# Induction Type watthour meter:-

OR

## Energy Meter:-

"An instrument which measures electrical energy is called an energy meter or watt hour meter"

Since electrical energy consumed by a load adds up as the time goes on (watt-hour = watts × hours), it is evident that watthour meter is an integrating type instrument.

→ It should be noted that the energy meters designed for DC circuits can be used on AC circuits but the reverse is not true.

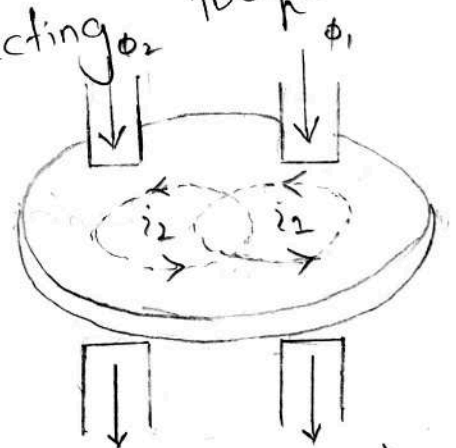
## Principle of Induction:-

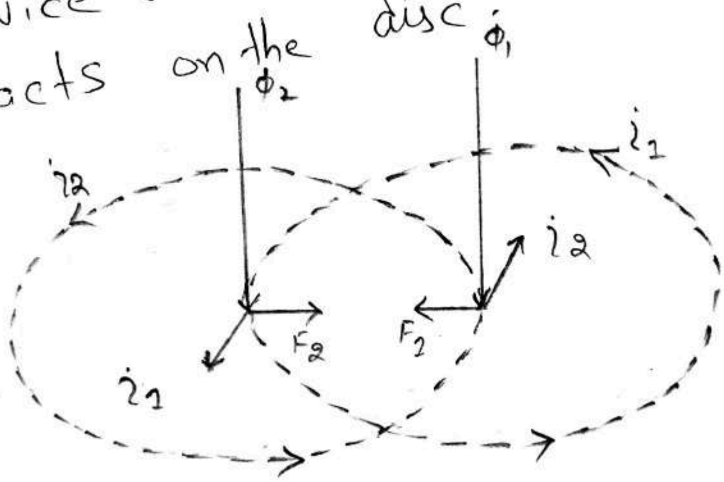

The above fig. shows the working principle of induction type energy meters.

→ Two alternating fluxes $\phi_1$ and $\phi_2$ (whose magnitude depends upon the current) having a phase diffence ($\Theta$) pass though a metallic disc, usually of copper or alluminium.

→ These alternating fluxes induce eddy currents in the disc.

→ The current produced by one flux reacts with the other flux and vice versa, to produce the deflecting torque that acts on the disc.




From the above phasor diagram, the fluxes produced by the two currents may be represented as:-

$$\phi_1 = \phi_{1m} \sin \omega t$$

$$\phi_2 = \phi_{2m} \sin(\omega t + \Theta)$$

Where $\Theta$ is the phase angle by which $\phi_2$ leads $\phi_1$.

The two fluxes $\phi_1$ and $\phi_2$ will induce emf's $e_1$ and $e_2$ respectively in the disc. Assuming $r$ to be the resistance offered by the disc to each induced emf, the induced currents are given by:-

$$i_1 = \frac{e_1}{r} = \frac{d\phi_1/dt}{r} = \frac{1}{r}\frac{d}{dt}(\phi_{1m}\sin\omega t)$$

$$i_1 = \frac{\omega\,\phi_{1m}\cos\omega t}{r}$$

as $r$ and $\omega$ are constant

$\therefore\ i_1 \propto \phi_{1m}\cos\omega t$

Similarly $i_2 \propto \phi_{2m}\cos(\omega t+\theta)$

As $F_1 \propto \phi_1 i_2$ & $F_2 \propto \phi_2 i_1$

$\therefore$ Resultant force $F \propto F_2 - F_1$

$$F \propto (\phi_2 i_1 - \phi_1 i_2)$$

$$F \propto \phi_{1m}\phi_{2m}\left[\sin(\omega t+\theta)\cos\omega t - \sin\omega t\cos(\omega t+\theta)\right]$$

$$F \propto \phi_{1m}\phi_{2m}\sin(\omega t+\theta-\omega t)$$

$$F \propto \phi_{1m}\phi_{2m}\sin\theta$$

The resultant force F will produce the deflecting torque ($T_d$) which is directly proportional to it.

$$\therefore\ \boxed{T_d \propto \phi_{1m}\phi_{2m}\sin\theta}$$

$$\left\{ \sin(\alpha-\beta) = \sin\alpha\cos\beta - \cos\alpha\sin\beta \right\}$$

→ It should be noted that when $\theta = 0°$ (i.e the two fluxes are in phase), then deflecting torque is zero.

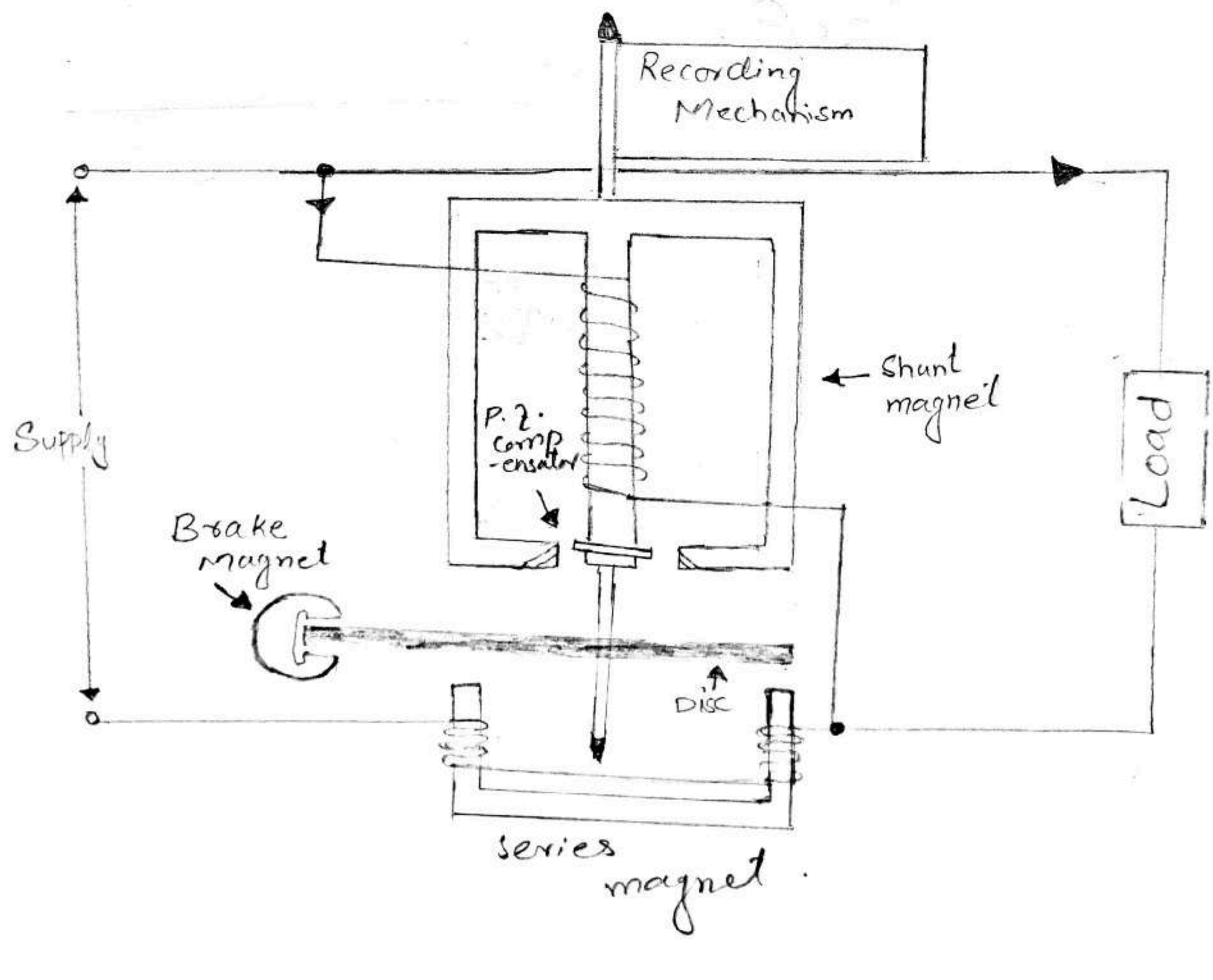
→ The deflecting torque will be maximum when $\theta = 90°$ i.e when the alternating fluxes have a phase difference of 90°.

→ The deflecting torque is the same at every instant since $\phi_{1m}$, $\phi_{2m}$ and $\theta$ are fixed for a given condition.

→ The direction of deflecting torque depends upon which flux is leading the other.

Construction:-

The below figure shows the construction of a single phase induction type energy meter.



(1):- It consists of (a) two ac electromagnets; the series magnet and Shunt magnet. (b) an alluminium disc or rotor placed between the two electromagnets (c) brake magnet and (d) counting mechanism.

(2):- The shunt magnet is wound with a wire of many turns as is connected across the supply so that it carries current proportional to the supply voltage. Due to the large number of turns, the coil of Shunt magnet is highly inductive. Hence the current (and the flux) passing through it lags the supply voltage by 90°.

The Series magnet is wound with a wire of few turns as is connected in series with the load so that it carries the load current. The coil of this magnet is highly non-inductive.

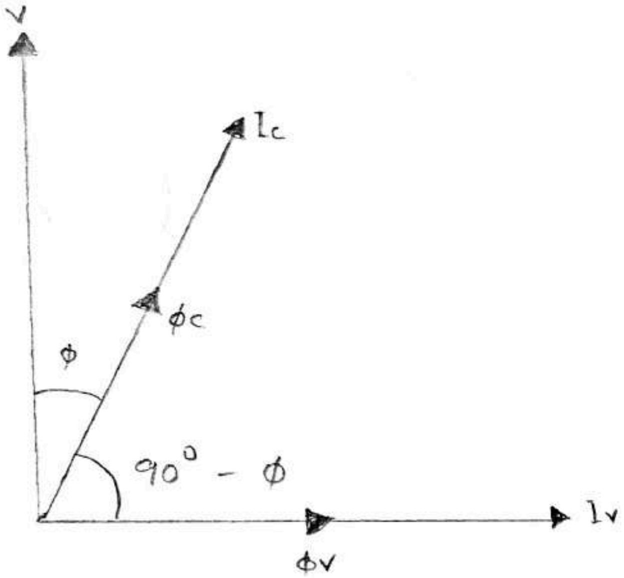
3):- A Thin alluminium disc mounted on the spindle is placed between the Shunt and Series magnets so that it cuts the fluxes of both the magnets.

<u>Working</u>:-

→ when the energy meter is connected in the circuit to measure energy, the shunt magnet carries current proportional to the supply voltage.

→ The series magnet carries the load current.
→ The two fluxes produced by the magnets, induce eddy currents in the alluminium disc.
→ The interaction between the fluxes and eddy currents produces the deflecting torque on the disc causing the disc to rotate.

## Phasor Diagram :-




Here V = Supply voltage
Iv = current carried by the shunt magnet
Ic = current carried by series magnet (= load current I)
ϕ = angle b/w supply voltage and Ic.

→ from the above phasor diagram, we can see that the current Iv) in the shunt magnet lags the supply voltage (v) by 90° and so does the flux ($\phi_v$) produced by it
→ The current (Ic) in the series magnet is the load current and hence lags behind the supply voltage (v) by ϕ. The flux ($\phi_c$) produced by this current (i.e Ic) is in phase with it.

It is clear that phase angle $\theta$ b/w the two fluxes is $(90^\circ - \phi)$ i.e

$$\theta = 90^\circ - \phi$$

$\therefore$ deflecting torque $T_d \propto \phi_v \phi_c \sin\theta$

$$T_d \propto V I \sin(90 - \phi)$$

$$[\because \phi_v \propto V \ \ \& \ \phi_c \propto I)$$

$$T_d \propto VI \left[\sin 90 \cos\phi - \cos 90 \sin\phi\right]$$

$$T_d \propto VI \left[(1)\cos\phi - 0\right]$$

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

or $T_d \propto$ AC power.

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

Braking mechanism:-

→ The braking torque ($T_B$) is provided by placing a permanent magnet near the rotating disc so that the disc rotates in the field established by the permanent magnet.

→ The eddy currents induced in the disc produces a braking torque that is proportional to the disc speed.

i.e Braking torque $\propto$ disc speed

or $T_B \propto n$

Suppose at an instant:-

$T_d \propto T_B$

So $P \propto n$

multiplying both sides by t, the time for which power is supplied.-

$P \times t \propto n \times t$

or Enegy $\propto N$

where $N(=nt)$ is the total number of revolutions in time (t).

→ The counting mechanism is so arranged that the meter indicates Kilowatt hours (kwh) directly and not the revolutions

<u>Meter Constant:-</u>

we have seen above that:-

$N \propto$ Energy

$N = K \times$ Energy

where K is a constant called meter constant.

$\therefore$ meter Constant $K = \frac{N}{\text{Energy}} = \frac{\text{No. of revolutions}}{\text{Kwh}}$

"Hence the number of revolutions made by the disc for 1Kwh of energy consumption is called meter constant".

For example:- If meter constant of an energy meter is 1500 rev/Kwh, it means that for consumption of 1Kwh, the disc will make 1500 revolutions.