Example 5.1  (chp5ex1)

A 220-kV, three-phase transmission line is 40 km long. The resistance per phase is 0.15 $\Omega$ per km and the inductance per phase is 1.3263 mH per km. The shunt capacitance is negligible. Use the short line model to find the voltage and power at the sending end and the voltage regulation and efficiency when the line is supplying a three-phase load of

(a) 381 MVA at 0.8 power factor lagging at 220 kV.
(b) 381 MVA at 0.8 power factor leading at 220 kV.

(a) The series impedance per phase is

$$Z = (r + j\omega L)\ell = (0.15 + j(2\pi \times 60 \times 1.3263 \times 10^{-3}) \times 40) = 6 + j20 \ \Omega$$
The receiving end voltage per phase is

\[ V_R = \frac{220 \angle 0^\circ}{\sqrt{3}} = 127 \angle 0^\circ \text{ kV} \]

The apparent power is

\[ S_R(3\phi) = 381 \angle \cos^{-1} 0.8 = 381 \angle 36.87^\circ = 304.8 + j228.6 \text{ MVA} \]

The current per phase is given by

\[ I_R = \frac{S^*_R(3\phi)}{3V^*_R} = \frac{381 \angle -36.87^\circ \times 10^3}{3 \times 127 \angle 0^\circ} = 1000 \angle -36.87^\circ \text{ A} \]

From (5.3) the sending end voltage is

\[ V_S = V_R + Z I_R = 127 \angle 0^\circ + (6 + j20)(1000 \angle -36.87^\circ)(10^{-3}) = 144.33 \angle 4.93^\circ \text{ kV} \]

The sending end line-to-line voltage magnitude is

\[ |V_S(L-L)| = \sqrt{3} |V_S| = 250 \text{ kV} \]

The sending end power is

\[ S_S(3\phi) = 3V_S I_S^* = 3 \times 144.33 \angle 4.93 \times 1000 \angle 36.87^\circ \times 10^{-3} = 322.8 \text{ MW} + j288.6 \text{ Mvar} = 433 \angle 41.8^\circ \text{ MVA} \]

Voltage regulation is

\[ \text{Percent } VR = \frac{250 - 220}{220} \times 100 = 13.6\% \]

Transmission line efficiency is

\[ \eta = \frac{P_R(3\phi)}{P_S(3\phi)} = \frac{304.8}{322.8} \times 100 = 94.4\% \]

(b) The current for 381 MVA with 0.8 leading power factor is

\[ I_R = \frac{S^*_R(3\phi)}{3V^*_R} = \frac{381 \angle 36.87^\circ \times 10^3}{3 \times 127 \angle 0^\circ} = 1000 \angle 36.87^\circ \text{ A} \]
The sending end voltage is

\[ V_S = V_R + Z I_R = 127 \angle 0^\circ + (6 + j 20)(1000 \angle 36.87^\circ)(10^{-3}) \]
\[ = 121.39 \angle 9.29^\circ \text{ kV} \]

The sending end line-to-line voltage magnitude is

\[ |V_{S(L-L)}| = \sqrt{3} V_S = 210.26 \text{ kV} \]

The sending end power is

\[ S_{S(3\phi)} = 3 V_S I_S^* = 3 \times 121.39 \angle 9.29 \times 1000 \angle -36.87^\circ \times 10^{-3} \]
\[ = 322.8 \text{ MW} - j 168.6 \text{ Mvar} \]
\[ = 364.18 \angle -27.58^\circ \text{ MVA} \]

Voltage regulation is

\[ \text{Percent } VR = \frac{210.26 - 220}{220} \times 100 = -4.43\% \]

Transmission line efficiency is

\[ \eta = \frac{P_{R(3\phi)}}{P_{S(3\phi)}} = \frac{304.8}{322.8} \times 100 = 94.4\% \]