EE 360: Homework # 6

No submission required

All questions are from the problem at the end of the class notes (the PDF file on transmission lines posted in Blackboard)

Problems 9-2, 9-6, 9-8, 9-9, 9-21, 9-22, 9-29, and 9-30

9-2

$A = 500\ MCM = 500{,}000\ cir\ mils$

$R_{DC,20} = \frac{\rho l}{A} = \frac{(10.66)(5280)}{500{,}000} = 0.1126\ \Omega/mi$

$R_{AC,60} = \frac{M + T_{60}}{M + T_{20}} R_{DC,20} = \left(\frac{241.5 + 60}{241.5 + 20}\right)(0.1126) = 0.1298\ \Omega/mi$

$X = 0.0636 \sqrt{\frac{\mu f}{R_{DC}}} = 0.0636 \sqrt{\frac{(1)(50)}{0.1298}} = 1.24 \approx 1.2$

From Table 5, $\alpha = 1.0107$

$R_{AC} = \alpha R_{DC} = (1.0107)(0.1298) = 0.1312\ \Omega/mi$

9-6

/km

mH/km

(a) $r' = re^{-1/4} = 0.02\, e^{-1/4} = 0.0156\ m$

$GMR_b = \sqrt{dr'} = \sqrt{(0.08)(0.0156)} = 0.0353\ m$

(b) $GMD = 6 + (2)(0.04) = 6.08\ m$

(c) $X_L = 0.2794 \left(\frac{f}{60}\right) \log \frac{GMD}{GMR_b} = 0.2794 \left(\frac{60}{60}\right) \log \left(\frac{6.08}{0.0353}\right) = 0.6248\ \Omega/mi$

$= 0.3883\ \Omega/km$

$X_T = 2 X_L = (2)(0.3883) = 0.7766\ \Omega/km$

9-8

$r' = re^{-1/4} = 0.015\, e^{-1/4} = 0.01168\ m$

(a) $L_a = 2 \times 10^{-7} \ln \frac{D}{r'} = 2 \times 10^{-7} \ln \left(\frac{4}{0.01168}\right) = 1.167 \times 10^{-6}\ H/m$

$= 1.167\ mH/km = 1.878\ mH/mi$

(b) $X_L = 2\pi f L = (2\pi)(60)(1.167) = 0.44\ \Omega/km = 0.708\ \Omega/mi$

9-21

$r = 1\text{ cm} = 0.01\text{ m}$, $d_b = 10\text{ cm} = 0.10\text{ m}$

$GMR_b = \sqrt{dr} = \sqrt{(0.10)(0.01)} = 0.0316\text{ m}$

$GMD = 5\text{ m}$

$$C_{an} = \frac{2\pi\epsilon}{\ln\left(\frac{GMD}{GMR_b}\right)} = \frac{(2\pi)(8.854\times10^{-12})}{\ln\left(\frac{5}{0.0316}\right)} = 10.98\times10^{-12}\text{ F/m}$$

$$= 10.98\times10^{-9}\text{ F/km} = 17.68\times10^{-9}\text{ F/mi}$$

$$C_T = C_{an}\,l = (17.68\times10^{-9})(50) = 0.884\times10^{-6}\text{ F}$$

$$X_T = \frac{1}{2\pi f C_T} = \frac{1}{(2\pi)(60)(0.884\times10^{-6})} = 3\text{ k}\Omega$$

9-22

$$r = \frac{d}{2} = \frac{3}{2} = 1.5\text{ cm} = 0.015\text{ m}$$

$$GMD = \sqrt[3]{(10)(10)(20)} = 12.6\text{ m}$$

$$X_C = \frac{2.862}{f}\times10^9\ln\left(\frac{GMD}{r}\right) = \frac{2.862}{60}\times10^9\ln\left(\frac{12.6}{0.015}\right) = 321\text{ M}\Omega\text{-m}$$

$$= 321\text{ k}\Omega\text{-km} = 200\text{ k}\Omega\text{-mi}$$

$$X_T = \frac{X_C}{l} = \frac{200\text{ k}\Omega\text{-mi}}{100} = 2\text{ k}\Omega$$

9-29

$l = 40\text{ km}$ (use short line model)

$Z = zl = (0.20+j0.50)(40) = 8+j20\ \Omega$

(a) $A = 1.0$

$B = Z = 8+j20 = 21.54\angle 68.2^\circ\ \Omega$

$C = 0$

$D = 1.0$

(b) $V_R = \frac{33{,}000}{\sqrt{3}}\angle 0^\circ = 19{,}052\angle 0^\circ$

$I_R = \frac{10{,}000}{\sqrt{3}(33)}\angle -\cos^{-1}0.9 = 175\angle -25.8^\circ\text{ A}$

$V_S = AV_R + BI_R = (1.0)(19{,}052\angle 0^\circ) + (8+j20)(175\angle -25.8^\circ)$

$= 21{,}983\angle 6.6^\circ\text{ V (line-to-neutral)} = 38.1\text{ kV (line-to-line)}$

(c) $I_R = \frac{10{,}000}{\sqrt{3}(33)}\angle \cos^{-1}0.9 = 175\angle 25.8^\circ\text{ A}$

$V_S = (1.0)(19{,}052\angle 0^\circ) + (8+j20)(175\angle 25.8^\circ)$

$= 19{,}162\angle 11.3^\circ\text{ V (line-to-neutral)} = 33.2\text{ kV (line-to-line)}$

9-30

$l = 80$ mi (use medium length line model)

$$A = D = \frac{ZY}{2} + 1 = \frac{(10+j50)(j30\times10^{-5})}{2} + 1 = 0.9925\angle 0.1^\circ$$

$$B = Z = 10+j50 = 51\angle 78.7^\circ\ \Omega$$

$$C = Y\left(\frac{ZY}{4}+1\right) = (j30\times10^{-5})\left[\frac{(10+j50)(j30\times10^{-5})}{4}+1\right] = 2.99\times10^{-4}\angle 90^\circ$$

(a) $$V_R = \frac{230{,}000}{\sqrt{3}}\angle 0^\circ = 132{,}790\angle 0^\circ\ V$$

$$I_R = \frac{V_R}{Z_L} = \frac{132{,}790\angle 0^\circ}{150\angle 36.9^\circ} = 885.3\angle -36.9^\circ\ A$$

$$V_S = AV_R + BI_R = (0.9925\angle 0.1^\circ)(132{,}790\angle 0^\circ) + (51\angle 78.7^\circ)(885.3\angle -36.9^\circ)$$
$$= 168{,}208\angle 10.4^\circ\ V \text{ (line-to-neutral)} = 291.34\ kV \text{ (line-to-line)}$$

$$I_S = CV_R + DI_R = (2.99\times10^{-4}\angle 90^\circ)(132{,}790\angle 0^\circ) + (0.9925\angle 0.1^\circ)(885.3\angle -36.9^\circ)$$
$$= 855.5\angle -34.7^\circ\ A$$

(b) $$V.R. = \frac{V_S/A - V_R}{V_R} = \frac{(291.34/0.9925) - 230}{230}100\% = 27.6\%$$

(c) $$S_S = 3V_S I_S^* = (3)(168{,}208\angle 10.4^\circ)(855.5\angle -34.7^\circ)^* = 431.7\times10^6\angle 45.1^\circ\ VA$$
$$= (304.7 + j\,305.8)\ MVA$$

$P_S = 304.7$ MW

$Q_S = 305.8$ MVAR

(d) $$P_R = 3V_R I_R \cos\theta_R = (3)(132{,}790)(885.3)\cos 36.9 = 282\times10^6\ W = 282\ MW$$

$$\eta = \frac{P_R}{P_S} = \frac{282}{304.7}100\% = 92.6\%$$