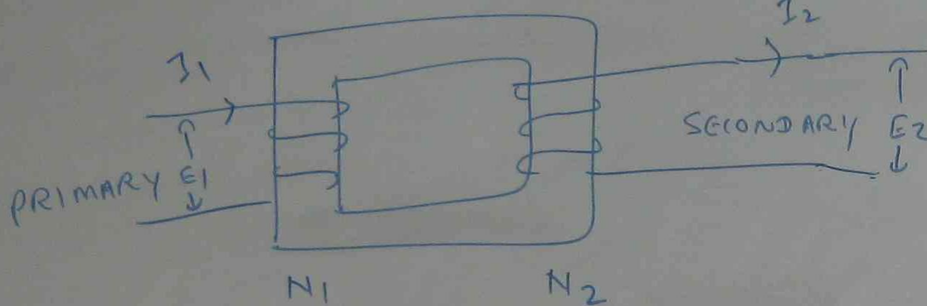
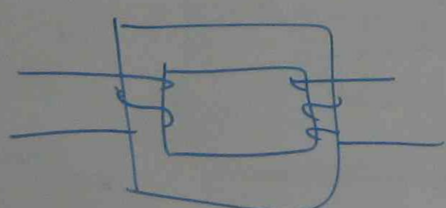


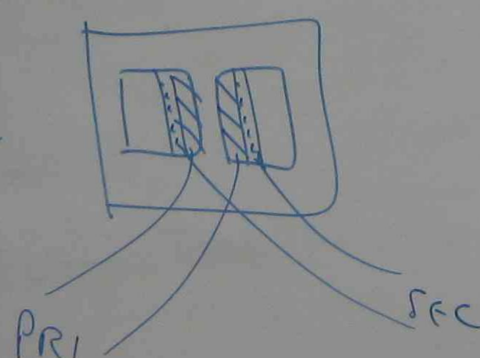
$$\frac{E_1}{E_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1}$$

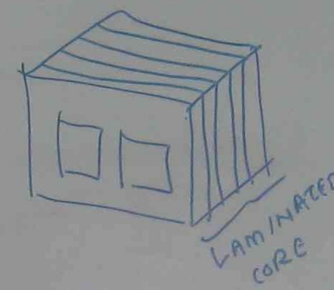
$$E = 4.44\, \phi f N$$

CORE



SHELL





TO REDUCE EDDY CURRENT & HYSTERESIS LOSS

POWER TRANSFORMER

SAME PRINCIPLE

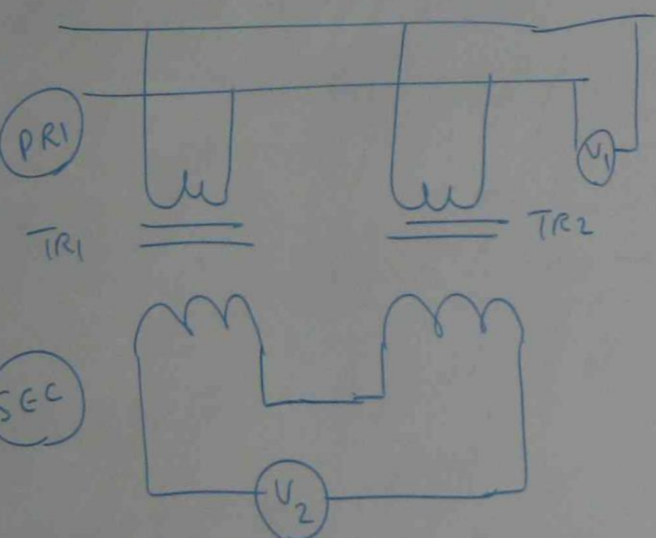
+

FORCED AIR COOLING

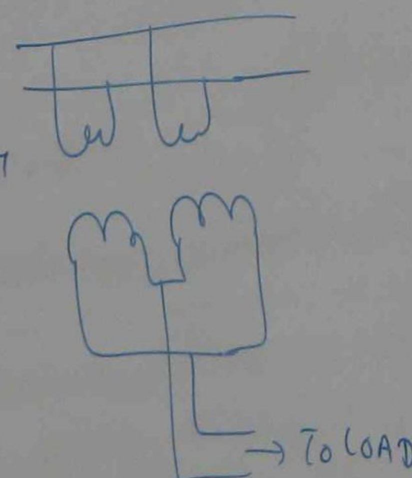
FORCED OIL COOLING

PARALLEL CONNECTION

- SAME VOLTAGE
- SAME RATING
- SAME POLARITY

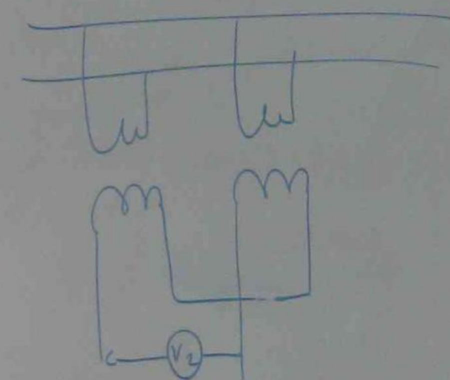


IF $V_2 \simeq 0$ → THEN CONNECT



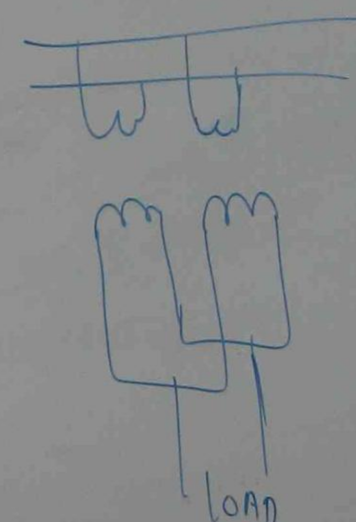
IF $V_2 \simeq$ LINE SECONDARY VOLTAGE

TEST AGAIN



IF $V_2 \simeq 0$

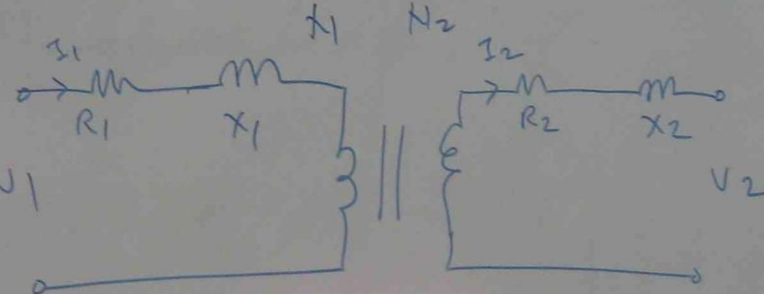
THEN CONNECT



IF
V_2 IS STILL NOT
EQUAL TO $\simeq 0$

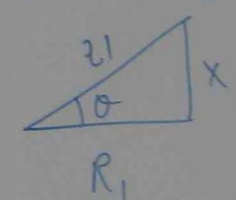
YOU CAN NOT CONNECT
THESE TWO TRANSFORMERS
IN PARALLEL

TRANSFORMER EQUIVALENT CIRCUIT



$X_1 = 2\pi f L_1$ (PRIMARY INDUCTIVE REACTANCE) (Ω)
$X_2 = 2\pi f L_2$ (SECONDARY INDUCTIVE REACTANCE) (Ω)
R_1 = PRIMARY RESISTANCE (Ω)
R_2 = SECONDARY RESISTANCE (Ω)

Z_1 = PRIMARY IMPEDANCE (Ω) = $Z_1 = \sqrt{R_1^2 + X_1^2} = R_1 + jX_1$



Z_2 = SECONDARY IMPEDANCE = $Z_2 = \sqrt{R_2^2 + X_2^2}$ (Ω)

$Z_2 = R_2 + jX_2$

$\frac{N_1}{N_2} =$

$\frac{V_1}{V_2}$

$$\frac{N_1}{N_2} = \text{TURN RATIO} = a$$

$$\boxed{\frac{V_1}{V_2} = \frac{N_1}{N_2} = a = \frac{I_2}{I_1}}$$ BASIC

$$\boxed{\frac{V_2'}{V_2} = \frac{N_1}{N_2} = a = \frac{I_2}{I_2'}}$$ MODIFIED (1)

V_2' = SECONDARY VOLTAGE REFER TO PRIMARY

I_2' = SECONDARY CURRENT REFER TO PRIMARY

X_1

$$\boxed{\frac{V_1}{V_1''} = \frac{N_1}{N_2} = a = \frac{I_1''}{I_1}}$$ MODIFIED FORMULA

V_1'' = PRIMARY VOLTAGE REFERRED TO SECONDARY

I_1'' = PRIMARY CURRENT REFERRED TO SECONDARY

$$\boxed{\frac{R_1}{R_2} = \frac{X_1}{X_2} = \frac{Z_1}{Z_2} = a^2}$$ BASIC

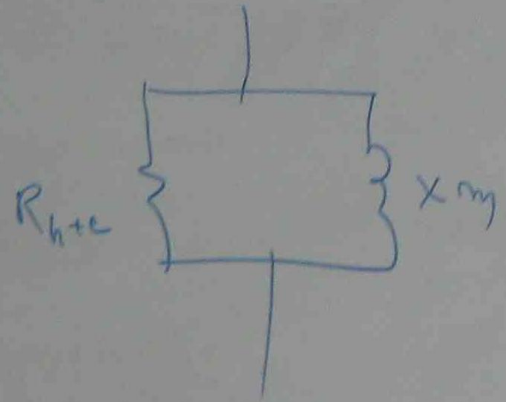
$$\left.\begin{aligned} \frac{R_2'}{R_2} = \frac{X_2'}{X_2} = \frac{Z_2'}{Z_2} = a^2 \\ \frac{R_1}{R_1''} = \frac{X_1}{X_1''} = \frac{Z_1}{Z_1''} = a^2 \end{aligned}\right\} \text{MODIFIED}$$

COMPLETE TRANSFORMER EQUIVALENT CIRCUIT

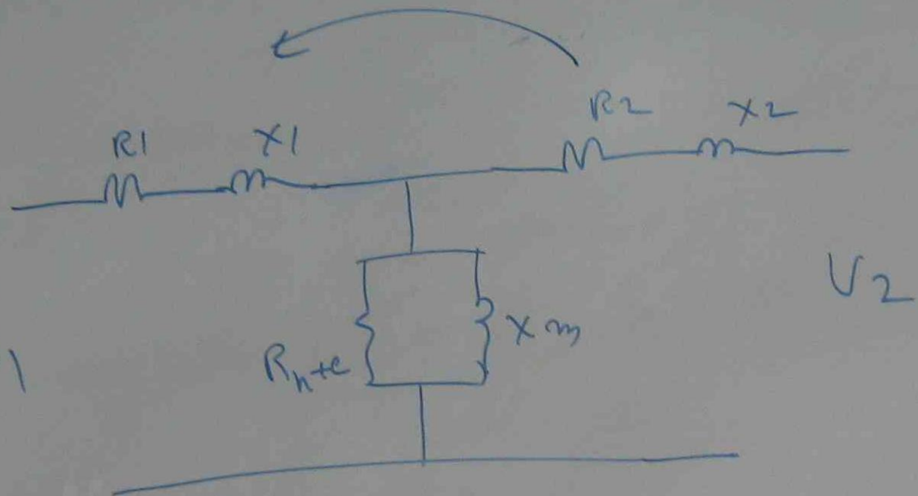
X_m = CORE INDUCTIVE REACTANCE

R_{h+e} = EDDY CURRENT + HYSTERESIS RESISTANCE of TRANSFORMER CORE

CORE →



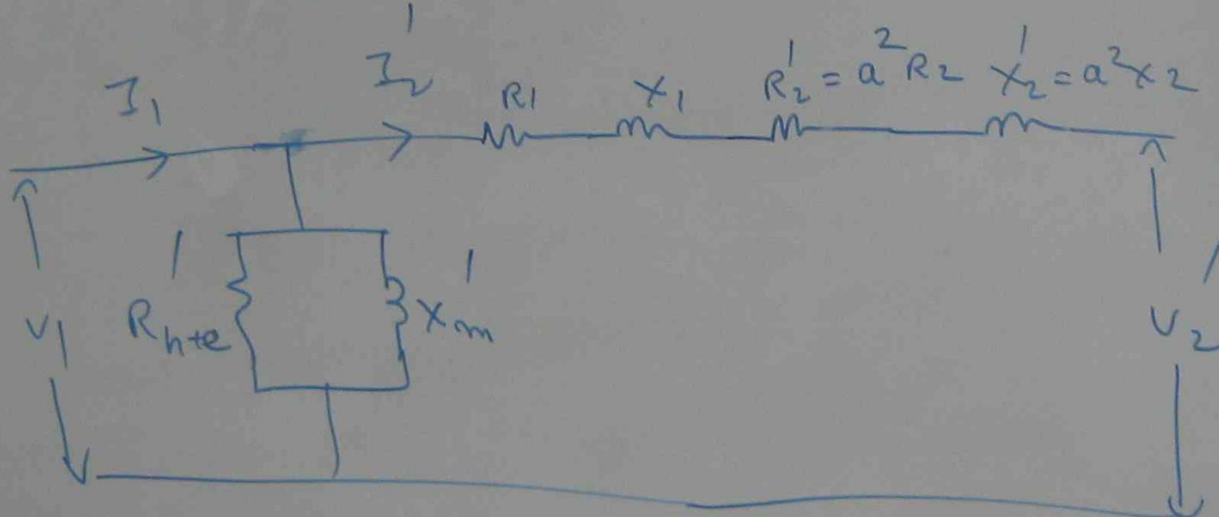
STANCE

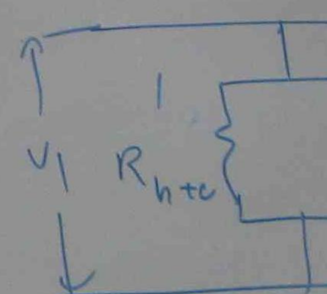


$R_1 + R_2' = R_e' =$

$X_1 + X_2' = X_e' =$

$Z_e' = \sqrt{(R_e')^2 +}$





R_2' = SECONDARY RESISTANCE REFERRED TO PRIMARY

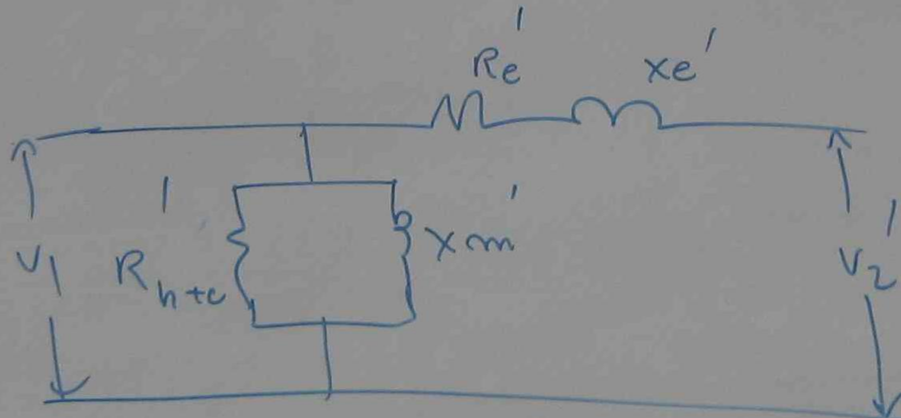
X_2' = ——— INDUCTING ——— REACTANCE

$R_1 + R_2' = R_e' =$ TOTAL EQUIVALENT RESISTANCE REFER TO PRIMARY

$X_1 + X_2' = X_e' =$ INDUCTIVE REACTANCE

$$Z_e' = \sqrt{(R_e')^2 + (X_e')^2} = R_e' + jX_e'$$ = TOTAL EQUIVALENT IMPEDANCE REFER TO PRIMARY

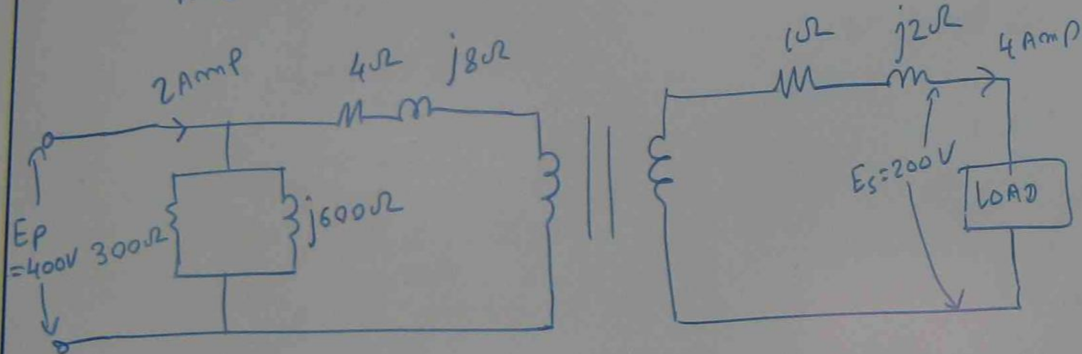
RRED TO PRIMARY



FINAL EQUIVALENT CIRCUIT OF TRANSFORMER

TUTORIAL 3

Q1 REFER THE FOLLOWING SINGLE PHASE TRANSFORMER EQUIVALENT CIRCUIT AND CALCULATE THE FOLLOWINGS.



(a) TURN RATIO

(b) SECONDARY RESISTANCE REFER TO PRIMARY

(c) SECONDARY INDUCTIVE REACTANCE REFER TO PRIMARY

(d) SECONDARY CURRENT REFER TO PRIMARY

(e) SECONDARY VOLTAGE REFER TO PRIMARY

PRIMARY	SECONDARY
$R_1 = 4\Omega$	$R_2 = 1\Omega$
$X_1 = j8\Omega$	$X_2 = j2\Omega$
$I_1 = 2\,Amp$	$I_2 = 4\,Amp$
$V_1 = 400V$	$V_2 = 200V$
$R'_{htc} = 300\Omega$	
$X'_m = j600\Omega$	

(a) TURN RATIO $(a) = \frac{V_1}{V_2} = \frac{400}{200} = 2$

(b) $R'_2 = a^2 R_2 = 2^2 \times 1 = 4\Omega$

(c) $X'_2 = a^2 X_2 = 2^2 \times j2 = j8\Omega$

(d) $I_2' = ?$

$$\frac{V_1}{V_2} = \frac{N_1}{N_2} = a = \frac{I_2}{I_1}$$

$$a = \frac{I_2}{I_2'}$$

$$I_2' = \frac{I_2}{a} = \frac{4}{2} = 2 \text{ Amp}$$

(e) $V_2' = ?$

$$\boxed{\frac{V_1}{V_2} = \frac{N_1}{N_2} = \frac{I_2}{I_1} = a}$$

$$\frac{V_1}{V_2} = a \longrightarrow \boxed{\frac{V_2'}{V_2} = a}$$

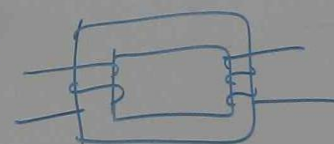
$$V_2' = aV_2 = 2 \times 200 = 400 \text{ V}$$

TUTORIAL 1

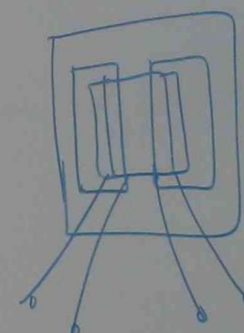
Q1 SKETCH CORE TYPE AND SHELL TYPE TRANSFORMER

Q2 WHY IS THE LAMINATED CORE USED IN TRANSFORMER?

Q1



CORE TYPE



SHELL TYPE

Q2 TO REDUCE HYSTERESIS AND EDDY CURRENT POWER LOSSES IN THE CORE, LAMINATED IRON CORE IS UTILIZED.

POWER LOSSES IN TRANSFORMER

- CORE LOSS (CONSTANT LOSS)
  - W_I
- WINDING LOSS (VARIABLE LOSS)
  - W_c (COPPER LOSS)
    - PRIMARY WINDING
    - SECONDARY WINDING

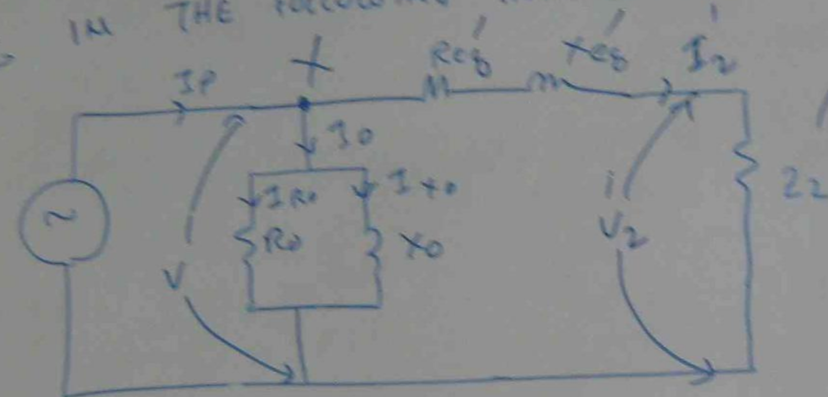
EQUIVALEN

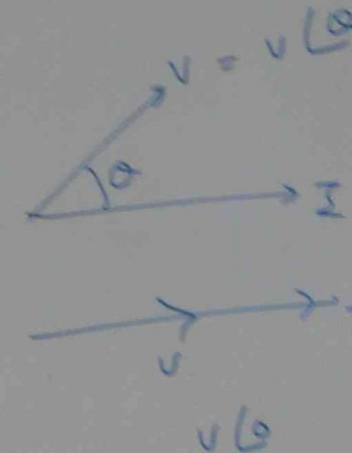
RESISTA

FI

TUTORIAL (3)

Q.2 IN THE FOLLOWING TRANSFORMER





loss >

RY

NG

QUIVALENT

RESISTANCE

$R'_{eq} = 0.2\,\Omega$, $X'_{eq} = j0.8\,\Omega$

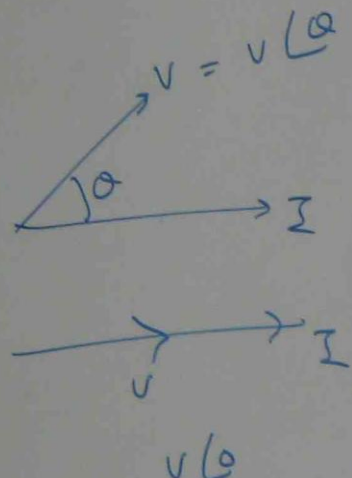
$R_0 = 300\,\Omega$, $X_0 = j400\,\Omega$

$V = 250\angle 0\ V$

$Z'_2 = 6 + j3\,\Omega$

FIND (a) IRON LOSS (b) NO LOAD CURRENT (c) SECONDARY LOAD CURRENT (d) TOTAL PRIMARY CURRENT (e) COPPER LOSSES (f) SECONDARY TERMINAL VOLTAGE (g) POWER IN WATT CONSUMED BY LOAD (h) % EFFICIENCY

Z_2



(a) IRON LOSS = CORE LOSS $= \dfrac{V^2}{R_0} = \dfrac{(250)^2}{300} = 208$ WATT

(b)

$$I_0 = \bar{I}_{R_0} + \bar{I}_{X_0}$$

$$\bar{I}_{R_0} = \frac{V}{R_0} = \frac{250}{300} = 0.833 \text{ Amp}$$

$$\bar{I}_{X_0} = \frac{V}{X_0} = \frac{250}{j400} = \frac{250}{400\angle 90} = 0.625\angle -90$$

$$= -j0.625$$

$$\bar{I}_0 = \bar{I}_{R_0} + \bar{I}_{X_0} = 0.833 + (-j0.625) = 0.833 - j0.625$$

$$\bar{I}_0 = \sqrt{0.833^2 + 0.625^2}\ \angle -\tan^{-1}\frac{0.625}{0.833} = 1.04\ \angle -36.86^\circ \text{ Amp}$$

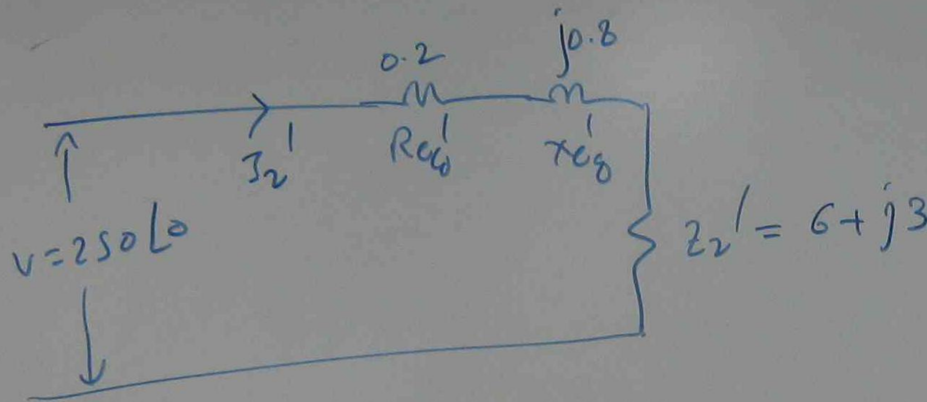
SECONDARY LOAD CURRENT

LOSSES (f) SECONDARY

WATT CONSUMED BY LOAD

EFFICIENCY

(c) SECONDARY LOAD CURRENT $= I_2' = ?$



$$I_2' = \frac{250\angle 0}{R_{eq}' + j\,x_{eq}' + Z_2'}$$

$$= \frac{250\angle 0}{0.2 + j0.8 + 6 + j3}$$

$$= \frac{250\angle 0}{6.2 + j3.8}$$

$$= \frac{250\angle 0}{\sqrt{6.2^2 + 3.8^2}\ \angle \tan^{-1}\frac{3.8}{6.2}} = \frac{250\angle 0}{7.27\angle 31.4}$$

$$= 34.3\angle -31.4^\circ \text{ Amp.}$$

(d) $I_p = I_2' + I_0$

$= 34.3\angle -31.4 + 1.04$

$= (34.3 \cos 31.4 - j\,34.3 \sin$

$= (34.3 \times 0.853 - j\,34.3 \times 0.5$

$= 29.25 - j17.8 +$

$= 30.08 - j18.4$

(e) COPPER LOSS

(f) $V_2' = V -$

(d) $I_p = I_2' + I_0$

$= 34.3\angle -31.4 + 1.04\angle -36.86$

$= (34.3\cos 31.4 - j\,34.3\sin 31.4) + (1.04\cos 36.86 - j\,1.04\sin 36.86)$

$= (34.3 \times 0.853 - j\,34.3 \times 0.521) + (1.04 \times 0.8 - j\,1.04 \times 0.6)$

$= 29.25 - j\,17.8 + 0.832 - j\,0.624$

$= 30.08 - j\,18.4$ Amp $= \sqrt{30.08^2 + 18.4^2}\ \angle -\tan^{-1}\dfrac{18.4}{30.08}$

$= 35.26\angle -31.4^\circ$ Amp

(e) COPPER LOSS $= (I_2')^2 \times R_{eq}' = (34.3)^2 \times 0.2 = 235.2$ WATT

(f) $V_2' = V - I_2'(R_{eq}' + jX_{eq}')$

4

-31.4° Amp

$$V_2' = 250\angle 0 - 34.3\angle{-31.4}\,(0.2+j0.8)$$

$$= 250\angle 0 - 34.3\angle{-31.4} \times \sqrt{0.2^2+0.8^2}\ \angle \tan^{-1}\frac{0.8}{0.2}$$

$$= 250\angle 0 - 34.3\angle{-31.4} \times 0.824\ \angle 75.9$$

$$= 250\angle 0 - 28.26\angle 75.9+(-31.4) = 250\angle 0 - 22.26\ \angle 44.5$$

$$= 250 - 28.26\,(\cos 44.5 + j\sin 44.5)$$

$$= 250 - 28.26\,(0.7132 + j0.7) = 250 - 20.15 - j19.78$$

$$= 229.85 - j19.78 = \sqrt{229.85^2+19.78^2}\ \angle -\tan^{-1}\frac{19.78}{229.85}$$

$$= 230.7\ \angle -4.91 \text{ VOLT}$$

(g) POWER IN LOAD $= (I_2')^2 \times R_{LOAD} = (34.3)^2 \times 6 = 7058.94$ WATT

(h) INPUT POWER = LOAD POWER + CORE LOSS + WINDING LOSS

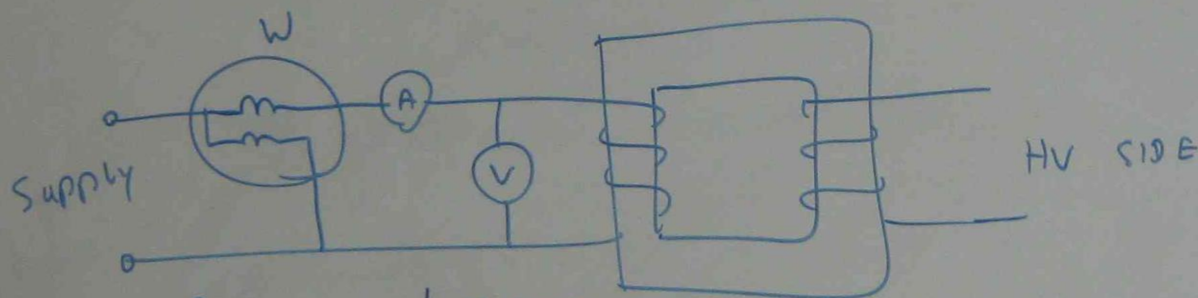
$$= 7058.94 + 208 + 235.2 = 7502.14\,W$$

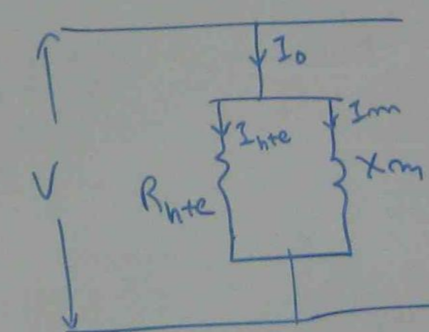
$$\%\ \text{Efficiency} = \frac{\text{OUTPUT}}{\text{INPUT}} \times 100 = \frac{7058.94}{7502.14} \times 100 = 94.08\%$$

TRANSFORMER OPEN CIRCUIT TEST / SHORT CIRCUIT TEST

TO FIND TRANSFORMER CORE RESISTANCE AND WINDING RESISTANCE, OPEN CIRCUIT TEST AND SHORT CIRCUIT TEST ARE DONE.

OPEN CIRCUIT TEST $\longrightarrow$ CORE RESISTANCE + INDUCTIVE REACTANCE





$$P = \frac{V^2}{R} \rightarrow R = \frac{V^2}{P}$$

$$R_{hte} = \frac{(\text{VOLT METER READING})^2}{\text{WATT METER READING}}$$

$$X_m = \frac{\text{VOLT METER}}{\text{AM METE}}$$

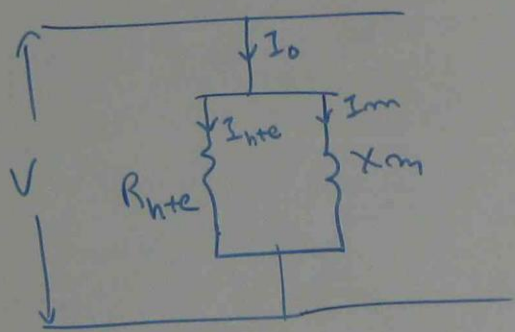
ST

AND WINDING RESISTANCE,

TEST ARE DONE.

NCE + INDUCTIVE REACTANCE

V SIDE



WATT METER READING (W) = VOLT METER READING (V) × AM METER READING (I) × COSθ

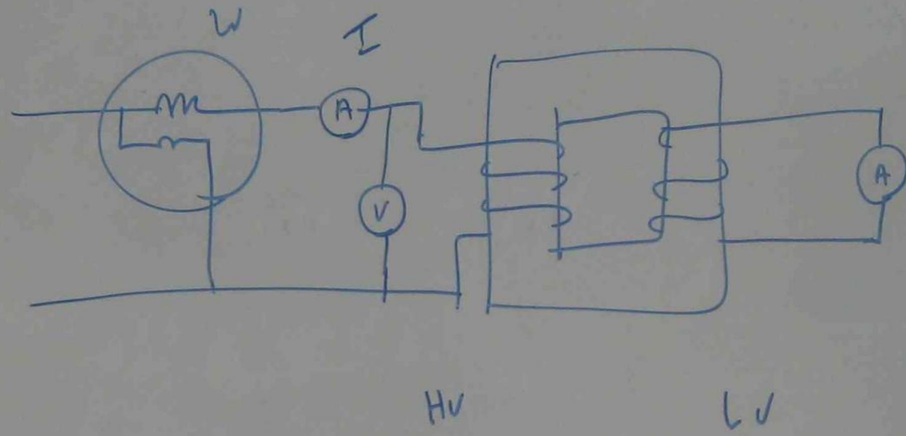
$$\cos\theta = \frac{W}{V \times I}$$

$$\theta = \cos^{-1}\frac{W}{VI}$$

$\sin\theta = \checkmark$

$$X_m = \frac{\text{VOLT METER READING}}{\text{AM METER READING} \times \sin\theta}$$

SHORT CIRCUIT TEST ⟶ WINDING RESISTANCE + INDUCTIVE REACTANCE



$$I^2 \times R_{WINDING} = W$$

$$R_{WINDING} = \frac{W}{I^2}$$

$$I \, Z_{WINDING} = V$$

$$Z_{WINDING} = \frac{V}{I}$$

$$X_{WINDING} = \sqrt{Z_{WINDING}^2 - R_{WINDING}^2}$$

TUTORIAL 4

1. IN OPEN CIRCUIT TEST ON 4 KVA SINGLE PHASE TRANSFORMER, THE FOLLOWING RESULTS ARE RECORDED.

$V_o = 250\ V$, $I_o = 1$ Amp, $P_o = 70$ WATT

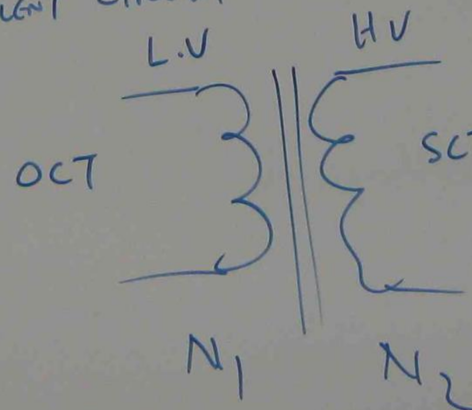
IN SHORT CIRCUIT TEST, THE FOLLOWING RESULTS ARE RECORDED

$V_{sc} = 100V$, $P_{sc} = 80W$, $I_{sc} = 7$ Amp

FIND R_{h+e}, X_m, R_{eq} (REFERRED TO PRIMARY), X_{eq} (REFERRED TO PRIMARY)

THEN DRAW THE EQUIVALENT CIRCUIT

OCT – OPEN CIRCUIT TEST
SCT – SHORT CIRCUIT TEST



OCT

$$R'_{h+e} = \frac{v^2}{P} = \frac{250^2}{70} = 892.8\,\Omega$$

$$W = VI\cos\theta$$

$$\cos\theta = \frac{W}{VI} = \frac{70}{250\times 1} = 0.28$$

$$\theta = \cos^{-1} 0.28 = 73.7^\circ$$

$$\sin\theta = \sin 73.7 = 0.959$$

$$X'_m = \frac{V}{I\sin\theta} = \frac{250}{1\times 0.959} = 260.68\,\Omega$$

SCT

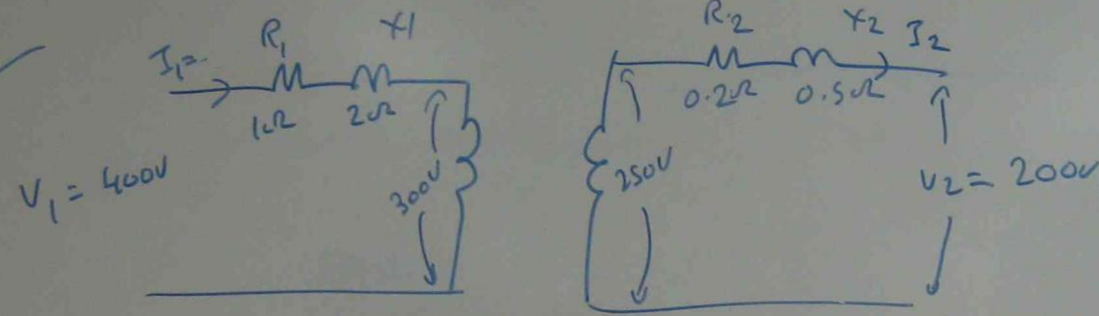
$$R''_{\text{WINDING}} = \frac{W}{I^2} = \frac{80}{7^2} = \frac{80}{49} = 1.632\,\Omega$$

$$Z''_{\text{WINDING}} = \frac{V}{I} = \frac{100}{7} = 14.28\,\Omega$$

$$X''_{\text{WINDING}} = \sqrt{\left(Z''_{\text{WINDING}}\right)^2 - \left(R''_{\text{WINDING}}\right)^2}$$

$$= \sqrt{(14.28)^2 - (1.632)^2} = 14.19\,\Omega$$

p.b



IN ABOVE CIRCUIT, FIND

(a) a

(b) Z_1

(c) I_1

(d) Z_2

(e) I_2

(f) R_2', X_2', Z_2'

(g) R_1'', X_1'', Z_1''

(h) % VOLTAGE REGULATION

(a) $a = \dfrac{V_1}{V_2} = \dfrac{400}{200} = 2$

(b) $Z_1 = \sqrt{R_1^2 + X_1^2} = \sqrt{1^2 + 2^2}$

$= \sqrt{5}$

$= 2.236\Omega$

(c) $I_1 = \frac{400-300}{Z_1}$

$= \frac{100}{2.236}$

$= 44.7$ Amp

(d) $Z_2 = \sqrt{R_2^2 + X_2^2}$

$= \sqrt{0.2^2 + 0.5^2}$

$= 0.538\Omega$

(e) $I_2 = \frac{250-200}{0.538}$

$= 92.9$ Amp

(f) $R_2' = a^2 R_2 = 2^2 \times 0.2 = 4 \times 0.2 = 0.8\Omega$

$X_2' = a^2 X_2 = 2^2 \times 0.5 = 4 \times 0.5 = 2\Omega$

$Z_2' = a^2 Z_2 = 2^2 \times 0.538 = 2.152\Omega$

(g) $R_1'' = \frac{R_1}{a^2} = \frac{1}{2^2} = \frac{1}{4} = 0.25\Omega$

$X_1'' = \frac{X_1}{a^2} = \frac{2}{4} = 0.5\Omega$

$Z_1'' = \frac{Z_1}{a^2} = \frac{2.236}{4} = 0.559\Omega$

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

$= \frac{250-200}{250} \times 100 = 20\%$