Electrodynamometer Wattmeter

- The instrument whose working depends on the reaction between the magnetic field of moving and fixed coils is known as electrodynamometer wattmeter. It is used for measuring the power of both the AC and DC circuits.

- Their working depends on the theory that the current carrying conductor placed in a magnetic field experiences a mechanical force. This mechanical force deflects the pointer which is mounted on the calibrated scale.

Construction

1. Fixed Coil :- Fixed coil is connected in series with the Load. It is considered as current coil because the Load current flows through it.

*.- Fixed coil is divided into two parts. These two elements are connected in parallel to each other. The fixed coil produces the uniform magnetic field which is essential for working of the instrument.

** Fixed coil is divided into two sections to give more uniform field near the centre zero and to allow passage of the instrument shaft.

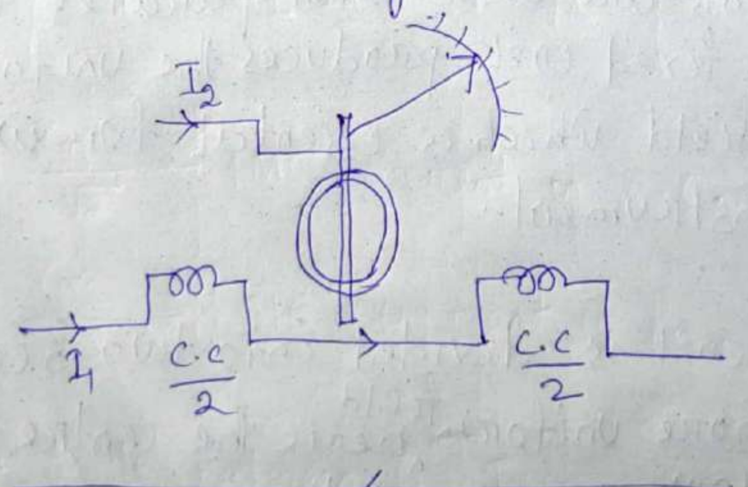
2. Moving Coil :- Moving coil is considered as the pressure coil of the instrument. It is connected in parallel with the supply voltage. The current flowing through moving coil is directly proportional to the supply voltage.

- Pointer is connected with the moving coil.

3. Control Arrangement :- The control system provides the controlling torque to the instrument. Spring control mechanism is used to provide the controlling torque.

4. Damping Arrangement :- Air friction damping method is used to produce the damping torque.

5. Scale and pointer :- The instrument uses a linear scale because the moving coil moves linearly.



Principle of operation:-

- Electrodynamometer type instruments work on the principle of dc motor i.e. when a current carrying conductor placed in a magnetic field, it experiences a mechanical force.

- Electrodynamometer type instrument has two types of coils i.e. fixed and moving coil.
- The pointer is fixed on the moving coil which is placed between the fixed coils. The current and voltage of the fixed and moving coil generate two magnetic fields. The interaction of these two magnetic fields deflects the pointer.

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

$T_i \rightarrow$ Instantaneous torque

$i_1 \rightarrow$ instantaneous current in C.C.

$i_2 \rightarrow$ Instanteous current in P.C.

$M \rightarrow$ Mutual inductance

$\theta \rightarrow$ deflection produced.

For AC supply; $i_1 = i_{m_1} \sin \omega t$

$$i_2 = i_{m_2} \sin(\omega t - \phi)$$

$\phi \rightarrow$ Phase angle difference bet^n i_1 & i_2.

Average torque, $T_d = \frac{1}{2\pi} \int_0^{2\pi} T_i \, d\omega t$

$$\Rightarrow T_d = \frac{1}{2\pi} \int_0^{2\pi} i_{m_1} \sin \omega t \cdot i_{m_2} \sin(\omega t - \phi) \frac{dM}{d\theta} \cdot d\omega t$$

$$\Rightarrow \boxed{T_d = \frac{i_{m_1} i_{m_2}}{2} \cos\phi \frac{dM}{d\theta}}$$

$$\Rightarrow T_d = \frac{i_{m_1}}{\sqrt{2}} \cdot \frac{i_{m_2}}{\sqrt{2}} \cos\phi \frac{dM}{d\theta}$$

$$\Rightarrow \boxed{T_d = I_1 \cdot I_2 \cos\phi \frac{dM}{d\theta}}$$ ✓

$I_1 = \frac{i_{m_1}}{\sqrt{2}}$ = RMS current in C.C.

$I_2 = \frac{i_{m_2}}{\sqrt{2}}$ = RMS current in P.C.

✓ ϕ = Angle between I_1 & I_2.

Note: Here $\cos\phi$ is not power factor.

* Inside the dynamometer instrument, instantaneous torque is producing but the pointer can't respond. Pointer can respond only for average value.

- Spring mechanism is used to produce controlling torque.

$$T_c = K_c \theta$$

- Air friction damping is used to produce the damping mechanism.

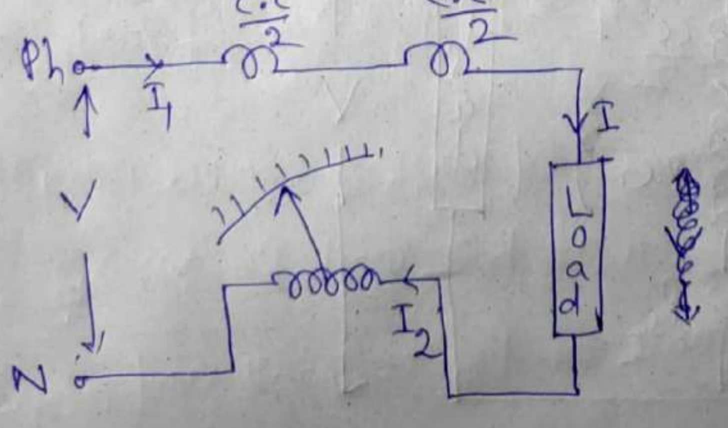
- At final steady state position, $T_c = T_d$.

$$\Rightarrow K_c \theta = I_1 I_2 \cos\phi \frac{dM}{d\theta}$$

$$\Rightarrow \boxed{\theta = \frac{I_1 I_2 \cos\phi}{K_c} \frac{dM}{d\theta}}$$

Case-1 :-

To convert as dynamometer type ammeters connect the C.C. and P.C. in series. This combination is connected in series with the Load.



$T_d = I_1 I_2 \cos\phi \frac{dM}{d\theta}$, $\theta = \frac{I_1 I_2 \cos\phi}{K_c} \frac{dM}{d\theta}$

As C.C. & P.C. connected in series

$I_1 = I_2 = I$, $\phi = 0^\circ$ $(\because I_1 = I_2)$

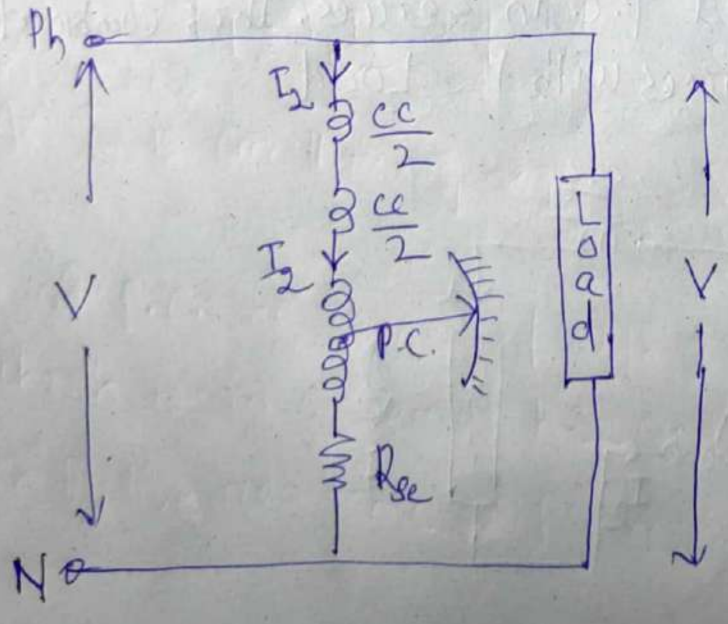
$$\Rightarrow \boxed{T_d = I^2 \frac{dM}{d\theta}} \quad \boxed{\theta = \frac{I^2}{K_e} \frac{dM}{d\theta}}$$

$\theta \propto I^2 \rightarrow$ Non-linear relation

- Dynamometer type ammeter has <u>pure</u> square Law scale and indicates rms current.

<u>Case-2</u> :

To convert as dynamometer type <u>voltmeter</u>, connect both C.C. and P.C. in series. This combination is connected in parallel with the Load.



$$T_d = I_1 I_2 \cos\phi \frac{dM}{d\theta} \; ; \; \theta = \frac{I_1 I_2 \cos\phi}{K_c} \frac{dM}{d\theta}.$$

As C.C & P.C are connected in series and the combination is connected across the supply;

$$I_1 = I_2 = \frac{V}{R_{se}} \, , \; \theta = 0^\circ \; (\because I_1 = I_2)$$

$$\boxed{T_d = \frac{V^2}{R_{se}^2} \frac{dM}{d\theta}} \qquad \boxed{\theta = \frac{V^2}{R_{se}^2 \cdot K_c} \cdot \frac{dM}{d\theta}}$$

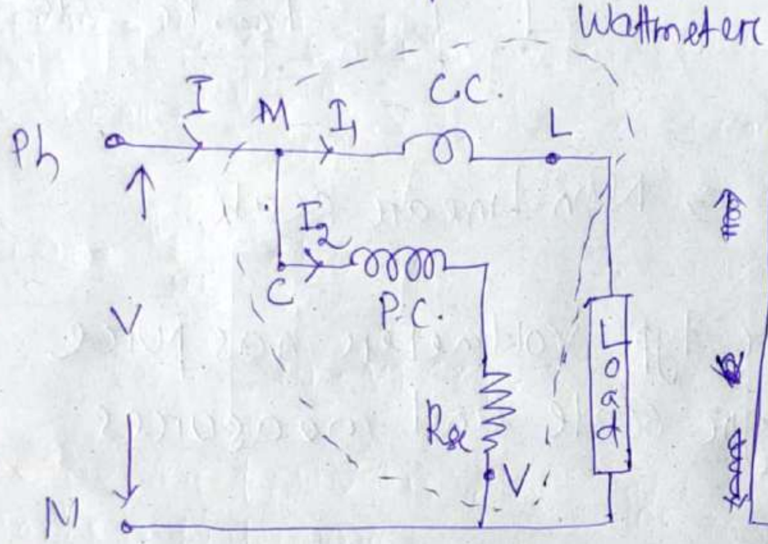
$\theta \propto V^2 \rightarrow$ Non-Linear scale.

- Dynamometer type voltmeter has pure square Law type scale and measures rms voltage.

Case-3 :-

- To convert a dynamometer wattmeter, connect current coil in series with Load and potential coil in parallel with Load.

- A high non-inductive resistance, R_{se} in the order of $K\Omega$ is connected in series with the P.C. to limit the current to a small value (usually upto 100mA).



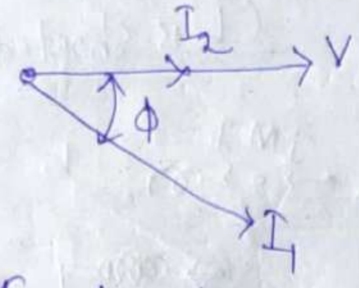
M → Main
L → Load
C → Common
V → Voltage

$$T_d = I_1 I_2 \cos\phi \frac{dM}{d\theta} \; ; \; \theta = \frac{I_1 I_2 \cos\phi}{K_c} \frac{dM}{d\theta}$$

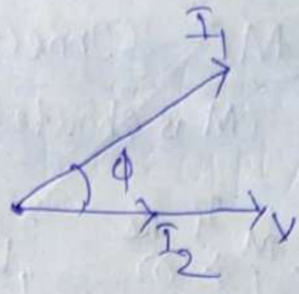
As I_2 is small ⇒ $I_1 \simeq I$, $I_2 = \frac{V}{R_{se}}$, $(\phi \neq 0)$ [as $I_1 \neq I_2$]

** P.C. is connected with a series resistance, R_{se} which is in order of $K\Omega$ and $R_{se} >>> X_{LPC}$, hence inductive reactance of PC is small and neglected.

- So current flowing through P.C, I_2 is considered in phase with voltage, V.



For Lag Load



For Lead Load.

So $T_d = I \cdot \frac{V}{R_{se}} \cdot \cos\phi \, \frac{dM}{d\theta}$

$$\Rightarrow \boxed{T_d = \frac{VI\cos\phi}{R_{se}} \frac{dM}{d\theta}}$$

At steady state; $T_c = T_d$

$$\Rightarrow K_c\theta = \frac{VI\cos\phi}{R_{se}} \frac{dM}{d\theta}$$

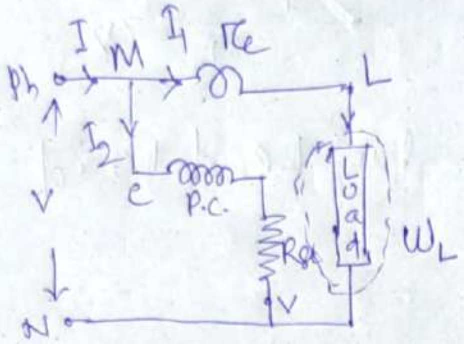
$$\Rightarrow \boxed{\theta = \frac{VI\cos\phi}{K_c \cdot R_{se}} \frac{dM}{d\theta}}$$

$\Rightarrow \theta \propto VI\cos\phi \propto$ Power $(\because P_{avg} = VI\cos\phi$

*- Scale is Linear.
- It works for both AC & DC.
- Dynamometer type wattmeter measures average active power.

Errors in Dynamometer wattmeter due to P.C. Connection:-

MC Connection
(M is shorted to C)



$$W_m = W_L + I_1^2 r_c$$

$$\text{Error} = W_m - W_L = I_1^2 r_c$$

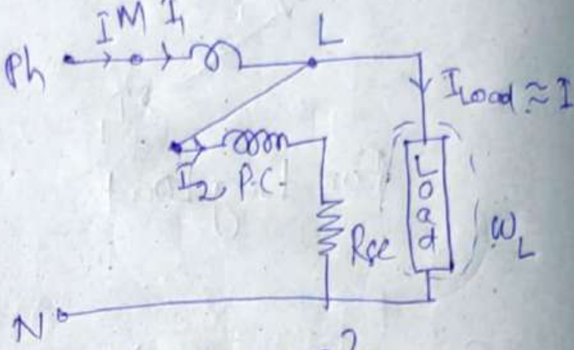
$$\%\ \text{Error} = \frac{W_m - W_L}{W_L} \times 100$$

$$\Rightarrow \boxed{\%\ \text{Error} = \frac{I_1^2 r_c}{W_L} \times 100};$$

$$W_L = VI\cos\phi.$$

- The measured power is more than the actual power because additionally C.C. power Loss is included.
- To reduce % error M.C. connection is used for small Loads i.e. Low current and high voltage application.

LC Connection
(L is shorted to C)



$$W_m = W_L + I_2^2 R_{se}$$

$$\text{Error} = W_m - W_L = I_2^2 R_{se}$$

$$\%\ \text{Error} = \frac{W_m - W_L}{W_L} \times 100$$

$$\Rightarrow \boxed{\%\ \text{Error} = \frac{I_2^2 R_{se}}{W_L} \times 100 = \frac{V^2}{R_{se}} \times 100}$$

$$\because I_2 = \frac{V}{R_{se}}$$

- The measured power is more than actual power because additionally P.C. power Loss is included.
- To reduce % error, LC connection is used for Large Loads i.e. high current and Low voltage applications.

[if $I_{Load} \uparrow$, $I_2 \downarrow$, $I_2^2 R_{se} \downarrow$

$\Rightarrow$ error $\downarrow$

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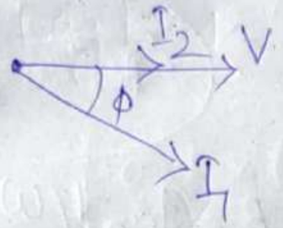
Error due to pressure coil self Inductance:-

Without inductance in P.C.

Here current, I_2 will be in phase with V.



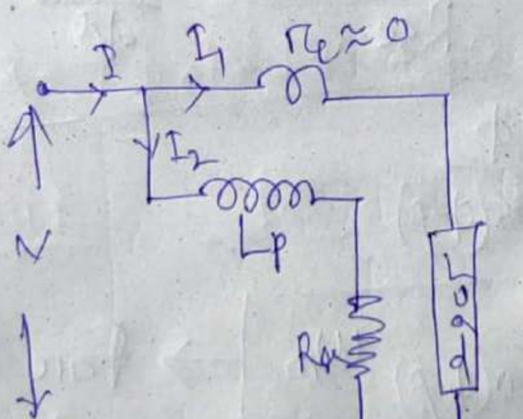
$$Z_p = R_{se}$$

$$T_d = I_1 I_2 \cos\phi \frac{dM}{d\theta}$$

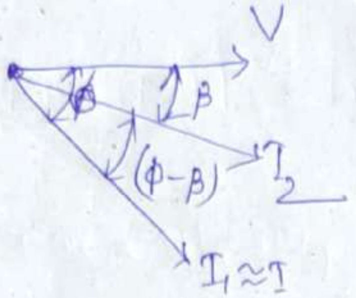
$$I_1 \approx I, \quad I_2 = \frac{V}{R_{se}}$$

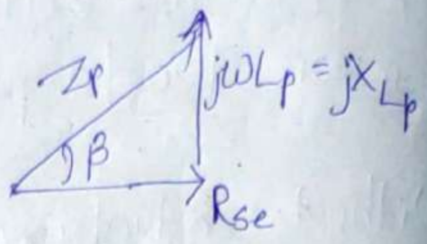
So $$T_d = \frac{VI\cos\phi}{R_{se}} \frac{dM}{d\theta} \rightarrow W_T \text{ (True value)} \quad \text{--- (1)}$$

With pressure coil inductance:-



Pressure coil current, I_2 will Lag voltage, V by an angle, β.





$$\cos\beta = \frac{R_{se}}{Z_p}$$

$$Z_p = R_{se} + j\omega L_p$$

$$\Rightarrow \boxed{Z_p = \frac{R_{se}}{\cos\beta}}$$

$$\beta = \tan^{-1}\left(\frac{\omega L_p}{R_{se}}\right)$$

Now $\quad T_d = I_1 I_2 \cos(\phi-\beta) \frac{dM}{d\theta}$

$$I_1 \simeq I, \quad I_2 = \frac{V}{Z_p} = \frac{V}{\left(\frac{R_{se}}{\cos\beta}\right)} = \frac{V\cos\beta}{R_{se}}$$

So $\boxed{T_d = \frac{VI\cos\beta\cos(\phi-\beta)}{R_{se}} \frac{dM}{d\theta}} \rightarrow \omega_m$ — (2)

$$\frac{(1)}{(2)} = \frac{\omega_T}{\omega_m} = \frac{\cos\phi}{\cos\beta \cdot \cos(\phi-\beta)}$$

$$\Rightarrow \boxed{\omega_T = \frac{\cos\phi}{\cos\beta \cdot \cos(\phi-\beta)} \omega_m} \rightarrow \text{For Lag pf}$$

$$\boxed{\text{Correction factor (CF)} = \frac{\cos\phi}{\cos(\phi \mp \beta)\cos\beta}}$$

'−' for Lag pf
+ for Lead pf

For Lag pf

$$\omega_T = \frac{\cos\phi}{\cos(\phi-\beta).\cos\beta}\cdot\omega_m$$

$$\Rightarrow \omega_T = \frac{\cos\phi}{(\cos\phi.\cos\beta+\sin\phi.\sin\beta)\cos\beta}\,\omega_m.$$

$$\Rightarrow \omega_T = \frac{\cancel{\cos\phi}}{\cancel{\cos\phi}.\cos\beta\left[1+\tan\phi.\tan\beta\right]\cos\beta}$$

$$\left(\frac{1}{\cos^2\beta} = \sec^2\beta = 1+\tan^2\beta\right)$$

$$\Rightarrow \omega_T = \frac{1+\tan^2\beta}{1+\tan\phi.\tan\beta}\cdot\omega_m$$

$$\Rightarrow \boxed{\omega_T = \frac{1}{1+\tan\phi.\tan\beta}\cdot\omega_m}$$

[β is very small so $\tan^2\beta \approx 0$

$$\frac{\omega_m}{\omega_T} = 1+\tan\phi.\tan\beta$$

$$\Rightarrow \frac{\omega_m}{\omega_T} - 1 = \tan\phi.\tan\beta$$

$$\Rightarrow \frac{\omega_m-\omega_T}{\omega_T} = \tan\phi.\tan\beta.$$

$\Rightarrow W_m - W_T = W_T \tan\phi . \tan\beta$

$\Rightarrow W_m - W_T = VI\cos\phi . \frac{\sin\phi}{\cos\phi} . \tan\beta$

$\Rightarrow \boxed{\text{Error} = W_m - W_T = VI \sin\phi . \tan\beta}$

$\% \text{ Error} = \frac{W_m - W_T}{W_T} \times 100 = \frac{VI \sin\phi . \tan\beta}{VI\cos\phi} \times 100$

$\Rightarrow \boxed{\% \text{ Error} = (\tan\phi . \tan\beta) \times 100}$

- If $\beta = 0$, then error = 0. For this P.C. voltage and P.C. current, I_2 must be in phase.

** To read the true power by dynamometer wattmeter, the nature of pressure coil should be highly resistive.

** Error = $W_m - W_T = VI \sin\phi \tan\beta$

ϕ	$\sin\phi$	$\cos\phi$	Error
0	0	upf	0
30°	0.5	0.86	0.5 $VI\tan\beta$
60°	0.86	0.5	0.86 $VI\tan\beta$
90°	1	0	$VI\tan\beta$

- Due to potential coil self inductance
  i) Wattmeter reads more than actual power; error is +ve for Lag pf.
  ii) Wattmeter reads Less than actual power, error is -ve for Lead pf.
  iii) Magnitude of error $\propto \frac{1}{\text{Load pf (Lag or Lead)}}$

UPF (Upper power factor) > 0.5 Lag
LPF (Lower power factor) < 0.5 Lag

- When ordinary dynamometer wattmeter is used for high pf Load's power measurement, error is minimum. It is negligible. But when same ordinary dynamometer wattmeter is used for Low pf Load's power measurements, error is very high. Hence ordinary dynamometer wattmeters are used for high pf Loads power measurements only. So it is called as UPF (0.5 lag) wattmeter.

- To measure Low pf Load power measurements; specially designed LPF wattmeter is used.

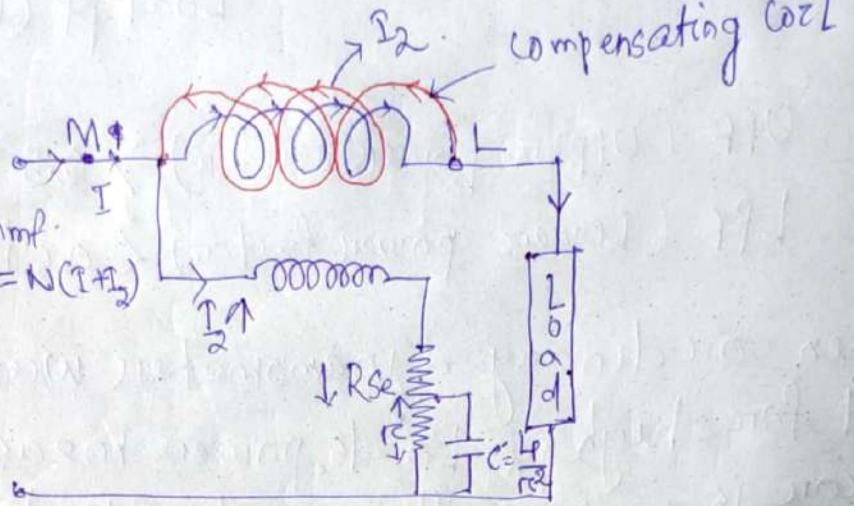
LPF (Low Power factor) wattmeter :-

- If the Load pf is Low, then in wattmeter, connection should be LC terminal shorted.

$$P = V \, I \, \cos\phi$$

(↑ LC connection)

Compensation:-



Modifications:-

i) A compensating capacitor is connected across a portion of multiplier to nullify the P.C. inductance effect.

$$C = \frac{L_P}{r^2}$$

ii) $$\uparrow T_d = \frac{VI\cos\phi \downarrow}{R_{se} \downarrow} \frac{dM}{d\theta}$$

As pf is Low, developed torque is not sufficient enough to produce deflection. It Leads to maloperation of the instrument.

- ~~Too produce the sufficient torque~~

- To avoid this maloperation, value of R_{se} is decreased such that the potential coil current, I_2 is increased 10 times the potential coil current of UPF wattmeter.

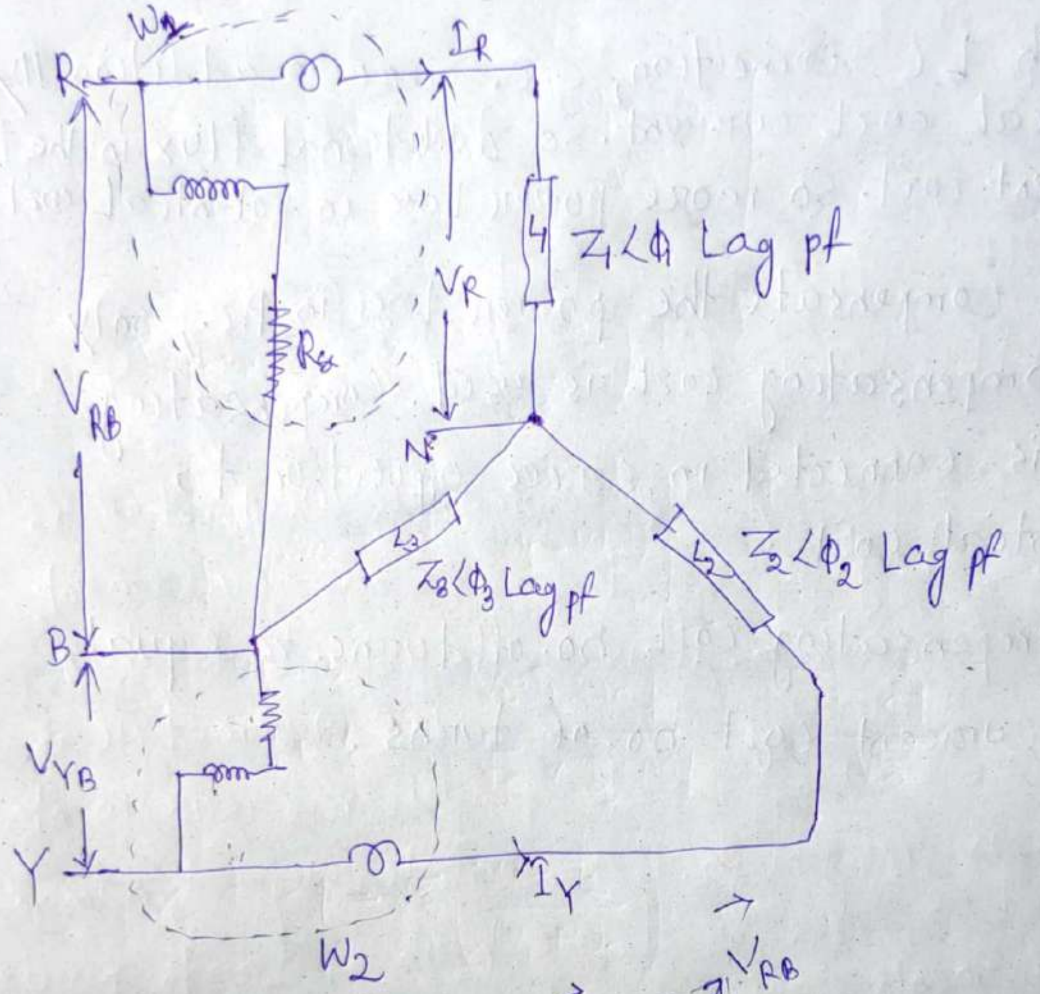
iii) With LC connection, C.C. carries additionally potential coil current. So additional flux in the current coil. So more power Loss in potential coil.

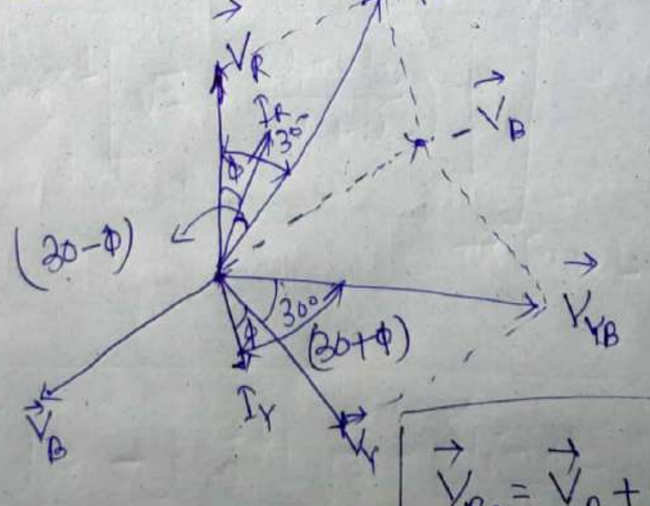
- To compensate the power Loss in P.C., only a compensating coil is used. Compensating coil is connected in series opposition to potential coil.

- Compensating coil no. of turns is equal to current coil no. of turns.

Power measurement by two wattmeter method:-

- Consider a 3-ϕ star connected balanced Load, assuming R-Y-B sequence and B-phase is made common





$$\vec{V}_{RB} = \vec{V}_R + (-\vec{V}_B)$$

$$V_{YB} = \vec{V}_Y + (-\vec{V}_B)$$

$$W_1 = \vec{V}_{RB}\vec{I}_R \cos(\vec{V}_{RB} \& \vec{I}_R)$$

$$W_2 = \vec{V}_{YB}\vec{I}_Y \cos(\vec{V}_{YB} \& \vec{I}_Y)$$

$$W_1 = V_{RB} I_R \cos(30-\phi)$$

$$W_2 = V_{YB} I_Y \cos(30+\phi)$$

For balanced Load, $V_{RB} = V_{YB} = V_L$, $I_R = I_Y = I_L$

$$\boxed{\begin{aligned} W_1 &= V_L I_L \cos(30-\phi) \quad \text{--- (1)} \\ W_2 &= V_L I_L \cos(30+\phi) \quad \text{--- (2)} \end{aligned}}$$

(1) + (2) ⇒

$$W_1 + W_2 = V_L I_L [\cos(30-\phi) + \cos(30+\phi)]$$

$$\Rightarrow W_1 + W_2 = V_L I_L [2\cos 30^\circ \cos\phi]$$

$$\Rightarrow \boxed{W_1 + W_2 = \sqrt{3}\, V_L I_L \cos\phi} \quad \text{--- (3)}$$

↳ 3-ϕ Load power

(1) - (2) ⇒

$$W_1 - W_2 = V_L I_L [\cos(30-\phi) - \cos(30+\phi)]$$

$$= V_L I_L (2\sin 30^\circ \sin\phi)$$

$$\Rightarrow \boxed{W_1 - W_2 = V_L I_L \sin\phi} \quad \text{--- (4)}$$

In star-connection :-

$$V_L = \sqrt{3}\, V_{ph} \,,\ I_L = I_{ph}$$

$$W_1 - W_2 = \sqrt{3}\, V_{ph} I_{ph} \sin\phi$$

$$\Rightarrow V_{ph} I_{ph} \sin\phi = \frac{W_1 - W_2}{\sqrt{3}}$$

$$\Rightarrow \boxed{Q_{1\text{-phase}} = \frac{W_1 - W_2}{\sqrt{3}}}$$

$$Q_{3\text{-phase}} = 3 \times \left(\frac{W_1 - W_2}{\sqrt{3}} \right)$$

$$\Rightarrow \boxed{Q_{3\text{-phase}} = \sqrt{3}\,(W_1 - W_2)}$$

$$\frac{(4)}{(3)} \Rightarrow \frac{W_1 - W_2}{W_1 + W_2} = \frac{V_L I_L \sin\phi}{\sqrt{3}\, V_L I_L \cos\phi} = \frac{\tan\phi}{\sqrt{3}}$$

$$\Rightarrow \tan\phi = \sqrt{3} \left(\frac{W_1 - W_2}{W_1 + W_2} \right)$$

$$\Rightarrow \boxed{\phi = \tan^{-1}\left[\sqrt{3} \left(\frac{W_1 - W_2}{W_1 + W_2} \right) \right]}$$

↳ For Lag pf

For Lead pf

$$\boxed{\phi = -\tan^{-1}\left[\sqrt{3} \left(\frac{W_1 - W_2}{W_1 + W_2} \right) \right]}$$

Effect of Load pf on wattmeter reading in two wattmeter method for Lag pf :-

$$W_1 = V_L I_L \cos(30-\phi) \Rightarrow \phi\uparrow, (30-\phi)\downarrow, \cos\phi\uparrow, W_1\uparrow$$

$$W_2 = V_L I_L \cos(30+\phi) \Rightarrow \phi\uparrow, (30+\phi)\uparrow, \cos\phi\downarrow, W_2\downarrow$$

i) $\cos\phi = \text{upf}, \ \phi = 0^\circ$

$$W_1 = \frac{\sqrt{3} V_L I_L}{2}, \quad W_2 = \frac{\sqrt{3} V_L I_L}{2}$$

$\Rightarrow$ $\boxed{W_1 = W_2}$ → Exactly equal.

ii) $\cos\phi = 0.866 \text{ Lag}, \ \phi = 30^\circ$

$$W_1 = V_L I_L, \quad W_2 = \frac{V_L I_L}{2}$$

$$W_2 = \frac{W_1}{2} \Rightarrow \boxed{W_1 = 2W_2}$$

iii) $\cos\phi = 0.5 \text{ Lag}, \ \phi = 60^\circ$

$$W_1 = \frac{\sqrt{3} V_L I_L}{2}, \quad W_2 = 0$$

iv) $\cos\phi = \text{zpf Lag}, \ \phi = 90^\circ$

$$W_1 = \frac{V_L I_L}{2}, \quad W_2 = -\frac{V_L I_L}{2}$$

$\boxed{W_2 = -W_1}$ → Exactly equal and opposite.

**

i) $\cos\phi > 0.5$ Lag; W_1 and W_2 are +ve.

$(0° < \phi < 60°)$

ii) $\cos\phi = 0.5$ Lag, W_1 is +ve & $W_2 = 0$.

$(\phi = 60°)$

iii) $\cos\phi < 0.5$ Lag, W_1 is +ve and W_2 is -ve.

$(60° < \phi < 90°)$

Note :-

- In two wattmeter method of 3-ϕ power measurement, always W_1 indicates more than actual value and W_2 indicates Less than actual value but sum of these two wattmeter result is correct.

- When pf is Less than 0.5, W_2 wattmeter has to indicate negative, but there is no reading below zero. To change the pointer direction, reverse either C.C. terminal or P.C. terminal but not both.

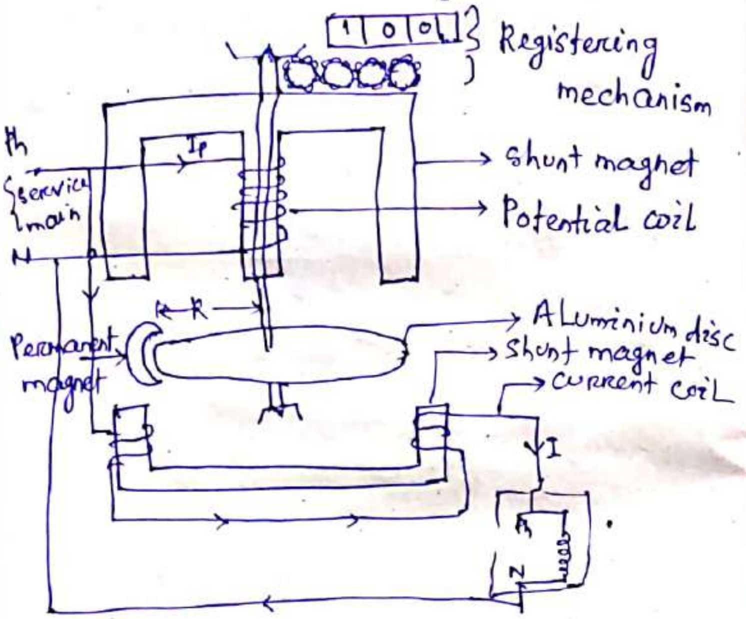
After this, take negative sign for W_2 reading.

** To measure 3-ϕ reactive power by 1-ϕ wattmeter, connect C.C. terminal in one phase and P.C. terminal across other two phases.

Measurement of Energy

- Integrating type instruments are used to record the electrical energy.

$$Energy = \int_0^t P\,dt = \int_0^t VI\cos\phi\,dt$$



It has core operating mechanism.

1> Driving mechanism:-

- Potential coil is placed on shunt magnet and carries current I_p proportional to supply voltage only.

- current coil is placed on two Limbs of series magnet and carries current, I_c proportional to Load, I.

2> Rotating mechanism:-

A Light weight 'AL' disc is placed on spindle. Speed of 'AL' disc is proportional to power consumed by Load.

3> Braking mechanism:-

- A permanent magnet is placed at the edge of 'AL' disc.
- It's position is adjustable by manufacturer to adjust the speed of disc.

$$N \propto \frac{1}{R}$$

N → Speed of disc

R → distance between spindle to permanent magnet.

4> Registering mechanism:-

- A train of reduction gears are used to count the no. of units proportional to the speed of 'AL' disc.

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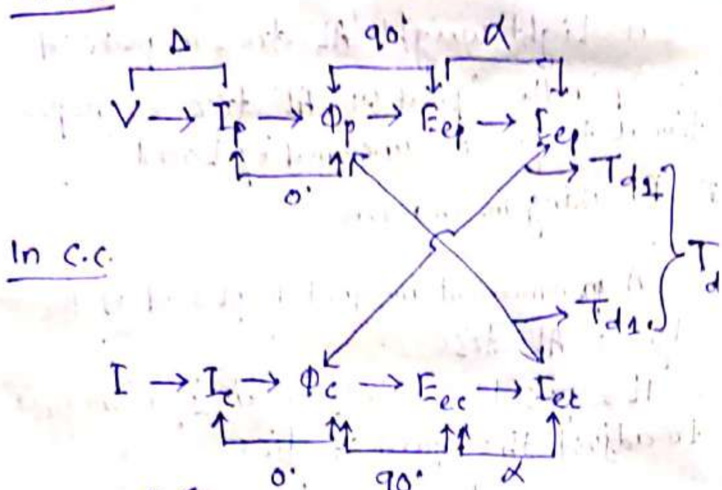
Operation:-

- Induction type energy meter works on induction motor principle.

In P.C.



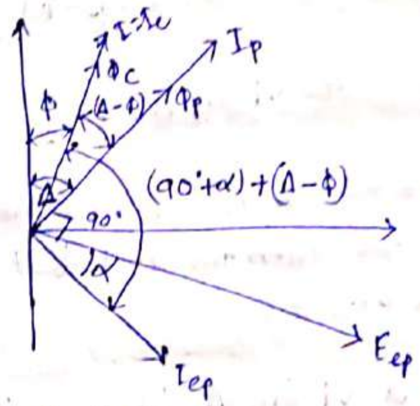
- Both T_{d1} and T_{d2} are producing due to the interaction of flux of one coil and eddy current of other coil.

- When load is present, both T_{d1} and T_{d2} are produced in the disc in opposite direction and difference of these two torques, the disc starts rotating.

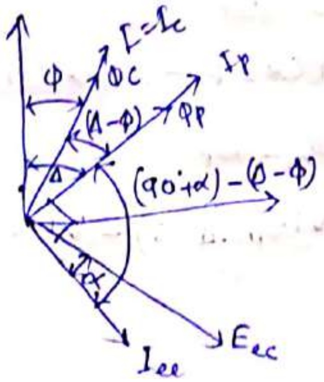
$$T_{d1} = \Phi_p I_{ec} \cos(\Phi_p \& I_{ec})$$

$$T_{d2} = \Phi_c I_{ep} \cos(\Phi_c \& I_{ep})$$

Potential coil emf



Current coil emf:-



So $T_{d_1} = VI\cos[(90+\alpha)-(\Delta-\phi)]$

$T_{d_2} = VI\cos[(90^\circ+\alpha)+(\Delta-\phi)]$

∴ Net driving torque, $T_d = T_{d_1} - T_{d_2}$

$\Rightarrow T_d = VI[[\cos(90+\alpha)-(\Delta-\phi)] - \cos[(90+\alpha)+(\Delta-\phi)]]$

$\Rightarrow T_d = VI[2\sin(90^\circ+\alpha)\sin(\Delta-\phi)]$

$\Rightarrow T_d = VI[2\cos\alpha \cdot \sin(\Delta-\phi)]$

$\Rightarrow \boxed{T_d \propto VI\sin(\Delta-\phi)}$

To produce maximum driving torque in operation, then the angle between C.C. flux and P.C. flux is 90°.

* $T_d \propto VI\sin(\Delta-\phi) \longrightarrow \omega_m$

if $\Delta = 90^\circ$

$T_d \propto VI\cos\phi \longrightarrow \omega_T$

Error $= \omega_m - \omega_T$

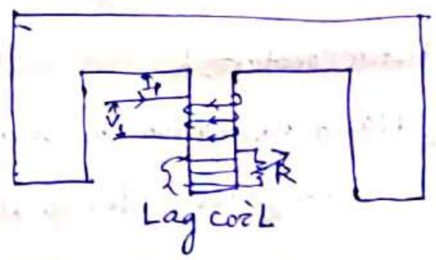
$= VI\sin(\Delta-\phi) - VI\cos\cos\phi.$

$\Rightarrow \boxed{\text{Error} = \omega_m - \omega_T = VI[\sin(\Delta-\phi) - \cos\phi]}$

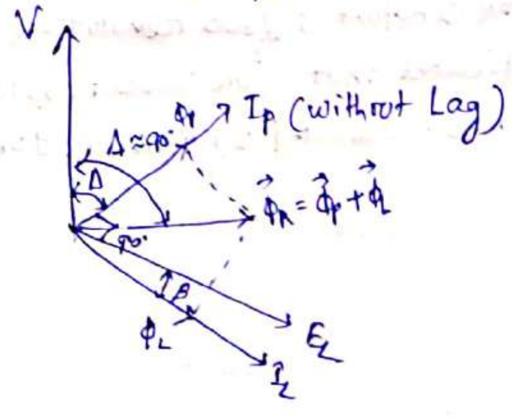
$\%\ \text{Error} = \frac{\omega_m-\omega_T}{\omega_T}\times 100 = \frac{VI[\sin(\Delta-\phi)-\cos\phi]}{VI\cos\phi}\times 100$

$\Rightarrow \boxed{\%\ \text{Error} = \frac{\omega_m-\omega_T}{\omega_T}\times 100 = \frac{\sin(\Delta-\phi)-\cos\phi}{\cos\phi}\times 100}$

Lag adjustment:-



$V \to I_p \to \phi_p \to E_L \to I_L \to \phi_L$ (90°, β)



- By using this Lag adjustment, Δ is approximately 90° is possible.
- Practically copper rings are placed at the bottom of central limb of shunt magnet. If these copper rings are pushed towards the potential coil, inductive nature of potential coil increases and Δ is approximately 90° is possible.

*

Energy meter constant, K

$$= \frac{\text{No. of revolutions made by disc}}{\text{Energy recorded in kWhr}}$$

⇒ K = No. of revolutions/Energy.

If meter constant is 2000 revolutions/kWhr it indicates that for 2000 revolutions, meter has recorded 1 kWhr i.e. 1 unit.

Creeping error:-

- Due to static friction, when using Light Load (5% of full Load), the produced driving torque is, T_d is very less. Then it has to start the disc and rotate the disc. But even it is not sufficient to start the disc due to static friction.
- To overcome static friction, a small iron piece is placed between aluminium disc and central Limb of shunt magnet (covering 15 to 20% of area). With this, small additional driving torque is produced. It is called static friction compensation.
- If an iron piece covers more than the required area of central Limb, more additional driving torque is produced. It is called over static friction compensation.

Creeping error definition:-

When potential coil is energized and no current flows in current coil, if aluminium disc runs slowly and continuously is called creeping error.

Causes:-

- The major reason is over static friction compensation.
- over voltage.
- Slippage of an instrument, excessive Lubrication, stray magnetic field etc.

Solution:-

To eliminate creeping error, two holes are drilled on opposite side of disc diametrically.