Power Transmission
Homework 6

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5.2

A 200-km, 230-kV, 60-Hz, three-phase line has a positive-sequence series impedance $z = 0.08 + j0.48\ \Omega$/km and a positive-sequence shunt admittance $y = j3.33 \times 10^{-6}$ S/km. At full load, the line delivers 250 MW at 0.99 p.f. lagging and at 220 kV. Using the nominal π circuit, calculate: (a) the ABCD parameters, (b) the sending-end voltage and current, and (c) the percent voltage regulation.

(a)

$$\rightarrow Z = (z)(l) = (0.08 + j0.48)(200) = 16 + j96\,\Omega = 97.33\angle 80.54°\Omega$$
$$\rightarrow Y = (y)(l) = (j3.33 \cdot 10^{-6})(200) = j6.66 \cdot 10^{-4}\,\text{S} = 6.66 \cdot 10^{-4}\angle 90°\text{S}$$
$$\rightarrow A = D = 1 + \frac{YZ}{2} = 1 + \frac{(16 + j96)(j6.66 \cdot 10^{-4})}{2} = \boxed{0.9681\angle 0.317°}$$
$$\rightarrow B = Z = \boxed{16 + j96\,\Omega}$$
$$\rightarrow C = Y(1 + \frac{YZ}{4}) = (j6.66 \cdot 10^{-4})\left(1 + \frac{(16 + j96)(j6.66 \cdot 10^{-4})}{4}\right) = \boxed{6.554 \cdot 10^{-4}\angle 90.16°}$$

(b)

$$V_{R,\phi} = \frac{220}{\sqrt{3}} = 127.02\text{ kV} \qquad S_{3\phi} = \frac{250}{0.99} = 252.53\text{ MVA}$$
$$\rightarrow I_R = \frac{S_{3\phi}}{\sqrt{3}V_{R,LL}} = \frac{252.53 \cdot 10^6}{\sqrt{3}(220 \cdot 10^3)}\angle(-\cos^{-1}(0.99)) = 662.8\angle - 8.11°\text{A}$$
$$\rightarrow V_S = AV_R + BI_R = (0.9681\angle 0.317°)(127.02 \cdot 10^3) + (16 + j96)(662.8\angle - 8.11°)$$
$$= \boxed{155.3\angle 23.6\text{ kV}}$$
$$\rightarrow I_S = CV_R + DI_R = (6.554 \cdot 10^{-4}\angle 90.16°)(127.02 \cdot 10^3) + (0.9681\angle 0.317°)(662.8\angle - 8.11°)$$
$$= \boxed{635.6\angle - 0.35°\text{ A}}$$

(c)

$$V_{RFL} = 127.02\text{ kV}, \quad V_{RNL} = \frac{|V_S|}{|A|} = \frac{155.3}{0.9681} = 160.42\text{ kV}$$
$$\rightarrow \%VR = \frac{V_{RNL} - V_{RFL}}{V_{RFL}}(100) = \frac{160.42 - 127.02}{127.02}(100) = \boxed{26.3\%}$$

5.26

A 350-km, 500-kV, 60-Hz, three-phase uncompensated line has a positive-sequence series reactance $x = 0.34\ \Omega$/km and a positive-sequence shunt admittance $y = j4.5 \times 10^{-6}$ S/km. Neglecting losses, calculate: (a) Z_c, (b) γl, (c) the ABCD parameters, (d) the wavelength λ of the line in kilometers, and (e) the surge impedance loading in MW.

(a) $Z_c = \sqrt{\frac{z}{y}} = \sqrt{\frac{j0.34}{j4.5 \cdot 10^{-6}}} = \boxed{274.87\,\Omega}$

(b) $\gamma = \sqrt{zy} = \sqrt{(j0.34)(j4.5 \cdot 10^{-6})} = j1.237 \cdot 10^{-3}$ rad/km
$\rightarrow \gamma l = (j1.237 \cdot 10^{-3})(350) = \boxed{j0.4329 \text{ rad}}$

(c)

$$A = D = \cosh(\gamma l) = \cos(0.4329) = \boxed{0.9078}$$
$$\rightarrow B = Z_c \sinh(\gamma l) = (274.87)\sinh(j0.4329) = j(274.87)\sin(0.4329) = \boxed{j115.3\,\Omega}$$
$$\rightarrow C = \frac{1}{Z_c}\sinh(\gamma l) = \frac{j}{274.87}\sin(0.4329) = \boxed{j1.526 \cdot 10^{-3}\,\text{S}}$$

(d) $\lambda = \frac{2\pi}{\beta} = \frac{2\pi}{1.237 \cdot 10^{-3}} = \boxed{5080 \text{ km}}$

(e) $\text{SIL} = \frac{V_{LL}^2}{Z_c} = \frac{(500 \cdot 10^3)^2}{274.87} = \boxed{909.5 \text{ MW}}$

5.27

Determine the equivalent π circuit for the line in Problem 5.26.

$$Z' = j115.3\,\Omega$$
$$\frac{Y'}{2} = \frac{j}{Z_c}\tan\left(\frac{\beta l}{2}\right) = \frac{j}{274.87}\tan\left(\frac{0.4329}{2}\right) = \boxed{j7.979 \cdot 10^{-4}\,\text{S}}$$

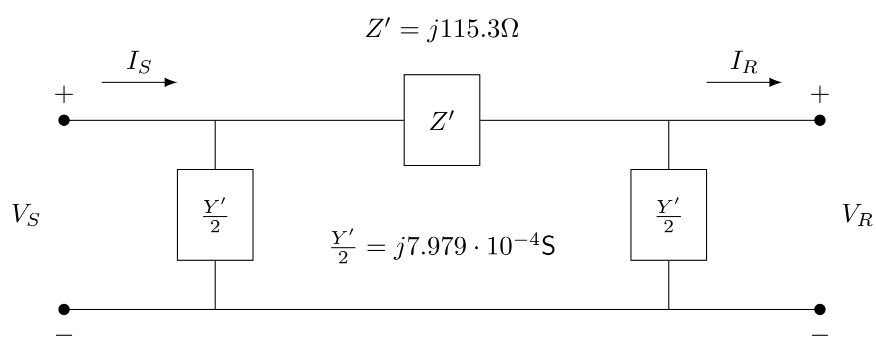

Figure 1: Equivalent π circuit for the transmission line in Problem 5.26.