Power System Analysis I **** Final **** August 26, 2010

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P1 (50): A three-phase, 60 Hz, completely transposed 765 kV, and 280 km transmission line has four 1,272,000 cmil 54/3 ACSR conductors per bundle and the following positive-sequence line constants:

$$\bar{z} = 0.022 + j0.35 \ \Omega/\text{km} \qquad \bar{y} = j4.625 \times 10^{-6} \ \text{S/km}$$

Full load at the receiving end of the line is 3500 MVA at 0.99 power factor leading and at 95% of the rated voltage. Assuming a medium-length line, determine the following:

a) Draw the nominal-π circuit model of the line

b) Find the ABCD parameters of the line

c) Find the sending-end voltage, current, and the real power

d) Find the percent voltage regulation

e) Find the transmission-line efficiency at full load

f) The approximate current carrying capacity of a 1,272,000 cmil 54/3 ACSR conductor is 1200 A. Based on this data, find the thermal limit of the line and evaluate the result.

$$\bar{A}=\bar{D}=\left(1+\frac{\bar{Y}\bar{Z}}{2}\right) \qquad \bar{B}=\bar{Z} \qquad \bar{C}=\bar{Y}\left(1+\frac{\bar{Y}\bar{Z}}{4}\right)$$

P2 (20): Approximately draw the practical loadability curve for a typical uncompensated transmission line, and also draw the voltage profile curves for different loading conditions. Based on these curves, explain the reasons why we should compensate the transmission lines.

P3 (30): A 300 km, 345 kV, 50 Hz three-phase uncompensated line has the following positive-sequence line constants:

$$\bar{z} = j0.32 \ \Omega/\text{km} \quad \bar{y} = j5.2 \times 10^{-6} \ \text{S/km}.$$

Rated line voltage is applied to the sending end of this line. Calculate the receiving-end voltage magnitude when the receiving end is terminated by

a) An open circuit

b) The surge impedance of the line

c) Also calculate the surge impedance loading (SIL) of the line.

$$A = \cos(\beta l) \qquad Z_C = \sqrt{\frac{\bar{z}}{\bar{y}}} \ [\Omega] \qquad \beta = \left|\sqrt{\bar{z}\bar{y}}\right| \ [\text{Radian}]$$

Note: β is in Radians.

SOLUTIONS

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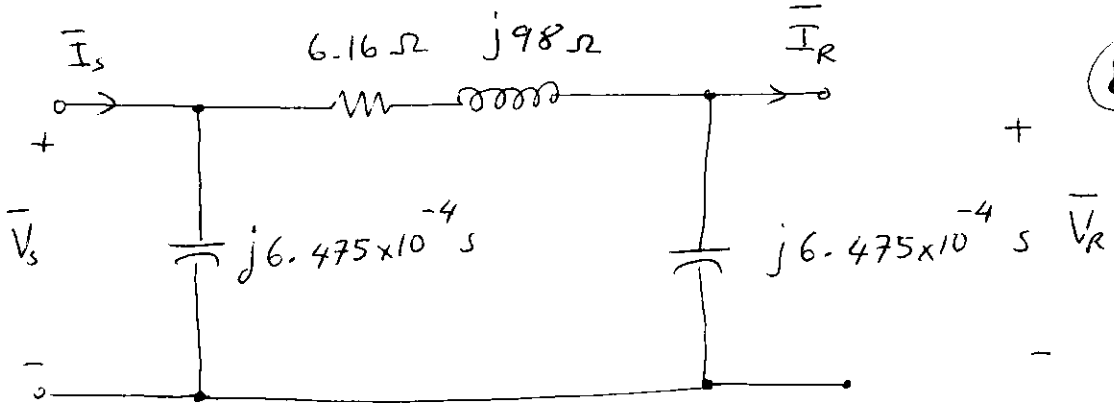
P1)

$$\bar{Z} = \bar{z} \cdot l = (0.022 + j0.35) \times (280) = (6.16 + j\,98)\ \Omega$$

$$\bar{Y} = \bar{y} \cdot l = (j4.625 \times 10^{-6}) \times (280) = j1.295 \times 10^{-3}\ S$$

(a)



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(b)

$$\bar{A} = \bar{D} = \left(1 + \frac{(6.16 + j\,98) \times (j1.295 \times 10^{-3})}{2}\right)$$

$$= \left[1 + \frac{(98.1934\angle 86.4^\circ) \times (1.295 \times 10^{-3}\angle 90^\circ)}{2}\right]$$

$$= 0.936545 + j3.9886 \times 10^{-3}$$

$$\bar{A} = \bar{D} = 0.93655\angle 0.244^\circ \quad 5$$

$$\bar{B} = 98.1934\angle 86.4^\circ\ \Omega \quad 2$$

$$\bar{C} = (1.295 \times 10^{-3}\angle 90^\circ)\left(1 + \frac{98.1934\angle 86.4^\circ \times 1.295 \times 10^{-3}\angle 90^\circ}{4}\right)$$

$$= -2.584972 \times 10^{-6} + j\,1.2539 \times 10^{-3}$$

$$= 1.2539 \times 10^{-3}\angle 90.118^\circ\ S \quad 2$$

(c)

$$\bar{I}_R = \frac{3500 \times 10^6}{\sqrt{3}(0.95 \times 765 \times 10^3)}\angle{+\cos^{-1}(0.99)} = 2780.5\angle 8.11^\circ\ A$$

$$\bar{V}_{RFL} = \frac{(0.95 \times 765\ kV)}{\sqrt{3}} = \frac{726.75}{\sqrt{3}} = 419.6\ kV_{LN}$$

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

$$= (0.93655\angle 0.244^\circ)(419.6) + (98.1934\angle 86.4^\circ)(2.78\angle 8.11^\circ)$$

$$= 371.5 + j273.8$$

$$\bar{V}_s = 461.5\angle 36.39^\circ \quad kV_{LN} \quad (5$$

$$\bar{I}_s = \bar{C}\cdot\bar{V}_R + \bar{D}\cdot\bar{I}_R$$

$$= (1.2539\times10^{-3}\angle 90.118^\circ)(419.6) + (0.93655\angle 0.244^\circ)(2.78\angle 8.11^\circ)$$

$$= 2.5749 + j0.90441 \quad (5$$

$$\bar{I}_s = 2.7291\angle 19.353^\circ \quad kA$$

$$\bar{S}_S = 3\times(461.5\angle 36.39^\circ)(2.7291\angle -19.353^\circ)$$

$$= 3778.44\angle 36.39^\circ - 19.353^\circ$$

$$= 3612.6 + j1107$$

$$P_S = 3612.6 \quad MW \quad (5$$

(d) $$\%VR = \frac{V_{RNL} - V_{RFL}}{V_{RFL}}\times100 = \frac{\frac{461.5}{0.93655} - 419.6}{419.6}\times100$$

$$= \frac{492.766 - 419.6}{419.6}\times100$$

$$= 17.437\,\%$$

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(e) $\%\eta = \frac{P_R}{P_S} \times 100 = \frac{3500 \times 0.99}{3612.6} = \frac{3465}{3612.6} \times 100 = 95.91\%$ (5)

(f) The thermal limit is $4 \times 1200 = 4800$ A

$I_S = 2729.1$ kA, which is less than 4800 A; so, the limit is not exceeded. (5)

(P2) (20)

(P3) $l = 300$ km

$\bar{z} = j0.32 \ \Omega/km$

$\bar{y} = j5.2 \times 10^{-6}$ S/km

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

when the line is terminated by an open circuit, $\bar{I}_R = 0$; so, $V_{RNL} = \frac{V_S}{A}$

$A = \cos(\beta l)$

$\beta = \left|\sqrt{\bar{z} \cdot \bar{y}}\right| = \left|\sqrt{(j0.32)(j5.2 \times 10^{-6})}\right| = 1.29 \times 10^{-3}$

$A = \cos(1.29 \times 10^{-3} \times 300)$

$= \cos(0.387)$

$\bar{A} = 0.926$

$V_{RNL} = \frac{345}{0.926} = 372.55 \ kV_{LL}$ (10)

(b) $|\bar{V}_R| = |\bar{V}_S| = 345 \ kV_{LL}$ (10)

(c) $SIL = \frac{345^2}{Z_c}$

$Z_c = \sqrt{\frac{j0.32}{j5.2 \times 10^{-6}}} = 248.069 \ \Omega$

$= \frac{345^2}{248.069} = 479.8$ MW (10)