8.2 Transmission Lines

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Q1 $3\cdot\phi$, 765 kV, 60 Hz, 300 km

$z = 0.0165 + j\,0.3306\ \Omega/\text{km}$

$y = j\,4.674 \times 10^{-6}\ \text{S/km}$.

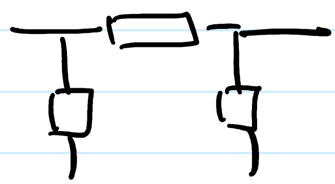
Find nominal π circuit.

$Z = zl = z(300) = (0.0165 + j\,0.3306)\,300$

$= 4.95 + j\,99.18\ \Omega$

$Y = yl = y(300)$

$= j\,1.4022 \times 10^{-3}\ \text{S}$



$A = D = 1 + \dfrac{YZ}{2} =$

$C = Y\left(1 + \dfrac{YZ}{4}\right) =$

$B = Z = 4.95 + j\,99.18\ \Omega$.

voltage rating of the line

Q2 3ϕ, 69 kV, short, 16 km long.

$z = 0.125 + j\,0.4375\ \Omega/\text{km}$.

$Z = [0.125 + j\,0.4375] \times 16\ \Omega/\text{km}$.

Load → 70 MVA, 0.8 lags, @ 64 kV

$A = D = 1$, $B = Z$, $C = 0$

$V_R = \dfrac{64 \times 10^3}{\sqrt{3}} \angle 0^\circ = 36.95 \angle 0^\circ\ \text{kV}$

$|S_{LOAD}| = 70 \times 10^6 = 3|V_R||I_R|$

$|I_R| = \dfrac{70 \times 10^6}{3 \times 36.95 \times 10^3} = 631.48\ \text{A}$.

$I_R = 631.48 \angle -36.87^\circ A$

$I_S = I_R = 631.48 \angle -36.87^\circ A$

$V_S = V_R + I_R Z$

$= 36.95 \times 10^3 \angle 0^\circ + 631.48 \angle -36.87^\circ (2 + 7j)$

$V_S = 40.71 \angle 3.91^\circ \, kV$

$|V_{S_{FL}}| = 40.71 \, kV$

$|V_{R_{FL}}| = 36.95 \, kV$

$\% VR = \dfrac{40.71 - 36.95}{36.95} \times 100$

$= 10.17\%$

$\eta = \dfrac{P_{3\phi R}}{P_{3\phi S}} \times 100\%$

$P_{3\phi R} = 70 \times 10^6 \times 0.8$

$= 56 \, MW$

$S_S = 3 \cdot V_S \cdot I_S^*$

$= 3 (40.71 \angle 3.91)(631.48 \angle -36.87)^*$

$= 58.39 + j50.37 \, MVA$

$P_{3\phi, S} = 58.39 \, MW$

$\eta = \dfrac{56}{} \times 100 = 95.91\%$

$$\eta = \frac{56}{58.39} \times 100 = 95.91\%$$

3) 200 km, 230 kV, 60 Hz,

$z = 0.08 + j0.48 \ \Omega/km$

$y = j3.33 \times 10^{-6} \ S/km.$

Load Parameters. - 250 MW @ 0.99 lag @ 220 kV

→ π circuit [Medium]

$Z = z\ell = 16 + j96 \ \Omega$ $\quad Y = j6.66 \times 10^{-4} S$

$$A = D = 1 + \frac{YZ}{2} = 0.9680 + j\,0.0053$$

$$C = Y\left[1 + \frac{YZ}{4}\right] = (-1.774 \times 10^{-6} + j\,6.554 \times 10^{-4})\,S$$

$B = Z = 16 + j96 \ \Omega$

→ $P_{Load} = 250\,MW. = 3 V_R I_R \cos\theta$

$$V_R = \frac{220 \times 10^3}{\sqrt{3}} \angle 0^0$$

$$|I_R| = \frac{250 \times 10^6}{\frac{220 \times 10^3}{\sqrt{3}} \times 3 \times 0.99} = 662.69A$$

$I_R = 662.69 \angle -8.11^0$

$$\begin{bmatrix} V_S \\ I_S \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

$V_S = A V_R + B I_R$

$$V_S = AV_R + BI_R$$
$$= 155.4\angle 23.58^\circ \text{ kV}$$

$$I_S = CV_R + DI_R$$
$$= 635.38\angle -0.34^\circ \text{ A}$$

4) 345 kV, 50 Hz, 130 km

$r = 0.036\ \Omega/\text{km}$, $l = 0.8\ \text{mH}/\text{km}$, $c = 0.112\ \mu F/\text{km}$

$g = 0$

Load → 270 MVA, 0.8 lag, @ 325 kV

$$Z = (r + j\omega l) \times 130$$
$$= (0.036 + j(2\pi.50 \cdot 0.8\times 10^{-3}))130$$
$$= 4.68 + j\,32.67\ \Omega$$

$$Y = (j\omega C) \times 130$$
$$= j((100\pi)0.112\times 10^{-6}) \times 130$$
$$= j\,4.57\times 10^{-4}\ S$$

$$A = D = 1 + \frac{YZ}{2} = 0.9925 + j\,0.0011$$

$$B = Z = 4.68 + j\,32.67\ \Omega$$

$$C = \left(1 + \frac{YZ}{4}\right)Y = (-0.2448\times 10^{-8} + j\,0.4557\times 10^{-5})\ S$$

a) Load → 270 MVA @ 0.8 lag @ 325 kV

$$V_R = \frac{325\times 10^3}{\sqrt{3}}\angle 0^\circ \text{ V} = 187.64 \text{ kV} \angle 0^\circ$$

$$|I_R| = \frac{270\times10^6}{3\times\frac{325\times10^3}{\sqrt{3}}} = 479.65\,A$$

$$I_R = 479.65\angle-36.87^\circ\,A$$

$$\begin{bmatrix} V_S \\ I_S \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_R \\ 479.65\angle-36.87^\circ \end{bmatrix}$$

$$V_S = 197.764\angle3.30^\circ\,kV$$

$$I_S = 430.27\angle-27.66^\circ\,A$$

$$\%\,VR = \frac{|V_{R\,N-L}| - |V_{R\,F-L}|}{|V_{R\,F-L}|}$$

$$V_{R\,N-L} = \frac{V_{S\,F-L}}{A} = \frac{197.764\angle3.30^\circ\,kV}{0.9925+j\,.0011}$$

$$= \frac{197.764\times10^3\angle3.30}{0.9925\angle0.0635^\circ}$$

$$|V_{R\,N-L}| = \frac{197.764\times10^3}{0.9925} = 199.25\,kV$$

$$\%\,VR = \frac{199.25-187.64}{187.64}\times100\%$$

$$= 6.19\%$$

$$S_{3\phi S} = 3V_S I_S^* = 218.9 + j\,131.3\,MVA.$$

$$P_{S3\phi} = 218.9\,MW$$

$P_{S3\phi} = 218.9\ MW$

$P_{R3\phi} = 270\,MVA \times 0.8 = 216\ MW$

$\eta = \frac{216}{218.9} \times 100\% = 98.7\%$

b) Load 270 MVA, @ 0.95 lag @ 325 kV.

$V_R = \frac{325 \times 10^3}{\sqrt{3}} \angle 0^\circ\ V$

$|I_R| = \frac{270 \times 10^6}{3 \times \frac{325 \times 10^3}{\sqrt{3}}} = \frac{|S|}{3 V_R} = 479.65\ A$

$I_R = 479.65 \angle -18.19\ A$

$$\begin{bmatrix} V_S \\ I_S \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_R \\ 479.65 \angle -18.19 \end{bmatrix}$$

$V_S = 193.796 \times 10^3 \angle 4.26^\circ\ V$

$I_S = 456.70 \angle -7.88\ A$

$|V_{R\,N\text{-}L}| = \left|\frac{V_S}{A}\right| = \left|\frac{193.796 \times 10^3 \angle 4.26}{0.9925 \angle 0.0635^\circ}\right|$

$= \frac{193.796 \times 10^3}{0.9925} = 195.26\ kV$

$V_{RF\text{-}L} = 187.64\ kV$

$$\% VR = \frac{195.26 - 187.64}{187.64} = 4.06\%$$

$$S_{3\phi s} = 3 V_s I_s^*$$
$$= 259.58 + j55.84 \text{ MVA}$$

$$P_{3\phi s} = 259.58 \text{ MW}$$

$$P_{3\phi R} = 270 \times 0.95 = 256.5 \text{ MW}$$

$$\eta = \frac{256.5}{259.58} \times 100\% = 98.8\%$$

→ steps to solve transmission line questions.

a) Find ABCD parameters.
- ↳ Find Z
  - ↳ z (length)
    - ↳ $(r + j\omega L)$
- ↳ Find Y
  - ↳ y (length)
    - ↳ $y(g + j\omega c)$

$z \rightarrow \Omega/km$

$y \rightarrow ℧/km$, S/km.

Short
$$\begin{bmatrix} 1 & Z \\ 0 & 1 \end{bmatrix}$$

Medium
$$\begin{bmatrix} 1+\frac{YZ}{2} & Z \\ Y\left(1+\frac{YZ}{4}\right) & 1+\frac{YZ}{2} \end{bmatrix}$$

b) From Load parameters find I_R & V_R [per phase]

c) Find V_s & I_s.

$$\begin{bmatrix} V_s \\ I_s \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

$$\begin{bmatrix} I_S \end{bmatrix} \quad \begin{bmatrix} C & D \end{bmatrix}\begin{bmatrix} I_R \end{bmatrix}$$

d) % V.R.

↳ $|V_{R_{NL}}| = \left| \frac{V_S}{A} \right|$

↳ $\% \, VR = \frac{|V_{R_{N-L}}| - |V_{R_{F-L}}|}{|V_{R_{F-L}}|}$

e) η - Efficiency $= \frac{P_{3\phi.R}}{P_{3\phi.S}} \times 100\,\%$

↳ $S_{3\phi,S} = 3 \, V_S \cdot I_S^*$

$= P_{3\phi,S} + j \, Q_{3\phi S}$

↳ $P_{3\phi,R} = S_{3\phi R} \times p.F$