KING FAHD UNIVERSITY OF PETROLEUM & MINERALS
Electrical Engineering Department
EE 306 – Term 172
HW # 3: Single Phase Transformers
(Solution)

Solution P1:

(a)

$V_{H(rated)} = 1000\,V$, $I_{H(rated)} = \frac{100\times10^3}{1000} = 100\,A.$

$V_{L(rated)} = 100\,V$, $I_{L(rated)} = \frac{100\times10^3}{100} = 1000\,A$

From open circuit test,

$$R_{cL} = \frac{100^2}{400} = 25\,\Omega.$$

$$I_{cL} = \frac{100}{25} = 4\,A.$$

$$I_{mL} = \sqrt{6^2 - 4^2} = 4.47\,A$$

$$X_{mL} = \frac{100}{4.47} = 22.37\,\Omega$$

Turns ratio $a = \frac{1000}{100} = 10$

Refer to high voltage side,

$R_{cH} = 25\times10^2 = 2500\,\Omega$, $X_{mH} = 2237\,\Omega$

From short circuit test,

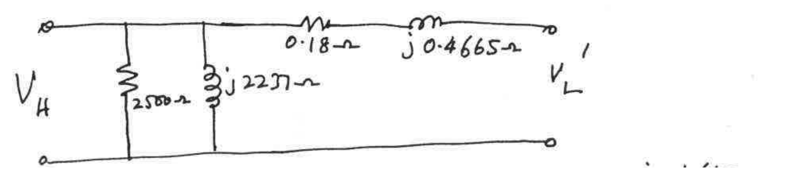
$$R_{eq\,H} = \frac{1800}{100^2} = 0.18\,\Omega.$$

$$Z_{eq\,H} = \frac{50}{100} = 0.5\,\Omega$$

$$X_{eq\,H} = \sqrt{0.5^2 - 0.18^2} = 0.4665\,\Omega$$

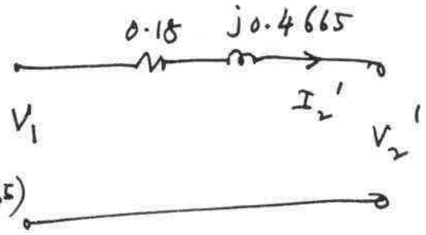
(b)

Equivalent circuit referred to H.V. side



(c)

$$V_1 = V_2' + I_2' Z_{eq\,H}$$



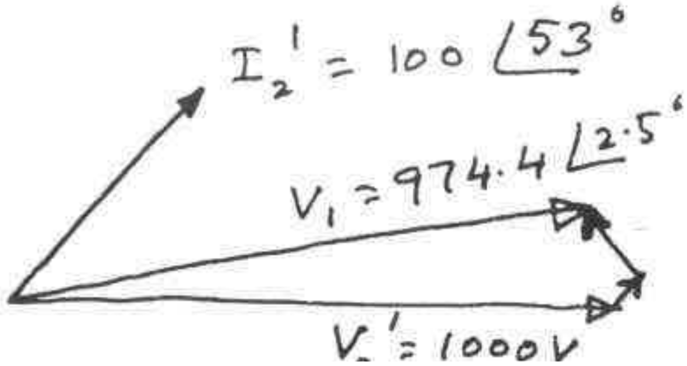
$$= 1000\angle 0^\circ + 100\angle 53^\circ (0.18 + j0.4665)$$

$$= 974.4\angle 2.5^\circ$$

$$V.R = \frac{974.4 - 1000}{1000} \times 100\,\% = -2.56\,\%$$

(d)

Phaser Diagram

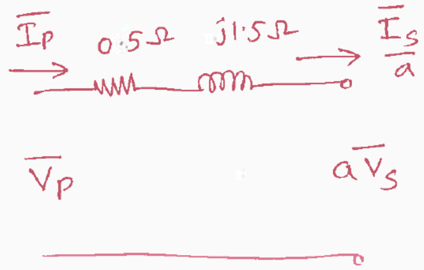


Solution P2:

Turn's Ratio $a = \frac{2400}{240} = 10$

Take the secondary voltage as reference phasor.

$\bar{V}_S = 240\angle 0^\circ$ V



The Secondary current is

$I_S = \frac{150{,}000}{240}\angle -\cos^{-1}0.85$

$= 625\angle -31.8^\circ$ A

$P_{output} = \frac{150{,}000 \times 0.85}{~~0.85~~} = 127{,}500$ W

$P_{cu} = I_P^2 R_{eq\,P} = \left(\frac{625}{10}\right)^2 \cdot (0.5) = 1953$ W

$P_{core} = 600$ W

The efficiency is,

$$\eta = \frac{P_{output}}{P_{output} + P_{core} + P_{cu}} \times 100$$

$$= \frac{127{,}500}{127{,}500 + 600 + 1953} \times 100$$

$$\eta = 98\%$$

Solution P3:

(a)

$$P_{out} = V_s I_s \cos\theta_s = 0.7 \times 30{,}000 \times 0.7 = 14{,}700\ W$$

$$P_{core} = 400\ W$$

$$P_{cu} = I_s^2 R_{eq,s} \Rightarrow R_{eq,s} = \frac{P_{cu}}{I_s^2} = \frac{1200}{\left(\frac{30{,}000}{240}\right)^2} = 0.0768\ \Omega$$

$$P_{cu}\ @\ 0.7\ \text{load} \Rightarrow P_{cu} = 0.7^2 * 1200 = 588\ W$$

$$\eta = \frac{P_{out}}{P_{out} + P_{core} + P_{cu}} \times 100$$

$$= \frac{14{,}700}{14{,}700 + 400 + 588} \times 100 = 93.7\ \%$$

(b)

I_s at max. efficiency

$$I_s = \left(\frac{P_{cu}}{R_{eq,s}}\right)^{1/2} = \left(\frac{400}{0.0768}\right)^{1/2}$$

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$$I_s = 72.168\ A$$

$$P_{out}\Big|_{\eta max} = V_s I_s \cos\theta_s$$

$$= 240 \times 72.168 \times 1$$

$$P_{out}\Big|_{\eta max} = 17320.5\ W$$

(c)

$$\eta_{max} = \frac{P_{out}}{P_{out} + P_{core} + P_{cu}} \times 100$$

$$= \frac{17320.5}{17320.5 + 400 + 400} \times 100$$

$$\eta_{max} = 95.58\%.$$

(d)

Output KVA at $\eta_{max} = 17.320$

Rated KVA $= 30$

η_{max} occurs at $\frac{17.320}{30} = 57.7\%$ of full load.