ex. A 45KVA, 2300 : 208-V_{rms} transformer has the following per-unit equivalent circuit parameters - $R_{eq} = 0.02$, $X_{eq} = 0.04$, $X_m = 20$, and $R_c = 90$. Determine the secondary equivalent circuit. Then, determine the voltage regulation and efficiency for loads of:

a) 40 KVA w/ 0.9 leading pf, b) 45 KVA w/ pf = 1, and c) 38 KVA w/ 0.65 lagging pf.

$$S_{base} = 45\,KVA,\ V_{base} = 208\,V_{rms}$$

$$\Downarrow$$

$$Z_{base} = \frac{V_{base}^2}{S_{base}} = \frac{208^2}{45\times10^3} = 0.961\overline{42}$$

$$R_{eq,s} = R_{eq\,pu}(Z_{base}) = 0.02(0.961\overline{42}) = 0.019228\overline{4}\ \Omega$$

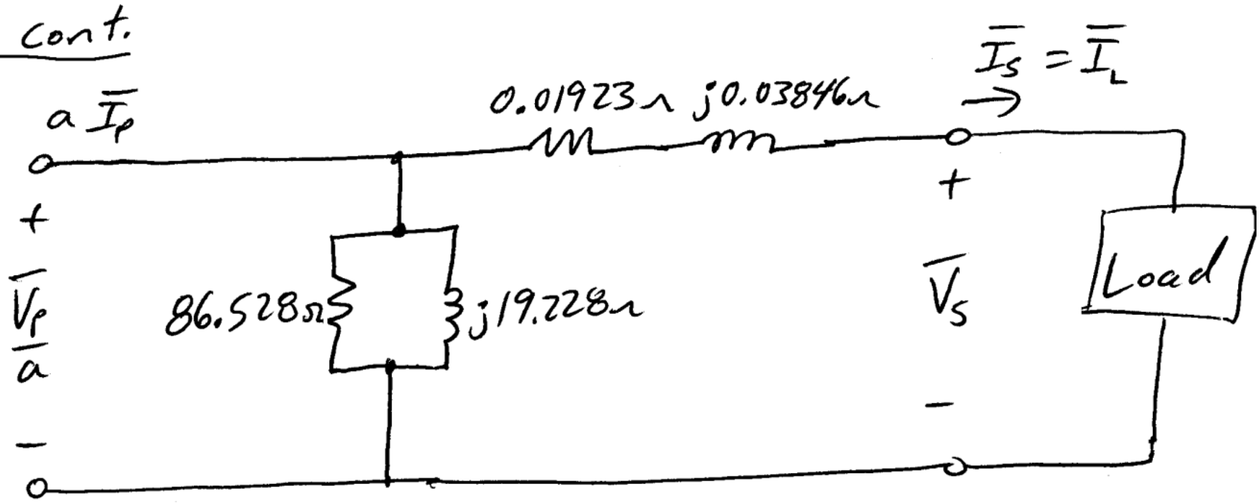
$$X_{eq,s} = X_{eq\,pu}(Z_{base}) = 0.04(0.961\overline{42}) = 0.0384569\ \Omega$$

$$R_{c,s} = R_{c,pu}(Z_{base}) = 86.528\ \Omega$$

$$X_{m,s} = X_{m,pu}(Z_{base}) = 19.228\overline{4}\ \Omega$$

$$a = \frac{2300}{208} = 11.0577$$

ex. cont.



a) Given $S_a = 40\text{KVA}$ & $pf_a = 0.9$ leading

Assume: $V_S = 208\,V_{rms}$ & $\underline{\bar{V}_S = 208\angle 0^\circ\,V_{rms}}$

$$I_S = I_L = \frac{S_L}{V_S} = \frac{40\times10^3}{208} = 192.3077\ A_{rms}$$

$$\theta_a = \cos^{-1}(0.9) = 25.841933^\circ \quad \text{leading}$$

$$\underline{\bar{I}_S = 192.3077\angle{+25.842^\circ}\ A_{rms}}$$

By KVL, $$\frac{\bar{V}_P}{a} = \bar{I}_S(0.01923 + j0.03846) + \bar{V}_S$$

$$= (192.3\angle 25.842^\circ)(0.01923 + j0.0385) + 208\angle 0^\circ$$

$$= 208.2685\angle 2.275^\circ\ V_{rms}$$

$$VR_a = \frac{V_P/a - V_S}{V_S}\times 100\% = \frac{208.2685 - 208}{208}\times 100\%$$

$$\underline{\underline{VR_a = +0.129\%}}$$

ex. cont.

a) cont.

$$P_{core} = \frac{(V_p/a)^2}{R_{c,s}} = \frac{208.2685^2}{86.528} = \underline{\underline{501.29\ W}}$$

$$P_{cu} = (I_s)^2 R_{eq,s} = (192.3077)^2\, 0.01923$$

$$= \underline{711.11\ W}$$

$$P_{out} = S_a(pf_a) = V_s I_s \cos\theta = (40\times10^3)(0.9)$$

$$= \underline{36{,}000\ W}$$

$$\eta_a = \frac{P_{out}}{P_{cu} + P_{core} + P_{out}} \times 100\% = \frac{36000}{501.29 + 711.11 + 36000} \times 100\%$$

$$\underline{\underline{\eta_a = 96.74\%}}$$

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b) Here, $S_b = 45\ \text{kVA}$ & $pf_b = 1 \Rightarrow \theta_b = 0°$

$$\bar{V}_s = 208\angle 0°\ V_{rms}, \quad I_s = \frac{45\times10^3}{208} = 216.346\ A_{rms}$$

$$\bar{I}_s = 216.346\angle 0°\ A_{rms}$$

$$\frac{\bar{V}_p}{a} = (216.346\angle 0°)(0.01923 + j0.03846) + 208\angle 0°$$

$$= 212.323\angle 2.246°\ V_{rms}$$

ex. cont.

b) cont.

$$VR_b = \frac{212.323 - 208}{208} \times 100\% = \underline{\underline{+2.08\%}}$$

$$P_{core} = \frac{(212.323)^2}{86.528} = \underline{521\,W}$$

$$P_{cu} = (216.346)^2 (0.01923) = \underline{900\,W}$$

$$P_{out} = 45\times10^3 (1) = \underline{45{,}000\,W}$$

$$\eta_b = \frac{45000}{521+900+45000} \times 100\% = \underline{\underline{96.94\%}}$$

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c) Here, $S_c = 38$ KVA + $pf_c = 0.65 \Rightarrow \theta_c = 49.4584°$

$\overline{V_s} = 208\angle 0°$ Vrms, $\quad I_s = \dfrac{38\times10^3}{208} = 182.6923$ Arms

lagging!

$$\overline{I_c} = 182.6923\angle\underline{-49.4584°} \text{ Arms}$$

$$\frac{\overline{V_p}}{a} = (182.6923\angle -49.4584°)(0.01923 + j0.03846) + 208\angle 0°$$

$$= 215.63085\angle 0.504° \text{ Vrms}$$

ex. cont.

c) cont.

$$VR_c = \frac{215.63 - 208}{208} \times 100\%$$

$$\underline{\underline{VR_c = 3.67\%}}$$

$$P_{core} = \frac{215.63^2}{86.528} = \underline{537.36\ W}$$

$$P_{cu} = (182.6923)^2\, 0.01923 = \underline{641.78\ W}$$

$$P_{out} = S_c\,(pf_c) = 38 \times 10^3 (0.65) = \underline{24{,}700\ W}$$

$$\eta_c = \frac{24{,}700}{537.36 + 641.78 + 24{,}700} \times 100\%$$

$$\underline{\underline{\eta_c = 95.4\%}}$$