Homework 4 solutions

4.10

From Eq. (4.5.10)

$$L_1 = 2\times10^{-7} Ln\left(\frac{D}{r'}\right)\frac{\text{H}}{\text{m}} \qquad D = 4\,\text{ft}$$

$$L_1 = 2\times10^{-7} Ln\left(\frac{4}{1.6225\times10^{-2}}\right) \qquad r' = e^{\frac{-1}{4}}\left(\frac{.5}{2}\right)\left(\frac{1\,\text{ft}}{12\,\text{in}}\right)$$

$$L_1 = \underline{\underline{1.101\times10^{-6}}}\ \frac{\text{H}}{\text{m}} \qquad r' = 1.6225\times10^{-2}\,\text{ft}$$

$$X_1 = \omega L_1 = (2\pi 60)(1.101\times10^{-6})(1000) = \underline{\underline{0.4153}}\,\Omega/\text{km}$$

4.11

(a) $L_1 = 2\times10^{-7}\ln\left(\frac{4.8}{1.6225\times10^{-2}}\right) = 1.138\times10^{-6}$ H/m

$X_1 = \omega L_1 = 2\pi(60)(1.138\times10^{-6})(1000) = 0.4292\,\Omega$/km

(b) $L_1 = 2\times10^{-7}\ln\left(\frac{3.2}{1.6225\times10^{-2}}\right) = 1.057\times10^{-6}$ H/m

$X_1 = 2\pi(60)(1.057\times10^{-6})(1000) = 0.3986\,\Omega$/km

L_1 and X_1 increase by 3.35% (decrease by 4.02%) as the phase spacing increases by 20% (decreases by 20%).

4.20

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

From Table A.4, $D_S = (0.0435\,\text{ft})\dfrac{1\,\text{m}}{3.28\,\text{ft}} = 0.0133\,\text{m}$

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

$$= 0.335\,\Omega/\text{km}$$

4.41

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

From Table A.4, $r = \dfrac{1.293}{2}\text{in}\left(\dfrac{0.0254\,\text{m}}{1\,\text{in}}\right) = 0.01642\,\text{m}$

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

$$C_1 = \frac{2\pi\varepsilon_0}{\ln\frac{D_{eq}}{D_{Sc}}} = \frac{2\pi\left(8.854\times10^{-12}\right)}{\ln\left(\frac{12.6}{0.16}\right)} = 1.275\times10^{-11}\,\text{F/m}$$

$$\overline{Y}_1 = j\omega C_1 = j2\pi(60)1.275\times10^{-11}(1000) = j4.807\times10^{-6}\,\text{S/km}$$

$$Q_1 = V_{LL}{}^2 Y_1 = (500)^2\,4.807\times10^{-6} = 1.2\,\text{MVAR/km}$$

5.14

(a) $\bar{Z}_C = \sqrt{\frac{\bar{z}}{\bar{y}}} = \sqrt{\frac{0.03 + j0.35}{4.4\times10^{-6}\angle 90°}} = 282.6\angle -2.45°\ \Omega$

(b) $\bar{\gamma} l = \sqrt{\bar{z}\,\bar{y}}\,(l) = \sqrt{(0.35128\angle 85.101°)(4.4\times10^{-6}\angle 90°)}(500)$

$$= 0.622\angle 87.55° = 0.02657 + j0.6210 \text{ pu}$$

5.38

From Problem 5.14

$\bar{A} = 0.8794\angle 0.66°$ pu; $\quad A = 0.8794$ and $\theta_A = 0.66°$

$\bar{B} = \bar{Z}' = 134.8\angle 85.3°\ \Omega$; $\quad Z' = 134.8$ and $\theta_Z = 85.3°$

$$P_{R\max} = \frac{500\times500}{134.8} - \frac{(0.8794)(500)^2}{134.8}\cos(85.3° - 0.66°)$$
$$= 1854.6 - 152.4 = 1702 \text{ MW}(3\phi)$$

For this loading at unity power factor,

$$I_R = \frac{P_{R\max}}{\sqrt{3}\,V_{RLL}(PF)} = \frac{1702}{\sqrt{3}(500)(1.0)} = 1.966 \text{ kA / Phase}$$

From Table A.4, the thermal limit for 3 ACSR 1113 kcmil conductors is $3 \times 1.11 = 3.33\ \text{kA/phase}$. The current 1.966 kA corresponding to the theoretical steady-state stability limit is well below the thermal limit of 3.33 kA.

5.41

(a) $\bar{Z} = \bar{z}l = (0.088 + j0.465)100 = 8.8 + j46.5\ \Omega$

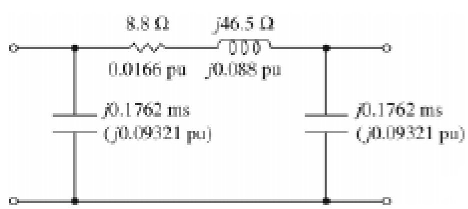
$$\frac{\bar{Y}}{2} = \frac{\bar{y}l}{2} = (j3.524 \times 10^{-6})100/2 = j0.1762\,\text{mS}$$

$$Z_{base} = V_{L\,base}^2 / S_{3\phi\,base} = \frac{(230)^2}{100} = 529\,\Omega$$

$$\therefore \bar{Z} = (8.8 + j46.5)/529 = 0.0166 + j0.088\,\text{pu}$$

$$\frac{\bar{Y}}{2} = j0.1762/(1/0.529) = j0.09321\,\text{pu}$$

The nominal π circuit for the medium line is shown below:



(b) $S_{3\phi\,rated} = V_{L\,rated}\, I_{L\,rated} \sqrt{3} = 230(0.9)\sqrt{3} = 358.5\,\text{MVA}$