Power System Analysis I **** Final *** January 14, 2011**** with Solutions

Student name: number:

P1 (30): A 150 km, 220 kV, 60 Hz three-phase over head transmission line has the following line constants.

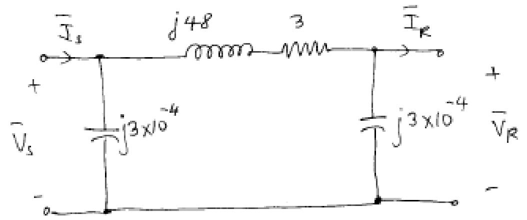
$$\bar{z} = (0.02 + j0.32)\ \Omega/km, \qquad \bar{y} = j4 \times 10^{-6}\ S/km$$

The three-phase load at the receiving-end absorbs 500 MW at 0.90 lagging power factor at 95 % of rated voltage. Use the approximate model of the line and

a) calculate the ABCD parameters of the line,
b) draw the nominal-π circuit model,
c) find the sending-end voltage.

Answers

a) A=D=0.9856∠0.05° , B=48.1∠86.4° Ohm, C=5.9568x10^{-4}∠90° S

b) 

c) Vs=167.995∠22.5° kV

P2 (30): A new transmission line is going to be installed to transmit power from a source to a load center. The load center is located 350 km away from the source and the total demand at the load center is 750 MW. Your job in this project is to design the transmission line.

a) Determine the rated voltage of this new transmission line based on the practical line loadability. Assume that the line is lossless, $\lambda = 5000$ km, $Z_C = 320\ \Omega$ and $\delta = 35°$.
b) For the voltage level obtained in (a), determine the theoretical maximum power that can be transferred by the line.

Answers

a) Vrated=433052 V
b) P=2.3486(SIL)=1376 MW

P3 (40): A three-phase, 60 Hz, completely transposed 765 kV and 400 km uncompensated transmission line has the following positive-sequence line constants:

$$\bar{z} = 0.02 + j0.4\ \ \Omega/\text{km} \qquad \bar{y} = j6 \times 10^{-6}\ \ \text{S/km}$$

The sending-end voltage is held constant at the rated line voltage. Assuming a **lossless** line and using the parameters of the exact model, determine the following:

a) The theoretical steady-state stability limit (theoretical maximum line loadability).
b) The practical line loadability.
c) The full-load current at 0.98 lagging power factor based on the above practical line loadability.
d) The exact receiving-end voltage for the full-load current found in part c.
e) The percent voltage regulation. Is this voltage regulation of the line acceptable?

Answers

a) Pmax=3902 MW
b) Practical=1853 MW
c) I_{RFL}=1.5∠ − 11.5° kA

d) $\frac{765}{\sqrt{3}}\angle\delta^\circ = 0.814\, V_{RFL} + j150\,(1.5\angle{-11.5^\circ})$

$= 0.814\, V_{RFL} + 225\angle 78.5^\circ$

$= 0.814\, V_{RFL} + 44.86 + j220.5$

$0.814 V_{RFL} = \sqrt{441.67^2 - 220.5^2} - 44.86$

$V_{RFL} = \frac{382.69 - 44.86}{0.814} = 415 \ kV_{LN} = 718.84\ kV_{LL}$

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e) $\%VR = \frac{765/0.814 - 718.84}{718.84} = \frac{940 - 719}{719} \times 100 = 30.7\ \%$

$\%VR = 30.7\%$ which is more than 10%.

5 So, line needs compensation.

5

Formulas:

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

Exact ABCD parameters of a lossless line:

$\overline{A} = \overline{D} = \cos(\beta l)$ $\quad \overline{B} = jZ_c \sin(\beta l)\ \Omega$ $\quad \overline{C} = j\frac{1}{Z_c}\sin(\beta l)\ \text{S}$

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 $P = V_{Spu} V_{Rpu}(\text{SIL})\frac{\sin\delta}{\sin(\frac{2\pi l}{\lambda})}$ W

$\overline{\gamma} = \sqrt{\overline{z}\,\overline{y}} = \alpha + j\beta\ \text{m}^{-1}$ $\quad \overline{Z}_C = \sqrt{\frac{\overline{z}}{\overline{y}}}\ \Omega$ $\quad \lambda = \frac{2\pi}{\beta}\ \text{m}$ $\quad \lambda = \frac{3\times10^8}{f}\ \text{m}$