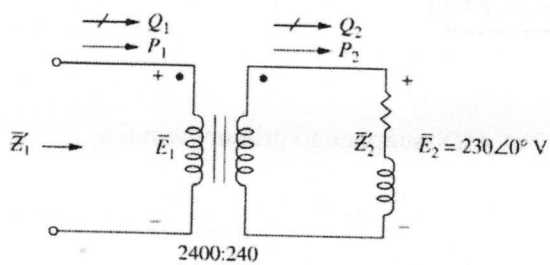


Homework 4 Solutions

3.4



$$(a) \quad E_1 = \frac{N_1}{N_2} E_2 = \frac{2400}{240} (230) = 2300 \text{ V}$$

$$(b) \quad \bar{S}_2 = \bar{E}_2 \bar{I}_2^*; \bar{I}_2 = \left(\frac{\bar{S}_2}{\bar{E}_2} \right)^* = \left[\frac{80 \times 10^3 \angle \cos^{-1} 0.8}{230 \angle 0^\circ} \right]^* = 347.8 \angle -36.87^\circ$$

$$\bar{Z}_2 = \frac{\bar{E}_2}{\bar{I}_2} = \frac{230 \angle 0^\circ}{347.8 \angle -36.87^\circ} = 0.6613 \angle 36.87^\circ \Omega$$

$$= 0.529 + j0.397 \Omega$$

$$(c) \quad \bar{Z}_1' = \left(\frac{N_1}{N_2} \right)^2 \bar{Z}_2 = 100 \bar{Z}_2 = 66.13 \angle 36.87^\circ \Omega$$

$$(d) \quad P_1 = P_2 = 80(0.8) = 64 \text{ kW}$$

$$Q_1 = Q_2 = 64 \tan(36.87^\circ) = 48 \text{ kVAR}$$

3.10 Rated current magnitude on the 66-kV side is given by

$$I_1 = \frac{15,000}{66} = 227.3 \text{ A}$$

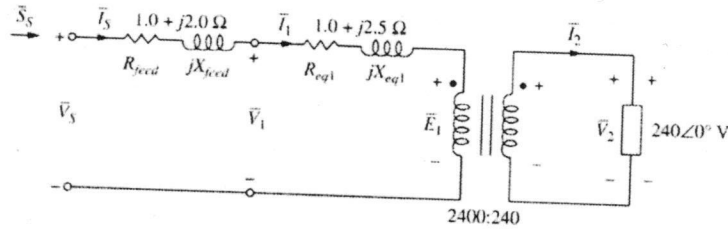
$$I_1^2 R_{eq1} = (227.3)^2 R_{eq1} = 100 \times 10^3$$

$$\therefore R_{eq1} = 1.94 \Omega \leftarrow$$

$$Z_{eq1} = \frac{5.5 \times 10^3}{227.3} = 24.2 \Omega$$

$$\text{Then } X_{eq1} = \sqrt{Z_{eq1}^2 - R_{eq1}^2} = \sqrt{(24.2)^2 - (1.94)^2} = 24.12 \Omega \leftarrow$$

3.14



$$(a) \quad \bar{I}_2 = \frac{52}{V_2} \angle -\cos^{-1}(P.F.) = \frac{50 \times 10^3}{240} \angle -\cos^{-1}(0.8) = 208.3 \angle -36.87^\circ \text{ A}$$

$$\bar{I}_1 = \frac{N_2}{N_1} \bar{I}_2 = \frac{1}{10} (208.3 \angle -36.87^\circ) = 20.83 \angle -36.87^\circ \text{ A}$$

$$\bar{E}_1 = \frac{N_1}{N_2} \bar{V}_2 = 10 (240 \angle 0^\circ) = 2400 \angle 0^\circ \text{ V}$$

$$\bar{V}_1 = \bar{E}_1 + (R_{eq1} + jX_{eq1}) \bar{I}_1$$

$$\begin{aligned} \bar{V}_1 &= 2400 \angle 0^\circ + (1 + j2.5)(20.83 \angle -36.87^\circ) \\ &= 2400 + 56.095 \angle 31.329^\circ \\ &= 2447.9 + j29.166 = \underline{2448. \angle 0.683^\circ \text{ V}} \end{aligned}$$

$$|V_1| = 2448.1 \text{ V}$$

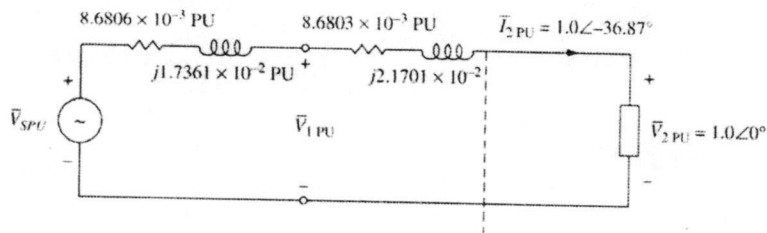
$$\begin{aligned} (b) \quad \bar{V}_s &= \bar{E}_1 + (R_{feed} + jX_{feed} + R_{eq1} + jX_{eq1}) \bar{I}_1 \\ &= 2400 \angle 0^\circ + (2.0 + j4.5)(20.83 \angle -36.87^\circ) \\ &= 2400 + 102.59 \angle 29.168^\circ \\ &= 2489.6 + j50.00 = \underline{2490. \angle 1.1505^\circ \text{ V}} \end{aligned}$$

$$|V_s| = 2490.1 \text{ V}$$

$$\begin{aligned} (c) \quad \bar{S}_s &= \bar{V}_s \bar{I}_s^* = (2490 \angle 1.1505^\circ)(20.83 \angle 36.87^\circ) \\ &= \underline{51868 \angle 38.05^\circ} \end{aligned}$$

$$\left. \begin{aligned} P_s &= \text{Re}(\bar{S}_s) = 40.87 \text{ kW} \\ Q_s &= \text{Im}(\bar{S}_s) = 31.95 \text{ kVARs} \end{aligned} \right\} \text{delivered to the sending end of feeder.}$$

3.19



Zone 1

$$S_{base} = 50 \text{ kVA}$$

$$V_{base1} = 2400 \text{ V}$$

$$Z_{base1} = (2400)^2 / 50 \times 10^3 \\ = 115.2 \Omega$$

Zone 2

$$V_{Base2} = 240 \text{ V}$$

$$(a) \bar{V}_{1pu} = 1.0 \angle 0^\circ + (8.6803 \times 10^{-3} + j2.1701 \times 10^{-2})(1.0 \angle -36.87^\circ) \\ = 1.0 + 0.023373 \angle 31.33^\circ = 1.01997 + j0.012157 \\ = 1.020 \angle 0.683^\circ \text{ pu}$$

$$\bar{V}_1 = \bar{V}_{1pu} V_{base} = (1.020 \angle 0.683^\circ)(2400) = \underline{2448 \angle 0.683^\circ \text{ V}}$$

$$(b) \bar{V}_{spu} = 1.0 \angle 0^\circ + (1.7361 \times 10^{-2} + j3.9063 \times 10^{-2})(1.0 \angle -36.87^\circ) \\ = 1.0 + 0.042747 \angle 29.168^\circ \\ = 1.03733 + j0.020833 = 1.0375 \angle 1.1505^\circ \text{ pu}$$

$$\bar{V}_s = \bar{V}_{spu} V_{base1} = (1.0375 \angle 1.1505^\circ)(2400) = \underline{2490 \angle 1.1505^\circ \text{ V}}$$

$$(c) P_{spu} + jQ_{spu} = \bar{V}_{spu} \bar{I}_{spu}^* = (1.0375 \angle 1.1505^\circ)(1.0 \angle 36.87^\circ) \\ = 1.0375 \angle 38.02^\circ = 0.8173 + j0.6390 \text{ per unit}$$

$$\left. \begin{aligned} P_s &= (0.8173)(50) = 40.87 \text{ kW} \\ Q_s &= (0.6390)(50) = 31.95 \text{ kVARs} \end{aligned} \right\} \text{delivered}$$

3.23 Select a common base of 100MVA and 22kV on the generator side; Base voltage at bus 1 is 22kV; this fixes the voltage bases for the remaining buses in accordance with the transformer turns ratios. Using Eq. 3.3.11, per-unit reactances on the selected base are given by

$$G : X = 0.18 \left(\frac{100}{90} \right) = 0.2; T_1 : X = 0.1 \left(\frac{100}{50} \right) = 0.2$$

$$T_2 : X = 0.06 \left(\frac{100}{40} \right) = 0.15; T_2 : X = 0.06 \left(\frac{100}{40} \right) = 0.15$$

$$T_3 : X = 0.064 \left(\frac{100}{40} \right) = 0.16; T_4 : X = 0.08 \left(\frac{100}{40} \right) = 0.2$$

$$M : X = 0.185 \left(\frac{100}{66.5} \right) \left(\frac{10.45}{11} \right)^2 = 0.25$$

$$\text{For Line 1, } Z_{BASE} = \frac{(220)^2}{100} = 484 \Omega \text{ and } X = \frac{48.4}{484} = 0.1$$

$$\text{For Line 2, } Z_{BASE} = \frac{(110)^2}{100} = 121 \Omega \text{ and } X = \frac{65.43}{121} = 0.54$$

The load complex power at 0.6 Lagging pf is $\bar{S}_{L(3\phi)} = 57 \angle 53.13^\circ \text{ MVA}$

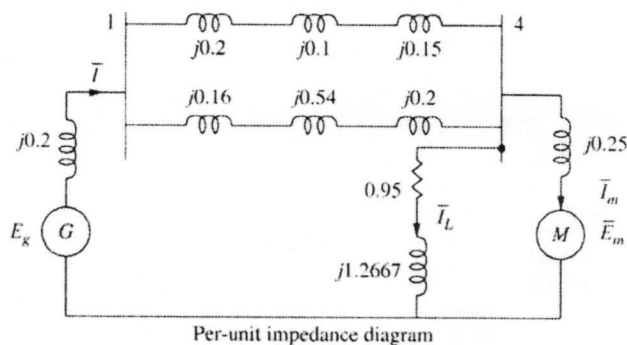
$$\therefore \text{The load impedance in OHMS is } \bar{Z}_L = \frac{(10.45)^2}{57 \angle -53.13^\circ} = \frac{V_{LL}^2}{\bar{S}_{L(3\phi)}^*}$$

$$= 1.1495 + j1.53267 \Omega$$

The base impedance for the load is $(11)^2 / 100 = 1.21 \Omega$

$$\therefore \text{Load Impedance in pu} = \frac{1.1495 + j1.53267}{1.21} = 0.95 + j1.2667$$

The per-unit equivalent circuit is shown below:



- 3.60 Losses are minimum at 0 degrees = 16.606 MW (there can be a ± 0.1 variation in this value values of the power flow solution tolerance).

