EE 460
Solution of Home Work #1

CHAPTER 4

4.1

$$R_{dc,20^\circ C} = \frac{\rho_{20^\circ C}\, l}{A} = \frac{(17.00)(1000 \times 1.016)}{1113 \times 10^3} = \underline{\underline{0.01552}}\ \frac{\Omega}{1000'}$$

$$R_{dc,50^\circ C} = R_{dc,20^\circ C}\left(\frac{50+T}{20+T}\right) = 0.01552\left(\frac{50+228.1}{20+228.1}\right)$$

$$R_{dc,50^\circ C} = (0.01552)(1.1209) = \underline{\underline{0.01739}}\ \frac{\Omega}{1000'}$$

$$\frac{R_{60Hz,50^\circ C}}{R_{dc,50^\circ C}} = \frac{0.0951\ \Omega/mi}{\left(0.01739\ \frac{\Omega}{1000'}\right)\left(5.28\ \frac{1000'}{mi}\right)} = \frac{0.0951}{0.0918} = \underline{\underline{1.035}}$$

The 60 Hz resistance is 3.5 % larger than the dc resistance, due to skin effect.

4.8

(a) FROM EQ. (4.4.10)

$$L_{int} = \left(\frac{1}{2} \times 10^{-7}\ \frac{H}{m}\right)\left(\frac{1000m}{1km}\right)\left(\frac{1000mH}{1H}\right) = 0.05\ mH/km$$

PER CONDUCTOR

(b) FROM EQ. (4.5.2)

$$L_x = L_y = 2 \times 10^{-7} \ln\left(\frac{D}{r'}\right)\ \frac{H}{m}$$

$$D = 0.5\ m \qquad r' = e^{-\frac{1}{4}}\left(\frac{0.015}{2}\right) = 5.841 \times 10^{-3}\ m$$

$$L_x = L_y = 2 \times 10^{-7} \ln\left(\frac{0.5}{5.841 \times 10^{-3}}\right)\frac{H}{m}\left(\frac{1000m}{km}\right)\left(\frac{1000\ mH}{H}\right)$$

$$= \underline{\underline{0.8899}}\ \frac{mH}{km} \text{ per conductor}$$

(c)

$$L = L_x + L_y = \underline{\underline{1.780}}\ \frac{mH}{km} \text{ per circuit}$$

4.17

a) $$GMR = \sqrt[9]{\left[\left(e^{-\frac{1}{4}}r\right)(2r)(2r)\right]^3} = r\sqrt[3]{4e^{-\frac{1}{4}}}$$

$$= \underline{\underline{1.4605\,r}}$$

b) $$GMR = \sqrt[16]{\underbrace{\left[\left(e^{-\frac{1}{4}}r\right)(2r)(4r)(6r)\right]^2}_{\text{Distances for each outer conductor}}\ \underbrace{\left[\left(e^{-\frac{1}{4}}r\right)(2r)(2r)(4r)\right]^2}_{\text{Distances for each inner conductor}}}$$

$$GMR = \sqrt[16]{\left(e^{-\frac{1}{4}}\right)^4(2)^6(4)^4(6)^2}\,(r) = \underline{\underline{2.1554\,r}}$$

(c) $$GMR = r\sqrt[81]{\underbrace{\left[\left(e^{-\frac{1}{4}}\right)(2)^2(4)^2\left(\sqrt{20}\right)^2\left(\sqrt{8}\right)\left(\sqrt{32}\right)\right]^4}_{\text{Distances for each corner conductor}} \times \underbrace{\left[\left(e^{-\frac{1}{4}}\right)(2)^3\left(\sqrt{8}\right)^2\left(\sqrt{20}\right)^2(4)\right]^4}_{\text{Distances for each outside non-corner conductor}} \times \underbrace{\left[\left(e^{-\frac{1}{4}}\right)(2)^4\left(\sqrt{8}\right)^4\right]}_{\text{Distances for the center conductor}}}$$

$$GMR = r\sqrt[81]{\left(e^{-\frac{1}{4}}\right)^9(2)^{24}\left(\sqrt{8}\right)^{16}\left(\sqrt{20}\right)^{16}(4)^{12}\left(\sqrt{32}\right)^4}$$

$$GMR = \underline{\underline{2.6374\,r}}$$

4.20

$$D_{eq} = \sqrt[3]{10 \times 10 \times 20} = 12.6\ m$$

FROM TABLE A.4, $D_S = (0.0435 ft)\ \frac{1m}{3.28 ft} = 0.0133 m$

$$X_1 = \omega L_1 = 2\pi(60)\ 2\times10^{-7} \ln\left(\frac{12.6}{0.149}\right) \frac{\Omega}{m} \times \frac{1000m}{1km}$$

$$= 0.335\ \Omega/km$$

4.21

(a) From Table A.4:

$$D_S = (0.0479)\left(\frac{1}{3.28}\right) = 0.0146\ m$$

$$D_{SL} = \sqrt[3]{(0.0146)(0.457)^2} = 0.145\ m$$

$$X_1 = (2\pi 60)\left[2\times10^{-7} \ln\left(\frac{12.60}{0.145}\right)\right]\times 1000 = \underline{\underline{0.337\ \frac{\Omega}{km}}}$$

(b) $D_S = (0.0391)\left(\frac{1}{3.28}\right) = 0.0119\ m$

$$D_{SL} = \sqrt[3]{(0.0119)(.457)(.457)} = 0.136\ m$$

$$X_1 = (2\pi 60)\left[2\times10^{-7} \ln\left(\frac{12.60}{0.136}\right)\right]\times 1000 = \underline{\underline{0.342\ \frac{\Omega}{km}}}$$

Results

ACSR Conductor	Aluminum Cross Section	X_1	
	kcmil	Ω/km	% Change
Canary	900	0.342	} 0.9%
Finch	1113	0.339	} 0.6%
Martin	1351	0.337	

4.41

$$D_{eq} = \sqrt[3]{10 \times 10 \times 20} = 12.6 \text{ m}$$

FROM TABLE A.4, $r = \frac{1.293}{2} \text{ in} \left(\frac{0.0254 \text{ m}}{1 \text{ in}}\right) = 0.01642 \text{ m}$

$$D_{SC} = \sqrt[3]{r d^2} = \sqrt[3]{0.01642 (0.5)^2} = 0.16 \text{ m}$$

$$C_1 = \frac{2\pi\varepsilon_0}{\ln \frac{D_{eq}}{D_{SC}}} = \frac{2\pi(8.854 \times 10^{-12})}{\ln\left(\frac{12.6}{0.16}\right)} = 1.275 \times 10^{-11} \text{ F/m}$$

$$\bar{Y}_1 = j\omega C_1 = j\,2\pi(60)\,1.275 \times 10^{-11}(1000) = j4.807 \times 10^{-6} \text{ S/km}$$

$$Q_1 = V_{LL}^2 Y_1 = (500)^2\, 4.807 \times 10^{-6} = 1.2 \text{ MVAR/km}$$

4.42

(a) FROM TABLE A.4, $r = \frac{1.424}{2}(0.0254) = 0.0181 \text{ m}$

$$D_{SC} = \sqrt[3]{0.0181 (0.5)^2} = 0.1654 \text{ m}$$

$$C_1 = \frac{2\pi(8.854 \times 10^{-12})}{\ln\left(\frac{12.6}{0.1654}\right)} = 1.284 \times 10^{-11} \text{ F/m}$$

$$\bar{Y}_1 = j\,2\pi(60)(1.284 \times 10^{-11})(1000) = j4.842 \times 10^{-6} \text{ S/km}$$

$$Q_1 = (500)^2\, 4.842 \times 10^{-6} = 1.21 \text{ MVAR/km}$$

(b) $r = \frac{1.162}{2}(0.0254) = 0.01476 \text{ m}$; $D_{SC} = \sqrt[3]{0.01476 (0.5)^2} = 0.1546 \text{ m}$

$$C_1 = \frac{2\pi(8.854 \times 10^{-12})}{\ln\left(\frac{12.6}{0.1546}\right)} = 1.265 \times 10^{-11} \text{ F/m}$$

$$\bar{Y}_1 = j\,2\pi(60)\,1.265 \times 10^{-11}(1000) = 4.77 \times 10^{-6} \text{ S/km}$$

$$Q_1 = (500)^2\, 4.77 \times 10^{-6} = 1.192 \text{ MVAR/km}$$

C_1, Y_1, AND Q_1 INCREASE 0.8% (DECREASE 0.7%) FOR THE LARGER, 1351 kcmil CONDUCTORS (SMALLEL, 700 kcmil CONDUCTORS).