

4-14

$$\textcircled{a} \quad a = \frac{4800}{240} = 20$$

$$Z_{E2} = \frac{1}{a^2} Z_{E1} = \frac{1}{(20)^2} (120 + j300) = 0.3 + j0.75 \Omega$$

$$\textcircled{b} \quad V_2 = 230 \angle 0^\circ \text{ V}$$

$$I_{2, \text{ref}} = \frac{10,000}{240} \angle -\cos^{-1} 1 = 41.67 \angle 0^\circ \text{ A}$$

$$\begin{aligned} V_1 &= aV_2 + \frac{I_2}{a} Z_{E1} \\ &= 20(230 \angle 0^\circ) + \left(\frac{41.67}{20} \angle 0^\circ\right)(120 + j300) \\ &= 4600 \angle 0^\circ + 2.083 \angle 0^\circ (120 + j300) \\ &= 4890 \angle 7.3^\circ \text{ V} \end{aligned}$$

4-15

$$V_2 = 230 \angle 0^\circ \text{ V}$$

$$I_2 = \frac{75,000}{(230)(0.85)} \angle -\cos^{-1} 0.85 = 383.63 \angle -31.8^\circ \text{ A}$$

$$a = \frac{2300}{230} = 10$$

$$\begin{aligned} \textcircled{a} \quad E_1 &= aV_2 + \frac{I_2}{a} (a^2 R_2 + ja^2 X_2) \\ &= 10(230 \angle 0^\circ) + \left(\frac{383.63}{10} \angle -31.8^\circ\right)(10)^2(0.003 + j0.0065) \\ &= 2322.9 + j15.1 = 2322.97 \angle 0.37^\circ \text{ V} \end{aligned}$$

$$\begin{aligned} I_1 &= \frac{I_2}{a} + E_1 \left(\frac{1}{R_c} + \frac{1}{jX_m}\right) = \frac{383.63}{10} \angle -31.8^\circ + E_1 \left(\frac{10^{-3}}{45} + \frac{10^{-2}}{j1}\right) \\ &= 33.14 - j22.54 = 40.08 \angle -34.2^\circ \text{ A} \end{aligned}$$

$$\begin{aligned} \textcircled{b} \quad V_1 &= E_1 + I_1 (R_1 + jX_1) = 2322.97 \angle 0.37^\circ + (40.08 \angle -34.2^\circ)(0.3 + j0.65) \\ &= 2347.5 + j29.78 = 2347.7 \angle 0.73^\circ \text{ V} \end{aligned}$$

$$\begin{aligned} \textcircled{c} \quad P_1 &= V_1 I_1 \cos \theta_{V_1, I_1} = (2347.7)(40.08) \cos (0.73 + 34.2) \\ &= 77.15 \text{ kW} \end{aligned}$$

$$\text{PF} = \cos (0.73 + 34.2) = 0.82 \text{ lagging}$$

4-19

$$a = \frac{2400}{240} = 10$$

$$V_2 = 240 \angle 0^\circ \text{ V}$$

$$I_2 = \frac{25,000}{240} \angle -\cos^{-1} 0.85 = 104.167 \angle -31.8^\circ \text{ A}$$

$$\begin{aligned} \textcircled{a} \quad V_1 &= aV_2 + \frac{I_2}{a} (R_{E1} + jX_{E1}) = 10(240 \angle 0^\circ) + \left(\frac{104.167}{10} \angle -31.8^\circ\right)(3.45 + j5.75) \\ &= 2462.3 \angle 0.74^\circ \text{ V} \end{aligned}$$

$$\textcircled{b} \quad \text{V.R.} = \frac{V_1 - aV_2}{aV_2} 100\% = \frac{2462.3 - 2400}{2400} 100\% = 2.6\%$$

$$\textcircled{c} \quad P_{\text{core}} = 120 \text{ W}$$

$$P_{\text{cu}} = \left(\frac{I_2}{a}\right)^2 R_{E1} = \left(\frac{104.167}{10}\right)^2 (3.45) = 374.3 \text{ W}$$

$$P_{\text{out}} = (25,000)(0.85) = 21,250 \text{ W}$$

$$\eta = \frac{P_{\text{out}}}{P_{\text{out}} + P_{\text{core}} + P_{\text{cu}}} 100\% = \frac{(21,250)(100\%)}{21,250 + 120 + 374.3} = 97.7\%$$

4-21

$$\textcircled{a} \quad P_{\text{out}} = (10)(0.8) = 8 \text{ kW} = 8000 \text{ W}$$

$$\begin{aligned} P_{\text{in}} &= P_{\text{out}} + P_{\text{core}} + P_{\text{cu}} \\ &= 8000 + 150 + 250 = 8400 \text{ W} \end{aligned}$$

$$\eta = \frac{P_{\text{out}}}{P_{\text{in}}} = \frac{8000}{8400} 100\% = 95.2\%$$

$$\textcircled{b} \quad P_{\text{out}} = \left(\frac{3}{4}\right)(10,000)(1.0) = 7500 \text{ W}$$

$$P_{\text{in}} = 7500 + 150 + \left(\frac{3}{4}\right)^2 (250) = 7790.6 \text{ W}$$

$$\eta = \frac{7500}{7790.6} 100\% = 96.3\%$$

$$\textcircled{c} \quad P_{\text{out}} = \left(\frac{1}{2}\right)(10,000)(0.6) = 3000 \text{ W}$$

$$P_{\text{in}} = 3000 + 150 + \left(\frac{1}{2}\right)^2 (250) = 3212.5 \text{ W}$$

$$\eta = \frac{3000}{3212.5} 100\% = 93.4\%$$

4-23

$$Z_{E1} = \frac{V_{sc}}{I_{sc}} = \frac{55}{10.4} = 5.29 \Omega$$

$$R_{E1} = \frac{P_{sc}}{I_{sc}^2} = \frac{375}{(10.4)^2} = 3.47 \Omega$$

$$X_{E1} = \sqrt{Z_{E1}^2 - R_{E1}^2} = \sqrt{(5.29)^2 - (3.47)^2} = 3.99 \Omega$$

$$\textcircled{a} \quad I_{FL} = \frac{25000}{240} = 104 \text{ A} \quad ; \quad a = \frac{2400}{240} = 10$$

$$\frac{I_{FL}}{a} = \frac{104}{10} = 10.4 \text{ A} \quad V_2 = 240 \angle 0^\circ$$

$$P_{core} = 165 \text{ W} = P_{oc}$$

$$P_{cu} = 375 \text{ W} = P_{sc}$$

$$P_{out} = (25000)(0.8) = 20,000$$

$$\eta = \frac{P_{out}}{P_{out} + P_{core} + P_{cu}} = \frac{20,000}{20,000 + 165 + 375} \cdot 100\% = 97.4\%$$

$$\textcircled{b} \quad Z_{E1} = 3.47 + j3.99 = 5.29 \angle 49^\circ$$

$$I_2 = 104 \angle -49^\circ$$

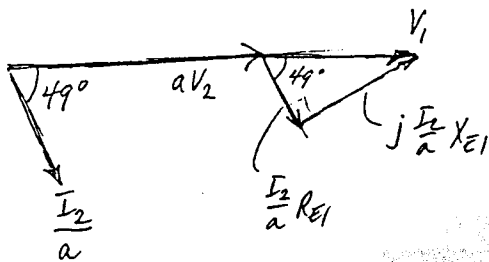
$$V_1 = aV_2 + \frac{I_2}{a} (R_{E1} + jX_{E1}) = 10(240 \angle 0^\circ) + \left(\frac{104}{10} \angle -49^\circ\right) (5.29 \angle 49^\circ)$$

$$= 2455 \angle 0^\circ$$

$$V.R. = \frac{V_1 - aV_2}{aV_2} \cdot 100\%$$

$$= \frac{2455 - 2400}{2400} \cdot 100\%$$

$$= 2.29\%$$



4.24 $a = \frac{2400}{240} = 10$

$$I_{1, rated} = \frac{50,000}{2450} = 20.8 \text{ A}$$

$$R_{c2} = \frac{V_{oc}^2}{P_{oc}} = \frac{(240)^2}{450} = 128 \Omega$$

$$G_{c2} = \frac{1}{R_{c2}} = 0.0078 \text{ S}$$

4.24 (Contd.)

$$Y_{02} = \frac{I_{oc}}{V_{oc}} = \frac{5}{240} = 0.02083 \text{ S}$$

$$B_{m2} = \sqrt{Y_{02}^2 - G_{c2}^2} = \sqrt{(0.02083)^2 - (0.0075)^2} = 0.0193 \text{ S}$$

$$X_{m2} = \frac{1}{B_{m2}} = 51.8 \Omega$$

$$R_{E1} = \frac{P_{sc}}{I_{sc}^2} = \frac{600}{(20.8)^2} = 1.39 \Omega$$

$$Z_{E1} = \frac{V_{sc}}{I_{sc}} = \frac{55}{20.8} = 2.64 \Omega$$

$$X_{E1} = \sqrt{Z_{E1}^2 - R_{E1}^2} = \sqrt{(2.64)^2 - (1.39)^2} = 2.24 \Omega$$

(a) $V_2 = 220 \angle 0^\circ$

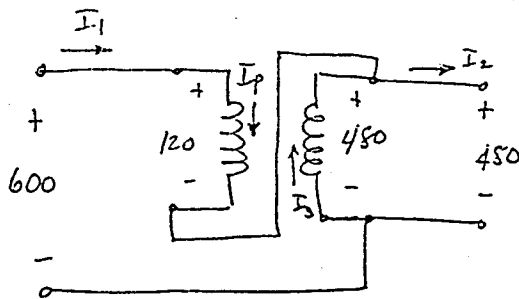
$$I_2 = 156 \angle -\cos^{-1} 0.8 = 156 \angle -36.9^\circ$$

$$V_1 = aV_2 + \frac{I_2}{a} (R_{E1} + jX_{E1}) = 10(220 \angle 0^\circ) + \left(\frac{156}{10} \angle -36.9^\circ\right)(1.39 + j2.24) \\ = 2238.4 \angle 0.4^\circ$$

$$\text{V.R.} = \frac{V_1 - aV_2}{aV_2} = \frac{2238.4 - 2200}{2200} \times 100\% = 1.7\%$$

4-29

(a)



$$I_p = \frac{5000}{120} = 41.67 \text{ A}$$

$$I_s = \frac{5000}{480} = 10.42 \text{ A}$$

(b) $I_1 = I_p = 41.67 \text{ A}$

$$V_1 = 600 \text{ V}$$

$$\text{kVA}_{\text{rating}} = V_1 I_1 = \frac{(600)(41.67)}{1000} = 25 \text{ kVA}$$

39 (Contd.)

(c) $P_{out} = (5000)(0.8) = 4000 \text{ W}$

$$\eta_t = 0.95 = \frac{4000}{4000 + \text{Losses}}$$

$$\text{Losses} = \frac{4000}{0.95} - 4000 = 210 \text{ W}$$

$$\eta_{\text{total}} = \frac{(25000)(0.8) 100\%}{(25000)(0.8) + 210} = 99\%$$

31

$$a = \frac{20}{2.4} = 8.33$$

(a) Reference phasor: $V_{ap} = 2.4 \angle 0^\circ \text{ kV}$

$$I_{2p} = \frac{6000/3}{(2.4)(0.85)} \angle -\cos^{-1} 0.85 = 980 \angle -31.8^\circ \text{ A}$$

$$I_{2L} = \sqrt{3} I_{2p} \angle -30^\circ = 1698 \angle -61.8^\circ \text{ A}$$

$$I_{1p} = \frac{I_{2p}}{a} = 118 \angle -31.8^\circ$$

$$I_{1L} = I_{1p} = 118 \angle -31.8^\circ$$

(b) $V_{2p} = 2.4 \angle 0^\circ \text{ kV}$

$$V_{2L} = V_{2p} = 2.4 \angle 0^\circ \text{ kV}$$

$$V_{1p} = a V_{2p} = 20 \angle 0^\circ \text{ kV}$$

$$V_{1L} = \sqrt{3} V_{1p} \angle 30^\circ = 34.5 \angle 30^\circ$$

35

$$P_{out} = (0.7)(300)(0.85) = 178.5 \text{ kW}$$

$$P_{core} = 2.2 \text{ kW}$$

$$P_{cu} = (0.7)^2 (3.8) = 1.86 \text{ kW}$$

$$\eta = \frac{P_{out}}{P_{out} + P_{core} + P_{cu}} = \frac{178.5}{178.5 + 2.2 + 1.86} 100\% = 97.8\%$$