EE-465 (Term 162)

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Solution of HW1

4.1 $$R_{dc,20°C} = \frac{\rho_{20°C}\, l}{A} = \frac{(17.00)(1000\times 1.02)}{1113\times 10^3} = 0.01558\,\Omega/1000' = 0.05112\ \Omega/\text{km}$$

$$R_{dc,50°C} = R_{dc,20°C}\left(\frac{50+T}{20+T}\right) = (0.05112)\left(\frac{50+228.1}{20+228.1}\right) = 0.05730\,\Omega/\text{km}$$

$$\frac{R_{60\text{Hz},50°C}}{R_{dc,50°C}} = \frac{0.0594\,\Omega/\text{km}}{\left(0.0573\frac{\Omega}{\text{km}}\right)} = \frac{0.0594}{0.0573} = 1.0366$$

The 60-Hz resistance is 3.66% larger than the dc resistance, due to skin effect.

4.4 (a) $$795\ \text{MCM} = (795\times 10^3\ \text{cmil})\left(\frac{\frac{\pi}{4}\ \text{sq}\cdot\text{mil}}{1\ \text{cmil}}\right)\left(\frac{1\,\text{in}}{1000\,\text{mil}}\right)^2\left(\frac{0.0254\,\text{m}}{1\,\text{in}}\right)^2$$

$$= 4.0283\times 10^{-4}\ \text{m}^2$$

(b) $$R_{60\text{Hz},50°C} = R_{60\text{Hz},75°C}\left(\frac{50+T}{75+T}\right)$$

$$= 0.0880\left(\frac{50+228.1}{75+228.1}\right)$$

$$= 0.0807\ \Omega/\text{km}$$

4.6 Total transmission line loss $P_L = \frac{2.5}{100}(190.5) = 4.7625\,\text{MW}$

$$I = \frac{190.5\times10^3}{\sqrt{3}(220)} = 500\,\text{A}$$

From $P_L = 3I^2R$, the line resistance per phase is

$$R = \frac{4.7625\times10^6}{3(500)^2} = 6.35\,\Omega$$

The conductor cross-sectional area is given by

$$A = \frac{(2.84\times10^{-8})(63\times10^3)}{6.35} = 2.81764\times10^{-4}\,\text{m}^2$$

$$\therefore d = 1.894\,\text{cm} = 0.7456\,\text{in} = 556{,}000\,\text{cmil}$$

4.8 (a) From Eq. (4.4.10)

$$L_{int} = \left(\frac{1}{2}\times10^{-7}\,\frac{\text{H}}{\text{m}}\right)\left(\frac{1000\,\text{m}}{1\,\text{km}}\right)\left(\frac{1000\,\text{mH}}{1\text{H}}\right) = 0.05\,\text{mH/km per conductor}$$

(b) From Eq. (4.5.2)

$$L_x = L_y = 2\times10^{-7}\ln\left(\frac{D}{r'}\right)\frac{\text{H}}{\text{m}}$$

$$D = 0.5\,\text{m}\quad r' = e^{\frac{-1}{4}}\left(\frac{0.015}{2}\right) = 5.841\times10^{-3}\,\text{m}$$

$$L_x = L_y = 2\times10^{-7}\ln\left(\frac{0.5}{5.841\times10^{-3}}\right)\frac{\text{H}}{\text{m}}\left(\frac{1000\,\text{m}}{\text{km}}\right)\left(\frac{1000\,\text{mH}}{\text{H}}\right)$$

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

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

4.18 $D_{eq} = \sqrt[3]{8\times 8\times 16} = 10.079\,\text{m}$

From Table A.4, $D_S = (0.0403\,\text{ft})\dfrac{1\,\text{m}}{3.28\,\text{ft}} = 0.0123\,\text{m}$

$$L_1 = 2\times 10^{-7}\ln(D_{eq}/D_S) = 2\times 10^{-7}\ln\left(\frac{10.079}{0.0123}\right) = 1.342\times 10^{-6}\,\text{H/m}$$

$$X_1 = 2\pi(60)L_1 = 2\pi(60)1.342\times 10^{-6}\frac{\Omega}{\text{m}}\times\frac{1000\,\text{m}}{1\,\text{km}} = 0.506\,\Omega/\text{km}$$

4.23 (a) The geometric mean radius of each phase is calculated as

$$R = \sqrt[4]{(r')^2(0.3)^2} \text{ where } r' = 0.7788\times 0.0074$$
$$= 0.0416\,\text{m}$$

The geometric mean distance between the conductors of phases A and B is given by

$$D_{AB} = \sqrt[4]{6^2(6.3)(5.7)} = 5.996 \approx 6\,\text{m}$$

Similarly, $D_{BC} = \sqrt[4]{6^2(6.3)(5.7)} = 5.996 \approx 6\,\text{m}$

and $D_{CA} = \sqrt[4]{12^2(12.3)(11.7)} = 11.998 \approx 12\,\text{m}$

The GMD between phases is given by the cube root of the product of the three-phase spacings.

$$D_{eq} = \sqrt[3]{6\times 6\times 12} = 7.56\,\text{m}$$

The inductance per phase is found as

$$L = 0.2\ln\frac{7.56}{0.0416} = 1.041\,\text{mH/km}$$

(b) The line reactance for each phase then becomes

$$X = 2\pi f\,L = 2\pi(60)1.041\times 10^{-3} = 0.392\,\Omega/\text{km per phase}$$

4.32 $C_n = \dfrac{2\pi\varepsilon_0}{\ln\left(\dfrac{D}{r}\right)} = \dfrac{2\pi(8.854\times 10^{-12})}{\ln\left(\dfrac{0.5}{0.015/2}\right)} = \underline{\underline{1.3246\times 10^{-11}}}\dfrac{\text{F}}{\text{m}}$ to neutral

$$\overline{Y}_n = j\omega C_n = j(2\pi 60)(1.3246\times 10^{-11})\frac{\text{S}}{\text{m}}\times 1000\frac{\text{m}}{\text{km}}$$

$\overline{Y}_n = \underline{\underline{j4.994\times 10^{-6}}}\dfrac{\text{S}}{\text{km}}$ to neutral

4.39 $D_{eq} = \sqrt[3]{8\times8\times16} = 10.079\,\text{m}$

For Table A.4, $r = \dfrac{1.196}{2}\text{in}\left(\dfrac{0.0254\,\text{m}}{1\,\text{in}}\right) = 0.01519\,\text{m}$

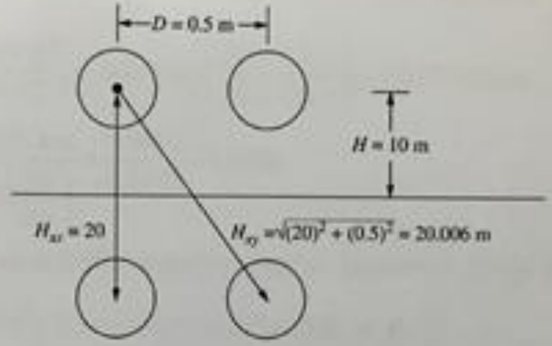
$$C_1 = \frac{2\pi\varepsilon_0}{\ln\left(\frac{D}{r}\right)} = \frac{2\pi\left(8.854\times10^{-12}\right)}{\ln\left(\frac{10.079}{0.01519}\right)} = 8.565\times10^{-12}\ \text{F/m}$$

$$\bar{Y}_1 = j\omega c_1 = j2\pi(60)8.565\times10^{-12}(1000) = j3.229\times10^{-6}\ \text{S/km}$$

For a 100 km line length

$$I_{chg} = Y_1 V_{LN} = \left(3.229\times10^{-6}\times100\right)\left(230/\sqrt{3}\right) = 4.288\times10^{-12}\ \text{kA/phase}$$

4.45



From Example 4.8,

$$C_{Xn} = \frac{2\pi\varepsilon_0}{\ln\left(\frac{D}{r}\right) - \ln\left(\frac{HXY}{HXX}\right)} = \frac{2\pi\left(8.854\times10^{-12}\right)}{\ln\left(\frac{0.5}{0.0075}\right) - \ln\left(\frac{20.006}{20}\right)}$$

$C_{Xn} = \underline{1.3247\times10^{-11}}\,\dfrac{\text{F}}{\text{m}}$ which is 0.01% larger than in Problem 4.32