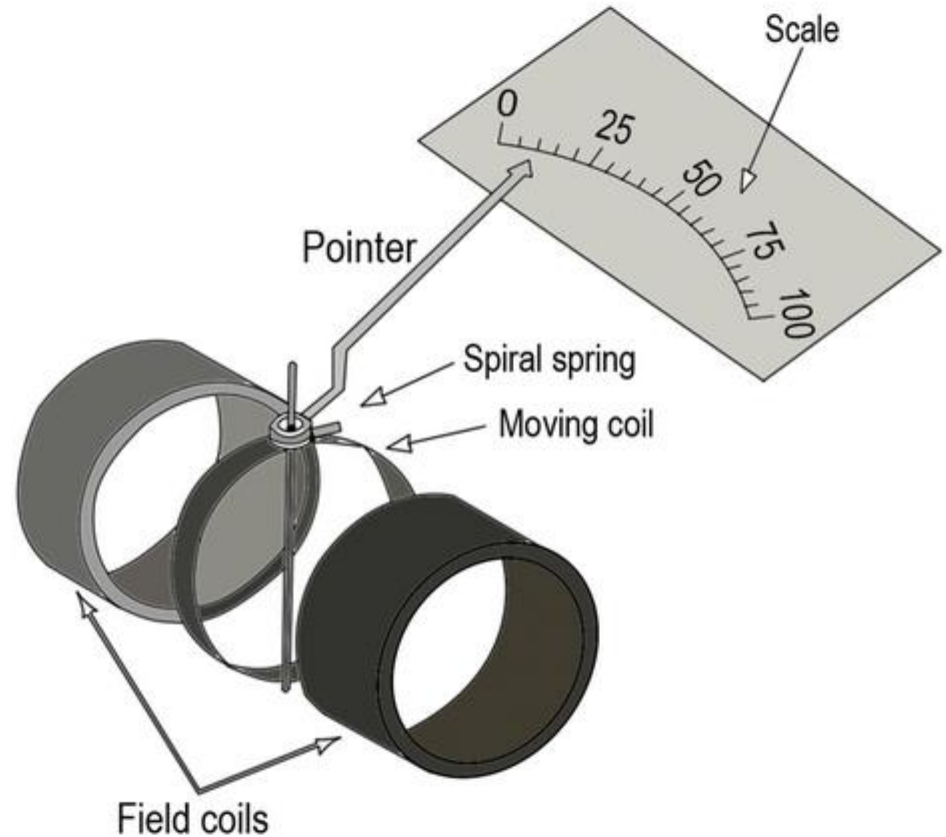
Dynamometer

- This instrument is suitable for the measurement of direct and alternating current, voltage and power.
- The deflecting torque in dynamometer is relies by the interaction of magnetic field produced by a pair of fixed air cored coils and a third air cored coil capable of angular movement and suspended within the fixed coil.

Dynamometer

The electrodynamometer wattmeter has a fixed coil divided into two parts and is connected in series with the load and caries the load current (I1). The moving coil is connected across the load through a series multiplier resistance (R) and carries a current (I2) proportional to the load voltage. The fixed coil is called as Current Coil and the moving coil is called as Potential Coil.

The controlling torque is provided by two spiral springs. Air friction damping is provided in electrodynamometer wattmeter. A pointer is attached with the moving coil.



Dynamometer

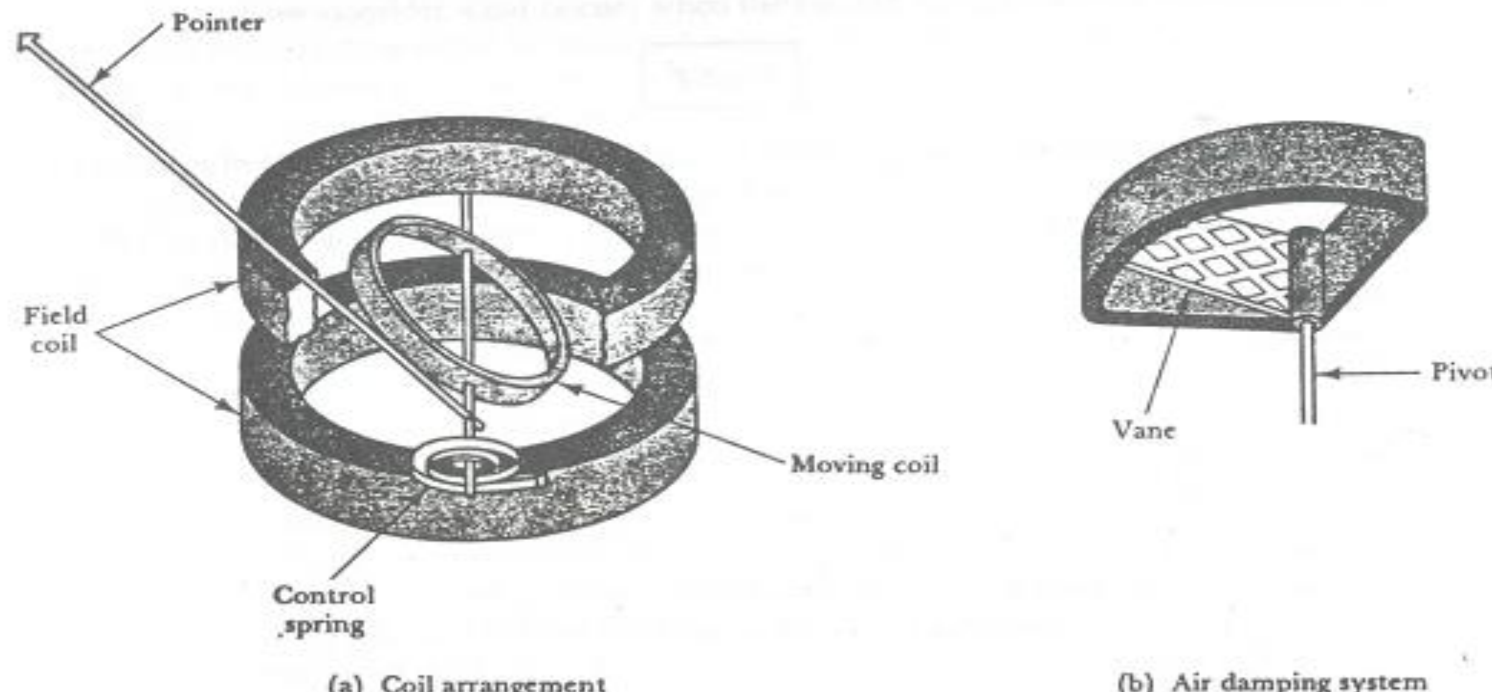


Figure 3-26 An electrodynamic instrument has a moving coil, as in a PMMC instrument, but the magnetic field is produced by two current-carrying field coils instead of a magnet. Damping is provided by an enclosed vane.

Another major difference from the PMMC instrument is that the electrodynamic instrument usualy has air damping. A lightweight vane pushes air around in an enclosure when the pivoted coil is in motion [see Figure 3-26(b)]. This damps out all rapid movements and oscillations of the moving system. As will be explained, electrodynamic instruments can be used on ac. The alternating current would induce unwanted eddy currents in a metallic coil former. Therefore, the damping method employed in a PMMC instrument would not be suitable for an electrodynamic instrument.

Normally, there is no iron core in an electrodynamic instrument, so the flux path is entirely an air path. Consequently, the field flux is much smaller than in a PMMC instrument. To produce a strong enough deflecting torque, the moving-coil current must be much larger than the small currents required in a PMMC instrument.

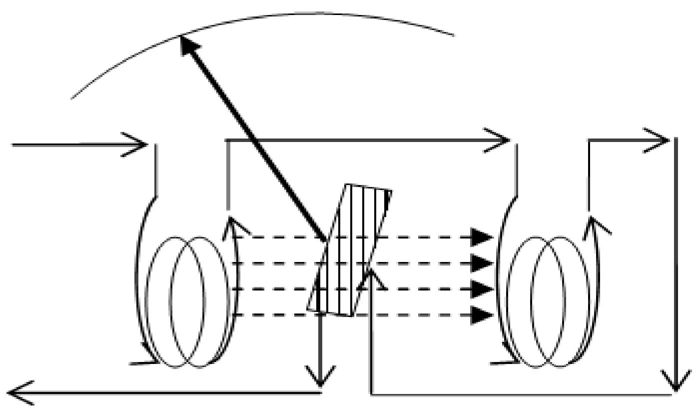
As in the case of the PMMC instrument, the deflecting torque of an electrodynamic instrument is dependent on field flux, coil current, coil dimensions, and number of coil turns. However, the field flux is directly proportional to the current through the field coils, and the moving-coil flux is directly proportional to the current through the moving coil. Consequently, the deflecting torque is proportional to the product of the two currents:

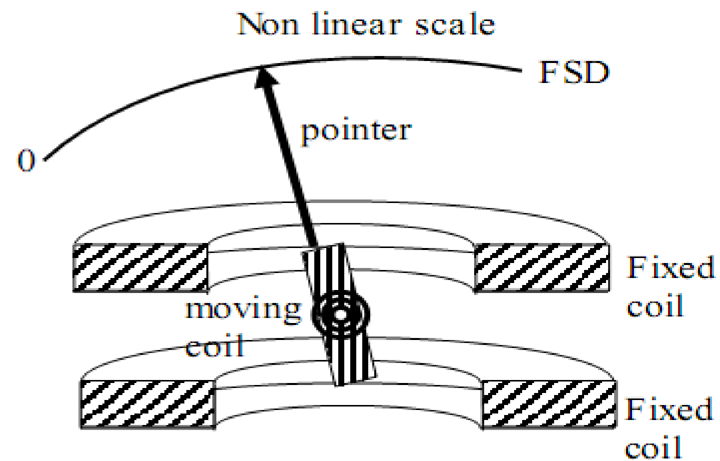
$$T_D \propto I_{\text{field coil}} I_{\text{moving coil}}$$

When the same current flows through field coils and pivoted coil, the deflecting torque is proportional to the square of the current:

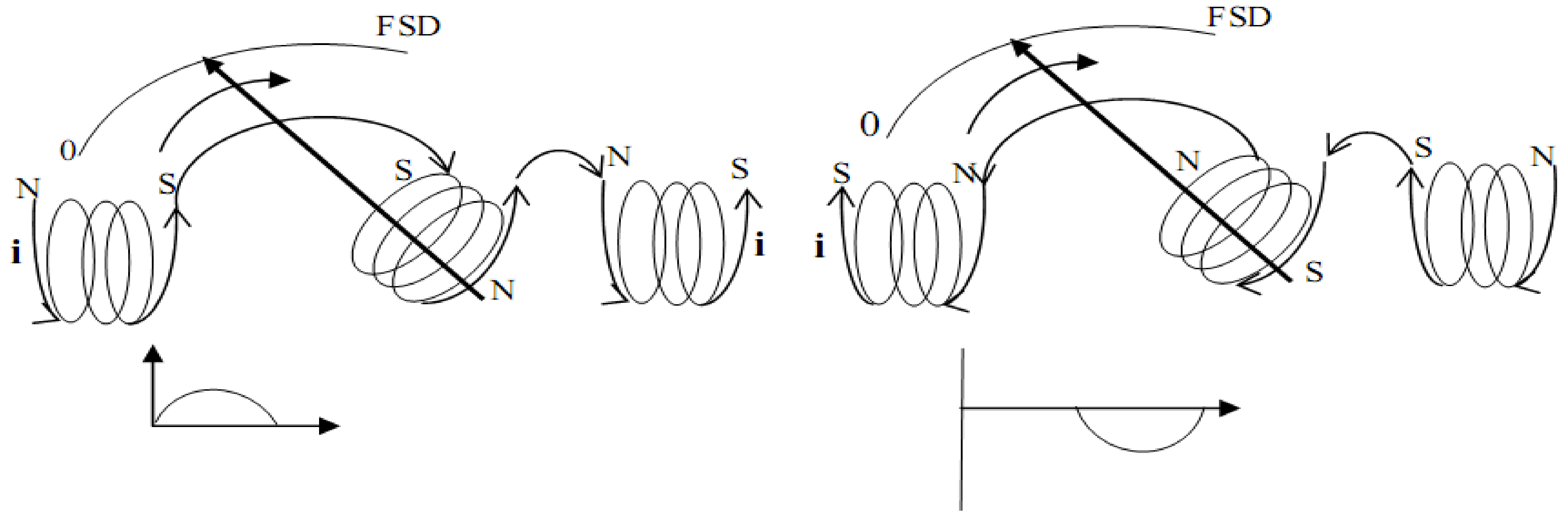
$$T_D \propto I^2$$

Dynamometer





Dynamometer



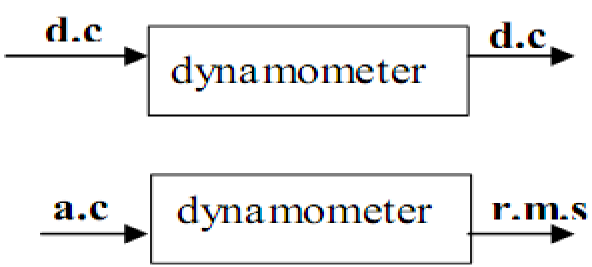
$T_i = N\vec{B}i_m A$, $\vec{B} \alpha i_f$ thus $T_i \alpha i_m i_f A \Rightarrow\Rightarrow$ so $T_i \alpha i^2$

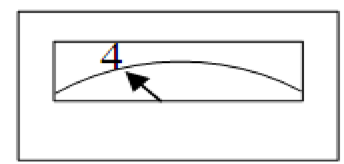
$\theta \alpha$ average i^2 , since $r.m.s = \sqrt{\text{average} f(t)^2}$

Dynamometer

The output scale is calibrated to give the r.m.s value of a.c signal by taking the square roots of the inside measured value.

O/P scale $= r.m.s = \sqrt{average(i)^2}$, for example if (average i^2) = 16 inside the measuring device, the output scale of the device will indicate (4)



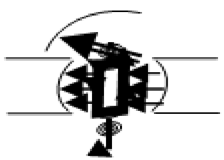


$$r.m.s = \sqrt{\frac{1}{T}\int_0^T f(t)^2 dt}$$

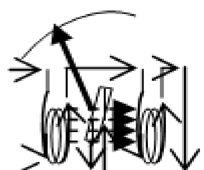
Meters

Meters

- d.c meters
  measure d.c or Av values
  - PMMC

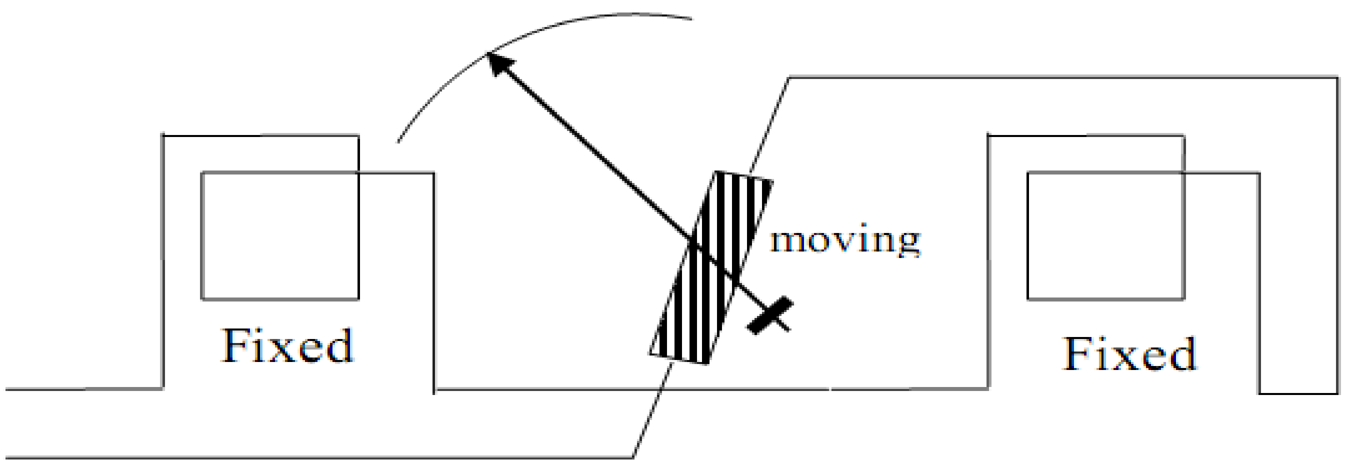
    T α i
    B constant
    linear scale
    θα i
  - dynamometer

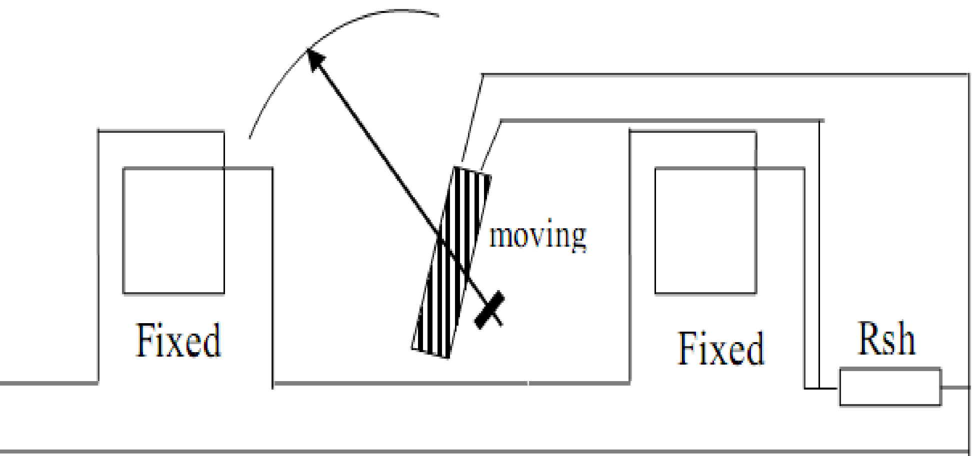
    T α i^2
    B varied
    non linear
    scale
    θα average i^2
- a.c meters
  measure r.m.s values
  - Average Responding
    a.c meter
    ⇓
    Rectifier + PMMC
  - True Responding
    a.c meter
    ⇓
    dynamometer

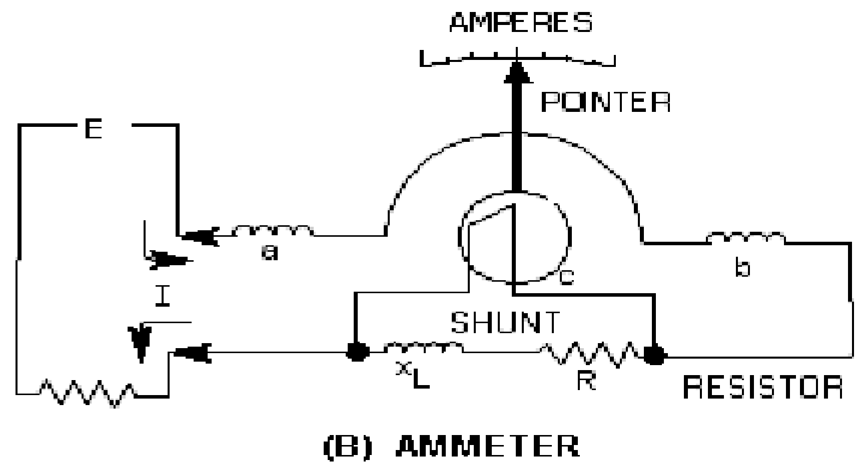
Dynamometer as Ammeter and Voltmeter

For small current measurement (5mA to 100mA), fixed and moving coils are connect in series.



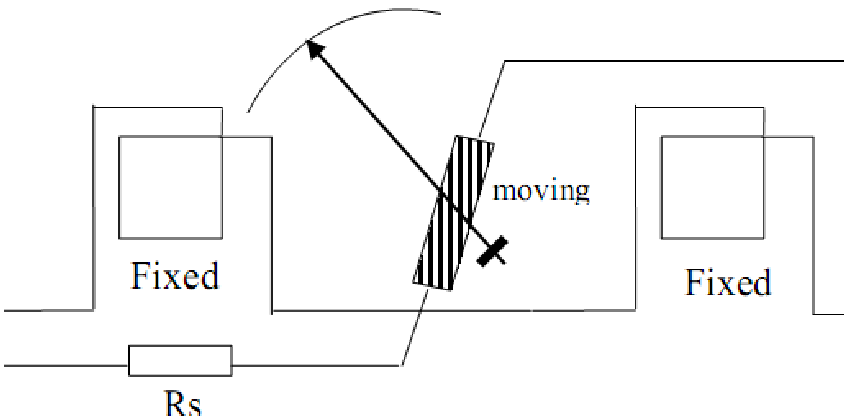
Dynamometer as Ammeter

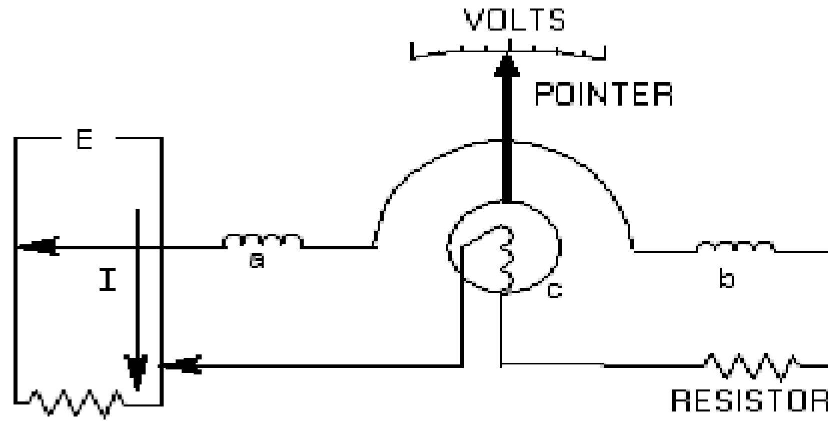




While larger current measurement (up to 20A) , the moving coil is shunted by a small resistance.

Dynamometer as Voltmeter





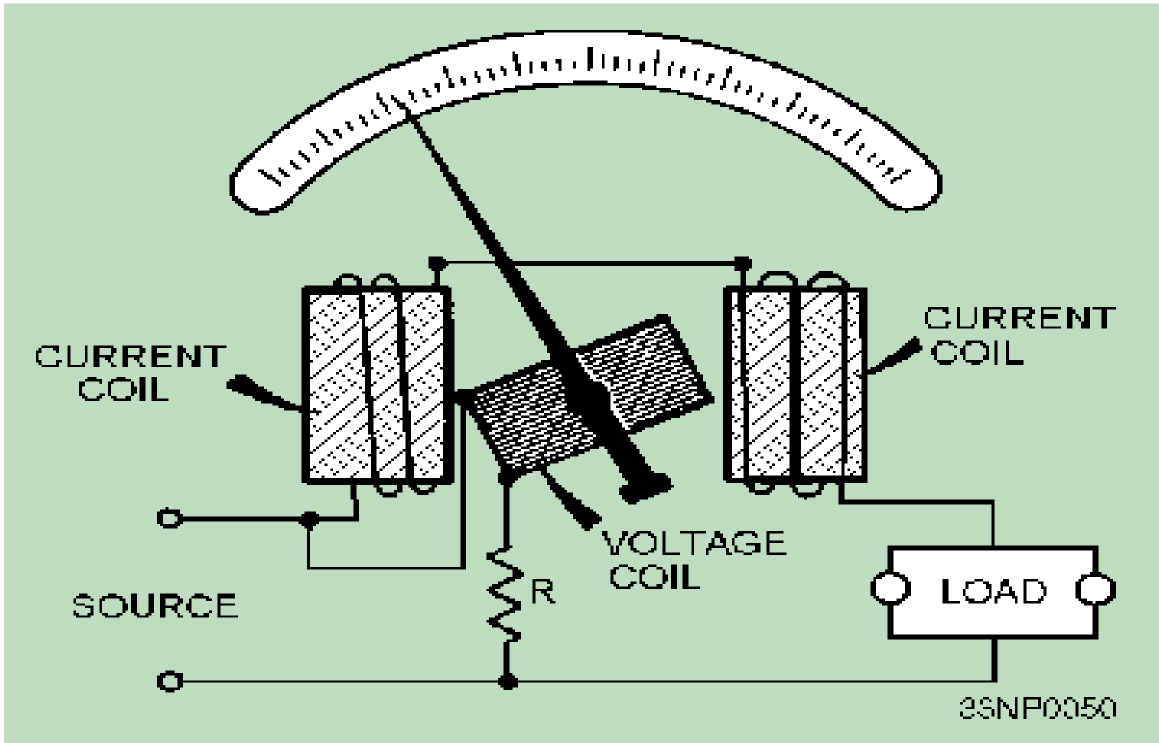
(A) VOLTMETER

To convert such an instrument to a voltmeter only a rather big series resistance is connected with the moving coil.

Electrodynamic Wattmeter

- The traditional analog wattmeter is an electrodynamic instrument. The device consists of a pair of fixed coils, known as *current coils*, and a movable coil known as the *potential coil*.
- The current coils connected in series with the circuit, while the potential coil is connected in parallel. Also, on analog wattmeters, the potential coil carries a needle that moves over a scale to indicate the measurement.
- A current flowing through the current coil generates an electromagnetic field around the coil. The strength of this field is proportional to the line current and in phase with it. The potential coil has, as a general rule, a high-value resistor connected in series with it to reduce the current that flows through it.
- The result of this arrangement is that on a dc circuit, the deflection of the needle is proportional to *both* the current *and* the voltage, thus conforming to the equation W=VA or $P=VI$.

Electrodynamic Wattmeter



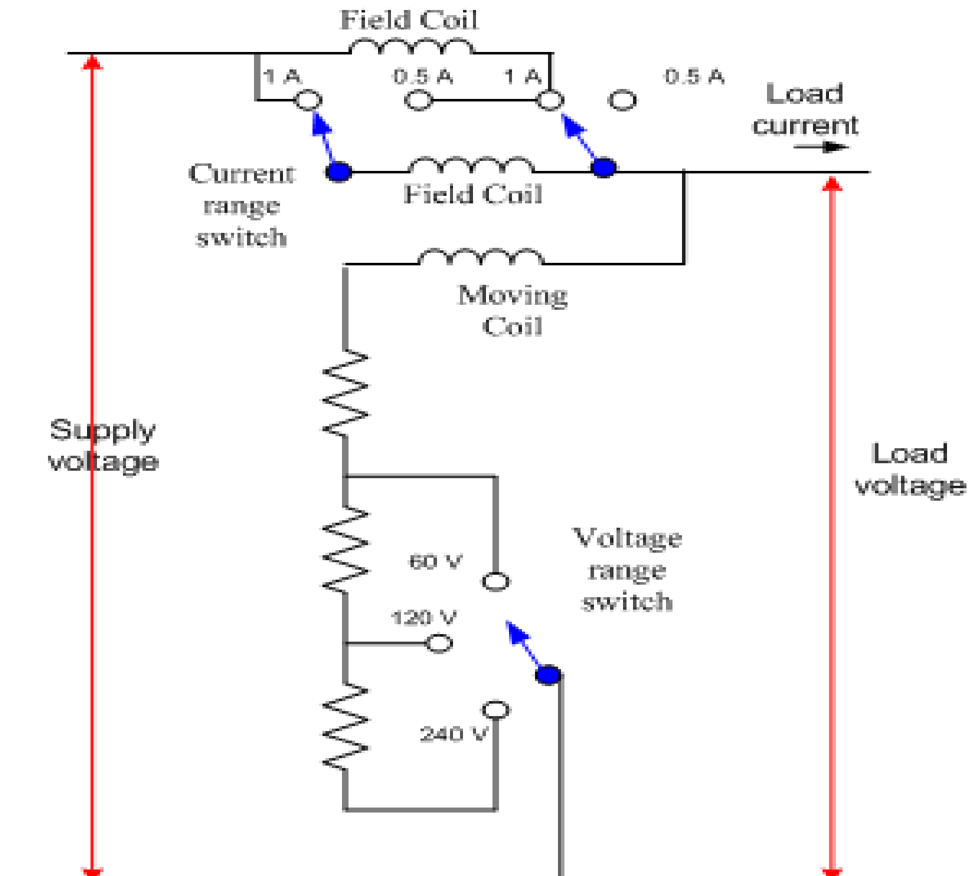
Electrodynamic Wattmeter

- The electrodynamic wattmeter is used to measure power taken from ac or dc power sources.
- The electrodynamic wattmeter, shown in figure 3-10, uses the reaction between the magnetic fields of two current-carrying coils (or sets of coils), one fixed and the other movable.
- When the current through the fixed-position field winding(s) is the same as current through the load and the current through the moving coil is proportional to the load voltage, then the instantaneous pointer deflection is proportional to the instantaneous power.
- The dynamometer-type wattmeter automatically compensates for the power factor error of the circuit under test. It indicates only the instantaneous power resulting from in-phase values of current and voltage. With out-of-phase relationships, a current peak through the moving coil never occurs at the same instant as the voltage peak across the load, resulting in less pointer deflection than when the current and voltage are in phase.

Electrodynamic Wattmeter

- When the load is disconnected, this meter will still indicate that power is being consumed in the circuit. This difficulty can be eliminated by incorporating two compensating windings, mounted with the primary fixed-coil current windings, as shown in figure 3-11.
- These stationary windings are used to produce a magnetic flux proportional to the current through the movable coil. As shown by the arrows, the currents through the primary movable coil and the compensating coil flow in opposite directions, producing a torque caused by the opposing magnetic fields.
- These opposing fields cancel. Hence, with the load removed from the circuit, the meter will indicate zero power through the load.

Multi-range Wattmeter



The electrodynamometer wattmeter

The wattmeter is an instrument for measuring the electric power (or the supply rate of electrical energy) in watts of any given circuit.

An instrument which measures electrical energy in watt hours (electricity meter or energy analyzer) is essentially a wattmeter which accumulates or averages readings.

The electrodynamometer wattmeter is used for the measurement of the power. The construction of the electrodynamometer wattmeter will be most similar to the construction of the electrodynamometer ammeter and voltmeter. They are two types of coils used. They are fixed coils or field coils and moving coil or voltage coils.

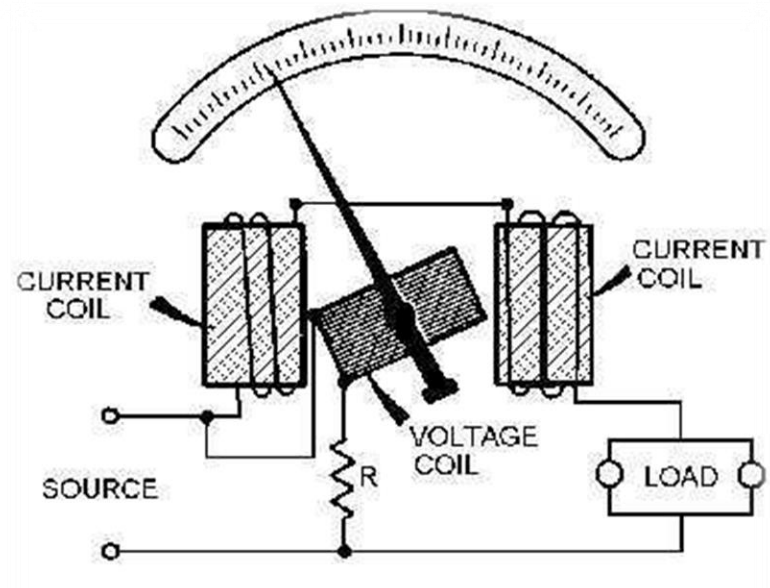


Fig.1 Simplified Circuit Diagram

They are two types of coils used. They are fixed coils or field coils and moving coil or voltage coils.

The fixed coils are connected in the series to the load and it is wound with the thick wire. This fixed coil carries the current of the load. The moving coils are connected parallel to the load or across the voltage.

This moving coil is mounted on the spindle and the spring control is used for the movement. The current of the moving coil is carried by the control springs. Hence the current through it should be controlled and limited such that it is carried safely.

The current flow can also be limited by connecting a non inductive resistance type resistor in the voltage circuit. Since the given potential is highly used by the connected resistor and for obtaining a higher range of output, the pressure coil circuit should be designed accordingly and the transformer should be used for the step down process.

The shunts should not be used for increasing the current range since because they are subjected to the temperature errors. To avoid the reading errors the mirror typed scales are to be used and a knife edged pointer is fixed to obtain an accurate reading and avoid the parallax error.

Electro-dynamic type instruments are similar to the PMMC-type elements except that the magnet is replaced by two serially connected fixed coils that produce the magnetic field when energized (Fig.2).

The fixed coils are spaced far enough apart to allow passage of the shaft of the movable coil. The movable coil carries a pointer, which is balanced by counter weights. Its rotation is controlled by springs. The motor torque is proportional to the product of the currents in the moving and fixed coils.

If the current is reversed, the field polarity and the polarity of the moving coil reverse at the same time, and the turning force continues in the original direction.

Since the reversing the current direction does not reverse the turning force,

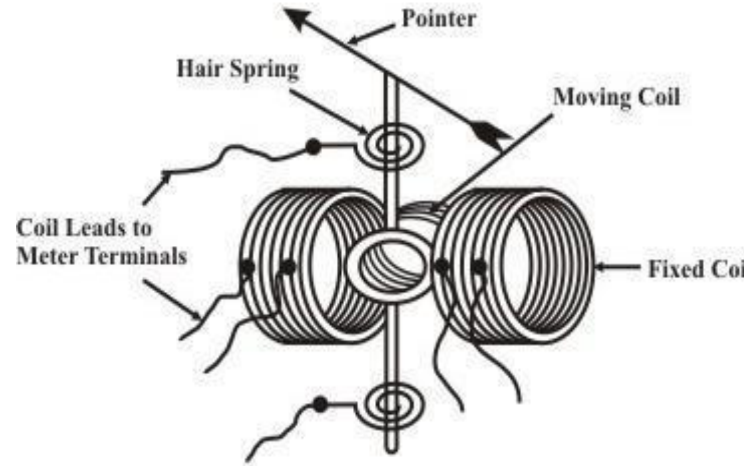


Fig. 2

this type of instruments can be used to measure AC or DC current, voltage, or its major application as a wattmeter for power measurement. In the first two cases, the moving and fixed are serially connected.

For power measurement, one of the coils (usually the fixed coils) passes the load current and other coil passes a current proportional to the load voltage. Air friction damping is employed for these instruments and is provided by a pair of Aluminum-vanes attached to the spindle at the bottom. These vanes move in a sector shaped chamber. Cost and performance compared with the other types of instruments restrict the use of this design to AC or DC power measurement.

Electro-dynamic meters are typically expensive but have the advantage of being more accurate than moving coil and moving iron instrument but its sensitivity is low. Similar to moving iron vane instruments, the electro dynamic instruments are true RMS responding meters.

When electro dynamic instruments used for power measurement its scale is linear because it predicts the average power delivered to the load and it is calibrated in average values for AC. Voltage, current and power can all be measured if the fixed and moving coils are connected appropriately.

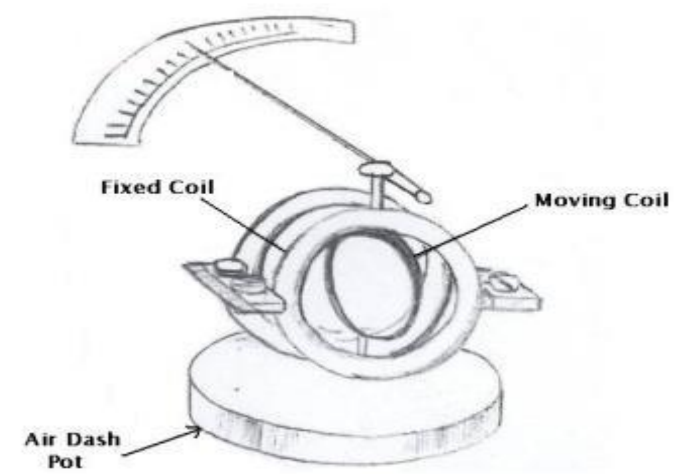


Fig.3 Dynamometer type Wattmeter

Fig.4 Analog Wattmeter

Fig. 5 Digital Wattmeter

Operation Principle

The working principle of a basic electrodynamometer instrument is same as the PMMC instrument. The only difference in this case is that the permanent magnet is replaced with two fixed coils connected in series. The moving coil is also connected in series with the fixed coils. The two fixed coils are connected to electromagnets in such a manner that they form poles of opposite polarity.

As the moving coil carries current through it and is being placed in the field of fixed coils, it experience a force due to which the moving coil rotates. The direction of this force is independent of the supply voltage as the current flowing through fixed coils and moving coil is one and the same. If the direction of current changes in the moving coil, then the field direction also changes, thus making the torque unidirectional.

Deflecting Torque:-

If the coil is carrying a current of , the force on a coil side = B×i×l×N ...(Newton)

∴Torque due to both coil sides =2rBilN ...Nm ...(1)

= G×i ...Nm

where is the Galvanometer constant.

[Note A= area of the coil (2rl)

N= no. of turns of the coil.

B = flux density (in Wb/ m^2)

l = length of the vertical side of the coil (in m).

2r= breadth of the coil (in m)

i= current (in ampere).

2Ar= area (in m^2)]

Truly speaking, the equation (1) is valid while the iron core is cylindrical and the air gap between the coil and pole faces of the permanent magnet is uniform. This result the flux density (B) is constant and the torque is proportional to the coil current and instrument scale is linear.

Advantages And Disadvantages Of Electro-dynamo Type Wattmeter

Advantages: -

- *The scale is uniformly divided.*
- *The power consumption can be made very low.*
- *The torque-weight ratio can be made high with a view to achieve high accuracy.*
- *A single instrument can be used for multi range ammeters and voltmeters.*
- *Error due to stray magnetic field is very small.*
- *Free from hysteresis and eddy current errors.*
- *Applicable to both dc and ac circuits.*
- *Precision grade accuracy for 40 Hz to 500 Hz.*

Disadvantages (Limitations):-

- *The instrument cost is high.*
- *Variation of magnet strength with time.*
- *Power consumption higher than PMMC but less than MI instruments*

Error in Electrodynamometer

The Errors are due to:-

1. Temperature error

2. Thermo electric error

3. Frictional error

4. Magnetic decay

Errors can be reduced by following the steps given below:-

1. ***Use of manganin resistance in series (swamping resistance) can nullify the effect of variation of resistance of the instrument circuit due to temperature variation.***
2. ***The stiffness of spring, permeability of magnetic core (Magnetic core is the core of electromagnet or inductor which is typically made by winding a coil of wire around a ferromagnetic material) decreases with increases in temperature.***
3. ***Proper pivoting and balancing weight may reduce the frictional error.***
4. ***Suitable aging can reduce the magnetic decay.***

1) Electro-Dynamometer As Ammeter

When ammeters for ranges above about 250mA , the moving coil cannot be connected in series with the fixed coil (note the control spring is unsuitable for currents above about 250mA). Therefore, the moving coil must be connected in parallel with the fixed coils as shown in Fig.6

Here the moving coil current is kept within 200 mA and the rest of current is passed through the fixed coil. Moving coil carries a small fraction of measured current through the moving coil.

For extreme accuracy the connection shown in Fig. 6 must fulfill the following conditions.

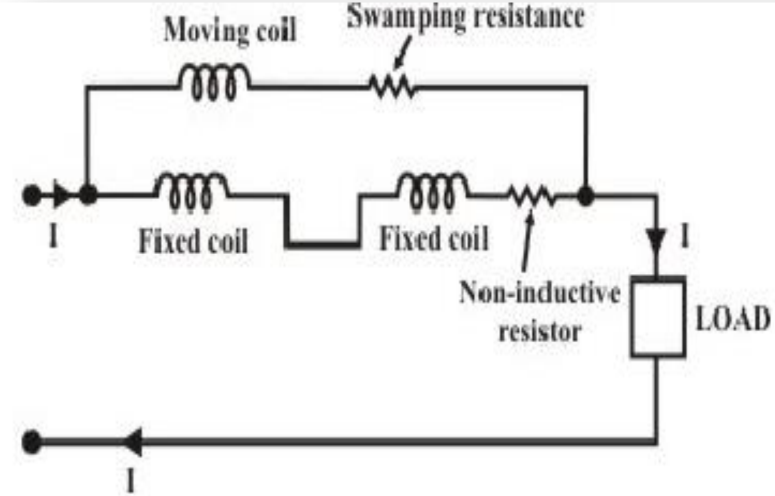


Fig.6: Electro dynamic Ammeter (above 250mA) connection

- *The resistance/reactance ratio must have the same value (i.e time constant of moving coil = time constant of fixed coil) for each branch.*

- *The percentage change of resistance with temperature must be the same for the two braches.*

2) Electro-Dynamometer As Voltmeter

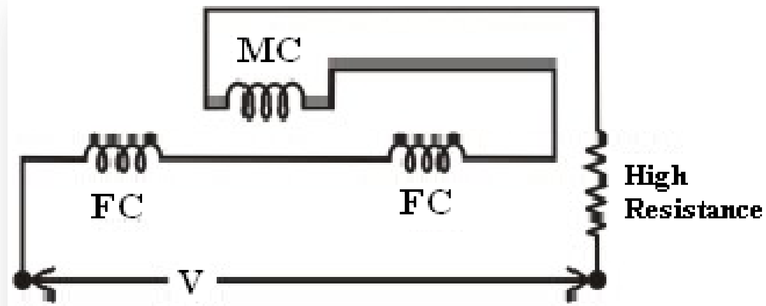


Fig.7 Electro-dynamic Volmeter Connection

The connection for use as a voltmeter is shown in Fig.7, in which fixed and moving coils are connected in series with a high series resistance having "zero resistivity coefficients".

This combination is connected across the voltage source or across the load terminal whose voltage is to be measured.

Electro-dynamic meter's use is much more common for ac voltmeters than for ac ammeters because of practical limitation on the current through the moving coil. Electro-dynamic ammeter needs to read r.m.s. values of alternating current accurately irrespective of signal waveform of distortion of signal waveform.

3) Electro-Dynamometer As Wattmeter

Perhaps the most important use of the electrodynamometer is for the wattmeter. The mechanism of electro dynamic wattmeter closely resembles that of an electro-dynamic ammeter, but the moving coil of wattmeter is connected in series with a high non–inductive resistance. It provides with separate terminals to connect across the load terminals.

The fixed coil is connected is series with the load to have the same load current. A typical connecti9on of an electrodynamometer for use as a wattmeter is shown in Fig. 8

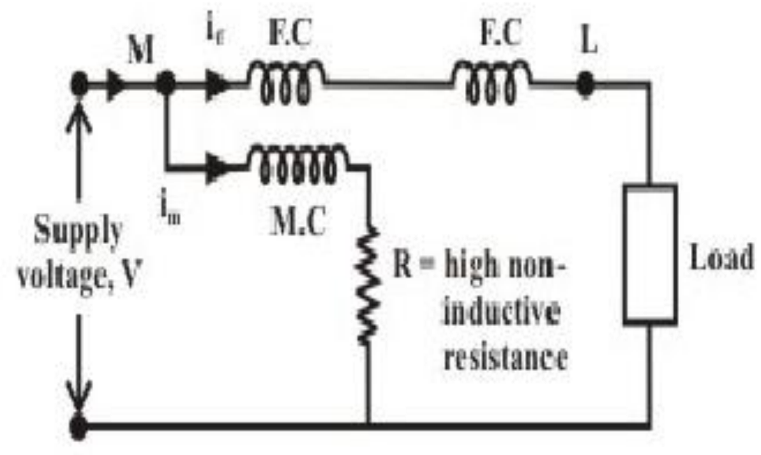


Fig.8 : Wattmeter Connection


THANK YOU