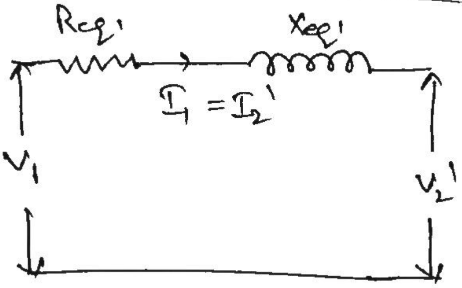
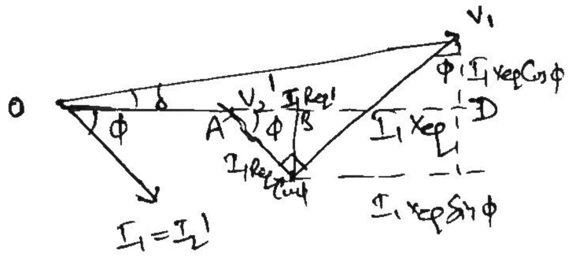
Voltage Regulation



→ It is diff b/w No-Load Voltage to full load vtg respect to No-load vtg.

$$* \ V.R. = \frac{N.L.\ vtg - F.L.\ vtg}{full\ load\ vtg}$$

$$\left(Reg. = \frac{V_1 - V_2'}{V_2'} \right)$$



$OD = V_1 \cos\delta$

$V_1 \approx V_1 \cos\delta$

$\boxed{OD = V_1}$ → No-load vtg

OA → full load vtg

$$V_1 - V_2' = OD - OA = AD$$

$$= AB + BD$$

$$= I_1 R_{eq} \cos\phi + I_1 X_{eq} \sin\phi$$

$$\left[Reg. = \frac{I_1 R_{eq1} \cos\phi + I_1 X_{eq1} \sin\phi}{V_2'} \right] \rightarrow \text{lagging}$$

↳ lagging p.f.

$$\left[Regulation = \frac{I_1 R_{eq1} \cos\phi - I_1 X_{eq1} \sin\phi}{V_2'} \right] \rightarrow \text{leading.}$$

Cond^n for Zero vtg Regulation

* Possible only on leading p.f. ✓
* -ve V.R. possible only on leading p.f. ✓

$$0 = \frac{I_1 R_{eq_1} \cos\phi - I_1 X_{eq_1} \sin\phi}{V_2'}$$

$$I_1 X_{eq_1} \sin\phi = I_1 R_{eq_1} \cos\phi$$

$$\frac{\sin\phi}{\cos\phi} = \frac{R_{eq}'}{X_{eq}'}$$

$$\tan\phi = \frac{R_{eq}'}{X_{eq}'}$$

Cond^n for Z.V.R. →

$$\boxed{\phi = \tan^{-1}\left(\frac{R_{eq}'}{X_{eq}'}\right)}$$

* Cond^n for max. V.R. →

$$\boxed{\phi = \tan^{-1}\left(\frac{X_{eq}'}{R_{eq}'}\right)}$$

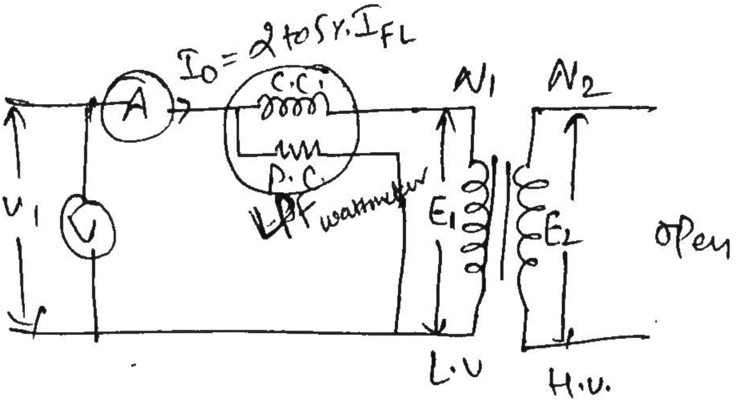
$$\text{Regulation} = \frac{I_1 R_{eq_1} \cos\phi \pm I_1 X_{eq_1} \sin\phi}{V_2'}$$

$$= \frac{I_1 R_{eq}'}{V_2'} \cos\phi \pm \frac{I_1 X_{eq}'}{V_2'} \sin\phi$$

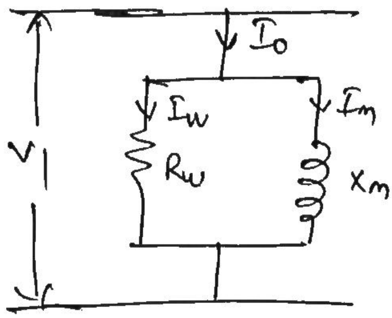
✓ $\text{Reg.} = \left[R_{e\,p.u.} \cos\phi \pm X_e \sin\phi \right]$ { * + → lag ; * − → lead. }

Open circuit test

↳ find core / iron loss



Wattmeter Reading



$\phi_0 \to > 75°$
& < 90°

$W = V_1 I_w$ watt

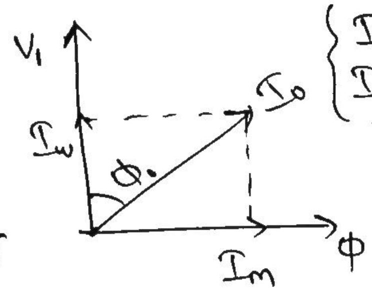
$[W = V_1 I_0 \cos\phi_0$ watt$]$

$I_0 = \sqrt{I_w^2 + I_m^2}$

$\{ I_w = I_0 \cos\phi_0$
$I_m = I_0 \sin\phi_0$

Reactive Power $= V_1 I_m$ VAR

$= V_1 I_0 \sin\phi_0$ V.A.R.

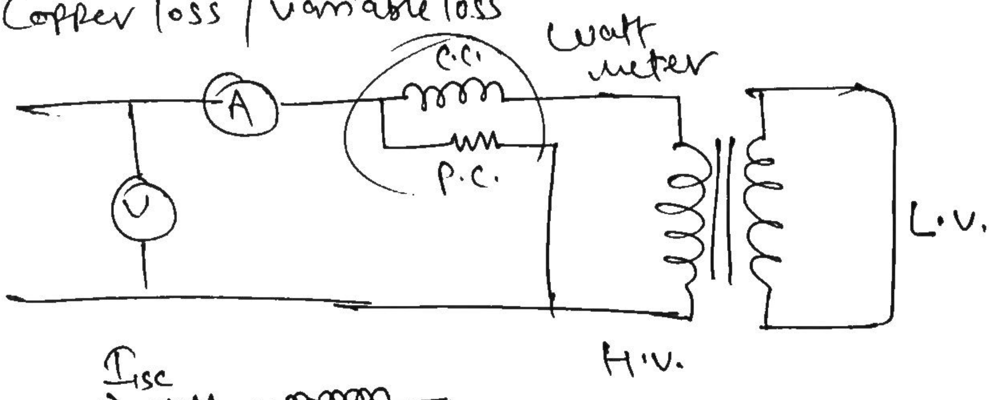


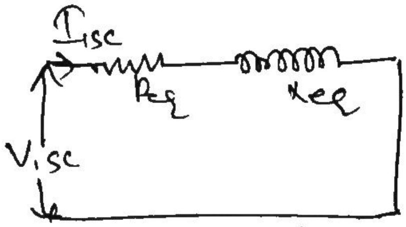
$I_w \to$ watt full component

$I_m \to$ magnetising component.

Short Circuit Test

↳ Copper loss / variable loss





equt circuit

$\{$ Cu loss $= V_{sc} I_{sc} \cos\phi_{sc} \}$

Efficiency : (η)

$$\eta = \frac{O/P\ Power}{I/P\ Power} = \frac{O/P\ Power}{O/P\ Power + losses}$$

O/P Power = $V_2 I_2 \cos\phi$ watt

Iron loss (P_i) = P_i watt

Cu loss = P_c watt

$$\eta = \frac{V_2 I_2 \cos\phi}{V_2 I_2 \cos\phi + P_i + P_c} \rightarrow \text{for full load} \quad \text{--- (1)}$$

If $m \rightarrow$ load ratio

$m = 1$ (full load)

$m = 1/2$ (half load)

$m = 1/4$ (one forth load)

$$\eta_{at\ m} = \frac{m \cdot V_2 I_2 \cos\phi}{m V_2 I_2 \cos\phi + P_i + m^2 P_c} \quad \text{--- (2)}$$

$S \rightarrow V_2 I_2$ (Rating)

$$\left\{ \eta_{at\ m} = \frac{m S \cos\phi}{m S \cos\phi + P_i + m^2 P_c} \right\} \quad \text{--- (3)}$$

Cond^n for max. efficiency

$$\eta = \frac{V_2 I_2 \cos\phi}{V_2 I_2 \cos\phi + P_i + P_c}$$

$$= \frac{V_2 I_2 \cos\phi}{\left(V_2 \cos\phi + \frac{P_i}{I_2} + I_2 R_{eq}\right)}$$

For max. η →

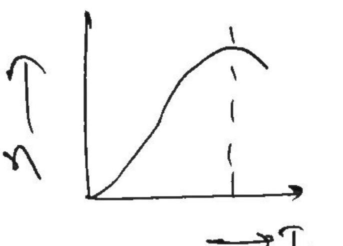
$$D = V_2 \cos\phi + \frac{P_i}{I_2} + I_2 R_{eq}$$

$$\frac{dD}{dI} = 0$$

$$0 - \frac{P_i}{I_2^2} + R_{eq} = 0$$

$$P_i = I_2^2 R_{eq}$$

* $\boxed{P_i = P_c}$ OR (Core loss = Cu loss) *



$$I_{2m} = I_{2fl} \times \sqrt{\frac{P_i}{P_c}}$$

$$V_2 I_{2m} = V_2 I_{2fl} \times \sqrt{\frac{P_i}{P_c}}$$

$$\left(S_m = S_{fl} \times \sqrt{\frac{P_i}{P_c}} \right)$$

✓ $\boxed{P_i = P_c}$

$$P_i = m^2 P_c$$

load ratio at max. efficiency → $m = \sqrt{\frac{P_i}{P_c}}$

Ex. $P_i = 300$ W

$P_c = 800$ W

for max eff. total load → ?

$\boxed{P_T = 600 \text{ watt}}$