P1 (25): A 30 km, 34.5 kV, 60 Hz three-phase line has positive-sequence series impedance $\bar{z} = 0.19 + j0.34\ \Omega/km$. The load at the receiving end absorbs 10 MVA at 33 kV.

- **a)** Calculate the ABCD parameters of the line,
- **b)** The sending end voltage for a load power factor of 0.9 lagging.
- **c)** The total apparent power at the sending end.

P2 (10): A 150 km, 500 kV, 60 Hz three-phase overhead transmission line, assumed to be lossless, has a series inductance of $L = 0.92\ \mu H/km$ per-phase and a shunt capacitance of $C = 11.5\ nF/km$ per-phase. Draw the nominal π circuit model of the line.

P3 (20): It is desired to transmit 2200 MW from a power plant to a load center located 300 km from the plant. It is planned to use an uncompensated over-head 500 kV, 60 Hz three-phase transmission line to transmit this power. The surge impedance of the line is given as $Z_C = 275\ \Omega$.
So, determine the minimum number of lines to be installed between the power plant and the load center if above line is used. Assume the practical loadability of the line when solving the problem.

P4 (45): A three-phase, 60 Hz, completely transposed 765 kV, and 370 km transmission line has four 1,272,000 cmil 54/3 ACSR conductors per bundle and the following positive-sequence line constants:

$$\bar{z} = 0.017 + j0.32\ \Omega/\text{km}, \qquad \bar{y} = j4.7\times10^{-6}\ \text{S/km}$$

The sending-end voltage is held constant at the rated line voltage. Assuming a lossless line, determine the following:

- **a)** The theoretical steady-state stability limit (maximum real power that the line can deliver to the receiving-end).
- **b)** The practical line loadability in MW.
- **c)** The full-load current at 0.99 leading power factor based on the above practical line loadability.
- **d)** The magnitude of the exact receiving-end voltage for the full-load current found in part (c).
- **e)** The percent voltage regulation for the above full-load current.
- **f)** Thermal limit of the line. The approximate current carrying capacity of the given conductor is 1200 A.

The ABCD parameters for a short line: $\bar{A} = \bar{D} = 1 \quad \bar{B} = \bar{Z} \quad \bar{C} = 0$

The ABCD parameters for a medium line: $\bar{A} = \bar{D} = 1 + \frac{\bar{Y}\bar{Z}}{2} \quad \bar{B} = \bar{Z} \quad \bar{C} = \bar{Y}\left(1 + \frac{\bar{Y}\bar{Z}}{4}\right)$

The exact ABCD parameters, propagation constant and characteristic impedance for any line length:

$$\bar{A} = \bar{D} = \cosh(\bar{\gamma} l) \quad \bar{B} = \bar{Z}_C \sinh(\bar{\gamma} l) \quad \bar{C} = \frac{1}{\bar{Z}_C}\sinh(\bar{\gamma} l) \quad \bar{\gamma} = \sqrt{\bar{z}\,\bar{y}} = \alpha + j\beta \quad \bar{Z}_C = \sqrt{\frac{\bar{z}}{\bar{y}}}\ \Omega$$

The exact ABCD parameters for a lossless line:

$$\bar{A} = \bar{D} = \cos(\beta l) \quad \bar{B} = jZ_c \sin(\beta l)\ \Omega \quad \bar{C} = j\frac{1}{Z_c}\sin(\beta l)\ \text{S} \quad \beta = \omega\sqrt{LC}\ m^{-1} \quad \lambda = \frac{2\pi}{\beta}\ m$$

$$\lambda = \frac{3\times10^8}{f}\ m \qquad \bar{Z}' = \bar{B}$$

Real power delivered by a lossless line is $P = P_S = P_R = \frac{V_S V_R}{X'}\sin\delta$ W

Real power delivered by a lossless line in terms of SIL is $P = V_{Spu} V_{Rpu} (SIL)\dfrac{\sin\delta}{\sin(\frac{2\pi l}{\lambda})}$ W

80 minutes

25 **Solution to P1**

$l = 30$ km 34.5 kV

a) $A = D = 1$ $C = 0$ $\bar{B} = \bar{Z} = (5.7 + j\,10.2)\ \Omega$ 5

b) $\bar{I}_R = \dfrac{10}{\sqrt{3}(33)} \angle -\cos^{-1}(0.9) = 0.175 \angle -25.842^\circ$ kA 3

$\bar{V}_S = \bar{A}\bar{V}_R + \bar{B}\bar{I}_R$

$= \dfrac{33}{\sqrt{3}} \angle 0^\circ + (11.685 \angle 60.8^\circ)(0.175 \angle -25.842^\circ)$

$= 19.05 + 2.045 \angle 34.96^\circ$

$= 20.726 + j\,1.1718$

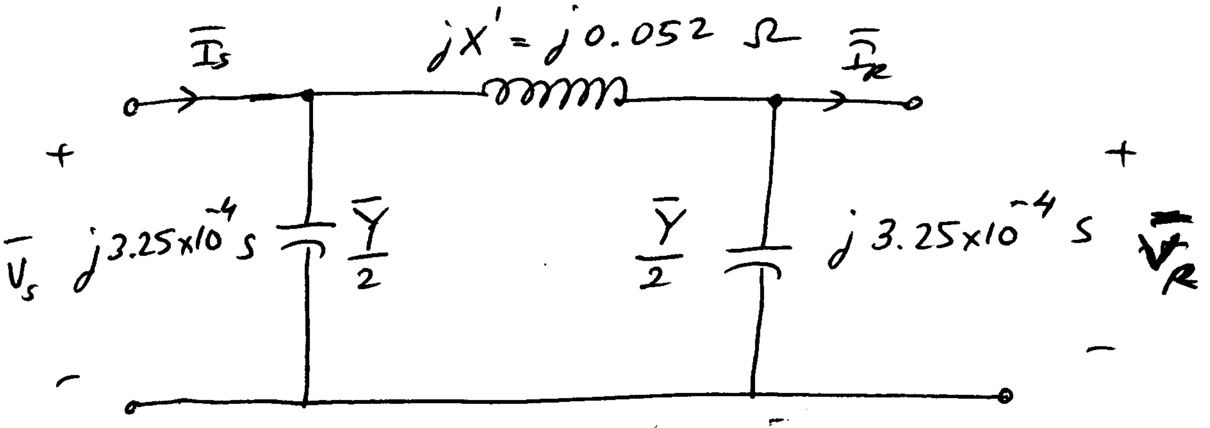
$\bar{V}_S = 20.76 \angle 3.236^\circ$ kV_{LN} 10

c) $S = 3(20.76)(0.175) = 10.899$ MVA 7

10 solution to P2

$\bar{Z} = jX = j(\omega)L \cdot l = j(377)\ 0.92 \times 10^{-6} \times 150 = j\,0.052\ \Omega$

$\bar{Y} = j\omega C \cdot l = j(377) \cdot (11.5 \times 10^{-9}) \times 150 = j\,6.5 \times 10^{-4}$ S 5



point 5

20 Solution to P3: 2

$$P = \frac{(1.0)(0.95)(SIL)\sin(30^\circ)}{\sin\left(\frac{2\pi l}{\lambda}\right)}$$

$$SIL = \frac{500^2}{275} = 909.1 \text{ MW}$$ 5

$$\lambda = \frac{3\times 10^8}{60} = 5000 \text{ km}$$

$$P = \frac{(1.0)(0.95)(909.1)(0.5)}{\sin\left(\frac{2\pi \times 300}{5000}\right)} = 1173. \text{ mW}$$ 10

$$\frac{2200 \text{ mW}}{1173} = 1.875$$ 5

So minimum 2 lines are needed.

45 Solution P4:

a) $P = \dfrac{V_S \cdot V_R}{X'}$ $\qquad Z_C = \sqrt{\dfrac{0.32}{4.7\times 10^{-6}}} = 260.93\ \Omega$ 2

$$\gamma l = \sqrt{Z \cdot y} \cdot l = \sqrt{j(0.32)\, j(4.7\times 10^{-6})} \cdot 370$$

$$\gamma l = j0.\cancel{45}38 = j\beta l \qquad \beta l = 0.4538 \text{ RAD}$$ 2

$$X' = (260.93)\sin(0.4538) = 114.4$$

$$P_{max} = \frac{765^2}{114.4} = 5116 \text{ mW}$$ 4 5002 mW

b) $$P = \frac{765^2 \times (0.95)\sin(30)}{114.4} = 2430 \text{ mW}$$ 7

2375.9 mW

c) $\bar{I}_{FL} = \dfrac{2430}{\sqrt{3}\,(0.95 \times 765)(0.99)} \angle + \cos^{-1}(0.99)$

$\bar{I}_{FL} = 1.95 \angle +8.11^\circ$ kA (5)

d) $\bar{V}_s = \bar{A}\bar{V}_R + \bar{B}\bar{I}_R$

$$\frac{765}{\sqrt{3}}\angle\delta^\circ = \underbrace{\cos(0.4538)}_{\bar{A}} V_R \angle 0^\circ + \left(\underbrace{114.4\angle 90^\circ}_{\bar{B} = jX'}\right)\left(1.95\angle 8.11^\circ\right)$$

$\bar{A} = \cos(0.4538) = 0.8988$

$441.67\angle\delta^\circ = 0.8988\,V_R + 223.08\angle 98.11^\circ$

$441.67\angle\delta^\circ = 0.8988V_R - 31.47 + j\,220.85$

$441.67^2 = (0.8988V_R - 31.47)^2 + (220.85)^2$

$V_R = 460.57$ kV_{LN} (10)

$V_R = 797.73$ kV_{LL}

e) $\%VR = \dfrac{765/0.8988 - 797.73}{797.73} \times 100 = \dfrac{851.13 - 797.73}{797.73} \times 100$

$\%VR = 6.695\,\%$ (10)

f) $4 \times 1200 = 4800$ A $\gg$ 1950 A (5)