

Induction Type watt hour 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 \times hours), it is evident that watt hour 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:-

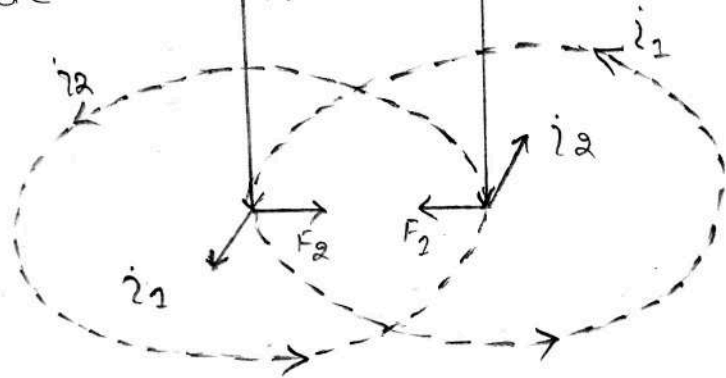
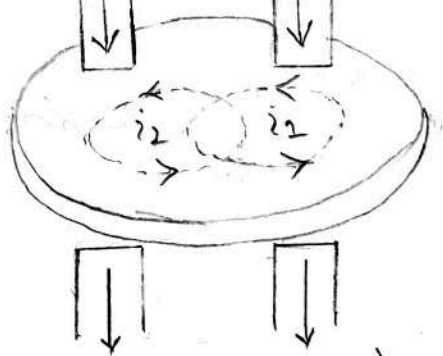


The above fig. shows the working principle of induction type energy meters.

→ Two alternating fluxes ϕ_1 and ϕ_2 (whose magnitude depends upon the current) having a phase difference (θ) pass through a metallic disc, usually of copper or aluminium.

→ 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 ϕ_1 and ϕ_2 .



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 θ is the phase angle by which ϕ_2 leads ϕ_1 .

The two fluxes ϕ_1 and ϕ_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:-

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

$$i_1 = \frac{\omega \phi_m \cos \omega t}{r}$$

as r and ω are constant

$$\therefore i_1 \propto \phi_m \cos \omega t$$

Similarly $i_2 \propto \phi_m \cos(\omega t + \theta)$

$$\text{As } F_1 \propto \phi_1 i_2 \quad \text{and} \quad F_2 \propto \phi_2 i_1$$

Resultant force $F \propto F_2 - F_1$

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

$$F \propto \phi_m \phi_m [\sin(\omega t + \theta) \cos \omega t - \sin \omega t \cos(\omega t + \theta)]$$

$$F \propto \phi_m \phi_m \sin(\omega t + \theta - \omega t)$$

$$F \propto \phi_m \phi_m \sin \theta$$

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

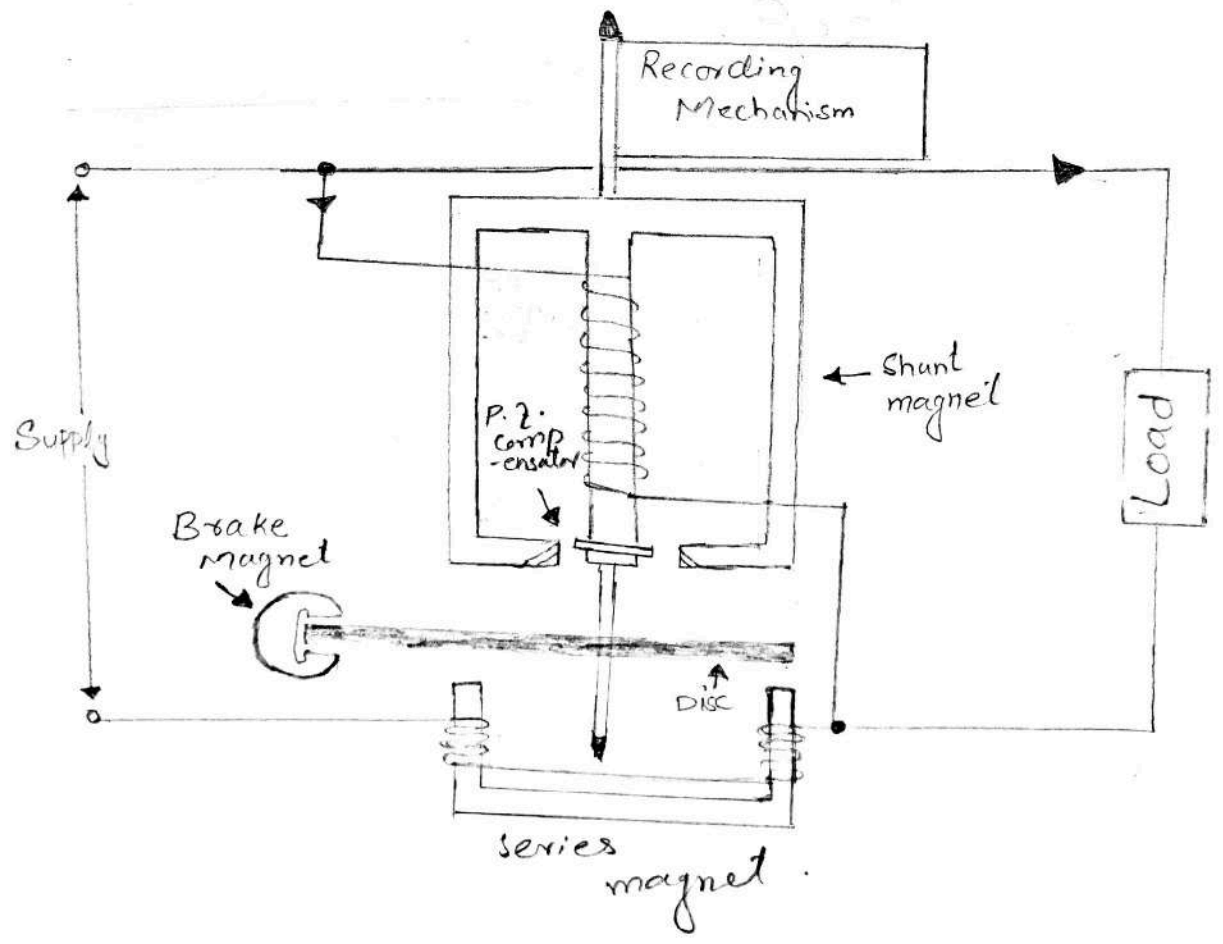
$$\therefore \boxed{T_d \propto \phi_m \phi_m \sin \theta}$$

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

- It should be noted that when $\theta = 0^\circ$ (i.e. the two fluxes are in phase), then deflecting torque is zero.
- The deflecting torque will be maximum when $\theta = 90^\circ$ i.e. when the alternating fluxes have a phase difference of 90° .
- The deflecting torque is the same at every instant since ϕ_{im} , ϕ_m and θ 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 aluminium 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.

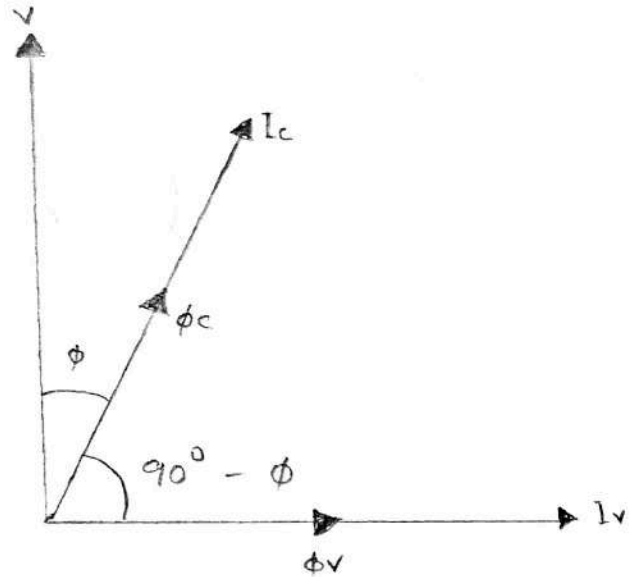
3):- A thin aluminium disc mounted on the spindle is placed between the shunt and series magnets so that it cuts the fluxes of both the magnets.

Working:-

→ 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 aluminium 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
 I_v = current carried by the shunt magnet
 I_c = current carried by series magnet (= load current I)
 ϕ = angle b/w supply voltage and I_c .

- From the above phasor diagram, we can see that the current (I_v) in the shunt magnet lags the supply voltage (V) by 90° and so does the flux (ϕ_v) produced by it.
- The current (I_c) in the series magnet is the load current and hence lags behind the supply voltage (V) by ϕ . The flux (ϕ_c) produced by this current (i.e. I_c) is in phase with it.

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

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

\therefore deflecting torque $T_d \propto \phi \nu \phi \cos \theta$
 $T_d \propto V I \sin(90 - \phi)$
 $[\because \phi \nu \propto E \phi \propto I]$

$$T_d \propto V I [\sin 90 \cos \phi - \cos 90 \sin \phi]$$

$$T_d \propto V I [(1) \cos \phi - 0]$$

$$T_d \propto V I \cos \phi$$

$\propto T_d \propto \text{AC power}$

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

● 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
 $\propto T_B \propto n$

Suppose at an instant:-

T_a & T_B

So P & n

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

$P \times t$ & $n \times t$

• or Energy & 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.

Meter Constant:-

• we have seen above that:-

N & Energy

$$N = K \times \text{Energy}$$

where K is a constant called meter constant.

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

"Hence the number of revolutions made by the disc for 1 kwh 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 1 kwh, the disc will make 1500 revolutions.