Power System Analysis I **** Final *** 20.01.2012

Student name: **Number:** SOLUTIONS

The Electrical and Electronics Engineering Department of Eskişehir Osmangazi University

P1 (40): A 150 km, 230 kV, 60 Hz three-phase line has a positive-sequence series impedance $\bar{z} = 0.08 + j0.48\ \Omega/\text{km}$ and a positive-sequence shunt admittance $\bar{y} = j3.33 \times 10^{-6}$ S/km. At full load, the line delivers 250 MW at 0.99 power factor lagging and at 220 kV. Using the nominal π circuit, calculate:

a) the ABCD parameters,
b) the sending-end voltage, current, and the real power,
c) the percent voltage regulation, and (is this value acceptable?)
d) the transmission-line efficiency at full load.
e) Is the percent voltage regulation found in part c within the limit?

$$\bar{Z} = 12 + j72 = 73\angle 80.54^\circ\ \Omega$$

$$\bar{Y} = j4.995\times10^{-4} = 5\times10^{-4}\angle 90^\circ\ S$$

a)
$$\bar{A} = \bar{D} = \left[1 + \frac{(73\angle 80.54^\circ)(5\times10^{-4}\angle 90^\circ)}{2}\right]$$

$$= \left[1 + \frac{-0.036 + j6\times10^{-3}}{2}\right] = 0.982 + j3\times10^{-3}$$

$$\bar{A} = \bar{D} = 0.982\angle 0.175^\circ \text{ per-unit} \quad 6$$

$$\bar{B} = \bar{Z} = 73\angle 80.54^\circ\ \Omega \quad 2$$

$$\bar{C} = 5\times10^{-4}\angle 90^\circ \left[1 + \frac{-0.036 + j6\times10^{-3}}{4}\right] = -7.5\times10^{-7} + j5\times10^{-4}$$

$$\bar{C} \cong 5\times10^{-4}\angle 90.1^\circ\ S \quad 3$$

b)
$$\bar{V}_S = \bar{A}\bar{V}_R + \bar{B}\bar{I}_R \qquad \bar{V}_R = \frac{220}{\sqrt{3}} = 127\ kV_{LN}$$

$$\bar{I}_R = \frac{250\times10^6}{\sqrt{3}(220000)(0.99)}\angle -\cos^{-1}(0.99)$$

$$\bar{I}_R = 662.7\angle -8.1^\circ\ A$$

$$\bar{V}_S = (0.982\angle 0.175^\circ)(127) + (73\angle 80.54^\circ)(0.6627\angle -8.1^\circ)$$

$$\bar{V}_S = 139.3 + j46.5 = 146.87\angle 18.5^\circ\ kV_{LN} \quad 7$$

$$\bar{I}_S = (5\times10^{-4}\angle 90.1^\circ)(127) + (0.982\angle 0.175^\circ)(0.6627\angle -8.1^\circ)$$

$$\bar{I}_S = 0.6444 - j0.02622 = 0.645\angle -2.33^\circ$$

$$\bar{I}_S = 645\angle -2.33^\circ\ A \quad 7$$

P2 (35): 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, determine the following:

a) The theoretical steady-state stability limit in MW and in terms of SIL.
b) The practical line loadability in MW and in terms of SIL.
c) The full-load current at 0.92 lagging power factor based on the above practical line loadability.

a) $P_{R\,max} = \dfrac{V_S \cdot V_R}{X'}$

$Z_c = \sqrt{\dfrac{j0.4}{j6\times10^{-6}}} = 258.2 \ \Omega$

$\gamma = j\beta = \sqrt{j0.4\,(j6\times10^{-6})} = 1.5492\times10^{-3}$

$X' = 258.2 \sin(0.62)$ $\qquad \beta l = 0.62$ RAD

$X' = 150 \ \Omega$

$P_{R\,max} = \dfrac{(765\times10^3)(765\times10^3)}{150} = 3902$ MW $\quad$ (10)

$SIL = \dfrac{765^2}{258.2} = 2267$ MW $\quad$ (2)

$P_{R\,max} = 1.72\ SIL$ $\quad$ (4)

b) $P_R = \dfrac{765 \times (0.95\times 765)\sin(35^\circ)}{150} = 2126$ MW $\quad$ (10)

$P_R = 0.9377\ SIL$ $\quad$ (2)

c) $\bar{I}_R = \dfrac{2126\times10^6}{\sqrt{3}\,(0.95\times 765000)\,(0.92)} \angle -\cos^{-1}(0.92)$

$\bar{I}_R = 1836 \angle -23.07^\circ$ A $\quad$ (7)

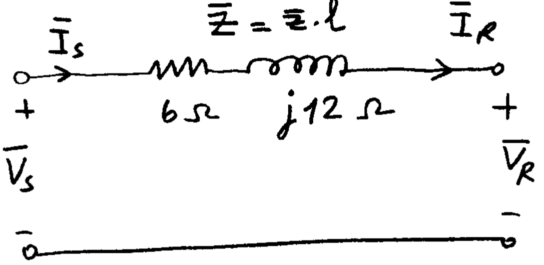
P3(25) A 60 km, 69 kV, 60 Hz three-phase line has positive-sequence series impedance $\bar{z} = 0.1 + j0.2\ \Omega/\text{km}$. The load at the receiving-end draws a current of 500 Ampere. Assume that the sending-end voltage is held constant at the rated line voltage.

a) Calculate the magnitude of the receiving-end voltage if the load power factor is 0.866 lagging

b) Calculate the magnitude of the receiving-end voltage if the load power factor is 0.6 leading

c) Comment about the effect of the load power factor on the voltage regulation of the line based on the results obtained in part **a** and **b**.

a)



$\bar{V}_R = 39837 - (6+j12)\,500\angle{-30^\circ}$

$\bar{V}_R = 34438\angle{-6.16^\circ}$ V

$V_R = 34438$ V

(8)

b) $\bar{V}_R = 39837 - (6+j12)\,500\angle{53.13^\circ}$

$\bar{V}_R = 43255\angle{-7.97^\circ}$ V $\qquad V_R = 43255$

(8)

c) for the result in part a : $\dfrac{34438}{39837} = 0.865$

this result is less than 0.95 . poor regulation

This is due to lagging power factor.

(9)

For the result in part b : $\dfrac{43255}{39837} = 1.086$ pu

Not acceptable since it is more than 1.05 pu .

The high voltage is due the leading power factor.

The ABCD parameters of a medium line

$$\bar{A} = \bar{D} = \left(1 + \frac{\bar{Z}\cdot\bar{Y}}{2}\right) \text{ per-unit} \qquad \bar{B} = \bar{Z}\ \Omega \qquad \bar{C} = \bar{Y}\cdot\left(1 + \frac{\bar{Z}\cdot\bar{Y}}{4}\right)\ \text{S}$$

The exact ABCD parameters of a lossless line

$$\bar{A} = \bar{D} = \cos\beta l \text{ per-unit} \qquad \bar{B} = jZ_c \sin\beta l\ \Omega \qquad \bar{C} = j\frac{1}{Z_c}\sin\beta l\ \text{S}$$

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

$X' = Z_c \sin\beta l\ \Omega \qquad \bar{Z}_c = \sqrt{\bar{z}/\bar{y}}\ \Omega \qquad \bar{\gamma} = \sqrt{\bar{z}\cdot\bar{y}}\ m^{-1}$

Real power delivered by a lossless line in terms of SIL is $\quad P_R = V_{Spu}\,V_{Rpu}\,(SIL)\frac{\sin\delta}{\sin(\beta l)}$