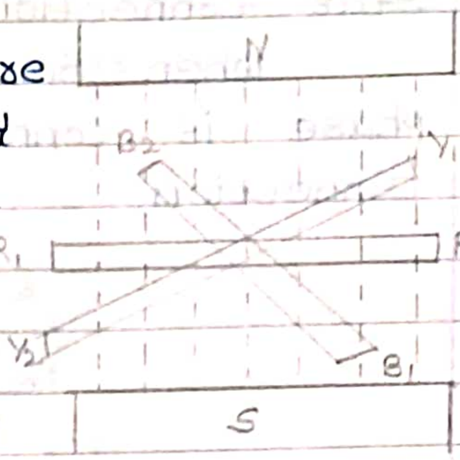
unit -4.

Polyphase AC circuit.

The Symetric circuit the all are Seprated by Same angel and induced emf Same magnitude and Same frequency.



$$\bar{e} = \bar{e}_R + \bar{e}_y + \bar{e}_B.$$

$$= E_m \sin \omega t + E_m \sin(\omega t - 120) + E_m \sin(\omega t + 120)$$

$$= E_m \sin \omega t + E_m [\sin \omega t \cos 120° - \cos \omega t \sin 120°] + E_m [\sin \omega t \cos 120° + \cos \omega t \sin 120°]$$

$$= E_m \sin \omega t + 2E_m \sin \omega t \left(\frac{-1}{2}\right)$$

$\therefore \bar{e} \Rightarrow 0$

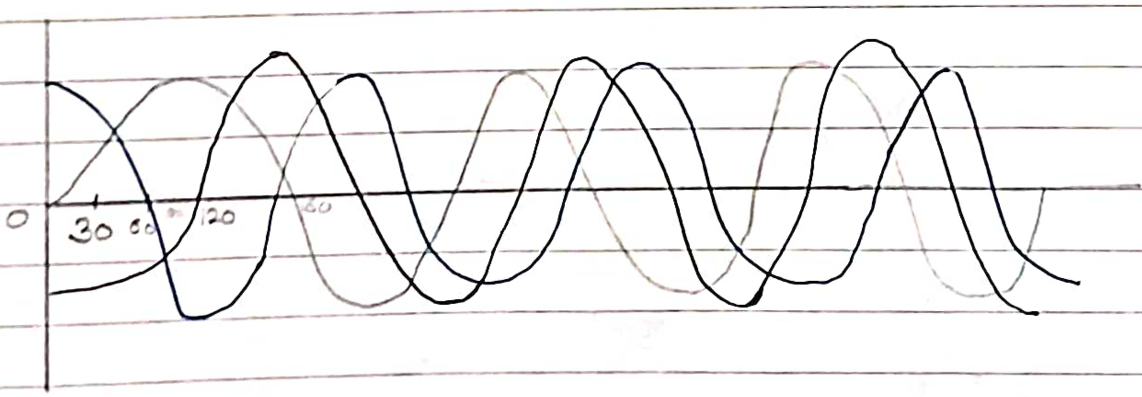
$\therefore \bar{e}_R + \bar{e}_y + \bar{e}_B = 0.$

$e_r = E_m \sin \omega t$

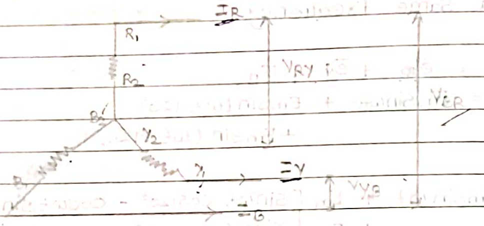
$e_y = E_m \sin(\omega t - 120°)$

$e_b = E_m \sin(\omega t - 240°)$

$= E_m \sin(\omega t + 120°)$

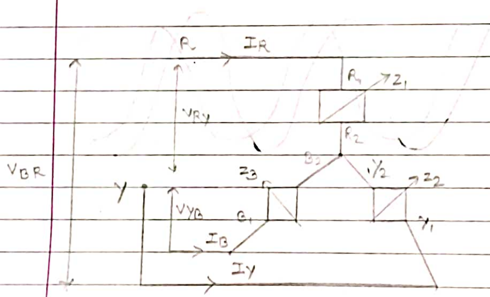


* Star connection (Y)
when second terminal of each of the phase is connected together it form star connection.



Line current :- current flowing through line
$I_R = I_Y = I_B = I_T$.

Line Voltage = Voltage from linear line
$V_{RY} = V_{YB} = V_{BR} = V_L$.



balence load :- Angle and magnitude of each Impedence must be same.

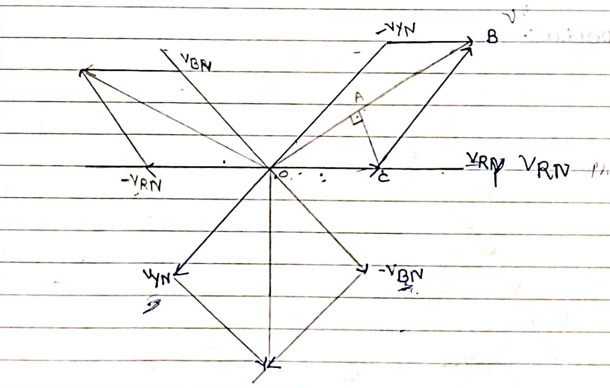
Phase voltage :- Voltage from phase to phase.
$V_{RN} = V_{YN} = V_{BN} = V_{ph}$

Phase current :- current flowing through phase
$I_R = I_Y = I_B = I_{ph}$

$\boxed{I_L = I_{ph}}$ * *

$\bar{V}_{RY} = \bar{V}_{RN} + \bar{V}_{NY} = \bar{V}_{RN} - \bar{V}_{YN}$.
$\bar{V}_{YB} = \bar{V}_{YN} + \bar{V}_{NB} = \bar{V}_{YN} - \bar{V}_{BN}$.
$\bar{V}_{BR} = \bar{V}_{BN} + \bar{V}_{NR} = \bar{V}_{BN} - \bar{V}_{RN}$

Reference as phase voltage * *



In Δ OAC

$OA = \frac{1}{2} OB$ $OC = V_{ph}$.

$OA = \frac{1}{2} V_L$ $\angle AOC = 30°$

$\cos 30° = \frac{OA}{OC}$ $\frac{\sqrt{3}}{2} = \frac{V_1}{2V_{ph}}$

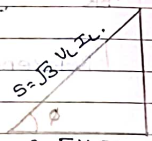
$\boxed{V_L = \sqrt{3}\, V_{ph}}$ **

Power, $P = V_{ph}\, I_{ph} \cos\phi$.

$= 3 \times \frac{V_L}{\sqrt{3}} \cdot I_L \cos\phi$. . . . 3 Phase.

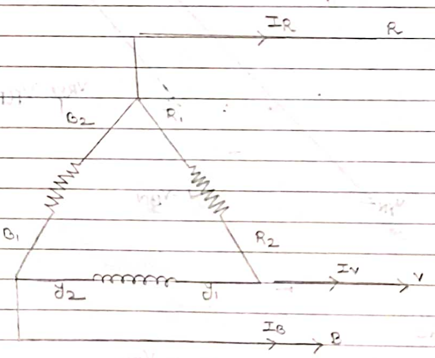
$P = \sqrt{3} \cdot V_L\, I_L \cos\phi$.

$Q = \sqrt{3} \cdot V_L I_L \sin\phi$.



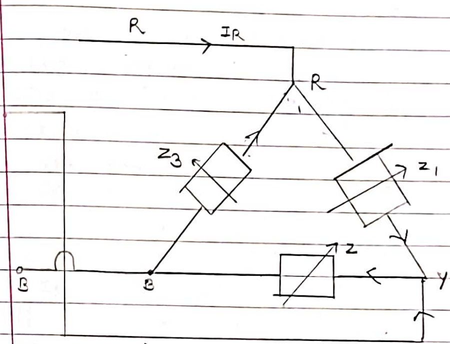
$P = \sqrt{3}\, V_L I_i \cos\phi$.

* Delta :-



$I_R = I_Y = I_B = I_L$

$V_{RY} = V_{YB} = V_{BR} = V_L$ //.



$V_{RY} = V_{YB} = V_{BR} = V_{ph}$

$I_{RY} = I_{YB} = I_{BR} = I_{ph}$.

$\boxed{V_L = V_{PH}}$ **

at node R,

KCL

$\boxed{\bar{I}_R + \bar{I}_{BR} = \bar{I}_{RY}}$

$\boxed{\bar{I}_R = \bar{I}_{RY} - \bar{I}_{BR}}$ — ①

at node Y

KCL

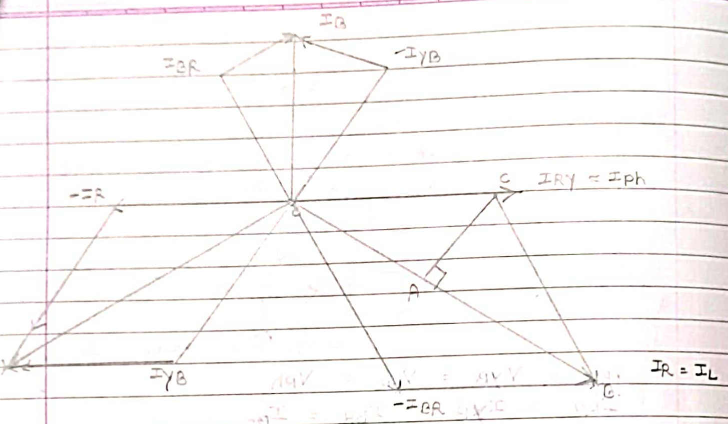
$\bar{I}_Y + \bar{I}_{RY} = \bar{I}_{YB}$

$\boxed{\bar{I}_Y = \bar{I}_{YB} - \bar{I}_{RY}}$ — ②

at node B.   KCL

$\bar{I}_Z + \bar{I}_{YB} = \bar{I}_{BR}$

$I_Z = \bar{I}_{BR} - \bar{I}_{YB}$ — ③



In ΔOAC

$OA = \frac{1}{2} I_L$ $\quad OC = I_{PH}$ $\quad \angle COA = 30°$

$\cos 30° = \frac{OA}{OC}$ $\quad \frac{\sqrt{3}}{2} = \frac{1}{2}\frac{I_L}{I_{ph}}$

$\therefore I_L = \sqrt{3}\, I_{PH}$.

$P = V_{PH}\, I_{PH} \cos\phi$.

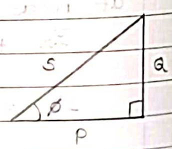
$P = 3 P_H\, I_{PH} \cos\phi$

$P = 3 V_L \frac{I_L}{\sqrt{3}} \cos\phi$

$\boxed{P = \sqrt{3}\, V_L I_L \cos\phi}$ Active Power.

$\boxed{Q = \sqrt{3}\, V_L I_L \sin\phi}$ Reactive Power.

$\boxed{S = \sqrt{3}\, V_L I_L}$ Apperent Power.



- If Quantity is not Specified as linear phase Quantity. It is Supported to be consider as line quantity.
- Impedence is Always Phase impedance.

Q. Three identical impedance, of $z = 12 + 13j\ \Omega$ are connected in Star across 3 Phase 440V 50 Hz Supply calculate
i) I_L ii) P iii) Q.

→

$I_{ph} = \frac{V_{ph}}{Z_{ph}}$ $\quad V_L = \sqrt{3}\ V_{ph}$

$V_{ph} = \frac{V_L}{\sqrt{3}} = 254.034$

$I_{ph} = \frac{254.034 \angle 0°}{17.691 \angle 47.29°}$

$\therefore I_{ph} = 14.3595 \angle -47.29°$ A.

$\therefore I_L = 14.3595$ A (magnitude).

ii) $P = \sqrt{3}\ V_L I_L \cos\phi$
$= \sqrt{3} \times 440 \times 14.3595 \times \cos(47.29)$
$= 7422.782$ watt.

iii) $Q = \sqrt{3}\ V_L I_L \sin\phi$
$= 8040.895$ VAR.

Q. 3 coils each haveing Resistance of $25\ \Omega$ & Inductive Reactance of $29\ \Omega$ are connected in Star to a 420 V, 3φ, 50 Hz Supply calculate i) line current ii) Power factor iii) Power Supply.

→ $R = 25\ \Omega$ $\quad X_L = 29\ \Omega$

420 V, 3φ, 50 Hz

i) I_L ii) Pf iii) Power Supply.

$I_{ph} = \frac{V_{ph}}{Z_{ph}}$ $\quad V_L = 420$ V.

$V_L = \sqrt{3}\ V_{ph}$ $\quad V_{ph} = 242.487$ V

Safety Precautions & measuring equipm.

1) Voltmeter :
Voltmeter has very high resistance So we use Voltmeter connecting in parallel as well as in parallel voltage is const.

2) Ammeter :
mA → 0 → 100 A. Range
(0-10) (0-5A)
A A

3) wattmeter : To measure power
M → main supply
V → Voltage.

multiplying factor: $\frac{V \times I \times \cos\phi}{\text{Ful Side deflection}}$

$R = 1100\ \Omega$.
$C = 22\text{nF}$.

charging voltage → 18 Subdiviso × 0.2 = 3.6 V.
time → 4 sub diviso × 5 = 20ms.

discharging voltage → 3.6 → 0
time → 20ms.

$19.999 = \frac{V_{ph}}{2}$

$19.999 = \frac{400}{2}$

$Z = 20 = \sqrt{R^2 + X^2}$
$400 = 400 + X^2$

$Z_{ph} = R \pm j(X_L - X_C)$ $\quad \because X_C = 0$
$Z_{ph} = 25 + 29j$
$38.288\ \angle 49.236°$

$I_{ph} = \frac{242.487\ \angle 0°}{38.288\ \angle 49.236°}$

$\therefore I_{ph} = 6.333\ \angle -49.236°$
$\therefore I_L = 6.333$ A (magnitude).

ii) $pf = \cos\phi = 0.652 = \cos(49.236°)$
iii) $P = \sqrt{3}\ V_L\ I_L \times \cos\phi$
$= \sqrt{3} \times 420 \times 6.333 \times 0.653$
$= 2659.86$ watt.
$= 3006.954$ watt.

Q. A delta connected balence load across 400V, 3Ø consists 3 identical impedenses each equal to $17 + 9j\ \Omega$. Find I_L, Reactive Power, Active Power.

→ $V_L = 400$ V, 3Ø, 50 Hz $\quad$ (Δ) delta
$Z_{ph} = 17 + 9j\ \Omega$ $\quad V_L = V_{ph}$
For Δ.
I_L $\quad I_L = \sqrt{3}\ I_{ph}$.

$I_{ph} = \frac{V_{ph}}{Z_{ph}} = \frac{400\ \angle 0°}{17 + 9j} = \frac{400}{19.235\ \angle 27.897°}$

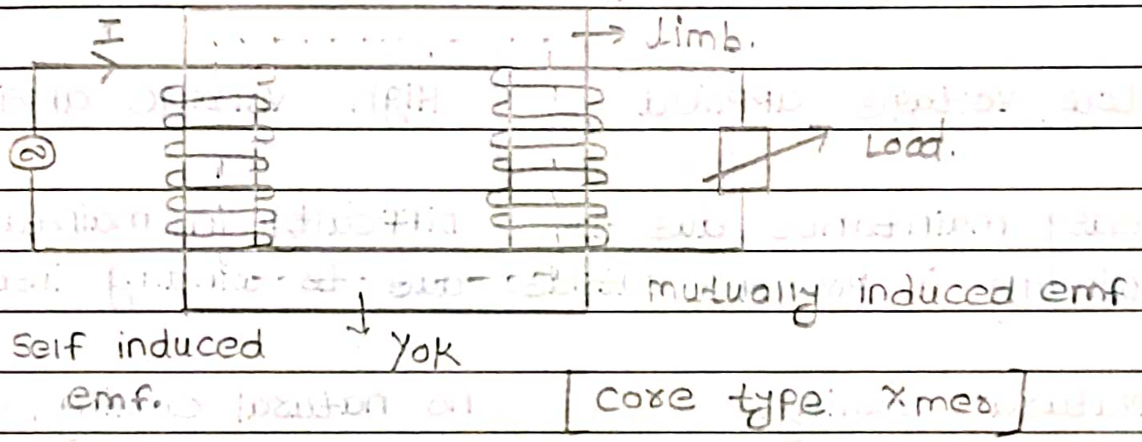
$I_{ph} = 20.795\ \angle -27.897°$
$I_L = \sqrt{3} \times 20.795$
$= 36.018$ A.
$P = \sqrt{3}\ V_L I_L \cos\phi$
$= \sqrt{3}\ 400 \times 36.018 \times \cos(27.897)$
$= 22054.101$ watt.
$Q = \sqrt{3}\ V_L I_L \sin\phi = 11675.566$ VAR.

unit - 4 Part B

Single phase transformer.

Transformer is used to transform electricity from one CKT to another by increase OE decrese Voltage But with Same frequency OE without changing frequency.

* working Principal of transformer.



when AC supply is Given to first coil then current start flowing through ckt. due to flow current flux will produec. due to AC supply there is change in flux So Accn to fraraday's law whenever change in flux linkage there will be induced emf So in coil one is self induced emf. At secondary side if there is no load So no current but due to current in first coil emf gets induced in Second Coil ∴ in second coil there is mutualy induced emf.

core is either of I or L Shape. material is high grade Stainess steel laminated core.

Core Type	Shell Type
① winding is present around core	core is present around winding.
② 2 limbs	3 limb.
③ 1 Path for flow Ø.	2 Path for flow of flux.
④ Low voltage applied	High voltage applied.
⑤ easy maintance due to winding is present outside.	Diffculty in maintance due to winding inside a core.
⑥ Natural cooling.	no natural cooling, cooling material is required for colling.

* Ratios of Xmer :-

$E_1 = 4.44 \times Ø m \times f \times N_1$

$E_2 = 4.44 \times Ø m \times f \times N_2$

$\frac{E_2}{E_1} = \frac{N_2}{N_1} = K$ .... Transformation Ration

If $K>1$	, $N_2 > N_1$	, $E_2 > E_1$	,	stepup Xformer
If $K<1$	, $N_2 < N_1$	$E_2 < E_1$		stepdown.
If $K=1$	, $N_2 = N_1$	$E_2 = E_1$		one : one Xformer

* Voltage ration

$\frac{E_2}{E_1} = \frac{V_2}{V_1} = K = \frac{N_2}{N_1}$

* current ratio :

For ideal transformer.

$V_{PP} = O/P.P$

$V_1 I_1 = V_2 I_2$

$\frac{I_1}{I_2} = \frac{V_2}{V_1}$

$\frac{N_2}{N_1} = \frac{V_2}{V_1} = \frac{I_1}{I_2} = K$ → current ratio.

Losses in Xmer :-

core loss (P_i) :- constant losses.

i) Hysterisis loss : $K_h B_m^{1.67} f V$

where $K_h \rightarrow$ hysterisis constant

$V \rightarrow$ volume

ii) Eddy current loss : $K_e B_m^2 f^2 t^2$

$K_e \rightarrow$ Eddy current const.

$t \rightarrow$ thickness of core.

copper loss (P_{cu}) :- varible losses due to current.

$P_{cu} = I_1^2 R_1 + I_2^2 R_2$

$= I_1^2 (R_1 + R_2')$

$P_{cu} = I_1^2 R_{1e}$ or $I_2^2 R_{2e}$.

$R_{1e} = R_1 + R_2'$

$\boxed{R_{1e} = R_1 + \frac{R_2}{K^2}}$ ... equivalent Resis. wrt to primary.

transformation ratio

$R_{2e} = R_1' + R_2$ ... equi Resis wrt to Secondary

$\boxed{R_{2e} = K^2 R_1 + R_2}$

$(P_{cu})_{FL} = (I^2)_{FL} \cdot R$

50%, $n = 0.5$

$(P_{cu})_{HL} = \frac{(I^2)_{FL}}{4} \times R$

$$\frac{(P_{cu})_{FL}}{(P_{cu})_{HL}} = \frac{(I)_{FL}^2 \times R \times 4}{(I)^2_{FL} \times R}$$

$$\frac{(P_{cu})_{FL}}{(P_{cu})_{HL}} = 4$$

$\therefore (P_{cu})_{HL} = \frac{1}{4} \times (P_{cu})_{FL}$

$\therefore \boxed{(P_{cu})_{HL} = n^2 \times (P_{cu})_{FL}}$

* KVA Rating of Xmer :-

$(V_1 \cdot I_1) = (VA \text{ rating})_1$

$(V_2 \cdot I_2) = (VA \text{ rating})_2$

$(KVA \text{ rating}) = \frac{V_1 I_1}{1000}$

$(KVA \text{ rating}) = \frac{V_2 I_2}{1000}$

$(I_1)_{FL} = \frac{(KVA \text{ Rating}) \times 1000}{V_1}$

$(I_2)_{FL} = \frac{(KVA \text{ Rating}) \times 1000}{V_2}$

* Efficiency of Xmer :-

$\% \eta = \frac{O/P \ P}{I/P \ P} \times 100$

O/P P < I/P P Always.

I/P = O/P P + losses

I/P = O/P P + P_i + $(P_{cu})_{FL}$.

$$\% \eta = \frac{O/P\ P}{O/P/P + P_i + (P_{cu})_{FL}}$$

$$\therefore \% \eta = \frac{V_2 I_2 \cos\phi}{V_2 I_2 \cos\phi + P_i + (P_{cu})_{FL}}$$

η at 50% loaded n = 0.5

$$(\% \eta)_{n\,load} = \frac{n V_2 I_2 \cos\phi}{n V_2 I_2 \cos\phi + P_i + n^2 (P_{cu})_{FL}}$$

Q. A 70 KVA, 1200/600 V single phase 50 Hz Xmer has iron loss of 750 W & full load copper loss of 1300 W. Find η % at full load with power factor 0.8 lagging → no effect.
ii) find efficiency at HL pf = 1.

→

$$\eta = \frac{(VA\ rating) \times \cos\phi}{(VA\ rating) \cos\phi + P_i + (P_{cu})_{FL}} \times 100$$

$$= \frac{70 \times 1000 \times 0.8}{70 \times 1000 \times 0.8 + 750 + 1300} \times 100$$

= 96.46 %

ii) $$\eta = \frac{0.5 \times 70 \times 1000}{0.5 \times 70 \times 1000 + 750 + 0.25 \times 1300} \times 100$$

η = 97.02 %

Q. A 3000/700 V 50 Hz, 65 KVA Xmer has FL copper loss of 1700 W & iron loss of 800 watt. Find Xmer eff. at

(3000 → Primary Voltage, 700 → Secondary)

i) FL with $\cos\phi$ = 0.7 leading
ii) A HL with $\cos\phi$ = 0.5 lagging

→

i) $$\eta = \frac{65 \times 1000 \times 0.7}{65 \times 1000 \times 0.7 + 800 + 1700} \times 100$$

= 94.79 %

ii) $$\eta = \frac{0.5 \times 65 \times 1000 \times 0.5}{0.5 \times 65 \times 1000 \times 0.5 + 800 + 0.25 \times 1700} \times 100$$

= 92.98 %

* condition for maximum efficiency :-

$$\frac{d\eta}{dI_2} = 0$$

$$\frac{d}{dI_2}\left[\frac{V_2 I_2 \cos\phi}{V_2 I_2 \cos\phi + P_i + I_2^2 R_{2e}}\right]$$

$$v \frac{du}{dI_2} - u \frac{dv}{dI_2} = 0$$

$$[V_2 I_2 \cos\phi + P_i + I_2^2 R_{2e}] V_2 \cos\phi - [V_2 I_2 \cos\phi] \times [V_2 \cos\phi + 2 I_2 R_{2e}] = 0$$

$$[V_2 I_2 \cos\phi + P_i + I_2^2 R_{2e}] \cancel{V_2 \cos\phi} = \cancel{V_2} I_2 \cancel{\cos\phi} [V_2 \cos\phi + 2 I_2 R_{2e}]$$

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$$[V_2 I_2 \cos\phi + P_i + I_2^2 R_{2e}] = V_2 I_2 \cos\phi + 2 I_2^2 R_{2e}$$

$$P_i = 2I_2^2 R_{2e} - I_2^2 R_{2e}.$$

$$\therefore \boxed{P_i = I_2^2 R_{2e}}$$

$$\therefore \boxed{P_i = P_{cu}}$$ ** condition for maximum efficiency.

IMP Note :-
copper losses should be equal to iron losses.
not iron losses equal to copper loss bcoz iron losses are constant they are not changing & copper losses are varible

* load current at η_{max}.

$$\boxed{P_{cu} = P_i}$$

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

but,
$$I_2 = I_{2m}.$$

$$I_{2m}^2 R_{2e} = P_i$$

$$I_{2m} = \sqrt{\frac{P_i}{R_{2e}}}$$

Divide by $(I_2)_{FL}$.

$$\frac{I_{2m}}{(I_2)_{FL}} = \frac{1}{(I_2)_{FL}} \sqrt{\frac{P_i}{R_{2e}}}$$

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$$\frac{I_{2m}}{(I_2)_{FL}} = \sqrt{\frac{P_i}{(I_2)_{FL}^2 R_{2e}}}$$

$$\therefore \boxed{I_{2m} = (I_2)_{FL} \sqrt{\frac{P_i}{(P_{cu})_{FL}}}}$$

* KVA Rating at η_{max} :

$$(KVA\ Rating) = \frac{V_2 I_2}{1000}$$

$$(KVA\ Rating)_{\eta max} = \frac{V_2 I_{2m}}{1000}$$

$$(KVA\ Rating)_{\eta max} = \frac{V_2 (I_2)_{FL}}{1000} \times \sqrt{\frac{P_i}{(P_{cu})_{FL}}}$$

$$\therefore (KVA)\ Rating)_{\eta max} = (KVA\ Rating)_{FL} \times \sqrt{\frac{P_i}{(P_{cu})_{FL}}}$$

* $$\%\ \eta_{max} = \frac{(VA\ Rating)_{max} \times \cos\phi}{(VA\ Rating)_{max} \times \cos\phi + 2P_i} \times 100.$$

Q. A Xmer is rated at 1200 KVA at FL it's copper loss is 1500 watt. & it's iron loss is 760 watt. Find η at FL for power factor 0.8 lagging
ii] η at HL for power factor unity
iii] η at 75% load with power factor 0.9 lagging.
4] load KVA for max effciency.
5] max efficiency at power factor = (0.75) load.

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→ i] $\eta = \frac{(VA\ Rating) \times \cos\phi}{(VA)\ Rating \times \cos\phi + P_i + (P_{cu})_{FL}}$

$= \frac{120 \times 1000 \times 0.8}{120 \times 1000 \times 0.8 + 760 + 1500} \times 100$

$= 97.69\%$

ii] $\eta = \frac{n\ (VA\ Rating) \times \cos\phi}{n\ (VA\ Rating) \times \cos\phi + P_i + n^2 (P_{cu})_{FL}} \times 100$

$\eta_{HL} = \frac{0.5 \times 120 \times 1000 \times 1}{0.5 \times 120 \times 1000 + 760 + 0.25 \times 1500} \times 100$

$= 98.14\%$

iii] $\eta_{75\%}$ $\therefore n = 0.75$

$\eta_{75\%} = \frac{0.75 \times 120 \times 1000 \times 0.9}{0.75 \times 120 \times 1000 \times 0.9 + 760 + 0.5625 \times 1500} \times 100$

$= 98.058\%$

iv] $(KVA)_{\eta max} = 120 \times \sqrt{\frac{760}{1500}}$

$= 85.4166$

consider this max KVA for η_{max}.

v] $\eta_{max} = \frac{85.4166 \times 1000 \times 0.75}{85.4166 \times 1000 \times 0.75 + 2 \times 760} \times 100$

$= 97.682\%$

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Q. A 300 KVA Single ϕ Xmer has iron loss of 1.8 Kwatt. Full load copper loss 2000 watt. Calculate $(\eta)_{FL}$ for $\cos\phi = 0.8$ lag & $(\eta)_{max}$ at $0.8 = \cos\phi$ lagg.

→ $(\eta)_{FL} = \frac{300 \times 1000 \times 0.8}{300 \times 1000 \times 0.8 + 1.8 \times 1000 + 2000} \times 100$

$= 98.44\%$

~~$(\eta)_{max}$~~ :

$(KVA)_{max} = 300 \times \sqrt{\frac{1.8 \times 1000}{2000}} = 284.604$

$\eta_{max} = \frac{284.604 \times 1000 \times 0.8}{284.604 \times 1000 \times 0.8 + 2 \times 1.8 \times 1000} \times 100$

$= 98.44\%$

* Voltage Regulation :-

$\%\ regn = \frac{V_{no\ load} - V_{FL}}{V_{FL}} \times 100$ ... Per unit regn.

% regn ~~wrt~~ Sec

$\%\ regn = \frac{V_{no\ load} - V_{FL}}{V_{NL}} \times 100$ ... Total Regulation

% reg^n w.r.t Secondary

$$\% \ reg^n = \frac{I_2 R_{2e} \cos\phi \pm I_2 X_{2e} \sin\phi}{V_2} \times 100 \quad \begin{matrix} + \rightarrow \text{lagg} \\ - \rightarrow \text{lead} \end{matrix}$$

% reg^n wrt primary

$$\% \ reg^n = \frac{I_1 R_{1e} \cos\phi \pm I_1 X_{1e} \sin\phi}{V_1} \times 100$$

R_{2e}	=	$R_2 + R_1'$	=	$R_2 + R_1 k^2$	
R_{1e}	=	$R_1 + R_2'$	=	$R_1 + \frac{R_2}{k^2}$	⚹
X_{2e}	=	$X_2 + X_1'$	=	$X_2 + X_1 k^2$	
X_{1e}	=	$X_1 + X_2'$	=	$X_1 + \frac{X_2}{k^2}$	

Q. A 200 KVA 1ϕ Xmer has primary Voltage 2500 Volt. & sec. Voltage 400 V. the Supply frequency is 50 Hz. the total effective Resistance & reactance w.r.t primary are 0.5Ω & 2Ω respectivey calculate voltage reg^n Xmer with 0.8 Power factor lagging.

ii) Find Vtg reg^n wit unity p.f.

→ Given.

$V_1 = 2500$

$V_2 = 400$

200 KVA

f = 50 Hz

$R_{1e} = 0.5\ \Omega$

$X_{1e} = 2\ \Omega$

i) P.f = (0.8) lag.

$$\% \ reg^n = \frac{I_1 R_{1e} \cos\phi + I_1 X_{1e} \sin\phi}{V_1}$$

$$(I_1)_{FL} = \frac{(\text{KVA Rating}) \times 1000}{V_1}$$

$$= \frac{200 \times 1000}{2500} = 80$$

$\cos\phi = 0.8$

$\phi = 36.86$

$\sin\phi = 0.6$.

$$\% \ reg^n = \frac{(80 \times 0.5 \times 0.8) + (80 \times 2 \times 0.6)}{2500} \times 100$$

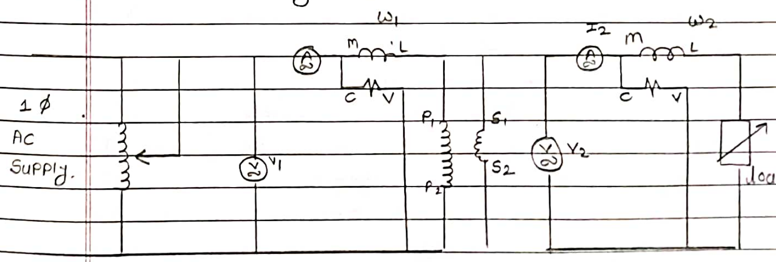
$= 5.12\ \%$.

ii) when pf unity then $\sin\phi = 0$.

$$\% \ reg^n = \frac{80 \times 0.5 \times 1}{2500} \times 100$$

$= 1.6\ \%$

* Direct loading test :-



$N_1 > N_2$

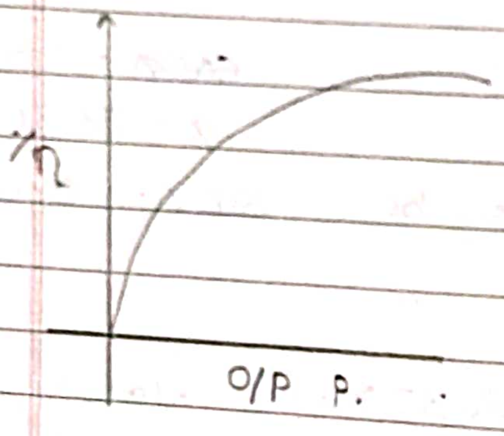
So step down Xmer

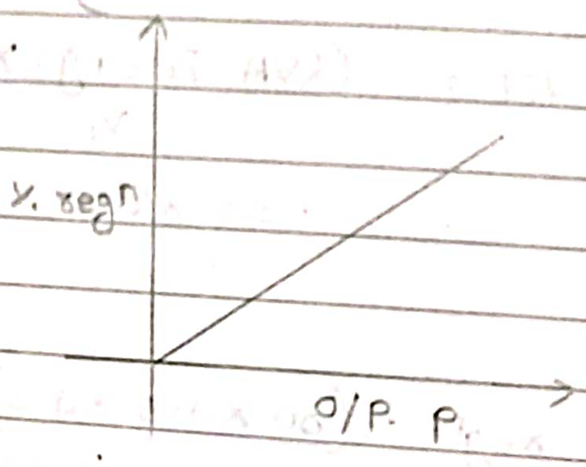
$\% \eta = \frac{\omega_2}{\omega_1} \times 100$

no load voltage.

$\% \text{ reg}^n = \frac{E_2 - V_2}{E_2} \times 100$

IMP graph draw exam.





* Auto Xmer.