Dynamometer type wattmeter

1 Introduction

Power is defined as the rate of doing work. It is also defined as the rate at which electrical energy is transmitted by the circuit. Its SI unit is watts (W). The power at any instant of time in a circuit is the product of the current flowing through the circuit and the voltage across its terminals as that instant. In a circuit the power can be determined with the help of voltmeter and ammeter, but the instrument that is used for the measurement of power is wattmeter.

2 Wattmeter

A wattmeter is a device used for the measurement of electrical power in a circuit. It is an inherent combination of an ammeter and a voltmeter. Is has mainly two coils, namely the current coil (CC) and the potential coil (PC) and has four terminals, M, L C and V, as shown in Fig.1.
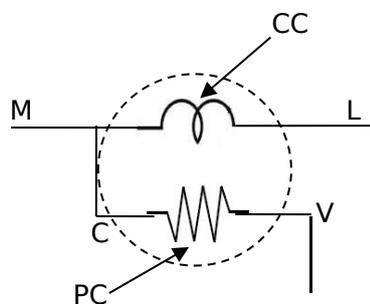

Fig.1

The two coils are connected in different circuits for the measurement of power. The current coil (CC) is connected in series with the load whose power is required to be measured, so that it carries the load current. The potential coil (PC) is connected in parallel with the load, so that it carries a current proportional to the load voltage. A non

inductive resistance is connected in series with the potential coil to limit the current through the coil to a small value.

2.1 Types of Wattmeter

An wattmeter depending upon the construction and operating principle can be classified into the following four catagories.

● Electrodynamometer Type Wattmeter

● Induction Type Wattmeter

● Electrostatic Wattmeter

● Thermocouple Type Wattmeter

In this section we will study the construction and the working principle of these wattmeter's.
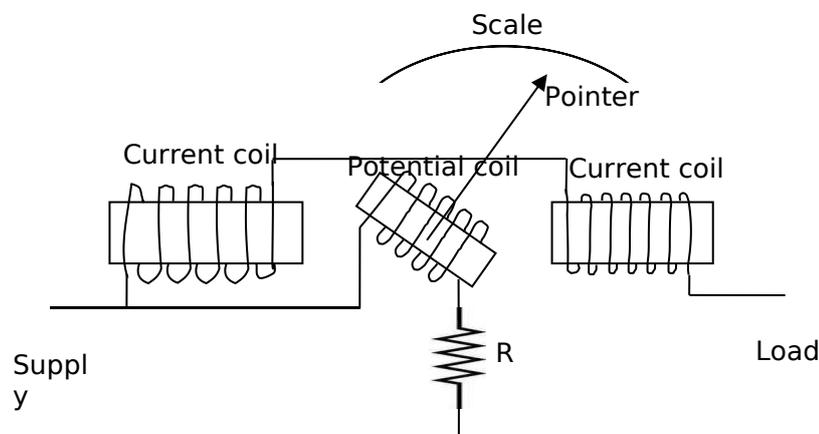
Electrodynamometer Type Wattmeter

Fig.12.12: Electrodynamometer type wattmeter

The schematic diagram of electrodynamometer type wattmeter is shown in Fig. It has two coils, the fixed coil or the current coil and moving coil or potential coil. The current coil is connected in series with the load and carries the load current. The moving coil or the potential coil is connected in parallel across the supply voltage. Thus

the potential coil carries the current proportional to the voltage. The non inductive resistance, R, connected in series with the potential coil, limits the current through this path to a smaller value.

The current coil is wound with heavy wires, which can be stranded or laminated, to reduce losses in the conductor due to the flow of large amount of current. The moving coil in mounted on a pivoted spindle and spring control is used for the system, with air friction damping system. Both the current coil and the potential coil are air cored.

Torque Equation
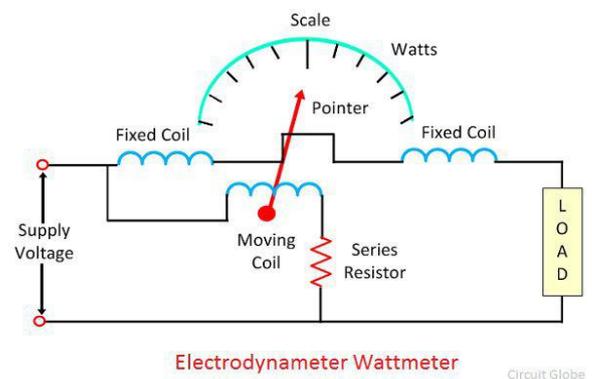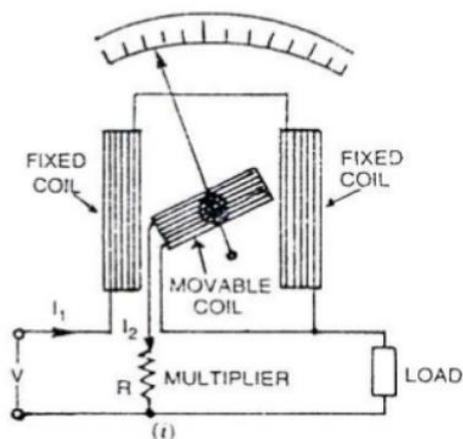
DC Input

Let V be the supply voltage
i be the load current
R be the resistance of the moving coil
Current through the fixed coil is $i_f = i$
Current through the moving coil is i_m

Since the moving coil is connected in parallel we can write

$$i_m = \frac{V}{R}$$

The deflecting torque is

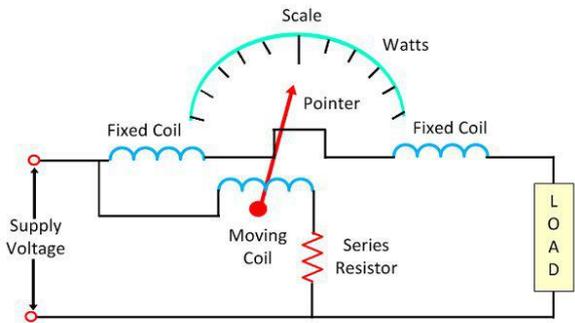$$T_d \propto i_f i_m \propto \frac{Vi}{R}$$

Since R is constant

$$T_d \propto Vi$$

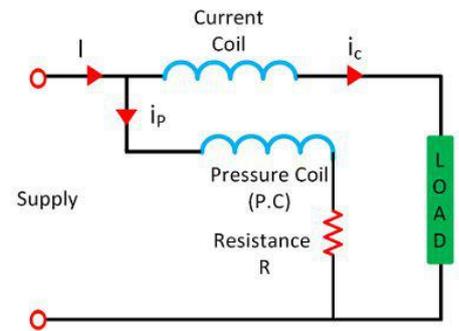Deflecting torque is thus proportional to power.

AC Input

The expression for instantaneous torque in AC is given by

$$T_i = i_1 i_2 \frac{dM}{d\theta}$$

Electrodynameter Wattmeter
Circuit Globe

Circuit of Electrodynamo Wattmeter
Circuit Globe

$$T_i = i_p i_c \frac{dM}{d\theta} \qquad\qquad (i)$$

Let the supply voltage is

$$v = \sqrt{2}\, V \sin \omega t$$

Let us assume that pressure coil has very high resistance and hence it is treated as a purely resistance. So,

$$i_p = \frac{v}{R} = \frac{\sqrt{2}\, V \sin \omega t}{R} = \sqrt{2}\, I_p \sin \omega t$$

Where

$$I_p = \frac{V}{R}$$

Since the current coil is inductive, let us assume that i_c will lag supply voltage v by some angle φ. So let

$$i_c = \sqrt{2}\ I \sin (\omega t - \varphi)$$

Substituting in equation (i) we get

$$T_i = (\sqrt{2}\ I_p \sin \omega t)(\sqrt{2}\ I \sin (\omega t - \varphi))\frac{dM}{d\theta}$$

$$= 2I_p I \sin \omega t \sin (\omega t - \varphi)\frac{dM}{d\theta}$$

$$= I_p I\ [\cos \varphi - \cos (2\omega t - \varphi)\frac{dM}{d\theta}$$

The average deflecting torque will be

$$T_d(average) = \frac{1}{T}\int [I_p I\ [\cos \varphi - \cos (2\omega t - \varphi)\frac{dM}{d\theta}]\ d\omega t$$

$$= I_p I \cos \varphi\ \frac{dM}{d\theta}$$

$$= \frac{V}{R}I \cos \varphi\ \frac{dM}{d\theta}$$

$$= \frac{P}{R}\frac{dM}{d\theta}$$

$$T_d(average)\alpha\ P$$

Errors in dynamometer type wattmeters

1. *Pressure coil inductance*

In an ideal dynamo-meter type watt meter the current in pressure coil in phase with the applied voltage . But in practically the pressure coil of watt meter has an inductance and current in it will lag behind the applied voltage . If there is no inductance the current in pressure coil will be in phase with the applied voltage . In the absence of inductance in pressure coil of wattmeter , it will read correctly in all power factors and frequency .

The wattmeter will read high when the load power factor is lagging ,as in that case the effect of pressure coil inductance is to reduce the phase angle between load current and pressure coil current . Hence the wattmeter will read high . This is very serious error.

The wattmeter will read low when the load power factor is leading as in that case the effect of pressure coil inductance is to increase the phase angle between load current and pressure coil current .Hence the wattmeter will read low.

2. *Pressure coil capacitance.*

The pressure coil circuit may have capacitance in addition with inductance.This capacitance mainly due to the inter turn capacitance of the series resistance.The effect of capacitance is opposite to that due to inductance.Therefore the wattmeter will read high when the load power factor is leading.

The inductance in pressure coil circuit will always more than inductance,hence the error caused by capacitance will be nullified by that due to inductance.

3.Error due to mutual inductance.

Errors may occurred due to the mutual inductance between the current and pressure coils of the watt meter.These errors are quite low at power frequencies.But they increased with increase in frequencies.

The effect of mutual inductance can be avoid by arranging the coil system in such a way that they have no mutual inductance.So we can eliminate the errors due to mutual inductance.The Drysdale Torsion head wattmeter is an example for such type.

4.Eddy Current errors.

Eddy currents are induced in the solid metal parts and within the thick conductors by the alternating magnetic field produced by the current coil.This eddy current produce their own magnetic field and it will alter that produced by the main current in the current coil and thus error occurred.

This error can be minimized by avoiding solid metal parts as much as possible and by using stranded conductors for high current applications.

5.Stray Magnetic field Errors.

The electrodynamometer type wattmeters has a weak operating field and therefore it effected by stray magnetic fields it will resulting in serious errors. Hence these instruments should be shielded against stray magnetic field.

6.Errors caused by vibration of moving system.

The torque on the moving system varies with frequency which is twice that of voltage.If the parts of the moving system has a natural frequency which is resonance with the frequency of torque pulsation,the moving system would vibrate with a considerable amplitude.These vibrations will cause errors.This error can be reduced by design.

7.Temperature Error.

The change in room temperature may affect the indication of wattmeter. This is because of change in temperature will change in resistance of pressure coil and stiffness of springs which provide controlling torque.This effect are opposite in nature and cancel each other.The use of material of having negligible temperature coefficient of resistance will reduce change in resistance the pressure coil with change in temperature.

8. Error due to the wattmeter connection.

For the measurement of power the wattmeter can be connected in two different ways, shown in Fig.12.15 (a) and Fig.12.15 (b).
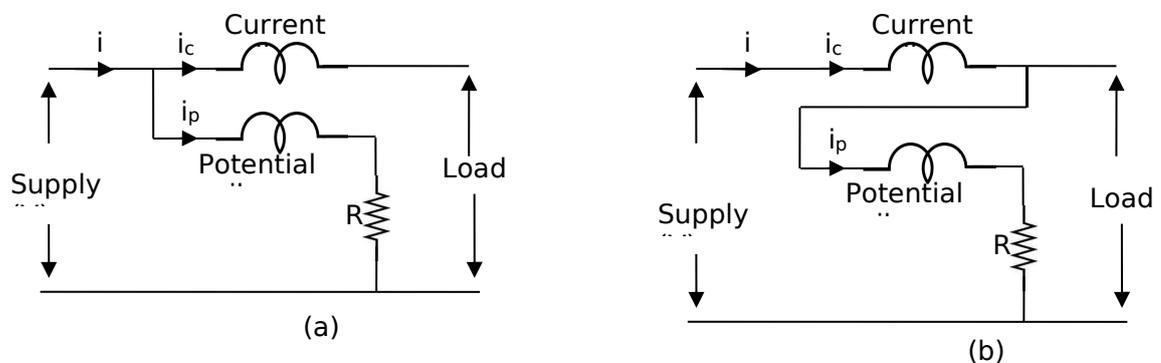

(a)   (b)

Fig.12.15: Different wattmeter

In the wattmeter connection shown in Fig.12.15 (a), the potential coil is connected in parallel to the supply. So the voltage across the pressure coil will be more than the voltage across the load. So the wattmeter reading will be,

Reading of the wattmeter
= Power consumed by the load
+ power loss in the current coil

In the wattmeter connection shown in Fig.12.15 (b), the potential coil is connected in parallel to the load. So the current through the current coil will be more than the load current. So the wattmeter reading will be,

Reading of the wattmeter
= Power consumed by the load
+ power loss in the pressure coil

If the load current is small and the voltage drop in the current coil is small, then the wattmeter connection shown in Fig. 12.15 (a) is preferred. If the load current is large

and the pressure coil current is small compared to the load current, then the wattmeter connection shown in Fig. 12.15 (b) is preferred.

Advantages and Disadvantages of Dynamometer Type Wattmeter

Some of the advantages and disadvantages of dynamometer type wattmeter are

Advantages

These instruments can be used on both A.C. and D.C measurement.

In dynamometer type wattmeter, the scale of the instrument is uniform in both DC as well as AC and the instrument is spring controlled.

High degree of accuracy can be obtained by careful design; hence these are used for calibration purposes.

They are also used as a transfer instruments.

Free from hysteresis errors.

Low power Consumption.

Light in weight.

Disadvantages

The error due to the inductance of the pressure coil at low power factor is very serious

In dynamometer type wattmeter, stray field may affect the reading of the instrument.

These instruments have a low sensitivity due to a low torque to weight ratio.

It introduces increased frictional losses.

They are more expensive than other type of instruments.

These instruments are sensitive to overload and mechanical impacts.