Homework Solution

(i) Load power factor is 0.9 lagging

(a) Series impedance per phase

$$Z = r.l + j\omega L.l = r.l + jx_L.l.$$

$$Z = 0.2357 \times 18 + j\,0.4139 \times 18$$

$$Z = 4.243 + j\,7.450 = \underline{8.574\angle 60.34^\circ\ \Omega}$$

(b) $\bar{V}_s = A\bar{V}_R + B\bar{I}_R$

For a short-line, $A = 1$, $B = Z$

$$\Rightarrow \bar{V}_s = \bar{V}_R + Z\bar{I}_R$$

Now $P_R = 2500 \times 10^3\,W$; $\cos\theta_R = 0.9$

$P_R = 3|V_R||I_R|\cos\theta_R$ or $\sqrt{3}|V_{R(L-L)}||I_R|\cos\theta_R$

$$|V_R| = \frac{|V_{R(L-L)}|}{\sqrt{3}} = \frac{11000}{\sqrt{3}} = \underline{6350.8\,V}$$

$\bar{V}_R = |V_R|\angle 0^\circ = \underline{6350.8\angle 0^\circ\ V}$; V_R taken as reference

$$|I_R| = \frac{P_R}{\sqrt{3} \times 11000 \times 0.9} = \frac{2500 \times 10^3}{\sqrt{3} \times 11000 \times 0.9} = \underline{145.8\,A}$$

$$\bar{I}_R = |I_R|\angle -\cos^{-1}0.9 = \underline{145.8\angle -25.84^\circ\ A}$$

$$\bar{V}_s = 6350.8\angle 0^\circ + (8.574\angle 60.34^\circ)(145.8\angle -25.84^\circ)$$

$$= 6350.8 + j0 + 1250.1\angle 34.5^\circ$$

$\bar{V}_s = 6350.8 + j0 + 1030.24 + j708.06$

$\bar{V}_s = 7381.04 + j708.06$

$\bar{V}_s = 7414.92 \angle 5.48^\circ \ V$

$\therefore \ |V_s| = 7414.92$

$|V_{s(L-L)}| = |V_s| \times \sqrt{3} = 12.84 \ KV$

(c) $\text{Percent V.R} = \dfrac{|V_{R(NL)}| - |V_{R(FL)}|}{|V_{R(FL)}|} \times 100$

At no load, $I_R = 0$

$\therefore V_s = V_R = V_{R(NL)} \Rightarrow |V_{R(N\text{-}L)}| = |V_s| \ ; \ |V_{R(F\text{-}L)}| = 11 \ KV$

$\text{Percent V.R} = \dfrac{12.84 - 11}{11} \times 100 = 16.72\%$

(ii) Load power factor is 0.9 leading

(b) $|V_R| = \underline{\underline{6350.8 \text{ V}}}$

$\bar{V}_R = |\bar{V}_R| \angle 0^\circ = \underline{\underline{6350.8 \angle 0^\circ \text{ V}}}$

$$|I_R| = \frac{2500 \times 10^3}{\sqrt{3} \times 11000 \times 0.9} = \underline{\underline{145.8 \text{ A}}}$$

$\bar{I}_R = |I_R| \angle \cos^{-1} 0.9 = 145.8 \underline{\underline{\angle 25.84^\circ \text{ A}}}$

$\bar{V}_s = 6350.8 \angle 0^\circ + (145.8 \angle 25.84^\circ)(8.574 \angle 60.34^\circ)$

$= 6350.8 \angle 0^\circ + 1250.1 \angle 86.18^\circ$

$= 6350.8 + j0 + 83.28 + j\,1247.32$

$\bar{V}_s = 6434.1 + j\,1247.32$

$\bar{V}_s = \underline{\underline{6553.9 \angle 10.97^\circ}} \text{ V}$

$|V_s| = 6553.9 \text{ V}$; $|V_{s(L-L)}| = 6553.9 \times \sqrt{3} = 11.\underline{\underline{352}} \text{ kV}$

(c) $$\text{Percent V.R} = \frac{|V_s| - |V_{R(FL)}|}{|V_{R(FL)}|} \times 100$$

$$= \frac{11.352 - 11}{11} \times 100 = \underline{\underline{3.2\,\%}}$$

(iii) Load power factor is Unity i.e. $\cos\theta_R = 1$

$$|V_R| = 6350.8\text{ V} \;;\quad \bar{V}_R = 6350.8\angle 0^\circ\text{ V}$$

$$|I_R| = \frac{2500\times 10^3}{\sqrt{3}\times 11000\times 1} = 131.22\text{ A}$$

$$\bar{I}_R = 131.22\angle \cos^{-1}(1) = 131.22\angle 0^\circ\text{ A}$$

$$\bar{V}_s = 6350.8\angle 0^\circ + (131.22\angle 0^\circ)(8.574\angle 60.34^\circ)$$

$$= 6350.8 + j0 + 1125.08\angle 60.34^\circ$$

$$= 6350.8 + j0 + 556.75 + j977.67$$

$$\bar{V}_s = 6907.55 + j977.67$$

$$\bar{V}_s = 6976.4\angle 8.06^\circ\text{ V}$$

$$|\bar{V}_s| = 6976.4 \;;\quad |\bar{V}_{s(L-L)}| = 12.08\text{ kV}$$

(c) Percent V.R $= \dfrac{12.08 - 11}{11}\times 100 = 9.82\%$