always check the zero reading first. Re-zero the instrument if possible, or at least measure and record the zero offset so that readings can be corrected later. It is also a good idea to check the zero reading throughout the experiment. Failure to zero a device will result in a constant error that is more significant for smaller measured values than for larger ones.**Physical variations** (random) — It is always wise to obtain multiple measurements over the widest range possible. Doing so often reveals variations that might otherwise go undetected. These variations may call for closer examination, or they may be combined to find an average value.**Parallax** (systematic or random) — This error can occur whenever there is some distance between the measuring scale and the indicator used to obtain a measurement. If the observer's eye is not squarely aligned with the pointer and scale, the reading may be too high or low (some analog meters have mirrors to help with this alignment).**Instrument drift** (systematic) — Most electronic instruments have readings that drift over time. The amount of drift is generally not a concern, but occasionally this source of error can be significant.**Lag time** and **hysteresis** (systematic) — Some measuring devices require time to reach equilibrium, and taking a measurement before the instrument is stable will result in a measurement that is too high or low. A common example is taking temperature readings with a thermometer that has not reached thermal equilibrium with its environment. A similar effect is **hysteresis** where the instrument readings lag behind and appear to have a "memory" effect, as data are taken sequentially moving up or down through a range of values. Hysteresis is most commonly associated with materials that become magnetized when a changing magnetic field is applied.**Personal errors** come from carelessness, poor technique, or bias on the part of the experimenter. The experimenter may measure incorrectly, or may use poor technique in taking a measurement, or may introduce a bias into measurements by expecting (and inadvertently forcing) the results to agree with the expected outcome.

1.3 TYPES OF ELECTRICAL MEASURING INSTRUMENTS…

Types of electrical measuring instruments are:

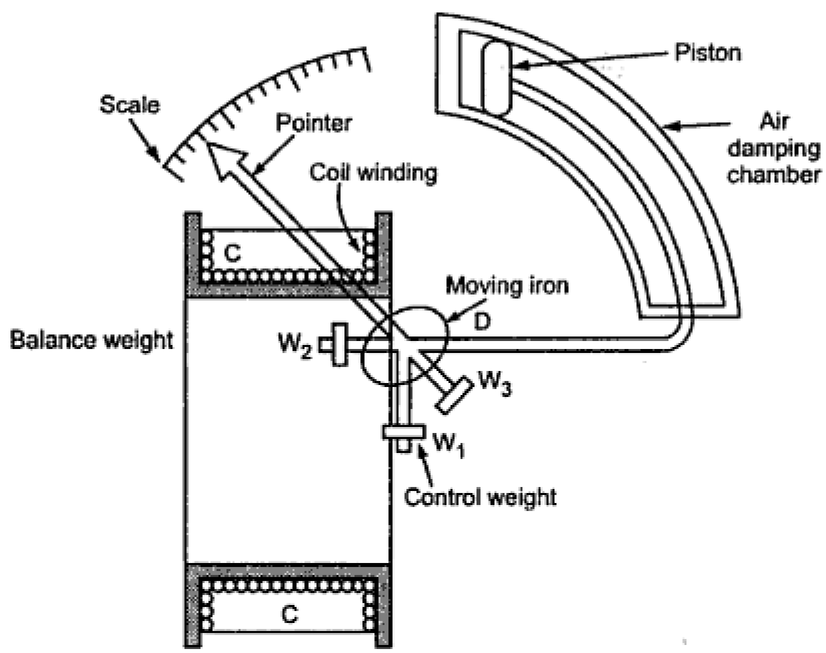
- Moving-iron instrument
- Moving-coil instrument
- Hotwire instrument
- Induction type instrument

Moving iron instrument:

In this type of instruments, deflection coil is made of soft iron which moves in the magnetic field. This type of instrument is principally used for the measurement of alternating currents and voltages, though it can also be used for D.C measurements.

There are two types of moving iron instruments:

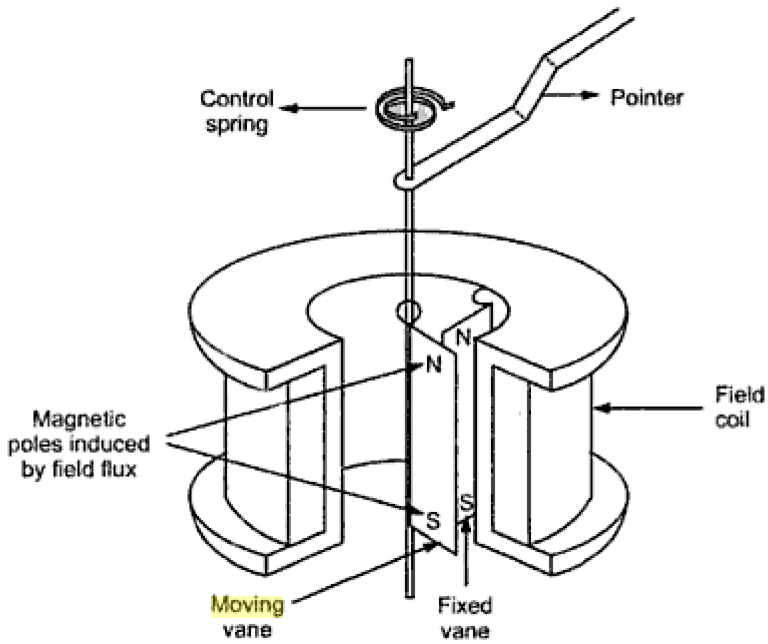
Attraction type:



A soft iron rod fixed to the shaft is magnetized and pulled inside the coil, the force of attraction is proportional to the force of the field inside the coil, which again is proportional to the force of the current.

When the current to be measured passes through the coil, a magnetic field is produced that draws the iron rod inward, thereby deflecting the pointer that moves on a calibrated scale.

Repulsion Type:



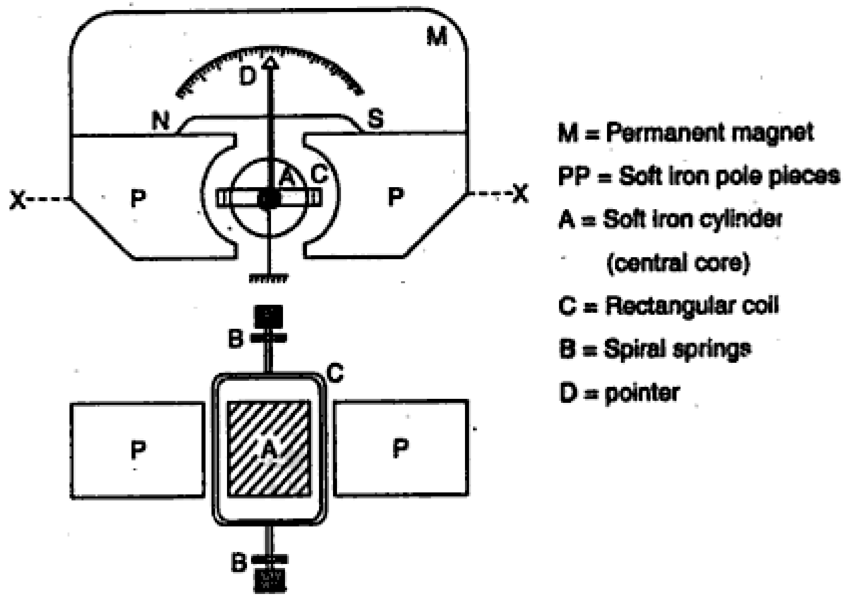
Two parallel rods of soft Iron are arranged along the axis of the fixed coil. One rod is fixed and other one will be movable. when current pass through both the rod, it induces a magnet field of same polarity causing repulsion between both the vanes resulting in the deflection of pointer.

Moving Coil instrument:

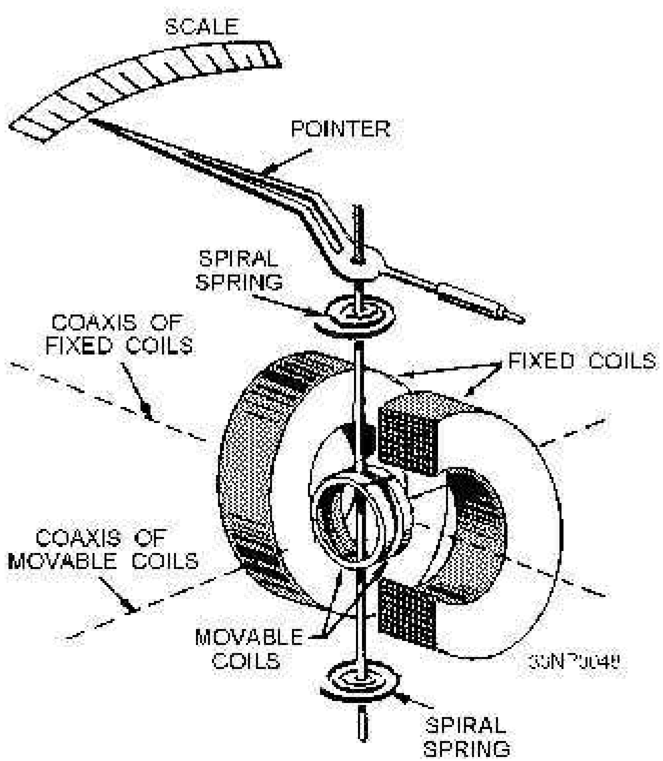
In this case the moving element is the current coil itself. There are two type of moving coil instrument:

Permanent Magnet type:

A coil wound in an aluminum or copper frame is placed in the radial magnetic field produced by a permanent U-shaped magnet provided with polar pieces of soft iron provided to reduce the magnetic field's reluctance by the air gap.

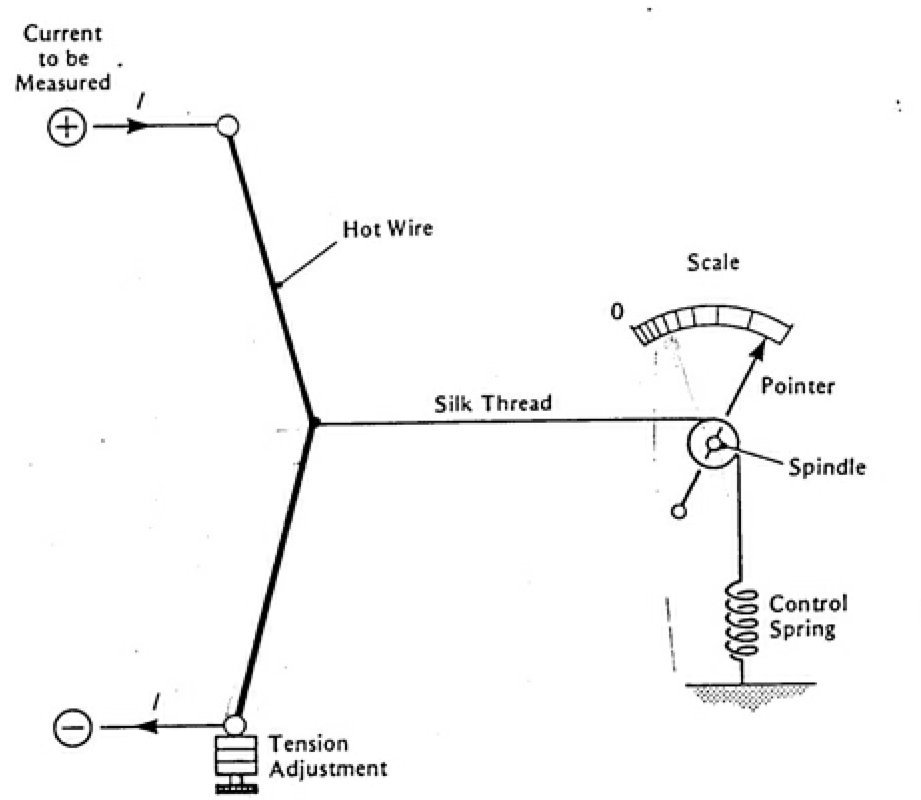


Dynamometer type



The permanent magnet in the mobile coil meter is replaced by electromagnetic coil. The movements of the electrodynamic meter use a stationary coil and mobile coils to develop interacting magnetic fields (ie, the electrodynamometer uses two electromagnetic fields in its operation).

Hot wire instrument:



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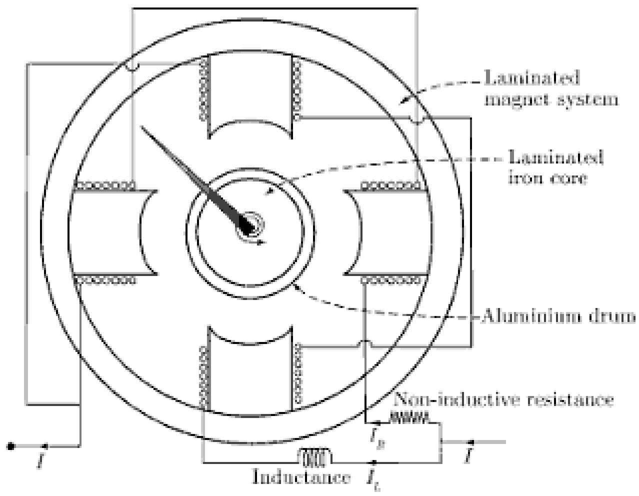
A hot wire is fixed between two points. The current must be measured to pass through the cable. As the current passes, the cable heats up and expands, sinking due to expansion. This extension is absorbed by the spring and silk thread, which makes the pulley turn, moving the pointer attached to it.

Induction-Type Instruments:

It works according to the principle of induction, that is, in the production of parasitic currents in a system in motion through alternating flows. These parasitic currents induced in a moving system interact with each other to produce a motor torque because the disk rotates to record the energy.

There are two types of induction type instruments:

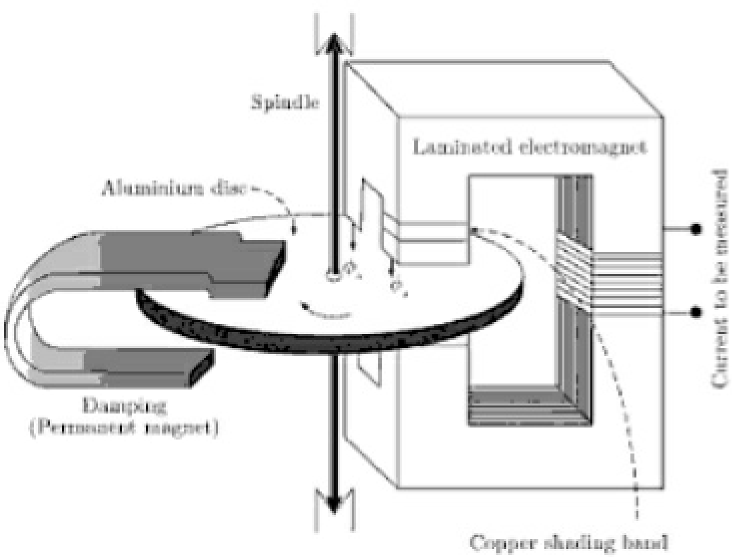
Ferraris-type Induction Instrument:



A rotating magnetic field is produced by two pairs of coils wound on a laminated magnet system. These pairs of coils are supplied from the same source, but a phase shift of about 90° occurs in the current flowing in them by connecting one inductance in series with one pair and a high resistance with the other, to produce a rotating magnetic field. This rotating field induces currents in an aluminium drum and causes this drum to follow its rotation. If the drum can rotate freely, it will rotate at a speed slightly lower than that of the rotating field but in the same direction of the field.

Shaded pole type Induction Instruments:

It consists of a laminated electromagnet that has an air space in which an edge of a thin aluminium disc rotates. This disc is mounted on an axis that has a pointer and is equipped with a control spring. Approximately one-third of the pole of the electromagnet is surrounded by a copper band that provides a phase shift arrangement.



When A.C current is supplied to the electromagnet, eddy currents are induced in the shading ring, and the flow within the shaded portion of the ring is delayed behind the main flow by an angle of 40-50°. This phase shift produces a torque on the rotating disk and measures the value of the current or voltage.

The instruments, which are used to measure any quantity are known as measuring instruments. This tutorial covers mainly the **electronic instruments**, which are useful for measuring either electrical quantities or parameters.

Following are the most commonly used electronic instruments.

- Voltmeter
- Ammeter
- Ohmmeter
- Multimeter

1.4

The movement of Permanent Magnet Moving Coil (PMMC) Instrument involves the influence of 3 torques.

1. Deflecting Torque,
2. Controlling Torque and
3. Damping Torque.

The balance of these torques over the pointer indicates the measured value.

1. **Deflection Torque :** This torque makes the pointer move away from the zero position to the desired reading. But, the applied deflection torque results in a reading greater than the desired reading.
2. **Controlling Torque :** This torque is responsible to compensate the extra deflection made by the pointer due to the deflection torque. Hence, the desired reading is indicated.
3. **Damping Torque :** This torque makes the pointer to return the pointer to the zero position gradually after the reading has been made.

   Damping torque can also be interpreted as the torque responsible for the pointer to come to an an equilibrium position i.e. at rest in the scale without oscillating to give accurate reading.

2.1 CONCEPT OF AMMETER AND VOLTMETER AND THEIR DIFFERENCE.

Difference Between Ammeter & Voltmeter

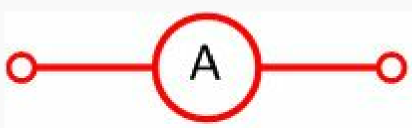
The major difference between the ammeter and the voltmeter is that the ammeter measures the flow of current, whereas the voltmeter measures the emf or voltage across any two points of the electrical circuit. The other differences between the ammeter and voltmeter are presented below in the comparison chart.

Electricity is measured in two ways. i.e., either through current or voltage. The current and voltage of the circuit are measured through ammeter and voltmeter. The working principle of the ammeter and voltmeter are same as that of the galvanometer.

The galvanometer uses a coil which is placed between the magnet. When the current flows through the coils, it becomes deflected. The deflection of the coils depends on the charge passing through it. This deflection is used for measuring the current or voltage. The galvanometer works as a voltmeter when the resistor is placed in series with the galvanometer.

Content: Ammeter Vs Voltmeter

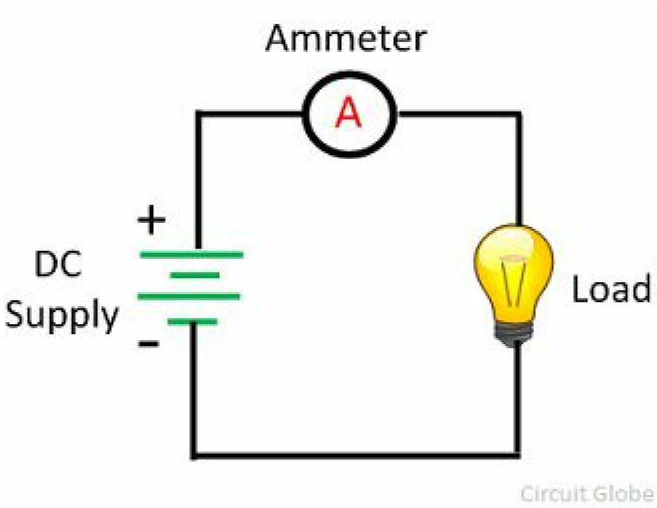
Comparison Chart

Basis For Comparison	**Ammeter**	**Voltmeter**
Definition	The instruments used for measuring the current.	It measures the voltage between any two points of the circuit.
Symbolic Representation		
Resistance	Low	High
Connection	It is connected in series with the circuit.	It is connected in parallel with the circuit.
Accuracy	More	Less
Changing of	Not possible	Possible

Basis For Comparison	Ammeter	Voltmeter
Range		

Definition of Ammeter

The ammeter is the measuring instruments which are used to measure the current in the circuit. It measures the small amount of current in milliamperes or micro-amperes. The ammeter is placed in series with the measuring circuit so that the whole current of the circuit passes through it.

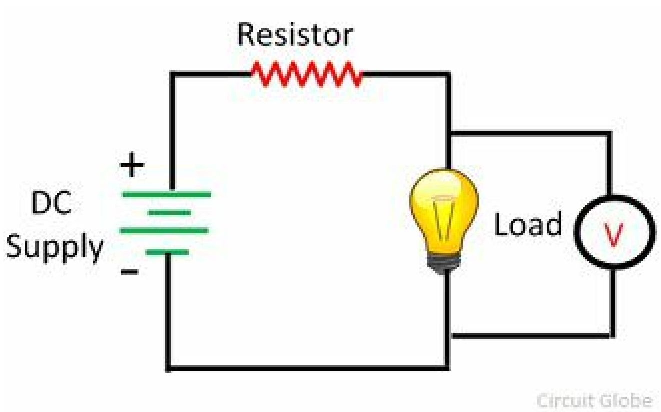


The resistance of the ammeter is very small as compared voltmeter. For ideal ammeter, the value of resistance is equal to zero. The small resistance does not obstruct the flow of current, and thus the ammeter measures the true value.

Definition of Voltmeter

The voltmeter is the voltage measuring devices. It is connected in parallel with the electrical circuit whose potential is to be measured. The connection polarity of the voltmeter is same as that of the ammeter i.e. the positive terminal is connected to the positive polarity of the supply and the negative potential is connected to the negative polarity.

The resistance across the voltmeter is very large as compared to the ammeter. This resistance does not allow the current to flow through the voltmeter and thus the exact value of the voltage across the measuring point is measured. The value of resistance in ideal voltmeter is approximately equal to infinity.



Key Differences between Ammeter and Voltmeter

The following are the key difference between Ammeter and Voltmeter.

1. The ammeter is defined as the device used for measuring the small value current flows in the circuit, whereas the voltmeter measures the potential difference between any two points of the electrical circuit.
2. The resistance of the ammeter is low. So that, the whole current of the circuit will pass through it. Whereas, the internal resistance of the voltmeter is very low so that the current from the circuit does not disturb the measuring of the voltmeter.
3. The ammeter is connected in series with the circuit for measuring the complete current, whereas the voltmeter is connected in parallel with the circuit. The potential difference of the parallel circuit remains same at all points. So for measuring the exact value of the potential difference, it is connected in parallel with the points whose voltage is to be measured.
4. The accuracy of the ammeter is more as compared to the voltmeter.
5. The measuring range of the voltmeter can be increases or decreases by changing the value of resistance whereas the range of ammeter can not be changed.

Nowadays, the current clamp is used for measuring the circuit current

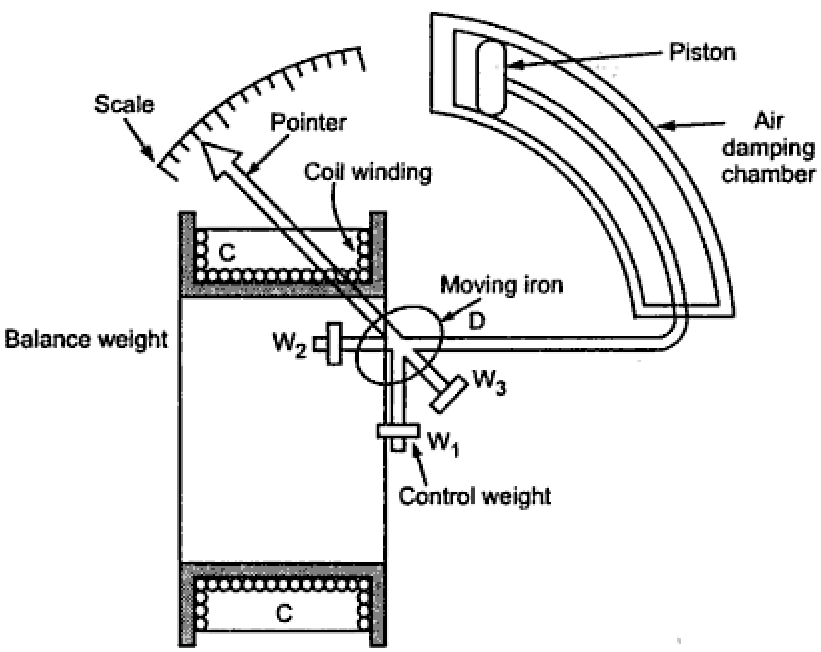
2.2

Moving iron instrument:

In this type of instruments, deflection coil is made of soft iron which moves in the magnetic field. This type of instrument is principally used for the measurement of alternating currents and voltages, though it can also be used for D.C measurements.

There are two types of moving iron instruments:

Attraction type:



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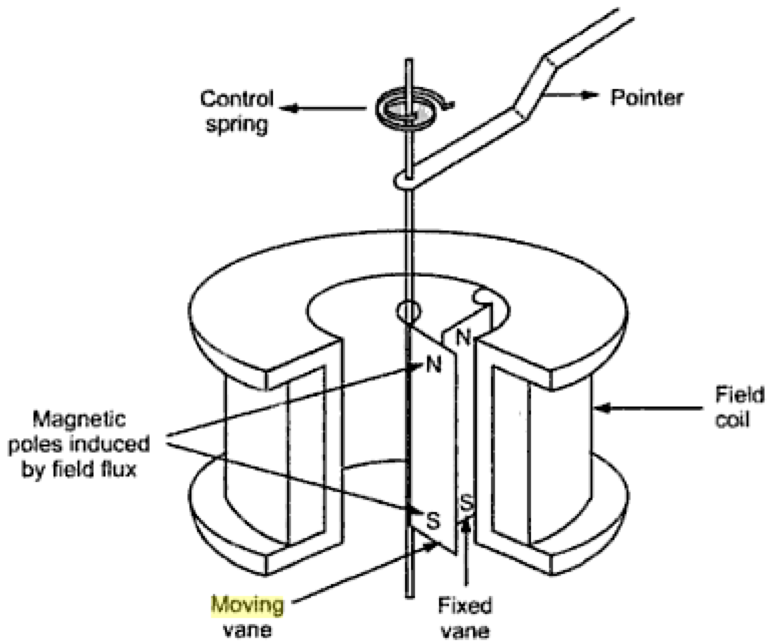
Repulsion Type:



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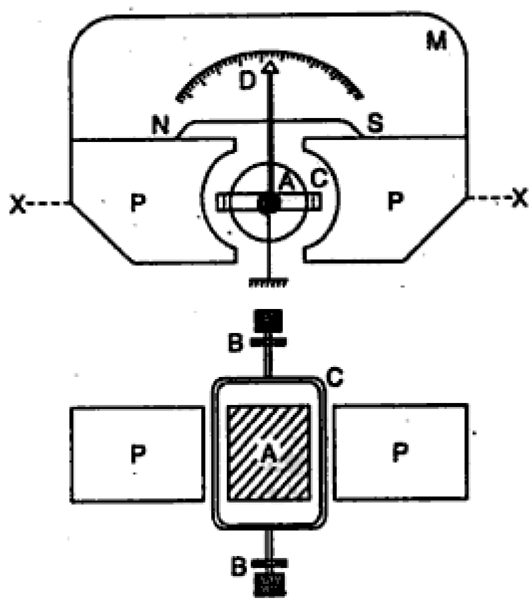
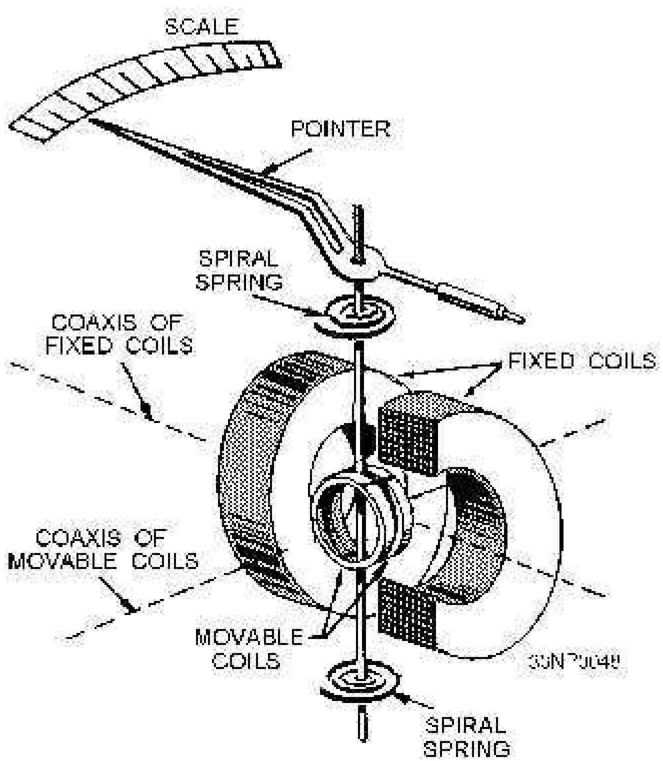


M = Permanent magnet
PP = Soft iron pole pieces
A = Soft iron cylinder
(central core)
C = Rectangular coil
B = Spiral springs
D = pointer

Dynamometer type



The permanent magnet in the mobile coil meter is replaced by electromagnetic coil. The movements of the electrodynamic meter use a stationary coil and mobile coils to develop interacting magnetic fields (ie, the *electrodynamometer uses two electromagnetic fields in its operation).*

2.3 MERITS AND DEMERITS OF THESE INSTRUMENTS

- **Advantages:**

i) Cheap, robust and give reliable service.

ii) Usable in both a.c. and d.c. circuits.

- **Disadvantages:**

i) Have non-linear scale.

ii) Cannot be calibrate with high degree of precision for d.c. on account of the affect of hysteresis in the iron vanes.

iii) Deflection up to 240º only may be obtained with this instrument.

iv) This instrument will always have to be put in the vertical position if it uses gravity control.

- **Errors with MI instruments:**

i) Due to hysteresis when used in a.c. and d.c.

ii) Due to stray magnetic fields when used both in a.c. and d.c.

iii) Due to frequency variation when used in a.c.

iv) Due to waveforms effect when used in a.c.

3 WATTMETERS

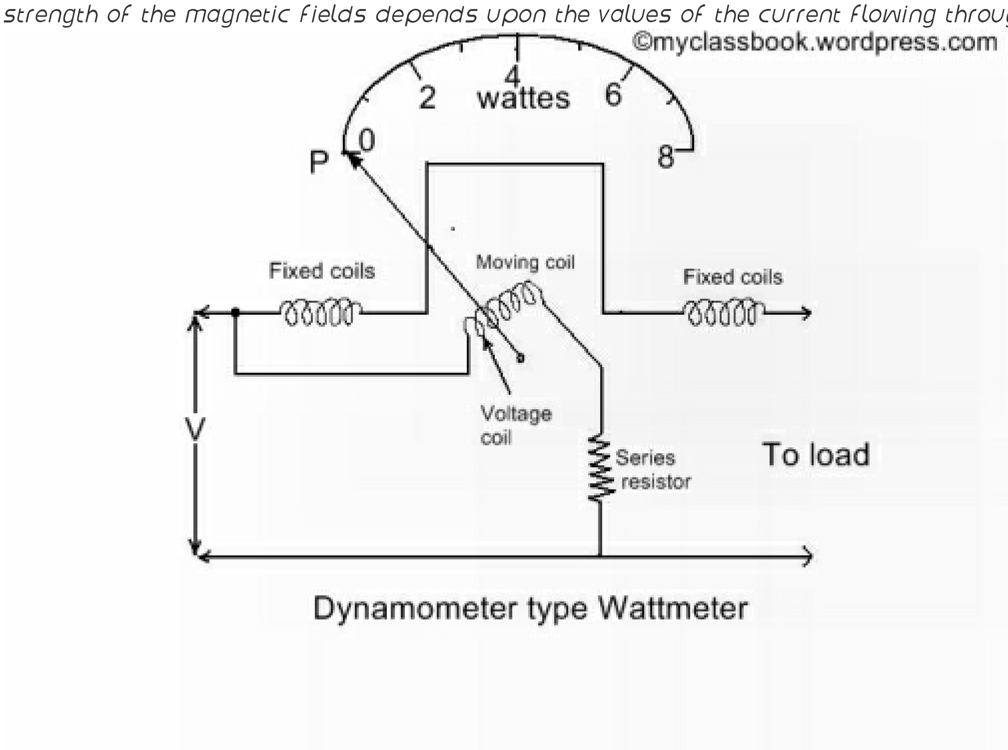
Construction and working principle of dynamometer type wattmeter

Dynamometer Type Wattmeter – Construction and working principle

Hello friends, in this post we will see construction and working principle & classification of dynamometer type wattmeter. We will also see the advantages and disadvantages of dynamometer type wattmeter.

Construction of Dynamometer Type Wattmeter:

The following figure shows the dynamometer wattmeter for measuring the power. ***If two coils are connected such that, current proportional to the load voltage, flows through one coil and current proportional to the load current, flows through another coil, the meter can be calibrated directly in watts.*** *This is true because the indication depends upon the product of the two magnetic fields. The strength of the magnetic fields depends upon the values of the current flowing through the coils.*



Dynamometer type wattmeter

Working of Dynamometer Type Wattmeter:

Let us consider

- *v=supply voltage*
- *i=load current and*
- *R=resistance of the moving coil circuit*
- *Current through fixed coils, i(f)=I*

- *Current through the moving coil, i(m)=v/R*
  Deflecting torque,

$$T_d \propto (i_f * i_m) \propto \frac{iv}{R}$$

- *For a DC circuit, the deflecting torque is thus proportional to the power.*
- *For any circuit with fluctuating torque, the instantaneous torque is proportional to instantaneous power. In this case, due to the inertia of moving parts, the deflection will be proportional to the average power. For sinusoidal alternating quantities, the average power is VI COSθ where*
- *V = r.m.s. value of voltage,*
- *I = r.m.s. value of current, and*
- *θ = phase angle between V and I*
  Hence an electrodynamic instrument, when connected as shown in the figure, indicates the power, irrespective of the fact it is connected in an AC or DC circuit.

Ranges:

1. *Current circuit: 0.25 A to 100 A with employing current transformers (CTs).*
2. *Potential circuit: 5V to 750 V without employing potential transformers (PTs).*

Advantages and Disadvantages of Dynamometer Type Instruments

Advantages and Disadvantages of Dynamometer Type Instruments

Advantages:

1. *These instruments are free from hysteresis losses and eddy current losses.*
2. *They have a precision grade accuracy.*
3. *These instruments can be used on both A.C and D.C. They are also used as a transfer instruments.*
4. *Electrodynamometer voltmeters are very useful where accurate RMS values of voltage, irrespective of waveforms, are required.*

Disadvantages:

1. *They have a non-uniform scale.*
2. *These instruments have a low sensitivity due to a low torque to weight ratio.*
3. *They are more expensive than either the PMMC or the M.I type instruments.*
4. *These instruments are sensitive to overloads and mechanical impacts. Therefore, they must be handled with great care.*

5. The operating current of these instruments is large due to the fact that they have a weak magnetic field.

Digital wattmeter

Digital

Digital wattmeters measure current and voltage electronically thousands of times a second, multiplying the results in a computer chip to determine watts. The computer can also perform statistics such as peak, average, low watts and kilowatt-hours consumed. They can monitor the power line for voltage surges and outages. In 2009, a variety of inexpensive digital wattmeters are available to consumers. With the falling price and improved capabilities of digital electronics, they have become popular for conveniently measuring power consumption in household appliances with an eye toward saving energy and money.

4

Construction and working of single phase energy meters

Single phase induction type energy meter

Induction type single phase energy meter:

Single phase induction type energy meter is extensively used to measure energy supplied to a single phase circuit.

Operating principle of Single phase induction type

energy meter:

The operation of induction type energy meter depends on the passage of alternating current through two suitably located coils producing rotating magnetic field which interacts with a metallic disc suspended near to the coils and cause the disc to rotate.

The current coil carries the line current and produces field in phase with the line current. The pressure coil is made highly inductive so that the current through it lags behind the supply voltage by 90 degrees. Thus, a phase difference of 90 degrees exists between the fluxes produced by the two coils. This sets up rotating field which interacts with the disc to cause it to rotate.

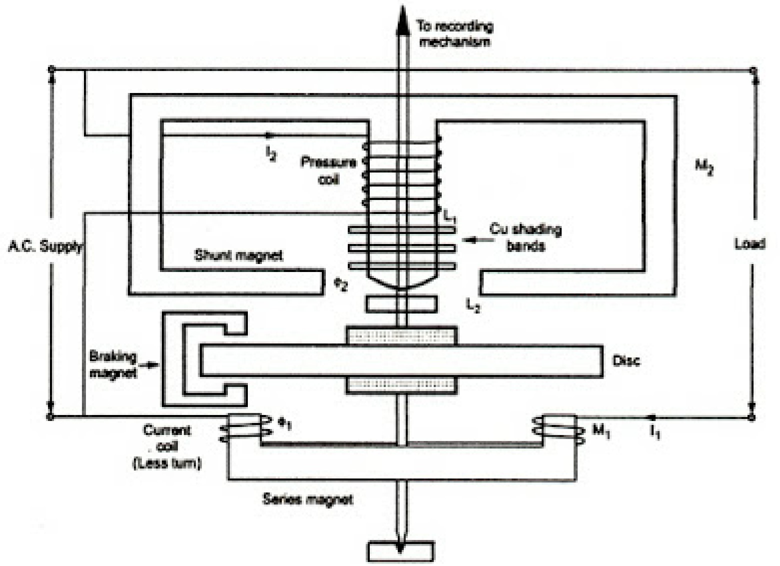
Construction of Single phase induction type energy meter:

A single phase induction type energy meter generally has:

1. Moving system

2. Operating mechanism

3. Recording mechanism



Single phase induction type energy meter diagram

1. Moving system: The moving system consists of a light aluminium disc mounted on a vertical spindle. The spindle is supported by a up-shaped jewelled bearings at the bottom end and has a spring journal bearing at the top end.

There is no pointer and control spring so that the disc makes continuous rotation under the action of deflecting torque.

2. Operating mechanism: It consists of series magnet, shunt magnet and breaking magnet.

Series magnet: The series magnet consists of a number of U-shaped laminations assembled together to form a core. A thick wire of few turns is wound on both legs of the U-shaped laminated core. The wound coil is known as current coil and is connected in series with the load so that it carries the load current. The series magnet is placed underside the aluminium disc and produces magnetic field proportional to and in phase with the current.

Shunt Magnet: The shunt magnet consists of a number of M-shaped laminations assembled together to form a core. A fine wire of large turns is wound on the central limb of this magnet. The wound coil is known as pressure coil and is connected across the load so that it carries current proportional to supply voltage. the shunt magnet is placed above the aluminium disc as shown.

In order to obtain deflecting torque, current in the pressure coil must lag behind the supply voltage by 90 degrees. This necessary phase shift is obtained by placing a copper ring over central limb of shunt magnet. This copper ring acts as a short circuited transformer secondary. As its inductance is high as compared with its resistance, the current circulating in the ring will lag by nearly 90 degrees behind the voltage producing it.

Braking magnet: The speed of aluminium disc is controlled to the required value by the C-shaped permanent braking magnet . The magnet is mounted so that the disc revolves in the air gap between the polar extremities. As the disc rotates, currents are induced in the disc because it cuts the flux produced by the breaking magnet. The direction of the current in the disc is such that it opposes the rotation of the disc. Since the induced currents in the disc are proportional to the speed of the disc, therefore, breaking torque is proportional to the disc speed.

3. Recording mechanism: The number of revolutions of the disc s a measure of the electrical energy passing through the meter and is recorded on dials which are geared to the shaft.

Working:

When the energy meter is connected in the circuit to measure electrical energy, the current coil carries the load current whereas the pressure coil carries current proportional to the supply voltage. The magnetic field due to current coil is in phase with line current whereas the magnetic field produced due to pressure coil lags approximately 90 degrees behind the supply voltage.

The current coil field produces eddy currents in the disc which reacts with the field due to the pressure coil. Thus, a driving force is created which causes the disc to rotate.

The braking magnet provides the braking torque on the disc. By altering the position of this magnet, desired speed can be obtained. The spindle is geared to the recording mechanism so that electrical energy consumed in the circuit is directly registered in kWh.

Merits and demerits of single phase energy meters

Advantages of Induction meter

- No moving iron.
- High torque is to weight ratio.
- The moving element has no electrical contact with the circuit.
- Less affected by stray magnetic field.
- More accurate on a wide range of loads.
- Good damping.

Disadvantages of Induction meter

- Without proper compensation measures, a considerable amount of errors are caused in the measurement due to temperature, waveform and frequency changes.
- Induction meters can use only for AC measurements.
- They consume a considerable amount of power.
- They have nonlinear scales.

Three phase energy meter working,construction

An energy meter is used to measure the energy consumed in the kilowatt hours. This is used in each and every house and industry for calculating the energy consumed by them. A **3-phase energy meter** has same elements as in case of a **single-phase energy meter.** We see each of them in detail in this post.

Construction of three phase energy meter:

A 3-phase energy meter has following systems. This systems are same for both single phase and three phase energy meters. They are:

1. Driving System.

2. Moving System.

3. Breaking System.

4.Registering or Counting System.

Driving System:

This consists of a coil wounded on central limb of a shunt electro magnet which acts as pressure coil also known as voltage coil. This coil should have high inductance which means that inductance to resistance ratio of this coil is very high. Because of this inductive nature the current , flux will lag behind supply voltage by 90° approximately.

Copper shading bands are provided on the shunt magnet's central limb to get 90° phase angle displacement between magnetic field set up by the shunt magnet and supply voltage. We have another series electro magnet on which current coil is wounded. This current coil is in series with the load so load current will flow through this.The flux produced by series magnet is proportional to and in phase with the load current. The driving system of 3-phase energy meter comprises of these elements.

Moving system:

On a vertical spindle or shaft a light rotating aluminium disc is attached. With the help of a gear arrangement aluminum disc is attached to the clock mechanism on front side of meter which helps to measure the energy consumed by load.

Eddy currents are induced due to time varying flux produced by series and shunt magnets. A driving torque is set up due to interaction between these two magnetic fields and eddy currents.

Therefore number of rotations of the disk is proportional to the energy consumed by the load in a certain time interval and is measured in kilowatt-hours (Kwh).

Breaking system:

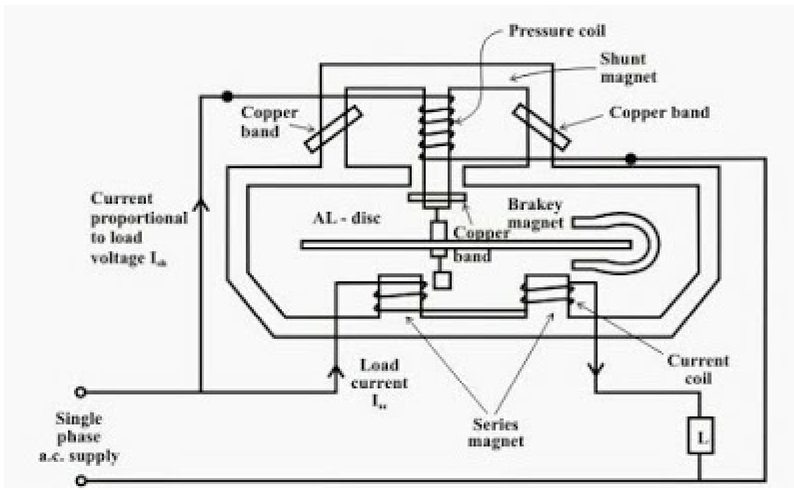
To damp aluminium disc we keep a small permanent magnet diametrically opposite to both the ac magnets(parallel,series). Now this disc moves in the magnet field crossing air gap. When this happens eddy currents are induced in aluminium disc which interacts with the magnetic field and produces breaking torque.

The speed of the rotating disc can be controlled by changing the position of the brake magnet or diverting some of the flux.

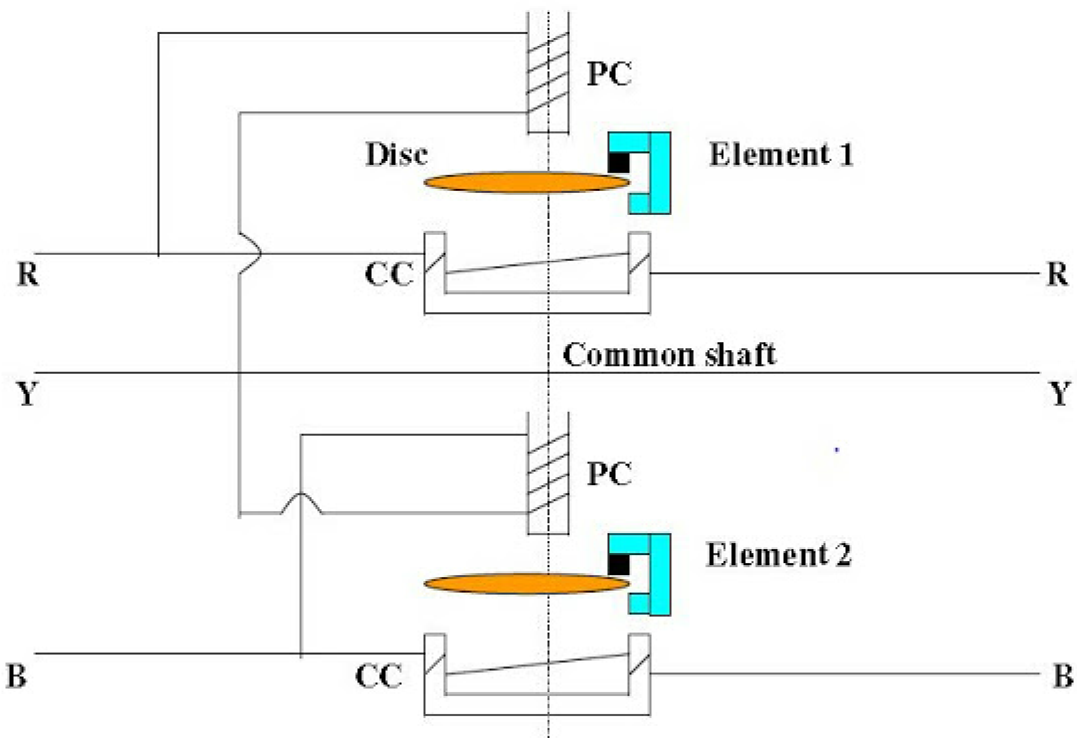
Counting system:

It has a gear system to which pointer is attached. This is connected to aluminium disc which drives this pointer. This pointer moves on the dial and gives number of times the is disc rotated.

These can be seen in the diagram given below:



A 3-phase induction motor has same four systems but they are arranged in a different way as shown in the figure given below.



This is a two element 3-phase energy meter. On a common spindle two discs are mounted and each disc has its own break magnet.

Moving system drives a gear Each unit is provided with its own copper shading ring, shading band, friction compensator, etc., to make adjustments for obtaining correct reading.

This gives ***construction of a 3 phase energy meter.***

Working of three phase energy meter:

Now let us see how a 3 phase energy meter works.

For same power/energy the driving torque should be equal in both elements. For adjusting torque in both the elements we have two current coils connected in phase opposition and two potential coils connected in parallel. Full load current passes through current coil and this arrangement causes two torques to be in opposition and the disc doesn't move if torques are equal. Magnetic shunt is adjusted if there is inequality in torques to make the disc to stand still. Before testing a 3 phase energy meter torque balance is obtained in this way.

Aluminium discs are acted upon by the two coils one is voltage coil and the other is current coil. Voltage coil produces magnetic flux proportional to voltage and current coil produces magnetic flux proportional to current. The voltage coil field lags by 90 degrees by using a lag coil.

Due to this two torques eddy currents are produced in the aluminium discs and discs rotate on a common shaft. Force exerted on the aluminium disc is proportional to product of instantaneous current and voltage. To this shaft a gear arrangement is made and a needle is attached to this gear so when discs rotates this needle moves on dial and counts the number of rotations of the disc.

A permanent magnet is used to produce a force in opposition and proportional to the speed of disc. When power is switched off this acts as break and makes the disc to stop rotating instead of rotating faster. Disc rotates at a speed proportional to power consumed.

Instantaneous power can be calculated by using below formula

$P_i = (3600 * N) / (T * R)$

where

P_i *= Real power being used at that point in time in kW*

T = Time (in seconds) for the disc to rotate through the N rotations or part of a rotation

N = The Number of full rotations counted.

R = The number of revolutions per Kilowatt hour (rev/kWh) of the meter being used.

Merits and demerits of three phase energy meters

Advantages of 3 Phase Over Single Phase System

*The three-phase system has three live conductors which supply the 440V to the large consumers. While the single phase system has one live conductor which is used for domestic purposes. The following are the main **advantages of 3 Phase system** over Single Phase system.*

- ***Higher Rating***
  The rating, i.e. the output of a three-phase machine is nearly 1.5 times the rating (output) of a single phase machine of the same size.

- ***Constant Power***
  In single phase circuits, the power delivered is pulsating. Even when the voltage and current are in phase, the power is zero twice in each cycle. Whereas, in the polyphase system, the power delivered is almost constant when the loads are in balanced condition.

- ***Power Transmission Economics***
  The three phase system requires only 75% of the weight of conducting material of that required by single phase system to transmit the same amount of power over a fixed distance at a given voltage.

- ***Superiority of 3 Phase Induction Motors***
  The three Phase induction motors have a widespread field of applications in the industries because of the following advantages are given below.

  *1. Three phase induction motors are **self-starting** whereas the single phase induction motor is not self-starting. This means the 1 –phase motor has no starting torque and hence it needs some auxiliary means to start at the initial stage.*

  *2. The three Phase Induction motors have **higher power factor** and **efficiency** than that of a single phase induction motor.*

- ***Size and Weight of alternator***
  The 3 Phase Alternator is small in size and light in weight as compared to a single phase alternator.

- ***Requirement of Copper and Aluminium***
  3 Phase system requires less copper and aluminium for the transmission system in comparison to a single phase transmission system.

- ***Frequency of Vibration***
  In 3 phase motor, the frequency of vibrations is less as compared to single phase motor because in single phase the power transferred is a function of current and varies constantly.

- ***Dependency***
  A single phase load can be efficiently fed by a 3 phase load or system, but 3 phase system cannot depend or feed by a single phase system.

- ***Torque***
  A uniform or constant torque is produced in a 3 phase system, whereas in a single phase system pulsating torque is produced.

Disadvantages of Three Phase over Single Phase are:

- *Greater cost of standby Units*
- *increased cost and inconvenience of repairs.*
- *In Single Phase transformer (three Single Phase Transformer) failure of one transformer, the other two, Single Phase Transformer still supply the power, while it is not possible in case of failing a Three Phase Transformer.*

4.1

What are the Errors and their Adjustments in 1Φ energy meter

Errors and their Adjustments in 1Φ energy meter

Energy meters should give correct readings over a period of several years under normal use conditions. Some of the common errors in energy meter and their remedial measures are discussed below.

1. ***Phase Error:*** *It is necessary that the energy meter should give correct reading on all power factors, which is only possible when the field setup by shunt magnet lags behind the applied voltage by 90°. But the flux due to shunt magnet does not lag behind the applied voltage exactly by 90° because of winding resistance and iron losses.*

   Adjustment: *The flux in the shunt magnet can be made to lag behind the supply voltage by exactly 90° by adjusting the position of shading band (or shading ring or shading coil) placed round the lower part of the control limb of the shunt magnet.*

   This adjustment is known as lag adjustment or power factor adjustment (or power factor compensator).

2. ***Speed Error:*** *Sometimes the speed of the meter is either fast or slow, resulting in the wrong recording of energy consumption.*

   Adjustment: *An error in the speed of the meter when tested on non-inductive load can be eliminated by correctly adjusting the position of the brake magnet.*

   Movement of the brake magnet in the direction of the spindle will reduce the braking torque and vice-versa.

3. **Friction Compensation (or) Friction Error:** Frictional forces at the rotor bearings and in the counting (or register) mechanism cause noticeable error especially at light loads. At light loads, the torque due to friction adds considerably to the braking torque on the disc rotor. Since, friction torque is not proportional to the speed but is roughly constant it can cause considerable error in meter reading.

Adjustment: This error can be reduced to an unimportant level by making the ration of the shunt magnet flux Φ_2 and series magnet flux Φ_1 large with the help of two shading rings (or shading bonds). These bonds embrace the flux contained in the two outer limb of the shunt magnet and thus eddy currents are induced in them which cause a phase displacement between the enclosed flux and the main gap flux. As a result, a small driving torque is exerted on the disc rotor, this torque being adjusted by variation of the positions of these bands to compensate for friction in the instrument. Correctness of friction compensation is achieved by running the meter at high load of about 8 to 10% of full load when the disc should rotate correctly. Over compensation leads to creep. This adjustment is known as *light load adjustment*.

4. **Creeping:** Sometimes the disc of the energy meter makes slow but continuous rotation at no load i.e. when the potential coil is excited but with no current flowing in the load. This is called creeping. This error may be caused due to over compensation for friction, excessive supply voltage, vibrations, stray magnetic fields etc.

Adjustment: in order to prevent this creeping on no load, two holes or slots are drilled in the disc on opposite sides of the spindle. This causes sufficient distortion of the field. The result is that the disc tends to remain stationary when one of the holes comes under one of the shunt magnet.

5. **Temperature Error:** The error due to variation in temperature are very small, because the various effects produced tend to neutralise one another.

The resistance of the disc of the potential coil and characteristics of magnetic circuit and the strength of break magnet are affected by the changes in temperature. Therefore, great care is exercised in the design of the meter to eliminate the errors due to temperature variations.

Frequency Variations: The meter is designed to give minimum error at a particular frequency (generally 50 Hz). If the supply frequency changes, the reactance of the coils also changes, resulting in a small error. Fortunately, this is not of much significance because commercial frequencies are held within close limits.

Voltage Variations: The error due to variation voltage is very small (usually 0.2% to 0.3%). This can be eliminated by the proper design of the magnetic circuit of the shunt magnet.

Simple numerical problems

Electrical Measurements Questions and Answers – Errors in Single Phase Energy Meters

This set of Electrical Measurements & Measuring Instruments Multiple Choice Questions & Answers (MCQs) focuses on "Errors in Single Phase Energy Meters".

1. Magnitude of flux in an energy meter varies __________

a) due to abnormal currents and voltages

b) due to high resistance and inductance values

c) due to change in the transformer turns

d) due to the induced e.m.f in the windings

View Answer

Answer: a
Explanation: In the driving system of an energy meter, magnitude of flux can be incorrect as a result of abnormal values of currents and voltages. This occurs due to change in the resistance of the pressure coil circuit.

2. Phase angles in an energy meter cannot be incorrect.

a) True

b) False

View Answer

Answer: b
Explanation: In an energy meter, phase angle errors occur as a result of improper adjustments of lag condition, abnormal frequencies etc,. Due to temperature, changes in resistance values also lead to error in the phase angle.

3. 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

View Answer

Answer: c
Explanation: In an energy meter, when the magnetic circuit is asymmetrical, a driving torque is produced. As a result of this driving torque, the energy meter creeps.

4. Supply voltage in an energy meter is __________

a) constant always

b) zero always

c) depends on the load

d) can fluctuate

View Answer

Answer: d
Explanation: Generally the supply voltage is constant in an energy meter. It can fluctuate as a result of unavoidable reasons leading to errors in the reading of the energy meter.

5. How is the flux of shunt coil related to voltage?

a) flux is proportional to square of voltage

b) directly proportional

c) inversely proportional

d) independent of each other

View Answer

Answer: a
Explanation: In an energy meter, the supply voltage may fluctuate as a result of unavoidable reasons leading to errors in the reading. Supply voltage causes the shunt flux to induce an e.m.f in the disc. This is results in a self braking torque proportional to square of the voltage.

6. How can temperature effect be compensated in an energy meter?

a) through heat sinks

b) by a temperature shunt

c) by using resistance

d) by using a coolant

View Answer

Answer: b
Explanation: The resistance of the copper and aluminium parts in an energy meter increase with an increase in the temperature. As a result the disc rotates with a speed that is higher than actual. Temperature effects can be compensated by making use of a temperature shunt on the brake magnet.

7. Disc rotates slowly in some energy meters.

a) True

b) False

View Answer

Answer: a
Explanation: Even when there is no current flow through the energy meter, disc rotates slowly. This is known as creeping. This is occurs as a result of the over compensation provided for friction.

8. 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

View Answer

Answer: b
Explanation: In an energy meter, creeping causes the disc to rotate even when there is no current flowing. By drilling two diametrically opposite holes under the edge of the poles of a shunt magnet, rotation of the disc is limited to a minimum value.

9. In some energy meters, creeping can be avoided by __________

a) attaching small gold pieces

b) attaching small aluminium pieces

c) attaching small iron pieces

d) attaching small zinc pieces

View Answer

Answer: c
Explanation: By attaching some iron pieces to the edge of the disc, creeping can be limited in some energy meters. Force of attraction that is experienced by the brake magnet as a result of the iron piece is enough to eliminate the creeping.

4.3

Maximum Demand Indicator

Definition: The maximum demand indicator measures the maximum amount of power requires by the consumer at the particular interval of time. The indicator is designed in such a way so that they measure the base and peak load but unable to measures the sudden short-circuit or starting high current of the motor. It is designed for recording the power over particular periods.

The maximum demand indicators are classified into four types.

1. Recording demand indicator
2. Average demand indicator
3. Thermal type maximum demand indicator
4. Digital Maximum Demand Indicator

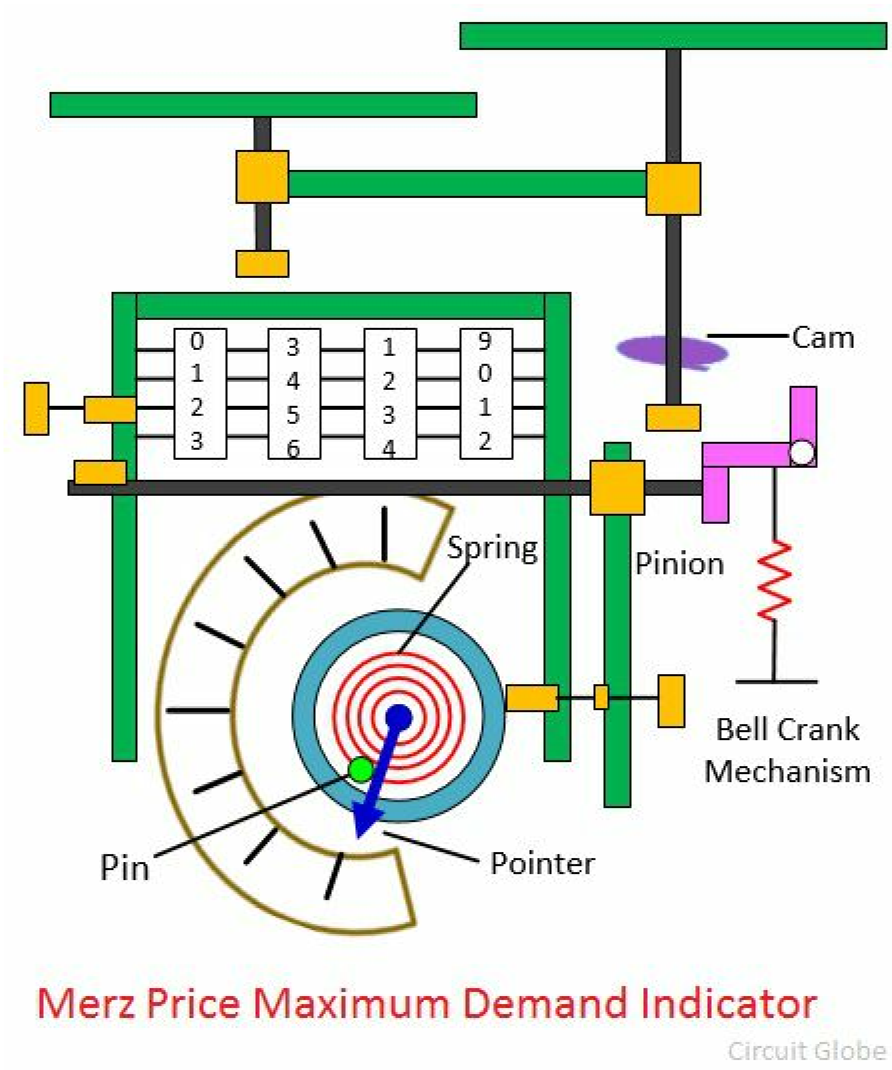
Construction of Maximum Demand Indicator

The maximum demand indicator has five main parts.

- Dial Connected to the moving system
- Pointer
- Reset Device
- Fraction device
- Indicating Pin

Average Demand Indicator

The average demand indicator is inbuilt into the energy meter. The energy meter and average demand indicator together measures the total power consumes and the maximum value of specific power at particular interval of time. The average demand indicator consists the complex speed dial mechanism.



The pin drive moves the dial forward for small duration (say for half an hour). The total power consumes at that interval is shown on the dial. The instrument consists the cam which is controlled by the timing gears. The cam brings back the pointer at zero positions.

The pointer records the total power consumes by the load at that particular interval of time. For the next half an hour, the pin again moved forward. But the pointer will move forward only when the total power consumed by the load is more than the previous periods.

The formula calculates the average maximum demand,

$$\text{Average Maximum Demand in kW} = \frac{\text{maximum energy recorded over a time in interval kWh}}{\text{time intervals in hours}}$$

The maximum demand meter can measure the power regarding kVarh or kVah. This can be done by adding the suitable meter which will calculate such quantities.

Advantages of Average Demand Indicator

- The average demand indicator has high accuracy.
- The instrument has uniform measuring scale.

Disadvantages of Maximum Demand Indicator

- The cost of the instrument is very high.
- Their construction is very complicated.

Nowadays, the cam is replaced by the electromagnetic relay and clutch the replaces the bell crank releasing device.

4 B

Digital energy meter

Digital Energy Meter

By Samson Jeba Kumar (Contributed Content) | Wednesday, November 30, 2011

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An electric meter or energy meter is an essential device that goes with consumption of commercially distributed energy.

An electric meter or energy meter is an essential device that goes with consumption of commercially distributed energy. It enables systematic pricing of energy consumed by individual consumer as it measures the amount of electrical energy consumed by a residence, business, or an electrically powered device [1]. They are typically calibrated in billing units, the most common one being the Kilowatts hour, which is equal to the amount of energy used by a load of one kilowatt over a period of one hour, or 3,600,000 joules.

Some meters measured only the length of time for which charge flowed, with no measurement of the magnitude of voltage or current. These were only suited for constant-load applications. Neither type is likely to be used today. In addition to metering based on the amount of energy used, other types of metering are available. Meters which measured the amount of charge (coulombs) used, known as ampere-hour meters, were used in the early days of electrification. These were dependent upon the supply voltage remaining constant for accurate measurement of energy usage, which was not a likely circumstance with most supplies.

Generally, electricity meters operate by continuously measuring the instantaneous voltage (volts) and current (amperes) and finding the product of these to give instantaneous electrical power (watts) which is then integrated against time to give energy used (Joules, Kilowatt-hours etc.). Meters for smaller services (such as small residential customers) can be connected directly in-line between source and customer. For larger loads, more than about 200 amps of load, current transformers are used, so that the meter can be located other than in line with the service conductors [2]. The meters fall into two basic categories, electromechanical and electronic. This paper dwells on the electronic meter (i.e. the digital meter)

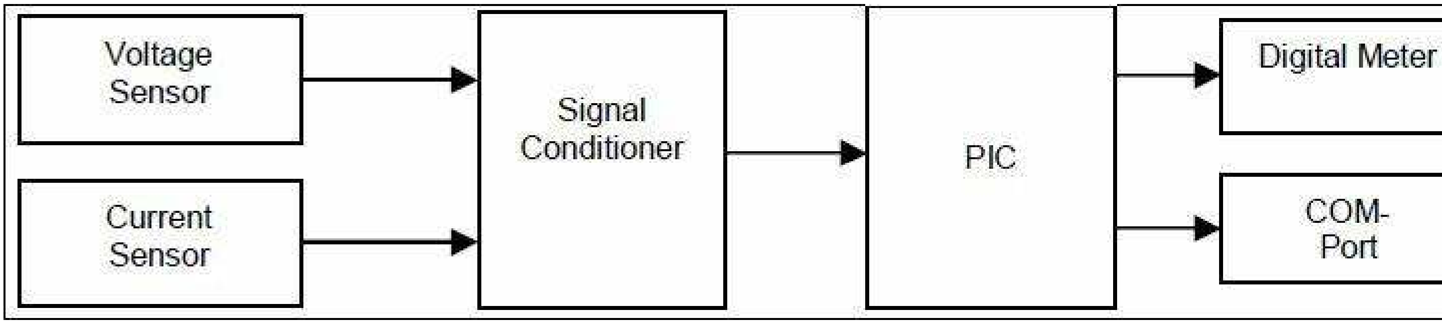
An example of a traditional electromechanical meter is shown in figure 1. It has a spinning disc and a mechanical counter display. This type of meter operates by counting the revolutions of a metal disc that rotates at a speed proportional to the power drawn through the main fuse box. Nearby coils spin the disc by inducing eddy currents and a force proportional to the instantaneous current and voltage. A permanent magnet exerts a damping force on the disc, stopping its spin after power has been removed. This class of meters has a number of limitations that has made it grossly irrelevant for use in smart energy initiative environment which include but not limited to its degree of accuracy.

There are many methods of error correction in digital electricity meters which are usually based on the known methods of A/D converters error correction, [5]. Most of these methods use software correction based on calibration process. While in digital electricity meter, percentage error could be as low as 0.01%, in analogue meters it is usually above 0.05%.

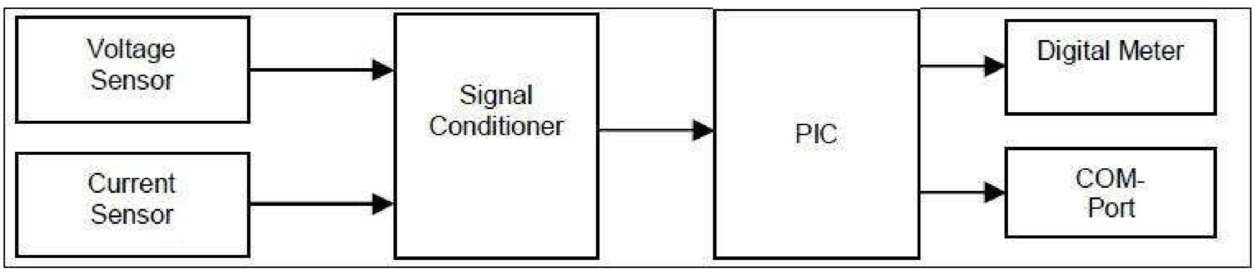
Secondly, the orientation problem associated with electromechanical energy meter is completely a nonissue in a digital energy meter. Hence installation is made easier. Thirdly, the user friendly display in the digital meters makes energy reading from time to time very easy. The fourth and the most serious setback of the electromechanical energy meter is its no-interface capability to external devices. This very set back is very serious in smart grid technology application.

Electronic meters measure energy using highly integrated components or other customized integrated circuits. These devices digitize the instantaneous voltage and current via a high-resolution sigma-delta ADC.Computing the product of the voltage and current gives the instantaneous power in watts. Integration over time gives energy used, which is usually measured in kilowatt hours (kWh).The design technique for digital meters is influenced by three major factors namely; desired device cost,efficiency and overall size. While the cost is influenced by users' general affordability, the efficiency and size must strictly comply with standard.

The block diagram for a digital meter. Here, two basic sensors are employed. These are voltage and current sensors. The voltage sensor built around a step down element and potential divider network senses both the phase voltage and load voltage. The second sensor is a current sensor; this senses the current drawn by the load at any point in time. It is built around a current transformer and other active devices (such as voltage comparator) which convert the sensed current to voltage for processing. The output from both sensors is then fed into a signal (or voltage) conditioner which ensures matched voltage or signal level to the control circuit, it also contain a signal multiplexer which enable sequential switching of both signal to the analogue input of the peripheral interface controller (PIC). The control circuit centered on a PIC integrated circuit. The PIC is selected because it contain ten bit analogue to digital converter (ADC), very flexible to program and good for peripheral interfacing.



The ADC converts the analogue signals to its digital equivalent; both signals from the voltage and current sensors are then multiplied by the means of embedded software in the PIC. Here the error correction is taken as the offset correction by determining the value of the input quality with short-circuited input and storing this value in the memory for use as the correction value device calibration. The PIC is programmed in C language. Such that apart from the multiplier circuit it simulates, it is able to use the received data to calculate power consumption per hour, as well as the expected charges. These are displayed on the liquid crystal display attached to the circuit.



5.

Miscellaneous measuring instruments

Construction working principle and application of Megger

What is Megger : Construction and Its Working Principle

- ELECTRONICS
  0 COMMENT

Devices which directly utilize electrical energy to provide desired or expected output or a result is known as Electrical devices. During the process of utilization of electrical energy, i,e, the negatively charged particles which are electrons not only flow from one end to another end in a current-carrying conductor but also changes its state from one form to another like heat to gain expected results. There are many electrical components and devices like a transformer, circuit breaker, transistors, resistors, electric motor, and refrigerators, gas fireplace, electric water heater tank, etc. In any electrical system, there may be losses based on the material of metal used (Losses a Degraded Output). Therefore losses should be maintained less. In order to protect these electrical systems from losses, there are certain parameters that are to be maintained and also certain instruments are used to keep track of the electrical systems to safeguard them. This article discusses what is a megger and its working.

What is Megger?

An instrument that is used to measure insulation resistance is a Megger. It is also known as meg-ohm-meter. It is used in several areas like multi-meters, transformers, electrical wiring, Etc. Megger device is used since the 1920s for testing various electrical devices which can measure greater than 1000meg-ohms.

Insulation Resistance

Insulation resistance is resistance in ohms of wires, cables, and electrical equipment, which is used to safeguard the electrical systems like electrical motors from any accidental damages like electrical shocks or sudden discharges of current leakages in wires.

Principle of Megger

The principle of Megger is based on moving coil in the instrument. When current is flowing in a conductor, which is placed in a magnetic field, it experiences a torque.

Where vectored Force = strength and direction of the current and magnetic field.

Case (i) Resistance of insulation = High; pointer of moving coil = infinity,

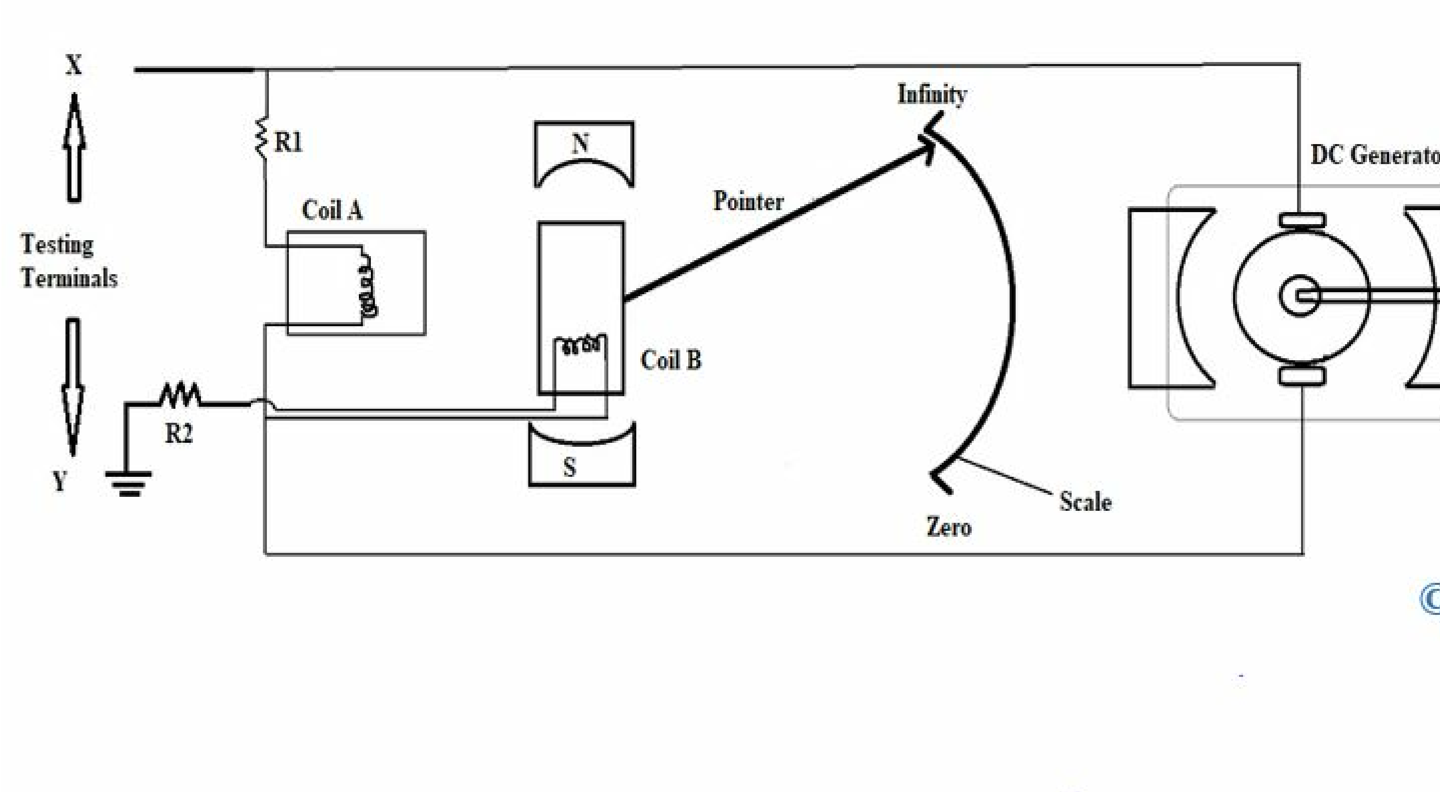
Case (ii) Resistance of insulation = Low; pointer of moving coil = zero.

It is the comparison between Insulation resistance and the known value of resistance**.** It provides the highest accuracy in measurement than other electrical measuring instruments.

Construction of Megger

Megger is used to measure a high value of resistance. Megger consists of the following parts.

- DC generator
- 2 Coils (Coil A, Coil B)
- Clutch
- Crank handle
- terminal X & Y



Block Diagram of Megger

- *Crank handle present here is rotated manually, and the clutch is used to vary the speed. This arrangement placed between magnets, where the entire set-up is called a DC generator.*
- *A Resistance scale is present towards the left of the DC generator, which provides the value of resistance ranging from 0 to infinity.*
- *There are two coils in the circuit Coil-A and Coil-B, which are connected to the DC generator.*

The two testing terminals X and Y which can be connected in the following manner

- *To calculate the resistance of the winding of the transformer, then the transformer is connected between the two testing terminals X and Y.*
- *If we want to measure the insulation of the cable, then the cable is connected between the two testing terminals A and B.*

Working of Megger

Megger here is used to measure

- *Insulation resistance*
- *Machine windings*

According to the principle of DC generator, whenever a current-carrying conductor is placed between the magnet fields, it induces a certain amount of voltage. The magnetic field generated between the two poles of the permanent magnet is used to rotate the rotor of the DC generator using the crank handle.
Whenever we rotate this DC rotor, some voltage and current are generated. This current flows through the Coil A and Coil B in an anti-clockwise direction.

Where coil A carries current = I_A and

Coil B carries current = I_B.

These two current produces fluxes $_A$ and $_B$ in two coils A and B.

- *On one side motor requires two fluxes to interact and produce reflecting torque, then the only motor runs.*
- *Whereas on the other side the two flux's $_A$ and $_B$ which are interacted with each other and then the pointer which is presented will experience some force by the production of deflecting torque "T_d", where the pointer shows the resistance value on the scale.*

Pointer

- *The pointer on the scale initially indicates infinity value,*
- *Where ever it experiences a torque, the pointer moves from infinity position to zero position on the resistance scale.*

Why the Instrument Initially shows infinity and Finally moves towards zero?

According to Ohm's law

R = V / I ; ---- (2)

If the current is maximum in the instrument, resistance is zero,

R a I/I; ---- (3)

If the current in minimum in the instrument, resistance is maximum.

R a I/ I↓<<<<<<<ł ł ł (4)

Which means, resistance and current are inversely proportional

R a I/I; ----5

If we rotate the crank handle at a particular speed. This, in turn, leads to the production of voltage in this rotor, and the high value of current also flows in anti-clockwise, through the two coils A and B.

Where this flow of current leads to the generation of deflecting torque like T_d in the circuit. Hence the pointer varies the resistance ranges from infinity to zero.

Why Pointer is Initially at Infinity?

Due to the non-rotation of the crank handle, hence there I no rotation in the DC motor.

(E) Emf of rotor = 0, ---- (6)
Current I = 0 ---- (7)
The two flux's $_A$ and $_B$ = 0. ---- (8)
Deflecting torque T_d = 0. ---- (9)

Therefore the pointer is at rest (infinity).

We know that

R a I/ I ; ---- (10)

Since I = 0, it means we get a high value of resistance which is infinity.

Practical Application Condition of AC and DC Motor

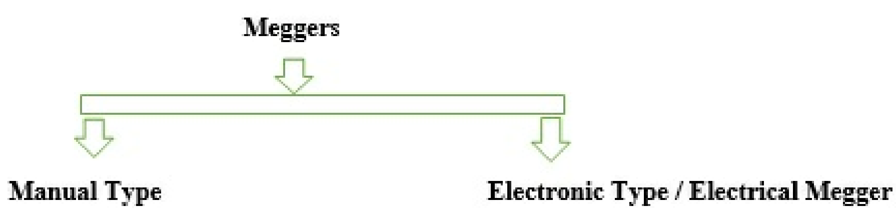
- *A DC motor consists of 4 terminals out of which 2 are rotor winding and the remaining 2 are stator winding. Out of which 2 rotor windings are connected to X terminal (+ve) and the remaining two are connected to Y terminal (-ve).If we move the crank handle, deflecting torque is produced which indicates a resistance value.*
- *An AC motor consists of 6 terminals out of which 3 are rotor winding and the remaining 3 for stator winding. Out of which 3 rotor windings are connected to X terminal (+ve) and the remaining two are connected to Y terminal (-ve). If we move the Crank handle, deflecting torque is produced which indicates a resistance value.*

In both AC and DC motor

Case (I): *If R = infinity, there is no interconnection between the winding, which is known as an open circuit.*

Case (II): *If R = infinity, there is an interconnection between the winding, which is known as a short circuit. It is the most dangerous condition; hence we have to disconnect the supply.*

Types of Meggers



types-of-megger

Components	*Analog Display,* *Hand Crank,* *Wire Terminals.*	*Digital Display,* *Wire Leads,* *Selection Switches,* *Indicators.*
Advantages	*No, External Power source is required to operate,* *Low cost*	*Easy to handle,* *Safe* *Less time consumption.*
Disadvantages	*Time consumption is high* *Accuracy is not high compared to Electronic type*	*The external Power source is required to operate,* *The initial cost is high.*

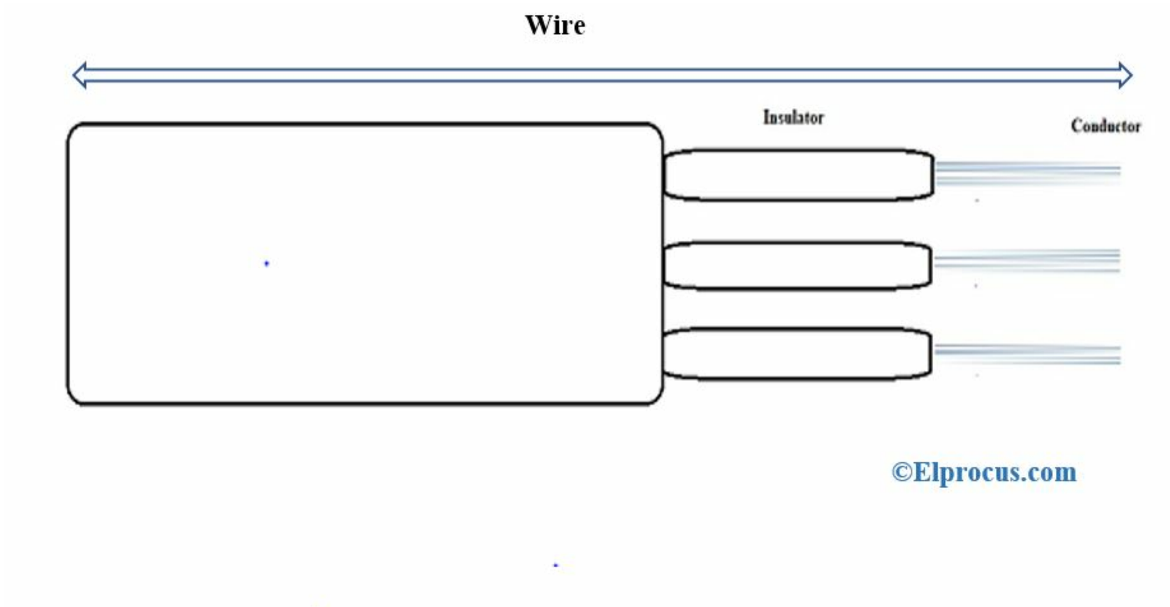
Megger for Insulation Resistance Test / IR Test

Let us consider a wire, which contains conducting material at the center and insulating material surrounding it.

Using this wire we test the insulation- resistance test with the help of megger.

Why Insulation Resistance Test to be Performed?

A wire contains conducting material at the center & insulating material at the surrounding of it. For instance, if the wire has the capacity of 6 Amps, there will be no damage if we provide 6 Amps of input current. In case if we provide input greater than 6 Amps then the wire will get damaged, and cannot be used further.

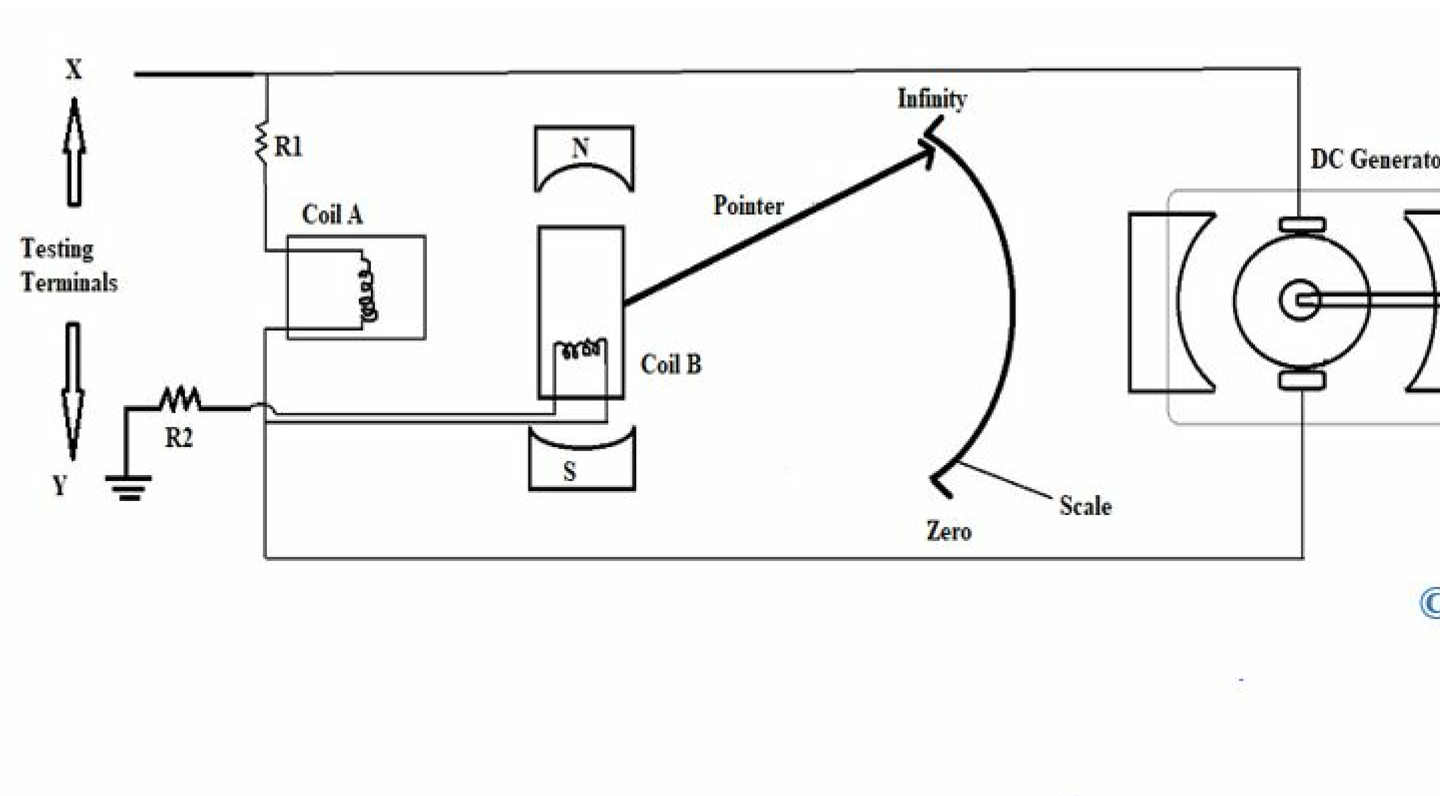


internal-wire

Units of Insulation = Mega Ohm's

Measurement of the High Resistance Value

The device which is used for measuring is Megger. To measure the insulation of the wire, one end of the wire terminal is connected to a positive terminal and the end is connected to the ground terminal or megger. When the crank handle is rotated manually, which induces emf in the instrument where the pointer deflects indicating the resistance value.



Megger-Construction

Applications of Megger

- The electrical resistance of insulator can also be measured
- Electrical systems and components can be tested
- Winding installation.
- Testing of battery, relay, ground connection…etc

Advantages

- Permanent magnet DC generator
- The resistance between the ranges zero to infinity can be measured.

Disadvantages

- There will be an error in reading value when the external resource has low battery,
- Error due to sensitivity
- Error due to a change in temperature.

Megger is an electrical instrument used to determine the range of resistances between zero to infinity. Initially, the pointer is at the infinite position, it gets deflected when an emf is generated from infinity to zero, which depends on Ohm's law. There are two types of meggers, manual and electrical megger. The main concept of megger is to measure insulation resistance and machine windings. Here is a question, which condition leads to a dangerous situation in megger operation, and what is done to overcome, state it with an example?

Frequency meter

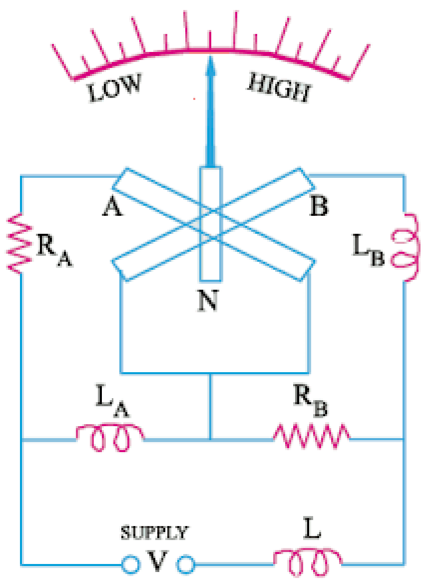
Analog Frequency Meter Working Principle

Leave a Comment / Electrical measuring instruments

*Hi friends, in this article, I am discussing about **analog frequency meter working principle** and hope you will find it informative and helpful.*

*The action of moving iron **analog frequency meter** depends on the variation in current drawn by two parallel circuits – one inductive and the other non-inductive – when the frequency changes.*

Construction of moving iron analog frequency meter



The construction and internal connections are shown in Figure. The two coils A and B are so fitted that their magnetic axes are perpendicular to each other. At their centers, a long and thin soft-iron pointer is pivoted, which aligns itself along the resultant magnetic field of the two coils. No controlling torque is provided in this instrument.

It will be noted that the various circuit elements constitute a Wheatstone bridge which becomes balanced at the supply frequency. Coil A has a resistance R_A in series with it and a coil L_A in parallel. Similarly, R_B is in series with coil B and L_B is in parallel.

The series inductance L helps to suppress higher harmonics in the current waveform and hence, tends to minimize the waveform errors in the indication of the instrument.

Analog frequency meter working principle

When the instrument is connected to the supply, currents pass through coils A and B and produce opposing torques. When supply frequency is high, currents through coil A is more whereas that through coil B is less due to the increase in the reactance offered by L_B.

Hence, the magnetic field of coil A is stronger than that of coil B. Consequently, the iron needle lies more nearly to the magnetic axis of coil A than that of B.

For low frequencies, coil B draws more current than coil A and, hence, the needle lies more nearly parallel to the magnetic axis of B than to that of coil A.

The variations of frequency are followed by the pointer as explained above.

The instrument can be designed to indicate a broad or narrow range of frequencies determined by the parameters of the circuit.

SINGLE PHASE POWER FACTOR METER

Power Factor Meter

Leave a Comment / Electrical measuring instruments

The power factor of a circuit can be found out from the wattmeter reading and voltmeter and ammeter readings suitably connected in the circuit.

Power factor = Wattmeter reading / (Voltmeter reading x ammeter reading).

Power factor = True Power / Apparent Power

This method involves mathematical calculations. Sometimes it is required to measure the power factor of the circuit instantaneously when the power factor of the load is varying continuously.

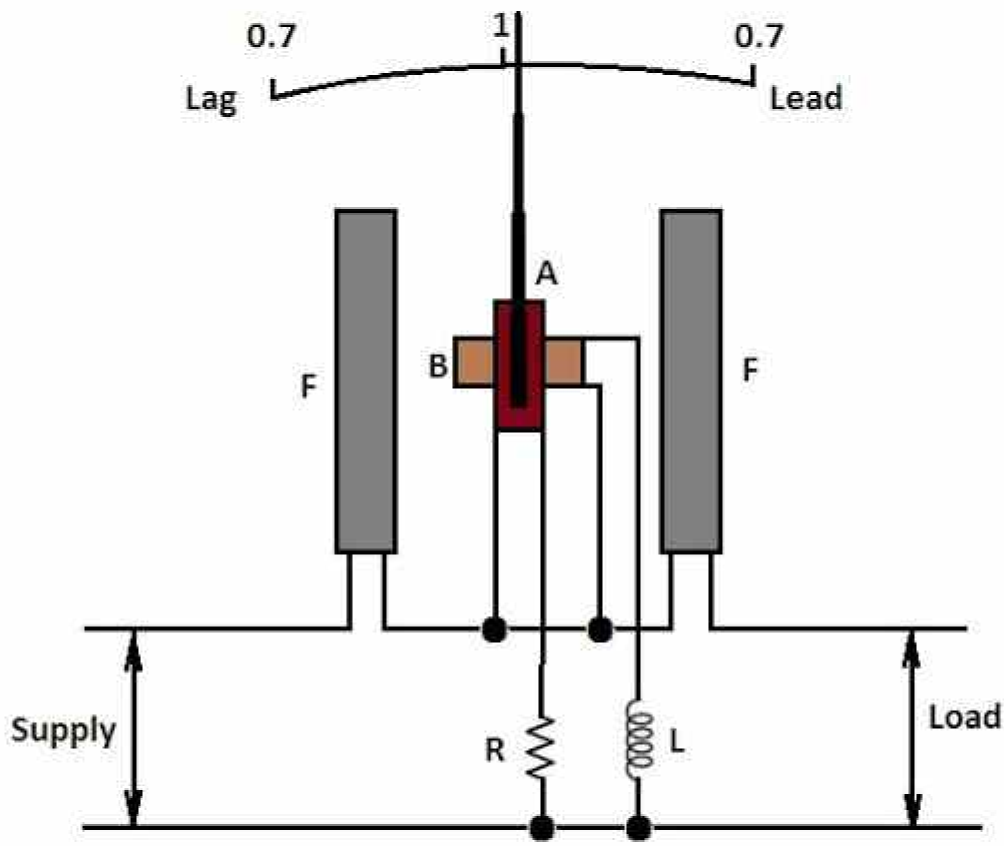
This purpose is served by connecting a dynamometer type power factor meter in the circuit. It indicates the power factor of the circuit directly on the scale by the deflection of a pointer.

Power Factor Meter Working Principle

The basic **working principle of power factor meter** is similar to that of dynamometer type wattmeter i.e. when the field produced by moving system tries to come in line with the field produced by the fixed coil, deflecting torque is exerted on the moving system which deflects the pointer attached to it (the moving system).

Construction of a Power Factor Meter

A dynamometer type power factor meter consists of two fixed coils FF connected in series carrying the load current (or a definite fraction of it) forming the current circuit, and two identical moving coils A and B fixed at the nearly right angle to each other pivoted on the same spindle forming the pressure circuit as shown in the figure.



Single phase power factor meter

https://yourelectricalguide.blogspot.in/

The current coils FF are wound with thick wire whereas pressure coils A and B are wound with fine wire. The pressure coils fixed on the same spindle, to which a pointer is attached, constitutes the moving system.

The pressure coil A is connected across the supply through a non-inductive resistant and pressure coil B is connected across the supply through highly inductive choke coil of inductance L. The value of resistance R and inductance L are so chosen that for the main supply frequency, the current in the two pressure coils A and B is the same.

Thus the fields produced by the two coils are of the same strength. The field produced by the coil B lags behind the field produced by the coil A slightly less than 90° because of resistance of the coil. Accordingly while fixing the coil B the plane of this coil is displaced from the plane of the coil A by the electrical angle which is slightly less than 90°.

However while discussing the action (working) of the instrument it will be assumed that the phase difference between the two currents flowing through the coils A and B is 90° and same is the angle between the planes of the coils.

Though power factor meter is an indicating instrument but no controlling torque is provided in this instrument. The currents are being led into the moving coils A and B by fine ligaments which exert no control.

Power Factor Meter Working

Since no controlling torque is provided in this instrument, therefore, when it is not connected in the circuit, the moving coils will remain in the position in which these are turned. This will only happen when the moving system is perfectly balanced.

When the instrument is connected to the load circuit, current flows through the fixed coils FF and Moving coils A and B, flux is set by the fixed coils and moving coils.

By the alignment of two fields, torque develops i.e. the resultant field produced by the moving coils tries to come in line with the field produced by the fixed coils and torque develops till both of them come in line with each other. There are three extreme conditions in which this instrument is connected in the circuit.

1. **When power factor of the circuit is unity**: In this case, current is in phase with circuit voltage. The current flowing through potential coil A is in phase with the voltage which is also in phase with the current flowing through current coil FF.

   At the same time, the current flowing through potential coil B lags behind voltage as well as the current flowing through current coil FF by 90°. Thus pressure coil A will experience a turning moment so its plane will come in position a parallel to the plane of the current coil FF. The torque acting on the pressure coil B is zero. Thus, the pointer indicates unity power factor on the scale.

2. **When power factor of the circuit is zero lagging**: In this case, current lags behind the circuit voltage by 90°. Therefore, the current flowing through pressure coil B will be in phase with the current in current coils FF, both being lagging behind the circuit voltage by 90°.

   The current flowing through pressure coil A will lead the current in current coil FF by 90°. Thus a turning moment acts on the pressure coil B and brings its plane parallel to the plane of current coil FF and pointer indicates zero power factor lagging.

3. **When power factor of the circuit is zero leading**: In this case current leads the circuit voltage by 90°. Therefore, the current flowing through pressure coil A lags the current in current coil FF by 90° and the current flowing through pressure coil B lags the current in current coil FF by 180°.

   Thus field produced by the moving system is just reversed to that in the case (2). Thus an opposite turning moment acts on the pressure coil B and brings its plane parallel to the plane of current coil FF and pointer indicates zero power factor leading.

For intermediate power factors the moving system of power factor meter takes up intermediate positions and the pointer indicates the power factor accordingly.

Working principle of synchroscope

Synchroscope Construction and Working

January 9, 2019 by admin

*Synchroscope is used to synchronize two alternators. **Synchronize** means that the machine of equal frequency and voltage are operating parallel to each other. We connect the alternator in parallel with one another with bus bar to shore the load. In electrical power system, a synchroscope is a device which indicates the degree to which two systems are synchronized with each other.*

Synchroscope Synchronization

*The **Synchroscope** determines the exact instant where the condition of synchronizing is satisfies. These conditions are:*

1. *The alternators should have equal magnitude of voltage.*
2. *They should have same frequency.*
3. *They should have same phase sequence. The function of this instrument is to indicate any difference in phase or in frequency. The phase sequence however is verified by a "phase sequence indicator". We can check the voltage with the help of two voltmeter.*

Types of Synchroscopes

*The **synchroscopes** are the special form of power factor meters and are of types*

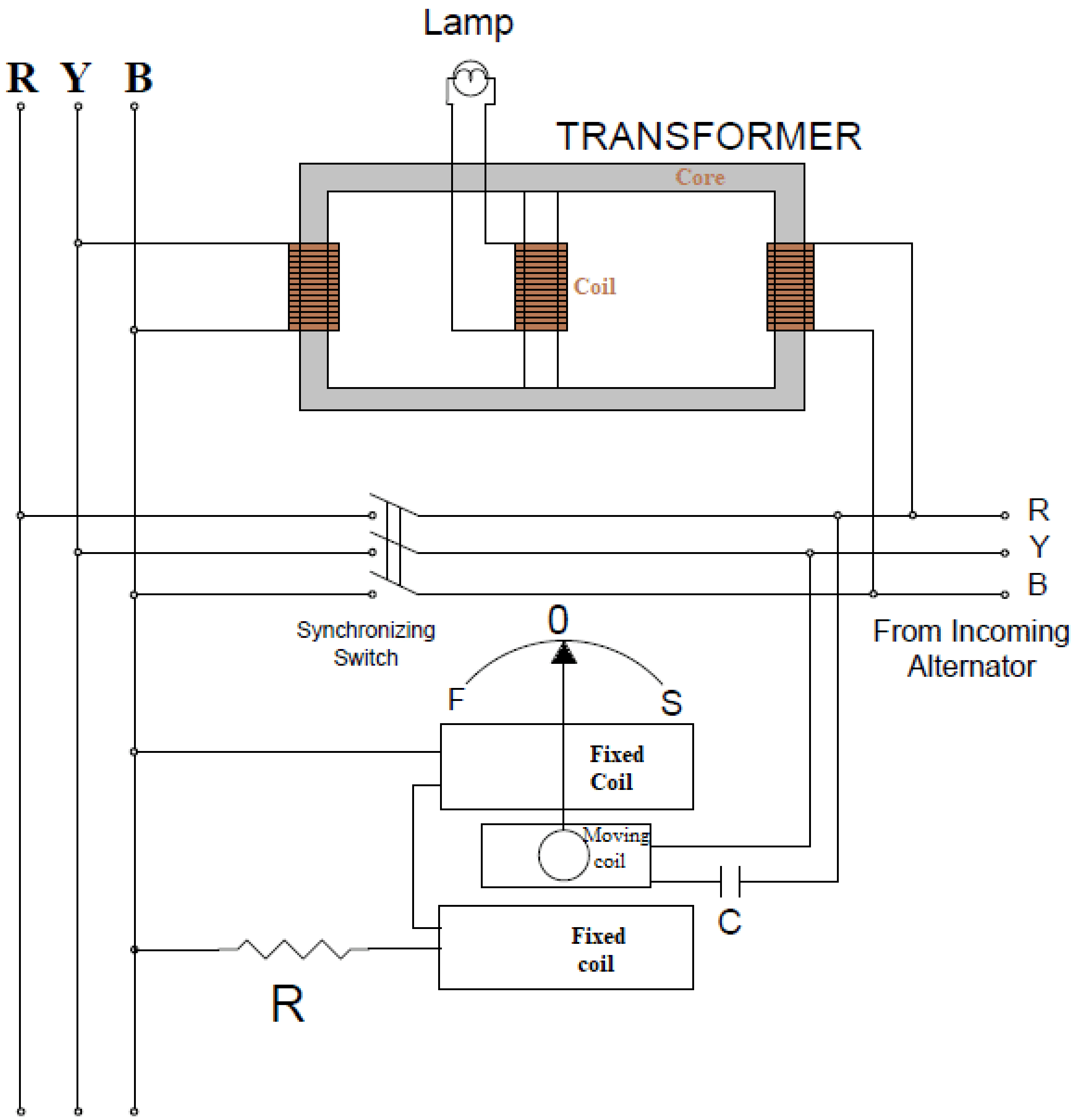
- ***Electrodynamic type synchroscopes.***
- ***Moving Iron type synchroscopes.***

ELECTRODYNAMIC (OR WESTON TYPE) SYNCHROSCPE

Construction

It consists of a three limb transformer and an electrodynamic instrument. The winding on one outer limb is connected with the bus bars and the winding on other outer limb is connected with the incoming alternator. The winding on the central limb of the transformer is connected to a lamp.

The windings or the outer limbs produce two fluxes. Two fluxes flows through the central limb, where the resultant flux is obtained which is the phasor sum of the two fluxes. This resultant flux induces an emf in the central limit winding.



Electrodynamic synchroscope

The outer windings are so arranged that when the voltages of the bus bar and of the incoming alternator are in limit are added up and induced emf in the central limit is maximum as a result, the lamp glows with maximum brightness.

Working

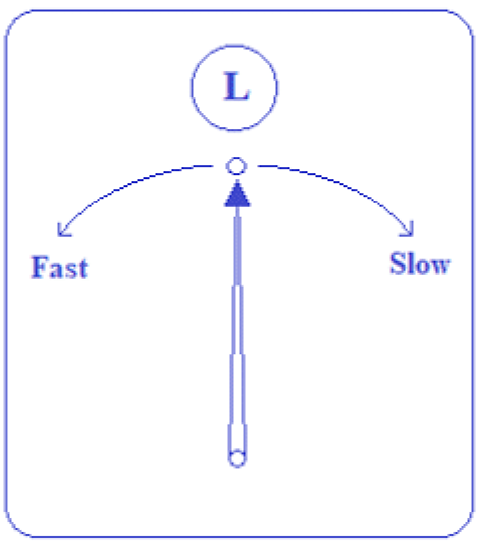
When the two voltages are 180 degree out of phase. Then the resultant flux is zero and no emf induced in the central limb winding. Thus the lamp does not glow at all.

If the frequency of the incoming alternator is different from the supply frequency of the bus bars, the lamp will flicker and the frequency of the flickering is equal to the difference of the two frequencies.

But the flickering of the lamp cannot indicate whether the incoming alternator is fast or slow. For this purpose an electrodynamic instrument is provided with the arrangement as shown in figure.

Coil Arrangement of Weston Type Synchroscope

The electrodynamic instrument consists of 2 fixed coils FF and a moving coil M. The fixed coils FF carry a small current and connected across any two bus bars through s resistance R. The moving coil M connected across the incoming alternator through a capacitor C. The moving coil carries a pointer which moves on a scale showing fast/slow (F/S).



Dial of Synchroscope

Figure shows the dial of electrodynamic synchroscope. Dial of the synchroscope mark with two arrows which indicates the direction of rotation of the pointer. This arrow indicates the anticlockwise and clockwise direction of pointer. The anticlockwise show fast movement and clockwise shows slow movement of incoming machine.

If the incoming machine's frequency is more than that of generator frequency , the pointer deflects toward fast mark and vice-versa. The correct instant of synchronizing is that where the pointer is visible at its central position and is moving very slowly.

MOVING IRON SYNCHRONOSCOPE

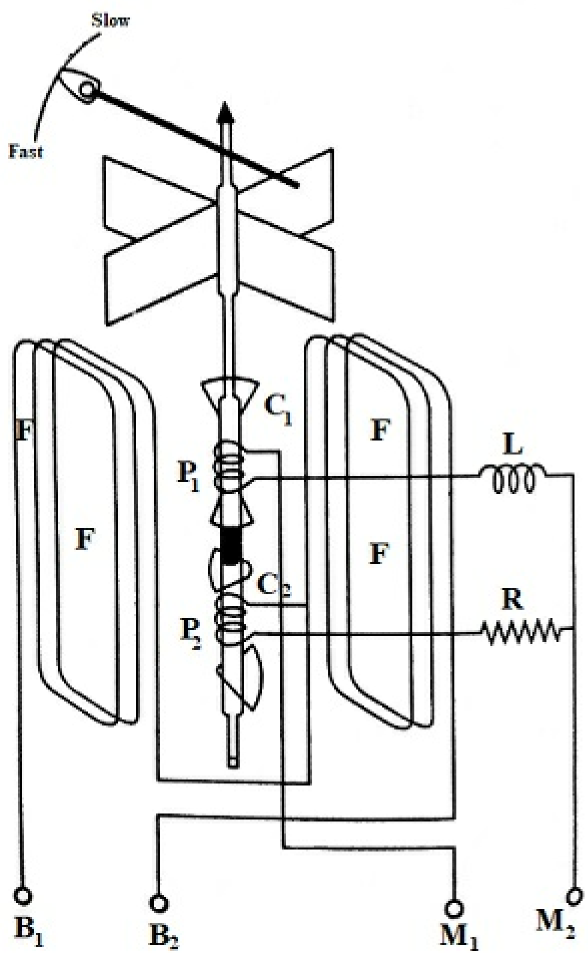
Construction

It consists of a fixed coil in two parts. The fixed coils FF are designed for a small current and are connected across two phases of the bus bars. There are two iron cylinders C1 and C2. Two iron cylinders are mounted on a spindle and are separated by spacers. Each cylinder is provided with two iron vanes whose axes are 180 apart.

The cylinders are excited by two pressure coils P1 and P2. These are connected to two phases of the incoming alternator. One pressure F coil has a resistance R and other has an inductance L connected in series. It establishes a 90 phase difference between their currents. The pointer attached with the spindle moves over a dial marked fast and slow.

Working of Moving Iron Synchroscope

When the frequency of the incoming alternator is same as that of the bus bars. Then instrument behaves as a moving iron P.F meter. The movement of the pointer is equal to the phase difference between the two voltages. The pointer does not deflect at all. If there is no phase difference between the two voltages.



Moving Iron type synchroscope

When the two frequencies are different. Then the pointer moves at a speed corresponding to the difference in the frequencies. The direction of motion of the pointer shows whether the alternator is "fast" or "slow". When the pointer is at zero, the synchronizing switch is closes automatically.

The M.I. synchronoscope are more common in use. They are cheaper and have long scale spread over 360.

Conclusion

So, the conclusion is that synchroscope is a helpful device for synchronization of two alternators.

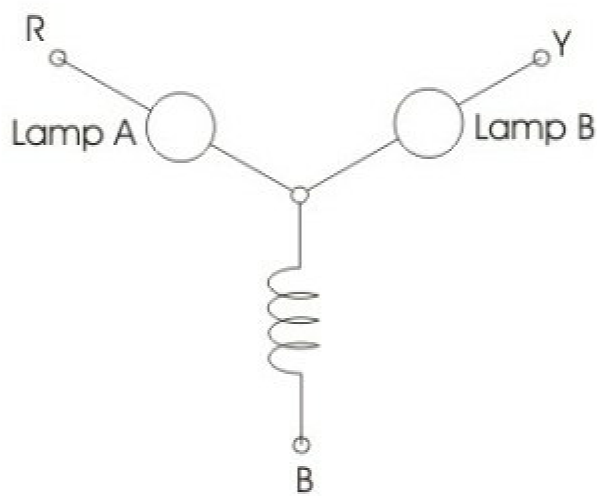
Working principle of phase sequence indicator

It works on the principle of induction motors. The principle of rotating type phase sequence indicator is similar to that of a three phase motor. Consider the working of a motor for a better understanding of these indicators. For three phase motors, we require three phase power supply, whereas this three phase power must be supplied in a particular sequence. Let us assume that the three phase supply given to the motor has a phase sequence of RYB, then the motor will rotate in clockwise direction – and, if the phase sequence of supply is reversed, then the motor will rotate in counter clockwise direction. This may cause severe problems to the load and entire system.

When a three phase supply is given to the coils, then the coils will produce a rotating magnetic field, and this rotating magnetic field produces eddy EMF in the rotatable aluminum disc, as shown in the diagram.

This eddy EMF produces eddy current on the aluminum disc, due to the interaction of the eddy currents with the rotating magnetic field a torque is produced which causes the aluminum disc to rotate. The clockwise direction rotation of the disc indicates the sequence as RYB, and the anti-clockwise rotation of the disc indicates the change in phase sequence.

Static Type Phase Sequence Indicator



Static Type Phase Sequence Indicator with Inductor

If the phase sequence is RYB, then the lamp B will glow brighter than the lamp A, and – if phase sequence is reversed – then the lamp A will glow brighter than the lamp B, as shown below in the lamp arrangement circuit diagram.

Now, let us see how this happens

Assume that the phase sequence is RYB, and consider the voltages as V_{ry}, V_{yb}, V_{br} as according to the diagram, and we have

$$V_{ry}=V$$

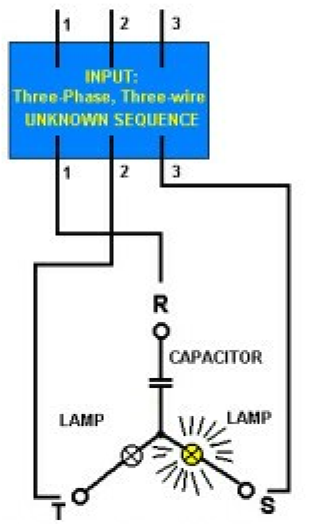
$$V_{yb}=V(-0.5-j0.866)$$

$$V_{br}=V(-0.5+j0.866)$$

Here, assuming a balanced operation such that we have Vry=Vbr=Vyb=V. We know that the algebraic sum of all phase currents is equal, then we can get the below equation.

$$I_r+I_y+I_b=0$$

From the above equations, we get the ratio of Ir and Iy as 0.27.



The brightest lamp indicates the phase that follows R (the capacitor terminal of the indicator).

It indicates that the voltage at the lamp A is only 27 percent of the lamp B. So, from this, we can observe that the lamp B will glow brighter than the lamp A in case of an RYB phase sequence. While in case of a reversed phase sequence, the lamp A is brighter than the lamp B.

Similarly, from the above circuit by replacing the inductor with a capacitor, as shown in the below figure, the indicator works similar to the above phase indicator.

Here two resistors are connected in series with the two Neon lamps to protect the lamps from over current and breakdown voltages. If the three phase supply is in the sequence of RYB, then the lamp A will be ON, and the lamp B will be off, and if the supply sequence is reversed, then the lamp A will be off while the lamp B will be on.

Working principle of tong tester

Tong tester or clamp meter basically works on the principle of mutual inductance . The same principle on which a transformer works. The clip or clamp or moving part of meter has a magnet in it which act as a magnetic core as in transformer. Over which there is a coil wounded, which acts as a secondary coil. The conductor here works as a primary coil and the clamp coil as a secondary coil. The current flowing through any conductor always has an electromagnetic field around it. Clamp meter uses this magnetic field to read the current value. When the conductor is placed in side the clamp its magnetic field cuts the core of magnet in clip/clamp. This induces an emf in magnetic core proportional to the current flowing in the conductor, which is sensed by secondary coli over it in meter. Hence meter reads the current value flowing through it.

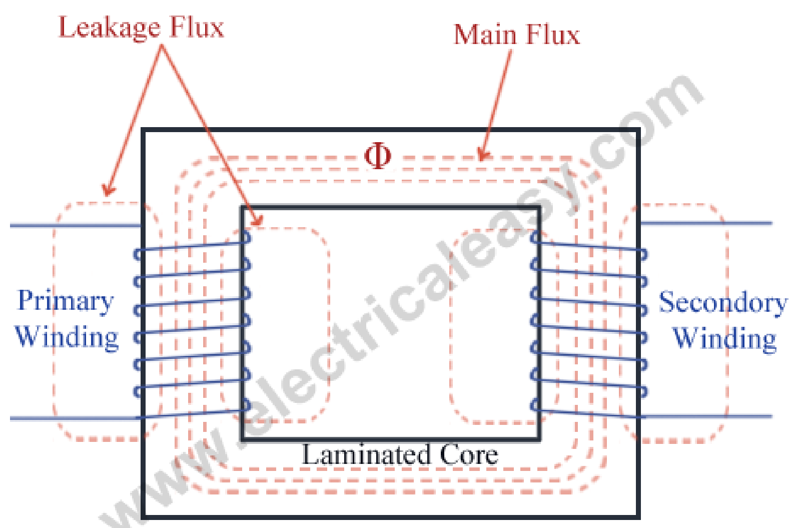
5.2

Construction working and application of transformers

Electrical Transformer - Basic construction, working and types

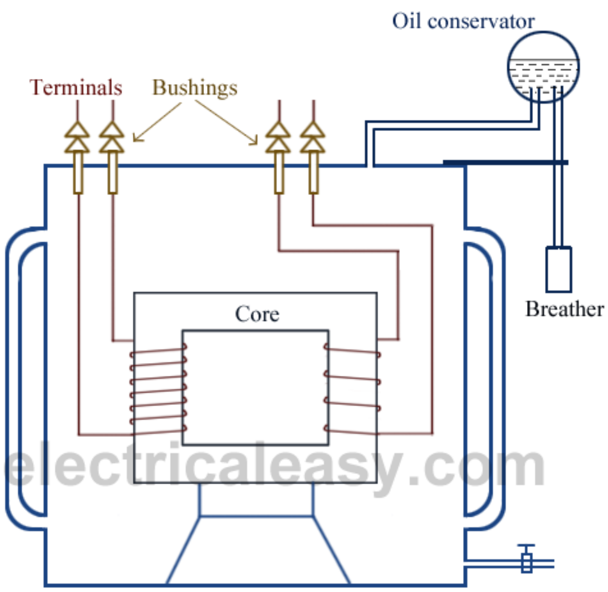
Electrical transformer **is a static electrical machine which transforms electrical power from one circuit to another circuit, without changing the frequency. Transformer can increase or decrease the voltage with corresponding decrease or increase in current.**

Working principle of transformer

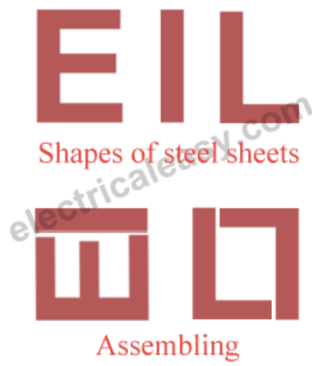


The **basic principle behind working of a transformer** is the phenomenon of mutual induction between two windings linked by common magnetic flux. The figure at right shows the simplest form of a transformer. Basically a transformer consists of two inductive coils; primary winding and secondary winding. The coils are electrically separated but magnetically linked to each other. When, primary winding is connected to a source of alternating voltage, alternating magnetic flux is produced around the winding. The core provides magnetic path for the flux, to get linked with the secondary winding. Most of the flux gets linked with the secondary winding which is called as 'useful flux' or main 'flux', and the flux which does not get linked with secondary winding is called as 'leakage flux'. As the flux produced is alternating (the direction of it is continuously changing), EMF gets induced in the secondary winding according to Faraday's law of electromagnetic induction. This emf is called 'mutually induced emf', and the frequency of mutually induced emf is same as that of supplied emf. If the secondary winding is closed circuit, then mutually induced current flows through it, and hence the electrical energy is transferred from one circuit (primary) to another circuit (secondary).

Basic construction of transformer



Basically a transformer consists of two inductive windings and a laminated steel core. The coils are insulated from each other as well as from the steel core. A transformer may also consist of a container for winding and core assembly (called as tank), suitable bushings to take our the terminals, oil conservator to provide oil in the transformer tank for cooling purposes etc. The figure at left illustrates the basic construction of a transformer.

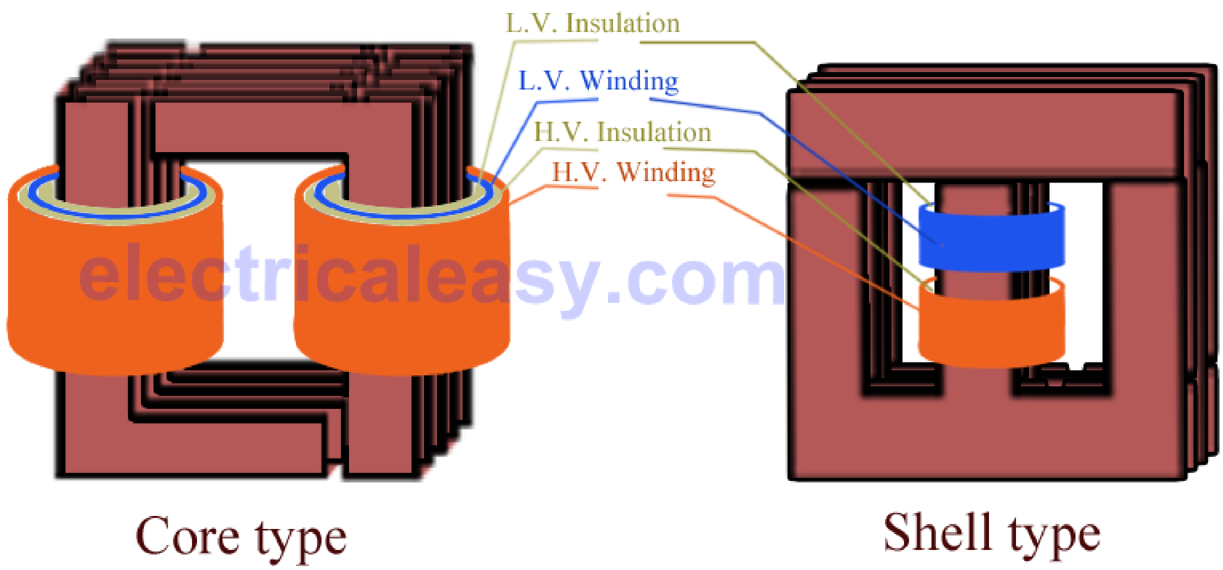


In all types of transformers, core is constructed by assembling (stacking) laminated sheets of steel, with minimum air-gap between them (to achieve continuous magnetic path). The steel used is having high silicon content and sometimes heat treated, to provide high permeability and low hysteresis loss. Laminated sheets of steel are used to reduce eddy current loss. The sheets are cut in the shape as E,I and L. To avoid high reluctance at joints, laminations are stacked by alternating the sides of joint. That is, if joints of first sheet assembly are at front face, the joints of following assemble are kept at back face.

Types of transformers

Transformers can be classified on different basis, like types of construction, types of cooling etc.

(A) On the basis of construction, transformers can be classified into two types as; (i) Core type transformer and (ii) Shell type transformer, which are described below.



(i) Core type transformer

In core type transformer, windings are cylindrical former wound, mounted on the core limbs as shown in the figure above. The cylindrical coils have different layers and each layer is insulated from each other. Materials like paper, cloth or mica can be used for insulation. Low voltage windings are placed nearer to the core, as they are easier to insulate.

(ii) Shell type transformer

The coils are former wound and mounted in layers stacked with insulation between them. A shell type transformer may have simple rectangular form (as shown in above fig), or it may have a distributed form.

(B) On the basis of their purpose

1. Step up transformer: Voltage increases (with subsequent decrease in current) at secondary.
2. Step down transformer: Voltage decreases (with subsequent increase in current) at secondary.

(C) On the basis of type of supply

1. Single phase transformer
2. Three phase transformer

(D) On the basis of their use

1. *Power transformer: Used in transmission network, high rating*
2. *Distribution transformer: Used in distribution network, comparatively lower rating than that of power transformers.*
3. *Instrument transformer: Used in relay and protection purpose in different instruments in industries*
   - *Current transformer (CT)*
   - *Potential transformer (PT)*

(E) On the basis of cooling employed

1. *Oil-filled self cooled type*
2. *Oil-filled water cooled type*
3. *Air blast type (air cooled)*

6 ELECTRONIC INSTRUMENTS

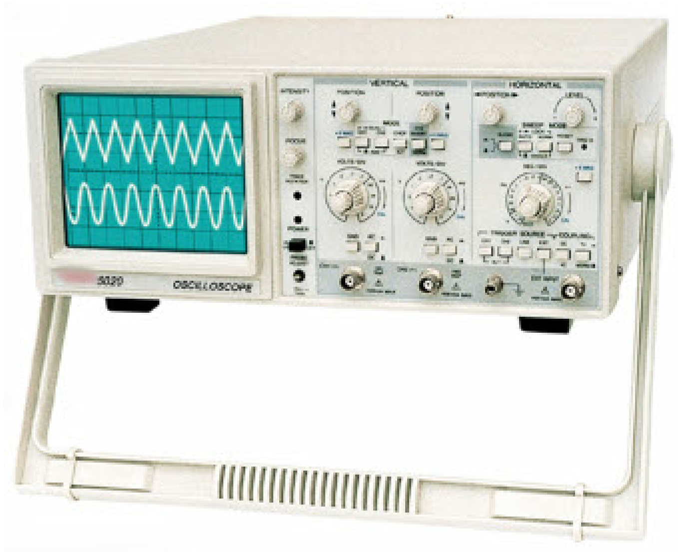
6.1

CRO (Cathode Ray Oscilloscope) Working and Applications

The CRO stands for a cathode ray oscilloscope. It is typically divided into four sections which are display, vertical controllers, horizontal controllers, and Triggers. Most of the oscilloscopes are used the probes and they are used for the input of any instrument. We can analyze the waveform by plotting amplitude along with the x-axis and y-axis. The applications of CRO's mainly involve in the radio, TV receivers, also in laboratory work involving research and design. In modern electronics, the CRO plays an important role in the electronic circuits.

What is a CRO?

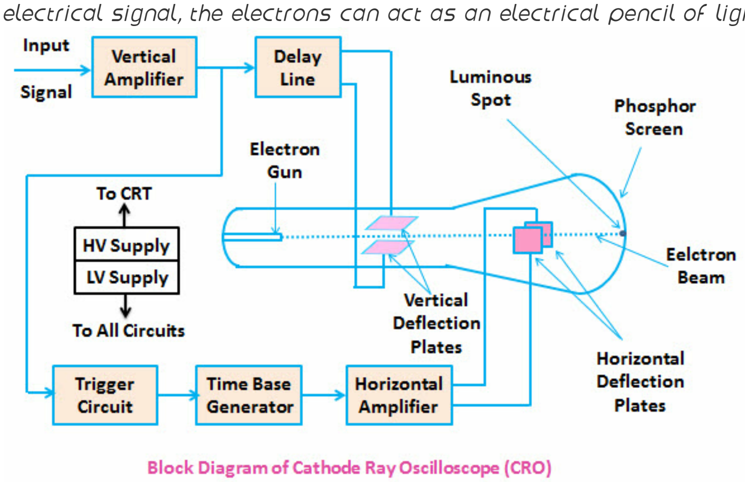
*The **cathode ray oscilloscope is an electronic test instrument**, it is used to obtain waveforms when the different input signals are given. In the early days, it is called as an Oscillograph. The oscilloscope observes the changes in the electrical signals over time, thus the voltage and time describe a shape and it is continuously graphed beside a scale. By seeing the waveform, we can analyze some properties like amplitude, frequency, rise time, distortion, time interval and etc.*



Cathode Ray Oscilloscope

Block Diagram of CRO

The following **block diagram shows the general purpose CRO contraction**. The CRO recruit the cathode ray tube and acts as a heat of the oscilloscope. In an oscilloscope, the CRT produces the electron beam which is accelerated to a high velocity and brings to the focal point on a fluorescent screen. Thus, the screen produces a visible spot where the electron beam strikes with it. By detecting the beam above the screen in reply to the electrical signal, the electrons can act as an electrical pencil of light which produces a light where it strikes.



Block Diagram of CRO

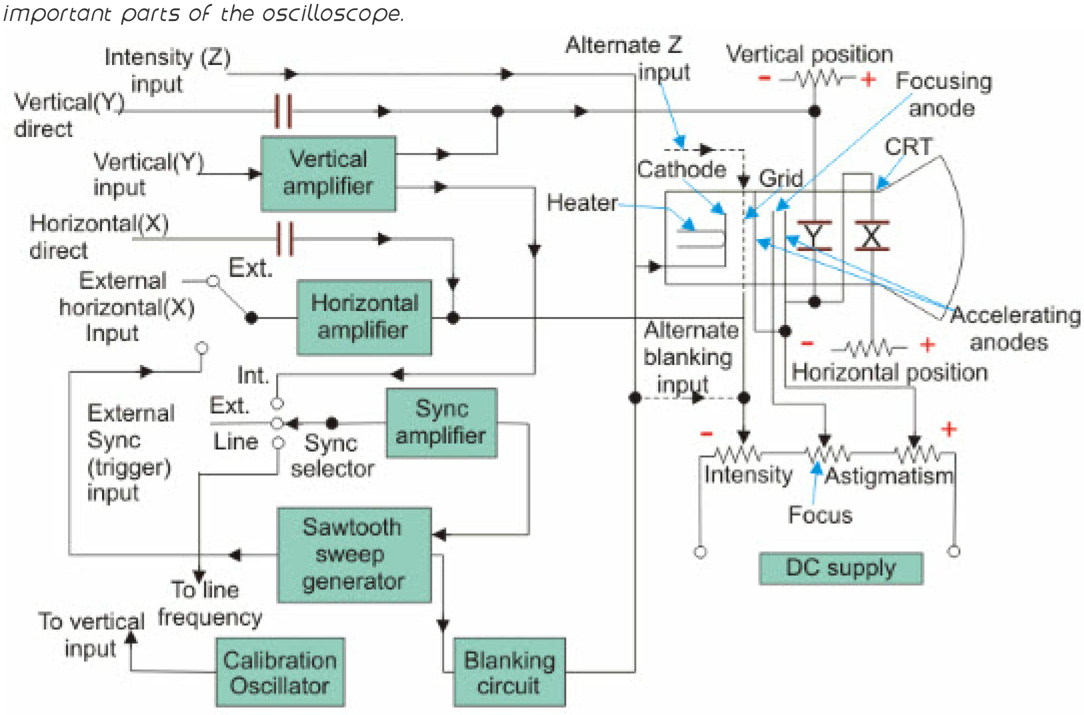
To complete this task we need various electrical signals and voltages. This provides the power supply circuit of the oscilloscope. Here we will use high voltage and low voltage. The low voltage is used for the heater of the electron gun to generate the electron beam. The high voltage is required for the cathode ray tube to speed up the beam. The normal voltage supply is necessary for other control units of the oscilloscope.

The horizontal and vertical plates are placed between the electron gun and the screen, thus it can detect the beam according to the input signal. Just before detecting the electron beam on the screen in the horizontal direction which is in X-axis a constant time-dependent rate, a time base generator is given by the oscillator. The signals are passed from the vertical deflection plate through the vertical amplifier. Thus, it can amplify the signal to a level will be provided the deflection of the electron beam.

If the electron beam is detected in the X-axis and the Y- axis a trigger circuit is given for the synchronizing these two types detections. Hence the horizontal deflection starts at the same point of the input signal.

Working of CRO

The following circuit diagram shows the ***basic circuit of a cathode ray oscilloscope***. In this, we will discuss important parts of the oscilloscope.



Working of CRO

Vertical Deflection System

The main function of this amplifier is to amplify the weak signal so that the amplified signal can produce the desired signal. To examine the input signals are penetrated to the vertical deflection plates through the input attenuator and number of amplifier stages.

Horizontal Deflection System

The vertical and horizontal system consists of horizontal amplifiers to amplify the weak input signals, but it is different to the vertical deflection system. The horizontal deflection plates are penetrated by a sweep voltage that gives a time base. By seeing the circuit diagram the sawtooth sweep generator is triggered by the synchronizing amplifier while the sweep selector switches in the internal position. So the trigger saw tooth generator gives the input to the horizontal amplifier by following the mechanism.Here we will discuss the four types of sweeps.

Recurrent Sweep

As the name, itself says that the saw tooth is respective that is a new sweep is started immodestly at the end of the previous sweep.

Triggered Sweep

Sometimes the waveform should be observed that it may not be predicted, thus the desired that the sweep circuit remains inoperative and the sweep should be initiated by the waveform under the examination. In these cases, we will use the triggered sweep.

Driven Sweep

In general, the drive sweep is used when the sweep is a free running but it is a triggered by the signal under the test.

Non-Saw Tooth Sweep

This sweep is used to find the difference between the two voltages. By using the non-sawtooth sweep we can compare the frequency of the input voltages.

Synchronization

The synchronization is done to produce the stationary pattern. The synchronization is between the sweep and the signal should measure. There are some sources of synchronization which can be selected by the synchronization selector. Which are discussed below.

Internal

In this the signal is measured by the vertical amplifier and the trigger is abstained by the signal.

External

In the external trigger, the external trigger should be present.

Line

The line trigger is produced by the power supply.

Intensity Modulation

This modulation is produced by inserting the signal between the ground and cathode. This modulation causes by brightening the display.

Positioning Control

By applying the small independent internal direct voltage source to the detecting plates through the potentiometer the position can be controlled and also we can control the position of the signal.

Intensity Control

The intensity has a difference by changing the grid potential with respect to the cathode.

Applications of CRO

- Voltage measurement
- Current measurement
- Examination of waveform

- *Measurement of phase and frequency*

Uses of CRO

In laboratory, the CRO can be used as

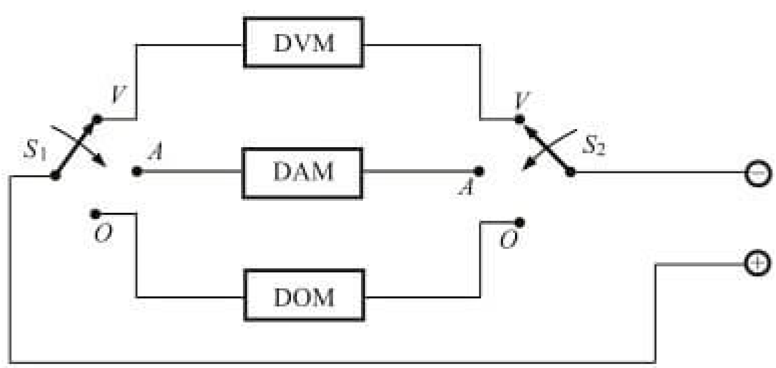
- *It can display different types of waveforms*
- *It can measure short time interval*
- *In voltmeter, it can measure potential difference*

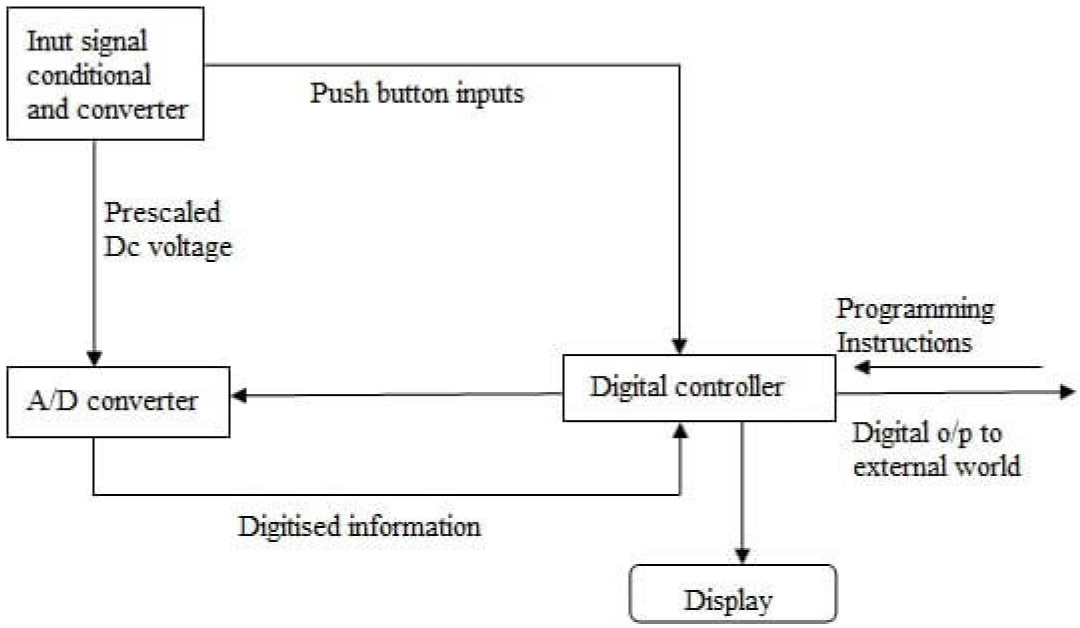
6.2

BLOCK DIAGRAM AND APPLICATIONS OF DIGITAL MULTIMETER

Block diagram of Digital multimeter

In digital multimeter, we can incorporate many types of meters like ohmmeter, ammeter, a voltmeter for the measurement of electrical parameters. Its block diagram is shown below in the figure. Let us have a look at its working and specification one by one.





Functions

Using a typical multimeter, we can measure:

- *Voltage in alternating current (AC) and direct current (DC) circuits*
- *Current in alternating current (AC) and direct current (DC) circuits*
- *Resistance of the entire circuit or across individual circuit components*

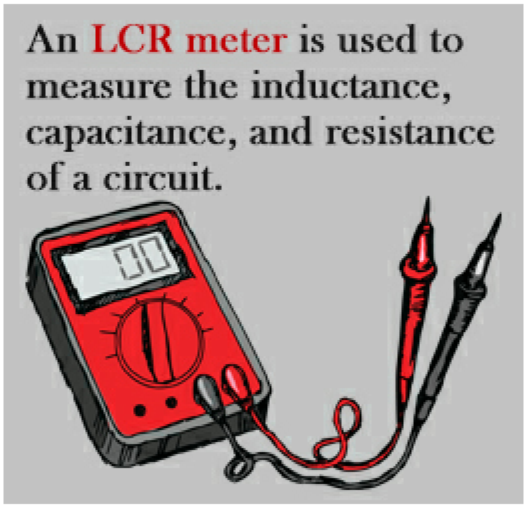
Some digital multimeters can test resistance up to 50 ohms with one milliohm (0.001 ohm) resolution. Others can be used to test a diode or measure transistor gain. There are even multimeters that can record minimum and maximum values and save the data through wireless internet.

Specialty multimeters are used to measure:

- *Capacitance of a capacitor*
- *Frequency of the incoming signal*
- *Temperature*

LCR METERS AND APPLICATIONS

LCR Meter Working Principle and Uses



An LCR meter is used to measure the impedance of a circuit or a device. This ScienceStruck article explains the uses, types, and some parameters related to LCR meters.

The LCR meter also measures D or Q. D stands for the dissipation factor. It is given by dividing the real part of the impedance by the imaginary part of the impedance (which is the reactance). Q stands for the quality factor. It is the inverse of D.

An LCR meter is used to measure the inductance, capacitance and resistance of a circuit. Hence, the name LCR meter.

When there is a change in the current flowing through a conductor, a corresponding change is induced in the voltage in it and in conductors surrounding it. This property is known as inductance. The ability of a body or a conductor to store electrical charge is known as capacitance. The opposition that a conductor offers to the passage of electric current through it is called resistance.

Working Principle

We pass an AC voltage through a DUT (Device Under Test). Now the LCR meter is used to measure the voltage and the current across the DUT. The magnitude of the impedance can be calculated from the ratio of these two quantities.

Uses of an LCR Meter

A digital LCR meter is used to measure the impedance flowing through a Device Under Test (DUT). It measures the voltage (V) across it, the current (I) flowing through it, and the phase angle between current and voltage. Subsequently, we can determine all the impedance parameters from these three factors.

Thus, an LCR meter measures the following parameters related to a circuit:

- inductance
- capacitance
- resistance

- dissipation factor
- quality factor
- current
- voltage
- phase angle between the current and voltage
- conductance
- susceptance

What is Impedance?

Impedance is the opposition that a circuit offers to the flow of direct or alternating current through it. It is a vector quantity composed of 2 scalars: resistance and reactance. Reactance is the name given to the opposition by an electronic component to the flow of alternating current due to capacitance and inductance.

Types of LCR Meters

1.Handheld LCR meters:

As the name suggests, these LCR meters are small in size and can be held in the hand; they are lightweight and also portable. They have a multiple test frequency, and the data it captures can be transferred to a PC via a USB port. They are generally used in field operations. They offer an accuracy in the range of 0.2% to 0.1%. The test frequency of a handheld LCR meter varies from 100 Hz, 120 Hz, 1 kHz, 10 kHz, and 100 kHz.

2.Benchtop LCR meters:

They are bulky in size. They can be operated on programmable frequencies. They offer an accuracy of 0.01%. They can be controlled via a computer. Test frequencies are above 100kHz.

Some Terms You Should Know

Test Frequency

LCR meters operate within the frequency range from 10Hz to 2Mhz. The DUT is used under its own frequency. LCR meters have to match the frequency of their measurement to the frequency that the DUT is tuned to.

Test Voltage

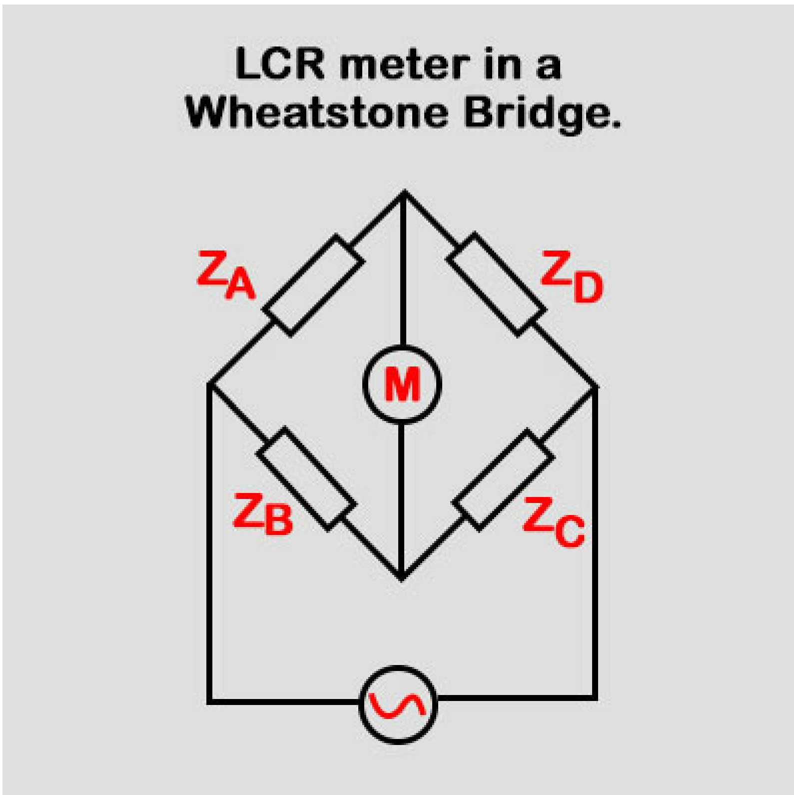
A particular voltage is applied to the DUT. The AC output voltage of an LCR meter has to match it.

Accuracy

If the accuracy of your measurement is high, it takes more time to record that measurement for the LCR meter. Accuracy is hampered if the measurement is recorded in a short time. Most LCR meters provide 3 speeds for measurement: slow, medium, and fast. You have to make a choice between speed and accuracy.

Some Techniques Used with LCR meters

Bridge Method



This method is employed for measuring frequencies below 100kHz. The DUT is placed in a Wheatstone Bridge. Z_D is the DUT. Z_B and Z_C are known impedances. Impedance of Z_A is varied until no current flows through Z_D.

Thus, the four impedances obey the equation:

$$Z_D / Z_A = Z_C / Z_B$$

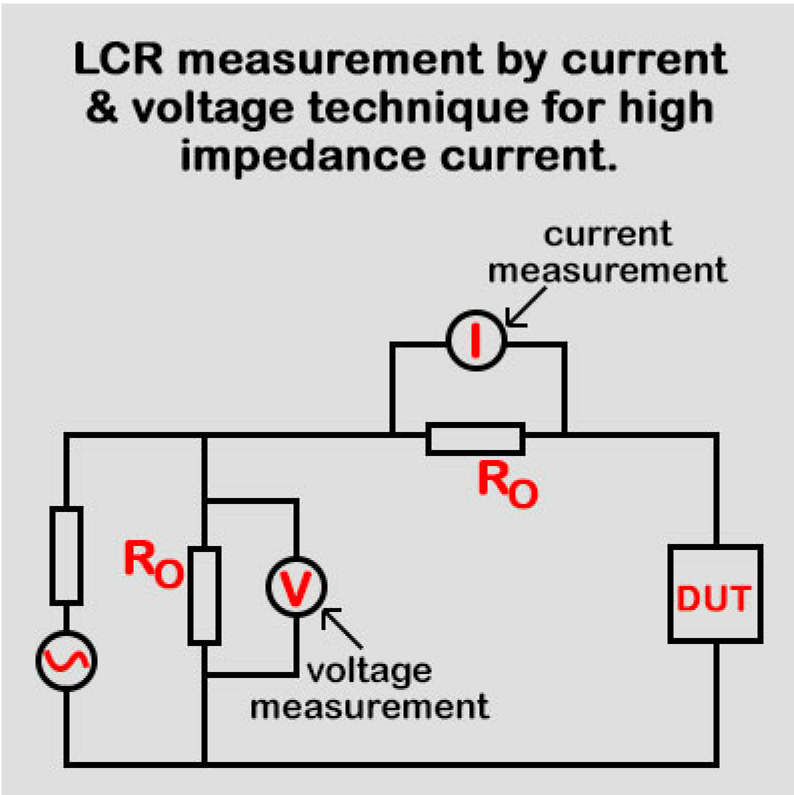
$$ZD = (ZC / ZB) ZA$$

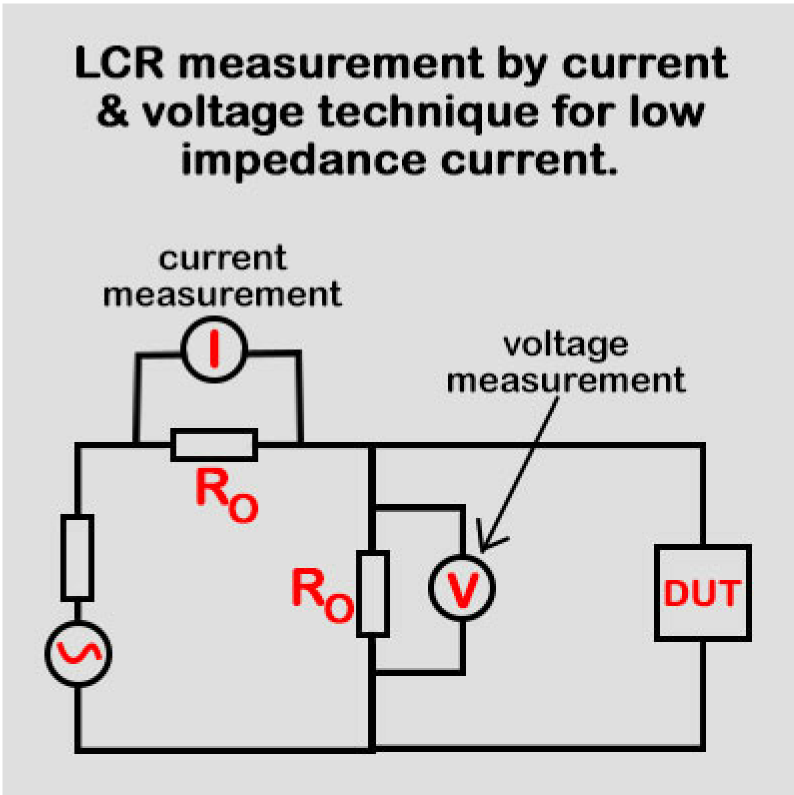
This way, we can find the impedance of the DUT.

LCR Measurement by Current-Voltage Technique

In this technique, the LCR measurement of a component is done by measuring the current and voltage. Then the impedance values are found out from these two quantities.

There are different arrangements for low impedance and high impedance circuits, which are as follows:





Both analog and digital LCR meters are available. While analog testers are cheaper, the digital variety scores on quality as it is more accurate.

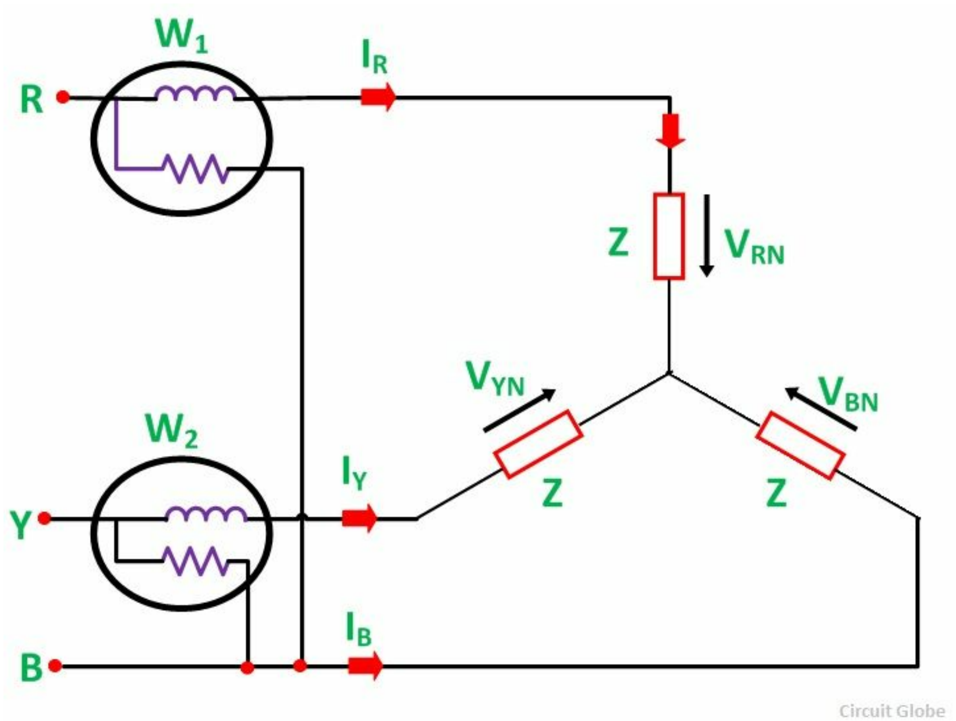
8 POWER MEASURES 3PHASE CIRCUIT BY

A. TWO WATTMETER METHOD WITH BALANCED AN UNBALANCED CIRCUITS

Two Wattmeter Method – Balanced Load Condition

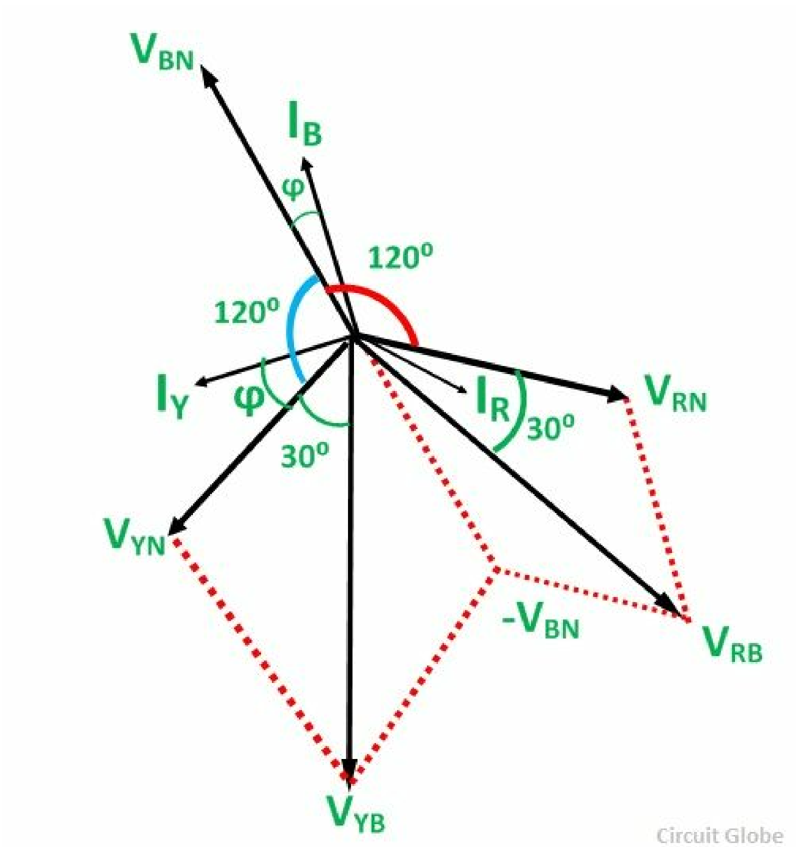
The **Two Wattmeter Method** is explained, taking an example of a balanced load. In this, we have to prove that the power measured by the Two Wattmeter i.e. the sum of the two wattmeter readings is equal to root 3 times of the phase voltage and line voltage (√3V.I.Cos) which is the actual power consumed in a 3 phase balanced load.

The connection diagram of a 3 phase balanced load connected as Star Connection is shown below.



Contents:

The load is considered as an inductive load, and thus, the phasor diagram of the inductive load is drawn below.



The three voltages V_{RN}, V_{YN} and V_{BN}, are displaced by an angle of 120 degrees electrical as shown in the phasor diagram. The phase current lag behind their respective phase voltages by an angle .

Now, the current flowing through the current coil of the Wattmeter, W_1 will be given as

$$W_1 = I_R$$

Potential difference across the pressure or potential coil of the Wattmeter, W_1 will be

$$W_1 = \overline{V_{RB}} = \overline{V_{RN}} - \overline{V_{BN}}$$

To obtain the value of V_{YB}, reverse the phasor V_{BN} and add it to the phasor V_{YN} as *shown in the phasor diagram above. The phase difference between V_{RB} and I_R is (30^0 −)*

Therefore, the power measured by the Wattmeter, W_1 is

$$W_1 = V_{RB} I_R \cos(30^\circ - \varphi)$$

Current through the current coil of the Wattmeter, W_2 is given as

$$W_2 = I_Y$$

Potential difference across the Wattmeter, W_2 is

$$W_2 = \overline{V_{YB}} = \overline{V_{RN}} - \overline{V_{BN}}$$

The phase difference V_{YB} and I_Y is (30^0 +).

Therefore, the power measured by the Wattmeter, W_2 is given by the equation shown below.

$$W_2 = V_{YB} I_Y \cos(30^\circ + \varphi)$$

Since, the load is in balanced condition, hence,

$$I_R = I_Y = I_B = I_L \text{ and}$$
$$V_{RY} = V_{YB} = V_{BR} = V_L$$

Therefore, the wattmeter readings will be

$$W_1 = V_L I_L \cos(30^\circ - \varphi) \quad \text{and}$$

$$W_2 = V_L I_L \cos(30^\circ + \varphi)$$

Now, the sum of two Wattmeter readings will be given as

$$W_1 + W_2 = V_L I_L \cos(30^\circ - \varphi) + V_L I_L \cos(30^\circ + \varphi)$$

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

$$W_1 + W_2 = V_L I_L [\cos 30^\circ \cos\varphi + \sin 30^\circ \sin\varphi + \cos 30^\circ \cos\varphi - \sin 30^\circ \sin\varphi$$

$$W_1 + W_2 = V_L I_L (2 \cos 30^\circ \cos\varphi) \quad \text{or}$$

$$W_1 + W_2 = V_L I_L \left(2 \ \frac{\sqrt{3}}{2} \cos\varphi\right)$$

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

$$W_1 + W_2 = P \ \ldots \ldots (1)$$

The above equation (1) gives the total power absorbed by a 3 phase balanced load.

Thus, the sum of the readings of the two Wattmeters is equal to the power absorbed in a 3 phase balanced load.

Determination of Power Factor from Wattmeter Readings

As we know that,

$$W_1 + W_2 = \sqrt{3} \, V_L I_L \cos\varphi \ \ldots \ldots \ldots (2)$$

Now,

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

$$W_1 - W_2 = V_L I_L \left[\cos 30^\circ \cos\varphi + \sin 30^\circ \sin\varphi - \cos 30^\circ \cos\varphi + \sin 30^\circ \sin\varphi\right]$$

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

$$W_1 - W_2 = V_L I_L \sin\varphi \;\ldots\ldots\ldots (3)$$

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

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

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

Power factor of the load is given as

$$\cos\varphi = \cos \tan^{-1} \sqrt{3}\, \frac{W_1 - W_2}{W_1 + W_2}$$

Determination of Reactive Power by Two Wattmeter Method

To get the reactive power, multiply equation (3) by √3.

$$\sqrt{3}\, (W_1 - W_2) = \sqrt{3}\, V_L I_L \sin\varphi = P_r$$

Therefore, the Reactive Power is given by the equation shown below.

$$P_r = \sqrt{3}\ (W_1 - W_2)$$

8

B.

Measurement of Three Phase Power: Three Wattmeter Method

Power measurement *in an AC circuit is measured with the help of a Wattmeter. A Wattmeter is an instrument which consists of two coils called* ***Current coil*** *and* ***Potential coil.*** *The current coil having low resistance is connected in series with the load so that it carries the load current. The potential coil having the resistance is connected across the load and carries the current proportional to the potential difference.*

For measuring the power in a 3 phase or Poly Phase system, more than one wattmeter is required, or more than one readings are made by one wattmeter. If more than one wattmeter is connected for the measurement, the process becomes convenient and easy to work with instead of taking various readings with one wattmeter.The number of wattmeters required to measure power in a given polyphase system is determined by Blondel's Theorem.

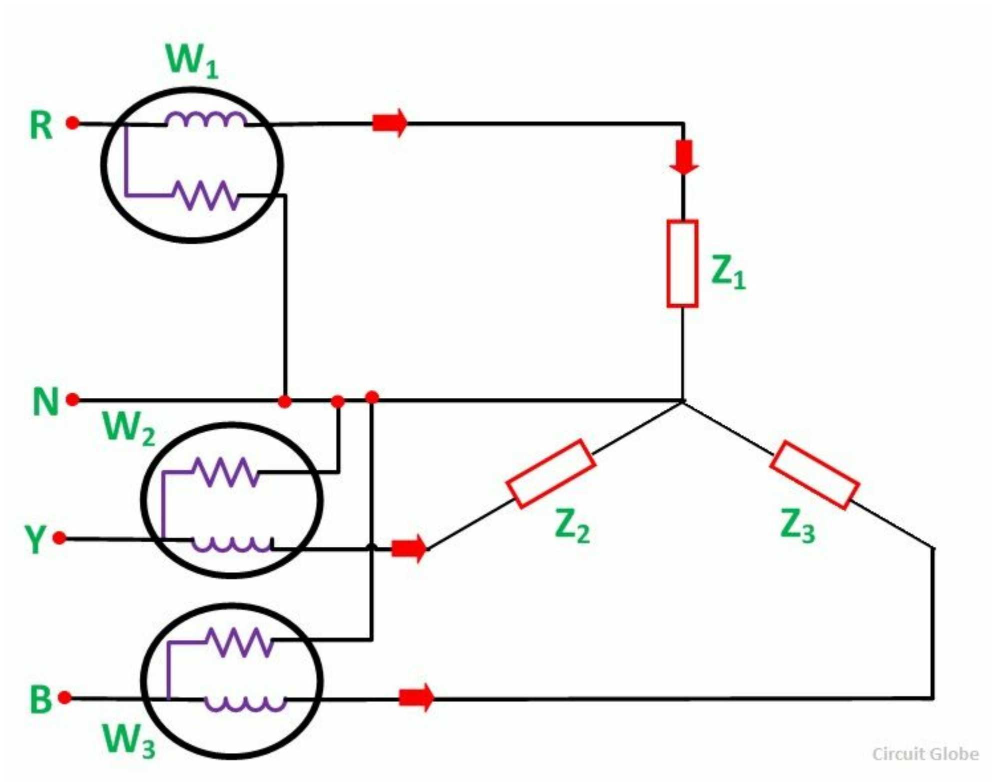
According to Blondel's theorem *– When power is supplied by the K wire AC system, the number of wattmeters required to measure power is one less than the number of wire i.e. (K-1), regardless the load is balanced or unbalanced.*

Hence, Three wattmeters are required to measure power in three phase, four wire system, whereas, only two wattmeters are required to measure the power in 3 phase, 3 wire system. Here in this article, a Three wattmeter method of power measurement is discussed.

Three-Wattmeter Method of Three Phase Power Measurement

Three Wattmeter method is employed to measure power in a 3 phase, 4 wire system.However, this method can also be employed in a 3 phase, 3 wire delta connected load, where power consumed by each load is required to be determined separately.

The connections for star connected loads for measuring power by Three wattmeter method is shown below.



The pressure coil of all the Three wattmeters namely W_1, W_2 and W_3 are connected to a common terminal known as the neutral point. The product of the phase current and line voltage represents as phase power and is recorded by individual wattmeter.

The total power in a Three wattmeter method of power measurement is given by the algebraic sum of the readings of Three wattmeters. i.e.

$$\text{Total power } P = W_1 + W_2 + W_3$$

Where,

$W_1 = V_1 I_1$

$W_2 = V_2 I_2$

$W_3 = V_3 I_3$

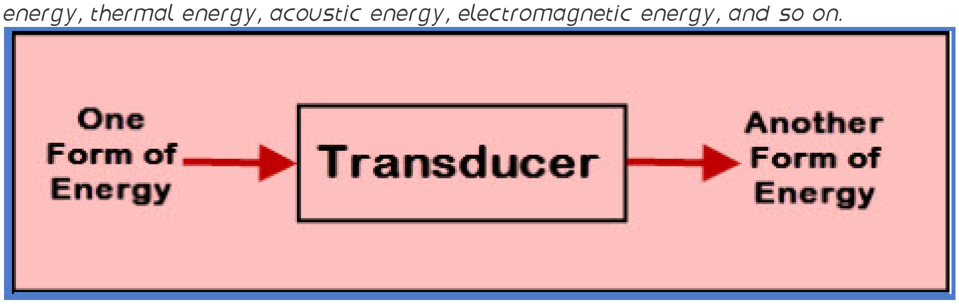
Except for 3 phase, 4 wire unbalanced load, 3 phase power can be measured by using only Two Wattmeter Method.

9. TRANSDUCERS

INTRODUCTION

What is a Transducer?

A transducer is an electrical device that is used to convert one form of energy into another form. In general, these devices deal with different types of energies such as mechanical, electrical energy, light energy, chemical energy, thermal energy, acoustic energy, electromagnetic energy, and so on.



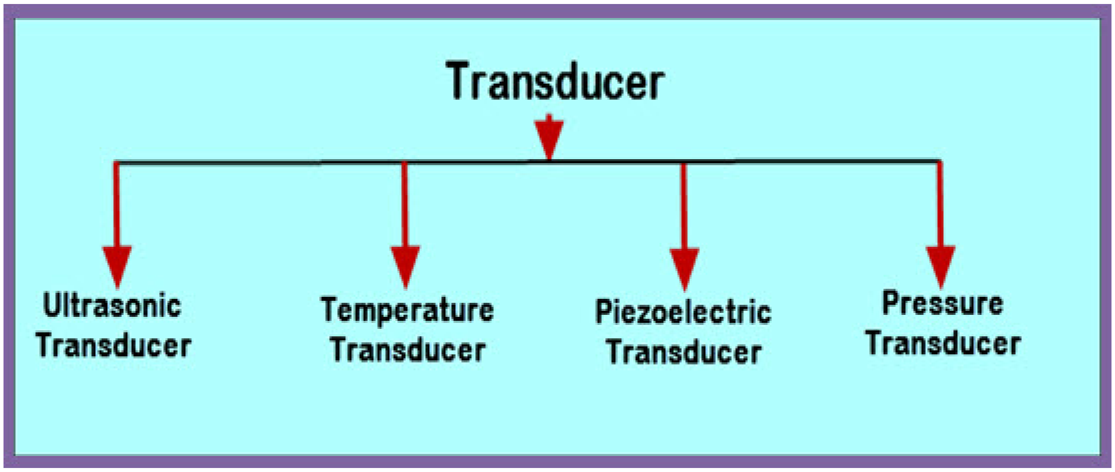
Transducer

For instance, consider a mic we use in daily life in telephones, mobile phones, that converts the sound into electrical signals and then amplifies it into the preferred range. Then, alters the electrical signals into audio signals at the o/p of the loudspeaker. Nowadays, fluorescent bulbs are used for lighting, changes the electrical energy into light energy.

The best examples of the transducer are mic, fluorescent bulb and speaker can be considered as a transducer. Likewise, there are different kinds of transducers used in electrical and electronic projects.

Transducer Types and Its Applications

There are a variety of transducer types like pressure transducer, piezoelectric transducer, ultrasonic transducer, temperature transducer, and so on. Let us discuss the use of different types of transducers in practical applications.



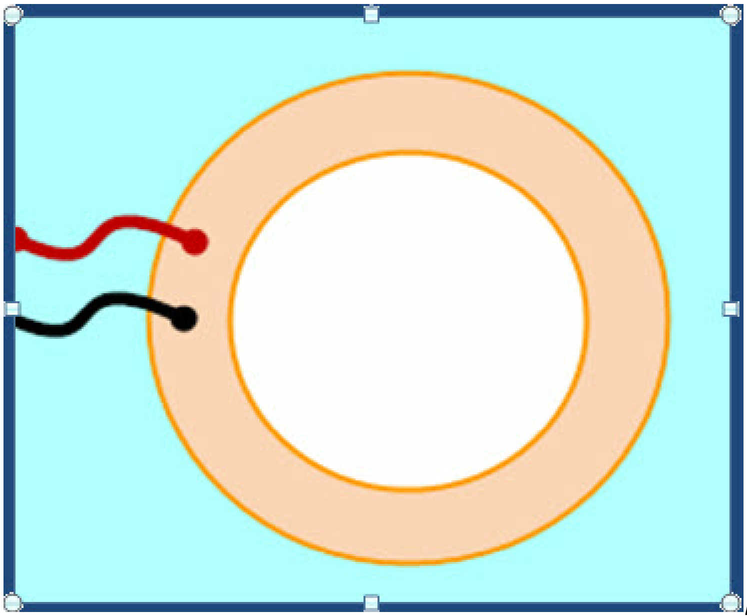
Transducer Types

Some transducer types like active transducer and passive transducers are based on whether a power source is required or not.

Active transducer doesn't require any power source for their operations. These transducers work on the principle of energy conversion. They generate an electrical signal that is proportional to the i/p. The best example of this transducer is thermocouple. Whereas passive transducer requires an external power source for their operation. They generate an o/p in the form of capacitance, resistance. Then that has to be converted to an equivalent voltage or current signal. The best example of a passive transducer is a photocell.

Piezoelectric Transducer

A piezoelectric transducer is a special kind of sensor, and the main function of this transducer is to convert mechanical energy into electrical energy. In the same way, electrical energy can be transformed into mechanical energy.

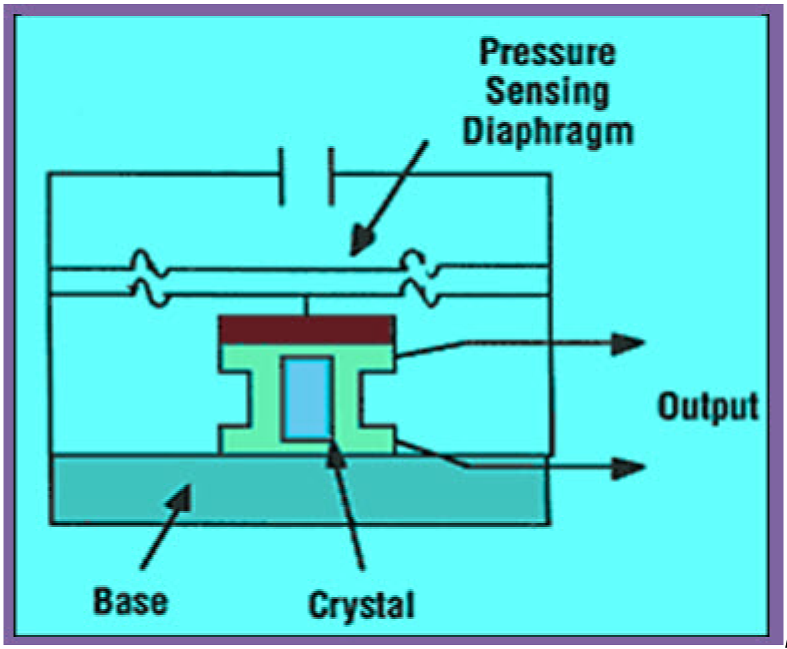

Piezoelectric Transducer

Piezoelectric Transducer Applications

- This transducer is mainly used to detect the sticks drummer's impact on electronic drum pads. And also used to detect the movement of the muscle, which can be named as acceleromyography.
- The load of the engine can be determined by calculating diverse absolute pressure, that can be done by using these transducers as the MAP sensor in fuel injection systems.
- This sensor can be used as a knock sensor in automotive engine management systems for noticing knock of the engine.

Pressure Transducer

A pressure transducer is a special kind of sensor that alters the pressure forced into electrical signals. These transducers are also called as pressure indicators, manometers, piezometers, transmitters, and pressure sensors.



Pressure Transducer

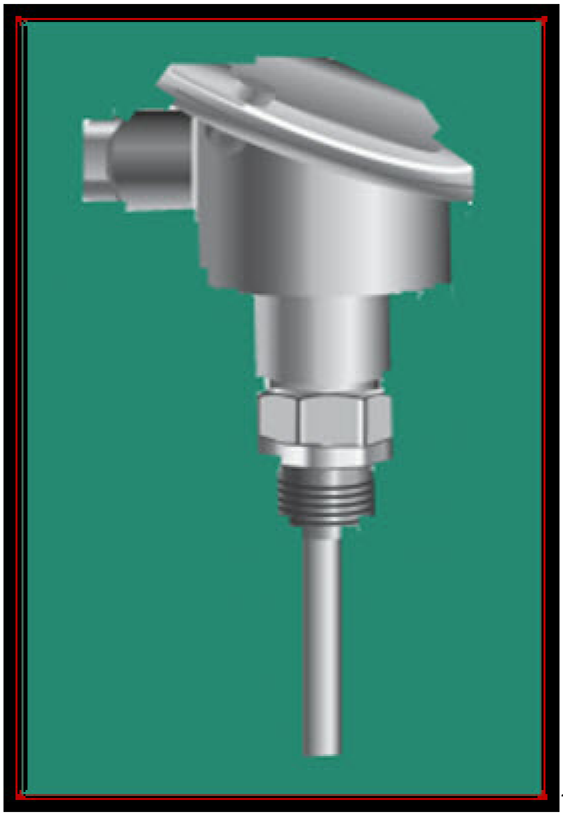
Application of Pressure Transducer

The pressure transducer is used to measure the pressure of the specific quantity like gas or liquid by changing the pressure into electrical energy. The different kinds of these transducers like an amplified voltage transducer, strain-gage base pressure transducer, millivolt (mv) pressure transducer, 4-20mA pressure transducer, and pressure transducer.

The applications of pressure transducer mainly involve in altitude sensing, pressure sensing, level or depth sensing, flow sensing and leak testing. These transducers can be used for generating an electrical power under the speed breakers on the highways or roads where the force of the vehicles can be converted into electrical energy.

Temperature Transducer

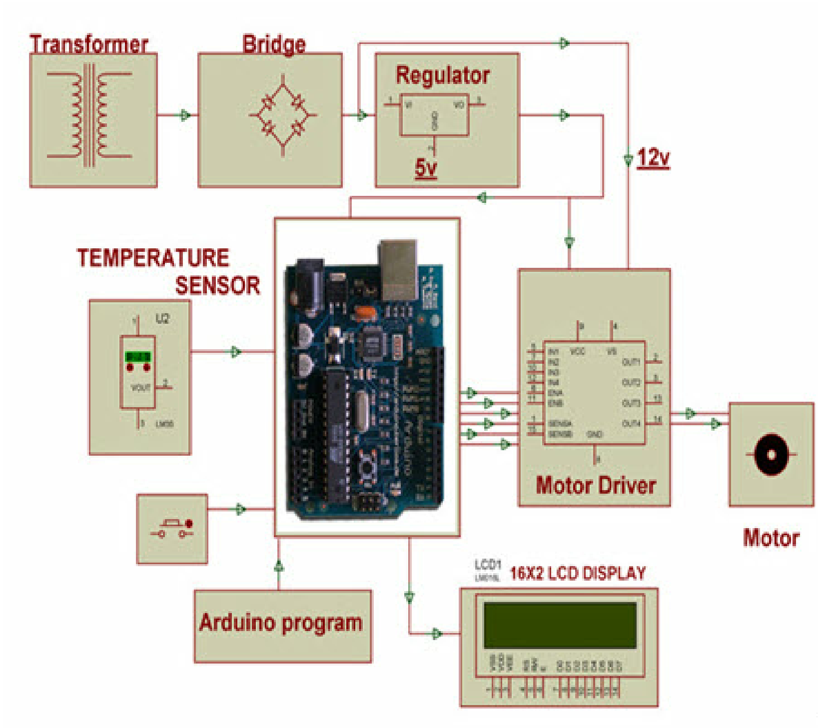
Temperature transducer is an electrical device that is used to convert the temperature of a device into another quantity like electrical energy or pressure or mechanical energy, then the quantity will be sent to the control device for controlling the temperature of the device.



Temperature Transducer

Application of Temperature Transducer

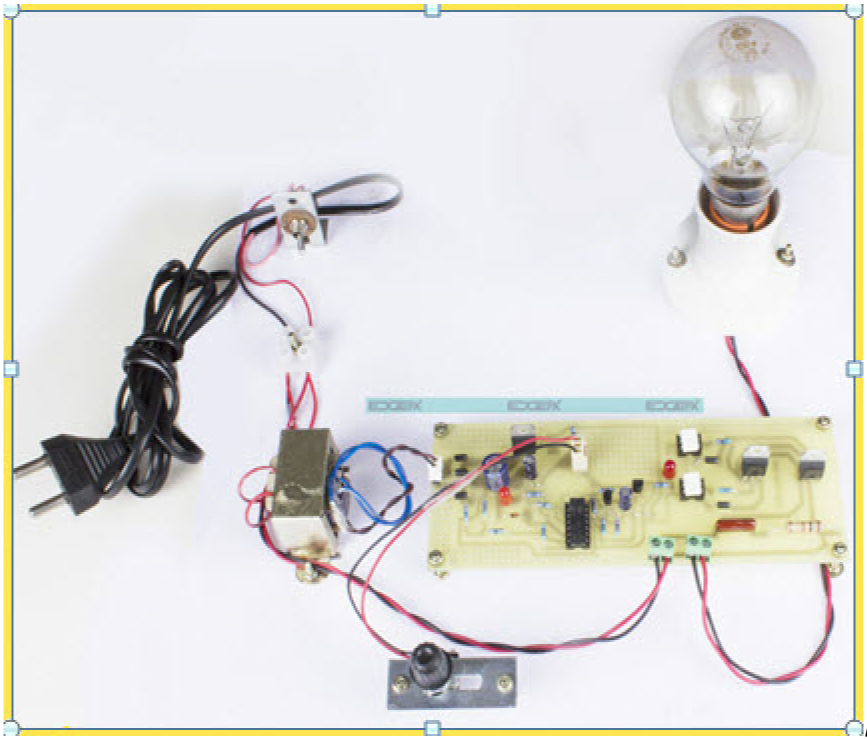
Temperature transducer is used to measure the temperature of the air such that to control the temperature of several control systems like air-conditioning, heating, ventilation, and so on.



Arduino based automatic fan speed regulator controlling of temperature Block Diagram

Let us consider a practical example of a temperature transducer that is used to control the temperature of any device based on the necessity for different industrial applications. An Arduino based automatic fan speed regulator controlling of temperature and exhibiting a measure of temperature on an LCD display.

In the proposed system, IC LM35 is used as a temperature transducer. An Arduino board is used to control the various functions that include analog to digital conversion and an LCD display that is connected in the above fig.

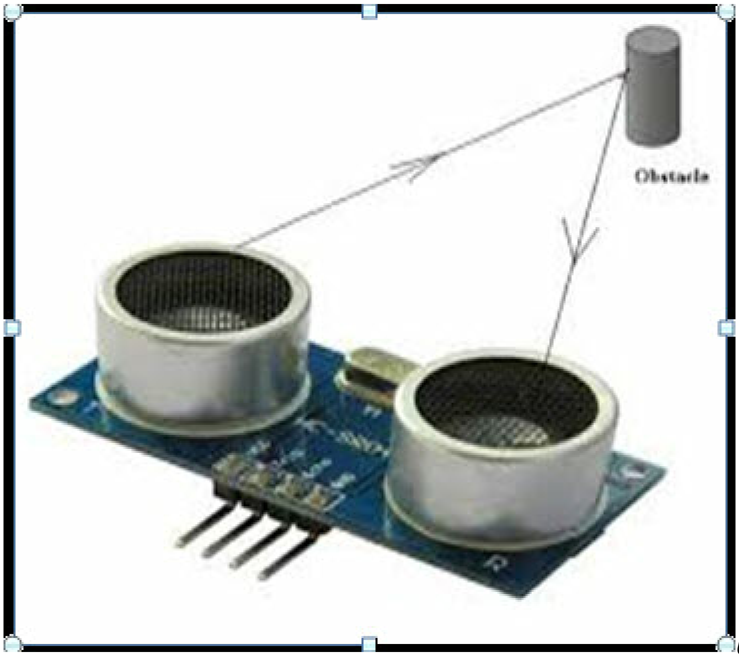


Practical Application of Temperature Transducer by Edgefxkits.com

The temperature can be fixed by using settings like INC and DEC for increasing and decreasing. Based on the temperature measured a pulse width modulation o/p will be generated by the program of an Arduino board. The output of this is used to control the DC fan through the motor driver IC.

Ultrasonic Transducer

The main function of the ultrasound transducer is to convert electrical signals to ultrasound waves. This transducer can also be called as capacitive or piezoelectric transducers.



Ultrasonic Transducer

Application of Ultrasonic Transducer

This transducer can be used to measure the distance of the sound based on reflection. This measurement is based on a suitable method compared to the straight methods which use different measuring scales. The areas which are hard to find, such as pressure areas, very high temperature, using conventional methods the measurement of the distance is not a simple task. So, this transducer-based measuring system can be used in this kind of zone.

Application of Ultrasonic Transducer Projects kit by Edgefxkits.com

The proposed system uses 8051 microcontrollers, power supplies, an ultrasonic transducer module that includes of transmitter and receiver, LCD display blocks are used which are shown in the above block diagram. Here, if any obstacle or any object is found that is detected by ultrasonic transducer then it transmits the waves and gets reflected back from the object and these waves are received by the transducer. The time consumed by the transducer for transmitting & receiving the waves can be noted by considering the velocity of sound. Then, based on the sound velocity and a pre-programmed microcontroller is performed such that the distance is measured and displayed on an LCD display. Here, the display is interfaced with a microcontroller. The ultrasonic transducer produces 40kHz frequency waves.

Transducer Characteristics

The characteristics of a transducer are given below that are determined by examining the o/p response of a transducer to a variety of i/p signals. Test conditions create definite operating conditions as closely as possible. The methods of computational and standard statistical can be applied to the test data.

- *Accuracy*
- *Precision*
- *Resolution*
- *Sensitivity*
- *Drift*
- *Linearity*
- *Conformance*
- *Span*
- *Hysteresis*
- *Distortion*

- *Noise*

10 MEASUREMENT OF TEMPERATURE

Different types of thermometer

What are the different types of thermometer?

The increasing importance of the thermometer in the diagnosis of patients has led to many new types of thermometer being invented to aid with the ease of taking temperatures. This is achieved by creating thermometers which concentrate on different parts of the body, with some more effective than others.

These include –

Digital thermometers

Digital thermometers are regarded as the fastest and most accurate type of thermometer. Readings are taken from under the tongue, from the rectum or under the armpit. They are easily found in local pharmacies and can be used at home or in the hospital.

Electronic ear thermometers

These use infrared technology to get their temperature reading. Electronic ear thermometers are less accurate as if there is too much wax in the ear it can give an incorrect reading. Despite being expensive, they are a lot easier to use on babies and young children, as it can be hard to get children to sit still for long enough while using digital thermometers.

Forehead thermometers

These thermometers also read heat using infrared, and are placed on the temporal artery. Forehead thermometers are also not as reliable as digital thermometers

Plastic strip thermometers

These thermometers can detect the presence of a fever in a patient, however, they do not give an exact temperature reading. They simply act as an indication that something might be wrong. To use them, you just place the strip on the forehead.

Pacifier thermometer

These thermometers are used predominantly in babies older than three months. They require the baby to be still for a couple of minutes and this can be a struggle. This means that sometimes the temperature can be inaccurate.

Glass and mercury thermometers

These thermometers are the old school way to take a temperature. You normally would place it under your tongue and watch the mercury rise. Once it stops, that would be your temperature. Unfortunately, due to the risk of mercury poisoning, this means of taking a temperature is not a good idea and you are highly recommended to consult with a healthcare body to discard any you might have.

What is a Thermocouple?

A Thermocouple is a sensor used to measure temperature. Thermocouples consist of two wire legs made from different metals. The wires legs are welded together at one end, creating a junction. This junction is where the temperature is measured. When the junction experiences a change in temperature, a voltage is created. The voltage can then be interpreted using thermocouple reference tables to calculate the temperature.

There are many types of thermocouples, each with its own unique characteristics in terms of temperature range, durability, vibration resistance, chemical resistance, and application compatibility. Type J, K, T, & E are "Base Metal" thermocouples, the most common types of thermocouples.Type R, S, and B thermocouples are "Noble Metal" thermocouples, which are used in high temperature applications (see thermocouple temperature ranges for details).

Thermocouples are used in many industrial, scientific, and OEM applications. They can be found in nearly all industrial markets: Power Generation, Oil/Gas, Pharmaceutical, BioTech, Cement, Paper & Pulp, etc. Thermocouples are also used in everyday appliances like stoves, furnaces, and toasters.

Thermocouples are typically selected because of their low cost, high temperature limits, wide temperature ranges, and durable nature.

Types of Thermocouples:

Before discussing the various types of thermocouples, it should be noted that a thermocouple is often enclosed in a protective sheath to isolate it from the local atmosphere. This protective sheath drastically reduces the effects of corrosion.

Type K Thermocouple (Nickel-Chromium / Nickel-Alumel): *The type K is the most common type of thermocouple. It's inexpensive, accurate, reliable, and has a wide temperature range.*

- *Thermocouple grade wire, −454 to 2,300F (−270 to 1260C)*
- *Extension wire, 32 to 392F (0 to 200C)*

Accuracy (whichever is greater):

- *Standard: +/- 2.2C or +/- .75%*
- *Special Limits of Error: +/- 1.1C or 0.4%*

Type J Thermocouple (Iron/Constantan): *The type J is also very common. It has a smaller temperature range and a shorter lifespan at higher temperatures than the Type K. It is equivalent to the Type K in terms of expense and reliability.*

Temperature Range:

- 

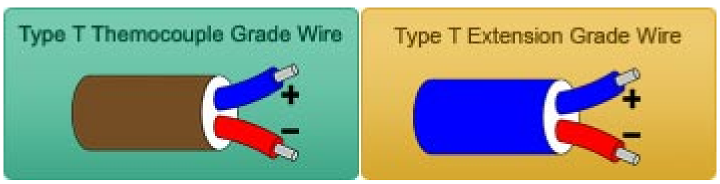
Thermocouple grade wire, -346 to 1,400F (-210 to 760C)
- Extension wire, 32 to 392F (0 to 200C)

Accuracy (whichever is greater):

- Standard: +/- 2.2C or +/- .75%
- Special Limits of Error: +/- 1.1C or 0.4%

Type T Thermocouple (Copper/Constantan): The Type T is a very stable thermocouple and is often used in extremely low temperature applications such as cryogenics or ultra low freezers.

Temperature Range:

- 

Thermocouple grade wire, -454 to 700F (-270 to 370C)
- Extension wire, 32 to 392F (0 to 200C)

Accuracy (whichever is greater):

- Standard: +/- 1.0C or +/- .75%
- Special Limits of Error: +/- 0.5C or 0.4%

Type E Thermocouple (Nickel-Chromium/Constantan): The Type E has a stronger signal & higher accuracy than the Type K or Type J at moderate temperature ranges of 1,000F and lower. See temperature chart (linked) for details.

Temperature Range:

- 

Thermocouple grade wire, -454 to 1600F (-270 to 870C)
- Extension wire, 32 to 392F (0 to 200C)

Accuracy (whichever is greater):

- Standard: +/- 1.7C or +/- 0.5%
- Special Limits of Error: +/- 1.0C or 0.4%

Type N Thermocouple (Nicrosil / Nisil): The Type N shares the same accuracy and temperature limits as the Type K. The type N is slightly more expensive.

Temperature Range:

- 

Thermocouple grade wire, -454 to 2300F (-270 to 392C)
- Extension wire, 32 to 392F (0 to 200C)

Accuracy (whichever is greater):

- Standard: +/- 2.2C or +/- .75%
- Special Limits of Error: +/- 1.1C or 0.4%

NOBLE METAL THERMOCOUPLES (Type S,R, & B):
Noble Metal Thermocouples are selected for their ability to withstand extremely high temperatures while maintaining their accuracy and lifespan. They are considerably more expensive than Base Metal Thermocouples.

Type S Thermocouple (Platinum Rhodium - 10% / Platinum): The Type S is used in very high temperature applications. It is commonly found in the BioTech and Pharmaceutical industries. It is sometimes used in lower temperature applications because of its high accuracy and stability.

Temperature Range:

- 

Thermocouple grade wire, -58 to 2700F (-50 to 1480C)
- Extension wire, 32 to 392F (0 to 200C)

Accuracy (whichever is greater):

- Standard: +/- 1.5C or +/- .25%
- Special Limits of Error: +/- 0.6C or 0.1%

Type R Thermocouple (Platinum Rhodium -13% / Platinum): The Type R is used in very high temperature applications. It has a higher percentage of Rhodium than the Type S, which makes it more expensive. The Type R is very similar to the Type S in terms of performance. It is sometimes used in lower temperature applications because of its high accuracy and stability.

Temperature Range:

- Thermocouple grade wire, -58 to 2700F (-50 to 1480C)
- Extension wire, 32 to 392F (0 to 200C)

Accuracy (whichever is greater):

- Standard: +/- 1.5C or +/- .25%
- Special Limits of Error: +/- 0.6C or 0.1%

Type B Thermocouple (Platinum Rhodium – 30% / Platinum Rhodium – 6%): The Type B thermocouple is used in extremely high temperature applications. It has the highest temperature limit of all of the thermocouples listed above. It maintains a high level of accuracy and stability at very high temperatures.

Temperature Range:

- Thermocouple grade wire, 32 to 3100F (0 to 1700C)
- Extension wire, 32 to 212F (0 to 100C)

Accuracy (whichever is greater):

- Standard: +/- 0.5%
- Special Limits of Error: +/- 0.25%

Thermocouple Junctions:

Grounded Thermocouples: This is the most common junction style. A thermocouple is grounded when both thermocouple wires and the sheath are all welded together to form one junction at the probe tip. Grounded thermocouples have a very good response time because the thermocouple is making direct contact with the sheath, allowing heat to transfer easily. A drawback of the grounded thermocouple is that the thermocouple is more susceptible to electrical interference. This is because the sheath often comes into contact with the surrounding area, providing a path for interference.

Ungrounded Thermocouples (Or Ungrounded Common Thermocouples): A thermocouple is ungrounded when the thermocouple wires are welded together but they are insulated from the sheath. The wires are often separated by mineral insulation.

Exposed Thermocouples (or "bare wire thermocouples"): A thermocouple is exposed when the thermocouple wires are welded together and directly inserted into the process. The response time is very quick, but exposed thermocouple wires are more prone to corrosion and degradation. Unless your application requires exposed junctions, this style is not recommended.

Ungrounded Uncommon: An ungrounded uncommon thermocouple consists of a dual thermocouple that is insulated from the sheath and each of the elements are insulated from one other.

Thermocouple Sheath Comparison:

316SS (stainless steel): This is the most common sheath material. It is relatively corrosion resistant and is cost effective.
304SS: This sheath is not as corrosion resistant as 316SS. The cost difference between 316SS and 304SS is nominal.
Inconel (registered trademark) 600: This material is recommended for highly corrosive environments.

Resistance Temperature Detector or RTD | Construction and Working Principle

A **Resistance Thermometer** or **Resistance Temperature Detector** is a device which used to determine the temperature by measuring the resistance of pure electrical wire. This wire is referred to as a temperature sensor. If we want to measure temperature with high accuracy, **RTD** is the only one solution in industries. It has good linear characteristics over a wide range of temperature.
The variation of resistance of the metal with the variation of the temperature is given as,

Where, R_t and R_0 are the resistance values at t°C and t_0°C temperatures. α and β are the constants depends on the metals.

This expression is for huge range of temperature. For small range of temperature, the expression can be,

In **RTD** devices; Copper, Nickel and Platinum are widely used metals. These three metals are having different resistance variations with respective to the temperature variations. That is called resistance-temperature characteristics. Platinum has the temperature range of 650°C, and then the Copper and Nickel have 120°C and 300°C respectively. The figure-1 shows the resistance-temperature characteristics curve of the three different metals. For Platinum, its resistance changes by approximately 0.4 ohms per degree Celsius of temperature.
The purity of the platinum is checked by measuring R_{100} / R_0. Because, whatever the materials actually we are using for making the RTD that should be pure. If it will not pure, it will deviate from the conventional resistance-temperature graph. So, α and β values will change depending upon the metals.

Construction of Resistance Temperature Detector or RTD

The construction is typically such that the wire is wound on a form (in a coil) on notched mica cross frame to achieve small size, improving the thermal conductivity to decrease the response time and a high rate of heat transfer is obtained. In the industrial RTD's, the coil is protected by a stainless steel sheath or a protective tube.

So that, the physical strain is negligible as the wire expands and increase the length of wire with the temperature change. If the strain on the wire is increasing, then the tension increases. Due to that, the resistance of the wire will change which is undesirable.So, we don't want to change the resistance of wire by any other unwanted changes except the temperature changes.
This is also useful to RTD maintenance while the plant is in operation. Mica is placed in between the steel sheath and resistance wire for better electrical insulation. Due less strain in resistance wire, it should be carefully wound over mica sheet. The fig.2 shows the structural view of an Industrial Resistance Temperature Detector.

Signal Conditioning of RTD

We can get this RTD in market. But we must know the procedure how to use it and how to make the signal conditioning circuitry. So that, the lead wire errors and other calibration errors can be minimized. In this RTD, the *change in resistance value is very small with respect to the temperature. So, the RTD value is measured by using a bridge circuit. By supplying the constant electric current to the bridge circuit and measuring the resulting voltage drop across the resistor, the RTD resistance can be calculated. Thereby, the temperature can be also determined. This temperature is determined by converting the RTD resistance value using a calibration expression. The different modules of RTD are shown in below figures.*

In two wires RTD Bridge, the dummy wire is absent. The output taken from the remaining two ends as shown in fig.3. But the extension wire resistances are very important to be considered, because the impedance of the extension wires may affect the temperature reading. This effect is minimizing in three wires RTD bridge circuit by connecting a dummy wire C. If wires A and B are matched properly in terms of length and cross section area, then their impedance effects will cancel because each wire is in opposite position. So that, the dummy wire C acts as a sense lead to measure the voltage drop across the RTD resistance and it carries no current. In these circuits, the output voltage is directly proportional to the temperature. So, we need one calibration equation to find the temperature.

Expressions for a Three Wires RTD Circuit

If we know the values of V_s and V_o, we can find R_g and then we can find the temperature value using calibration equation. Now, assume $R_1 = R_2$:

If $R_3 = R_g$; then $V_o = 0$ and the bridge is balanced. This can be done manually, but if we don't want to do a manual calculation, we can just solve the equation 3 to get the expression for R_g.

This expression assumes, when the lead resistance $R_L = 0$. Suppose, if R_L is present in a situation, then the expression of R_g becomes,

So, there is an error in the RTD resistance value because of the R_L resistance. That is why we need to compensated the R_L resistance as we discussed already by connecting one dummy line 'C' as shown in fig.4.

Video Presentation on Resistance Temperature Detector or RTD

Limitations of RTD

*In the RTD resistance, there will be an I^2R power dissipation by the device itself that causes a slight heating effect. This is called as self-heating in RTD. This may also cause an erroneous reading. Thus, the electric current through the **RTD** resistance must be kept sufficiently low and constant to avoid self-heating.*

*A **thermal imager** (also known as a **thermal camera**) is essentially a **heat** sensor that is capable of detecting tiny differences in temperature. The device collects the **infrared** radiation from objects in the scene and creates an electronic **image** based on information about the temperature differences.*

DEFINITION

thermal imaging

Thermal imaging is a method of improving visibility of objects in a dark environment by detecting the objects' infrared radiation and creating an image based on that information.

Thermal imaging, near-infrared illumination, low-light imaging and are the three most commonly used night vision technologies. Unlike the other two methods, thermal imaging works in environments without any ambient *light. Like near-infrared illumination, thermal imaging can penetrate obscurants such as smoke, fog and haze.*

Here's a brief explanation of how thermal imaging works: All objects emit infrared energy (heat) as a function of their temperature. The infrared energy emitted by an object is known as its heat signature. In general, the hotter an object is, the more radiation it emits. A thermal imager (also known as a thermal camera) is essentially a heat sensor that is capable of detecting tiny differences in temperature. The device collects the infrared radiation from objects in the scene and creates an electronic image based on information about the temperature differences. Because objects are rarely precisely the same temperature as other objects around them, a thermal camera can detect them and they will appear as distinct in a thermal image.

Thermal images are normally grayscale in nature: black objects are cold, white objects are hot and the depth of gray indicates variations between the two. Some thermal cameras, however, add color to images to help users identify objects at different temperatures.