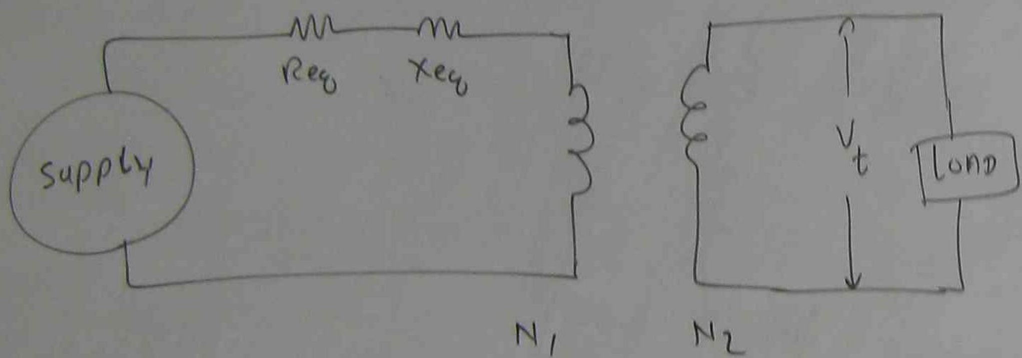
% VOLTAGE REGULATION OF TRANSFORMER

$$\% \text{ VOLTAGE REGULATION} = \frac{\text{NO LOAD VOLTAGE} - \text{FULL LOAD VOLTAGE}}{\text{NO LOAD VOLTAGE}} \times 100$$



LAGGING P.F $\Rightarrow$ % VOLTAGE REGULATION $= \dfrac{I_s' \left(R_{eq}' \cos\theta + X_{eq}' \sin\theta\right)}{V_p} \times 100$

LEADING P.F $\Rightarrow$ % VOLTAGE REGULATION $= \dfrac{I_s' \left(R_{eq}' \cos\theta - X_{eq}' \sin\theta\right)}{V_p} \times 100$

POWER FACTOR

$$\% \text{ VOLTAGE REGULATION} = \frac{I_s' R_{eq}'}{V_P} \times 100 \cos\theta + \frac{I_s' X_{eq}' \times 100}{V_P} \sin\theta$$

$$\boxed{\% \text{ VOLTAGE REGULATION} = \% R_{eq}' \cos\theta + \% X_{eq}' \sin\theta} \leftarrow \text{LAGGING p.f}$$

$$\boxed{\% \text{ VOLTAGE REGULATION} = \% R_{eq}' \cos\theta - \% X_{eq}' \sin\theta} \leftarrow \text{LEADING PF}$$

Pb 1 $\% R = 2$, $\% X = 4$ FIND % VOLTAGE REGULATION AT 0.8 PF LAGGING.

$$\% \text{ VOLTAGE REGULATION} = \% R \cos\theta + \% X \sin\theta$$

$\cos\theta = 0.8 \rightarrow \theta = \cos^{-1} 0.8 = 36.8^\circ$

$\sin\theta = \sin 36.8 = 0.6$

$\% V \text{ REG} = 2 \times 0.8 + 4 \times 0.6$

$= 1.6 + 2.4$

$= 4\%$

pb 2

$N_p = 400$, $N_s = 80$ $R_p = 0.3\,\Omega$, $R_s = 0.01\,\Omega$

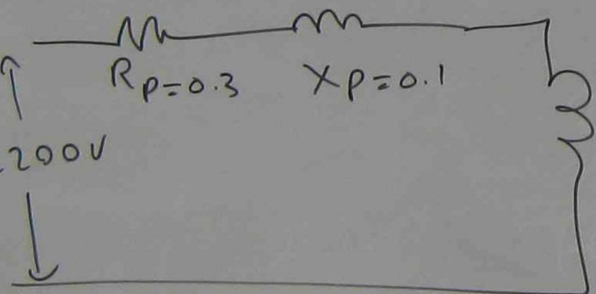
$X_p = 0.1\,\Omega$, $X_s = 0.03\,\Omega$

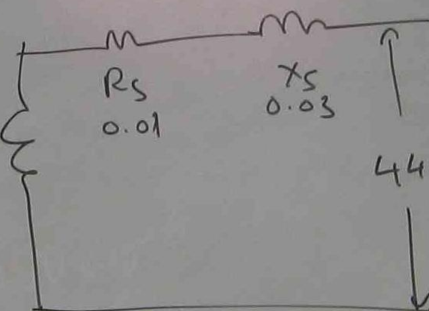
$V_p = 2200\,V$, $V_s = 440\,V$

FIND Z_{eq}', V_s', % REGULATION FOR 0.8 PF LAGGING

% REGULATION FOR 0.8 PF LEADING

(TRANSFORMER IS 100 KVA, 1ϕ)





$$\%\ \text{VOLTAGE REGULATION} = \frac{I'(R_{eq}\cos\theta + X_{eq}\sin\theta)}{V_p} \times 100$$

$$I' = \frac{KVA \times 10^3}{\text{PRIMARY VOLTAGE}} = \frac{100 \times 10^3}{2200} = 227.3\ \text{Amp}$$

$PF = \cos\theta$

$\theta = \cos^{-1} p.f$

$= \cos^{-1} 0.8$

$= 36.8$

$\sin\theta = \sin 36.8$

$= 0.6$

for

$$R_{eq} = R_p + \left(\frac{NP}{NS}\right)^2 R_s = 0.3 + \left(\frac{2200}{440}\right)^2 \times 0.01 = 0.3 + 25 \times 0.01 = 0.55\,\Omega$$

$$X_{eq} = X_p + \left(\frac{NP}{NS}\right)^2 X_s = 0.1 + \left(\frac{2200}{440}\right)^2 \times 0.03 = 0.1 + 25 \times 0.03 = 0.85\,\Omega$$

% VOLTAGE REGULATION for 0.8 PF LAGGING $= \dfrac{227.3\,(0.55 \times 0.8 + 0.85 \times 0.6)}{2200} \times 100 = 9.8\,\%$

% VOLTAGE REGULATION for 0.8 PF LEADING $= \dfrac{227.3\,(0.55 \times 0.8 - 0.85 \times 0.6)}{2200} \times 100 = -0.72\,\%$

$R_S = 0.01\,\Omega$

$X_S = 0.03\,\Omega$

$V_S = 440V$

0.8 PF LAGGING

0.8 Pf LEADING

$$R_{eq} = R_p + \left(\frac{N_P}{N_S}\right)^2 R_S = 0.3 + \left(\frac{2200}{440}\right)^2 \times 0.01 = 0.3 + 25 \times 0.01 = 0.55\,\Omega$$

$$X_{eq} = X_p + \left(\frac{N_P}{N_S}\right)^2 X_S = 0.1 + \left(\frac{2200}{440}\right)^2 \times 0.03 = 0.1 + 25 \times 0.03 = 0.85\,\Omega$$

% VOLTAGE REGULATION for 0.8 PF LAGGING $= \dfrac{227.3\,(0.55 \times 0.8 + 0.85 \times 0.6)}{2200} \times 100 = 9.8\,\%$

% VOLTAGE REGULATION for 0.8 PF LEADING $= \dfrac{227.3\,(0.55 \times 0.8 - 0.85 \times 0.6)}{2200} \times 100 = -0.72\,\%$

$PF = \cos\theta$

$\theta = \cos^{-1} p.f$

$= \cos^{-1} 0.8$

$= 36.8$

$\sin\theta = \sin 36.8$

$= 0.6$

MAXIMUM REGULATION

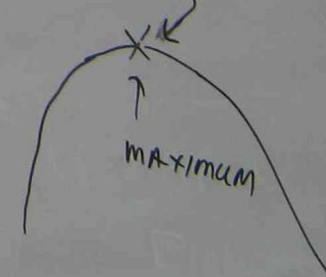
$$\%REG = \%R\cos\theta + \%X\sin\theta$$

$$\frac{d\,\%REG}{d\theta} = \frac{d}{d\theta}\left(\%R\cos\theta + \%X\sin\theta\right)$$

$$0 = -\%R\sin\theta + \%X\cos\theta$$

MAXIMUM REGULATION

$\dfrac{dR}{dx} = 0 \rightarrow$ MAXIMUM POINT



$\left(\frac{2200}{440}\right)^2 \times 0.01 = 0.3 + 25 \times 0.01 = 0.55\ \Omega$

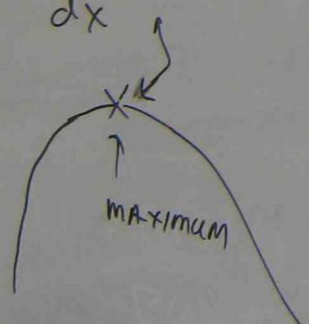
$\left(\frac{2200}{440}\right)^2 \times 0.03 = 0.1 + 25 \times 0.03 = 0.85\ \Omega$

$\frac{.8 + 0.85 \times 0.6)}{0} \times 100 = 9.8\ \%$

$\frac{.8 - 0.85 \times 0.6)}{00} \times 100 = -0.72\ \%$

θ

$\frac{dR}{dx} = 0 \rightarrow$ MAXIMUM POINT



MAXIMUM REGULATION

$\% R \sin\theta = \% X \cos\theta$

$\frac{\sin\theta}{\cos\theta} = \frac{\% X}{\% R}$

$\boxed{\tan\theta = \frac{\% X}{\% R}}$ MAXIMUM REGULATION

pb: IF $\% R = 3$, $\% X = 5$, FIND $\%$ REG=? P.F LAGGING

$\tan\theta = \frac{\% X}{\% R} = \frac{5}{3} = 1.667$

$\theta = \tan^{-1} 1.667 = 59.64$

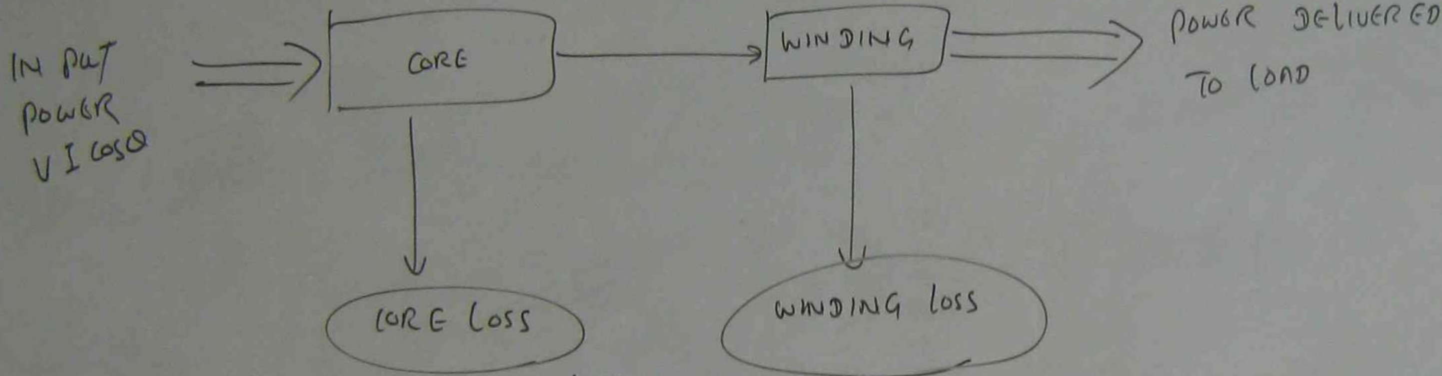
$\% REG = \% R \cos\theta + \% X \sin\theta$

$= 3 \times \cos 59.64 + 5 \sin 59.64$

$= 3 \times 0.6 + 5 \times 0.8$

$= 5.8\ \%$

TRANSFORMER LOSSES AND EFFICIENCY



EDDY CURRENT LOSS
HYSTERISIS LOSS
MAGNETISING LOSS

COPPER LOSS

$$\%\ \text{EFFICIENCY} = \frac{\text{INPUT POWER} - (\text{CORE LOSS} + \text{WINDING LOSS})}{\text{INPUT POWER}} \times 100$$

IF TRANSFORMER IS SUPPLYING THE LOAD LESS THAN FULL LOAD

$$\text{LOAD RATIO} = L = \frac{\text{ANY LOAD (VA (OR) KVA)}}{\text{FULL LOAD (VA (OR) KVA)}}$$

$$\underset{(\text{KW})}{\text{ANY LOAD OUTPUT}} = L \times \text{FULL LOAD KVA} \times \text{P.F}$$

$$\text{ANY LOAD COPPER LOSS} = L^2 \times \text{FULL LOAD COPPER LOSS}$$

Pb 1d, 500KVA TRANSFORMER 6600/440 V

IRON LOSS = 2.9KW, FULL LOAD COPPER LOSS = 4KW

FIND (a) % EFFICIENCY AT FULL LOAD 0.8 PF LAGGING

(b) % EFFICIENCY AT 1/2 LOAD 0.8 PF LAGGING

(a) L = 1 FULL LOAD

$$\text{OUTPUT} = L \times \underset{\text{KVA}}{\text{FULL LOAD}} \times \text{P.f}$$

$$= 1 \times 500 \times 0.8 = 400 \text{ KW}$$

IRON LOSS = 2.9 KW

COPPER LOSS = 4 KW

$$\%\text{EFFICIENCY} = \frac{\text{INPUT} - \left(\text{CORE LOSS} + \text{WINDING LOSS}\right)}{\text{INPUT}} \times 100$$

<OR>

$$\%\text{EFFICIENCY} = \frac{\text{OUTPUT}}{\text{OUTPUT} + \text{CORE LOSS} + \text{WINDING LOSS}} \times 100$$

$$= \frac{400}{400 + 2.9 + 4} \times 100$$

$$= 98.3\%$$

N FULL LOAD

LOSS

V

4 KW

AGGING

IGING

(a) $L = 1$ FULL LOAD

$$\text{OUTPUT} = L \times \underset{\text{KVA}}{\text{FULL LOAD}} \times \text{P.F}$$

$$= 1 \times 500 \times 0.8 = 400 \text{ KW}$$

IRON LOSS = 2.9 KW

COPPER LOSS = 4 KW

$$\text{\% EFFICIENCY} = \frac{\text{INPUT} - \left(\underset{\text{LOSS}}{\text{CORE}} + \underset{\text{LOSS}}{\text{WINDING}}\right)}{\text{INPUT}} \times 100$$

<OR>

$$\text{\% EFFICIENCY} = \frac{\text{OUTPUT}}{\text{OUTPUT} + \text{CORE LOSS} + \text{WINDING LOSS}} \times 100$$

$$= \frac{400}{400 + 2.9 + 4} \times 100$$

$$= 98.3\%$$

(b) $\text{OUTPUT} = L \times \text{FULL LOAD KVA} \times \text{P.F}$

$$= \frac{1}{2} \times 500 \times 0.8$$

$$= 200 \text{ KW}$$

IRON LOSS = 2.9 KW

$$\tfrac{1}{2} \text{ LOAD COPPER LOSS} = \left(\frac{1}{2}\right)^2 \times 4 = 1 \text{ KW}$$

$$\text{\% EFFICIENCY} = \frac{200}{200 + 2.9 + 1} \times 100$$

$$= 98\%$$

MAXIMUM EFFICIENCY OF TRANSFORMER

MAXIMUM EFFICIENCY ⟶ TOTAL IRON LOSS = TOTAL COPPER LOSS AT MAXIMUM EFFICIENCY LOAD

$$W_I = L_{MAX}^2 \, W_{CFL}$$

WI = IRON LOSS

W_{CFL} = FULL LOAD COPPER LOSS

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100 pb / FIND THE LOAD AT MAXIMUM EFFICIENCY OF THE FOLLOWING SINGLE PHASE TRANSFORMER

KVA = 1000, VOLTAGE RATIO = 6600/400 IRON LOSS = 4 KW

FULL LOAD COPPER LOSS = 6 KW.

MAXIMUM EFFICIENCY IS ACHIEVED AT 0.6 PF LAGGING.

AT MAXIMUM EFFICIENCY

$$W_I = L_{MAX}^2 \, W_{CFL}$$

$$4 = L_{MAX}^2 \times 6$$

$$L_{MAX} = \sqrt{\frac{4}{6}} = 0.816$$

OUTPUT AT $L_{MAX} = L_{MAX} \times$ RATED KVA $\times$ pf

$= 0.816 \times 1000 \times 0.6 = 489.89 \text{kw}$

$W_I = 4$ kw

$$W_{c \text{ AT MAX EFFCY}} = L_{max}^2 \, W_c \, FL$$

$$= (0.816)^2 \times 6$$

$$\simeq 3.99 \text{ kw}$$

$$\% \text{ EFFICIENCY} = \frac{\text{OUTPUT}}{\text{OUTPUT} + W_I + W_{c\,L_{MAX}}} \times 100$$

$$= \frac{489.89}{489.89 + 4 + 3.99} \times 100$$

$$\simeq 98.3\%$$