Power System Analysis I Final January 18, 2010 SOLUTIONS
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P1 (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 **lossy** line, determine the following:

a) The theoretical steady-state stability limit in MW.
b) The practical line loadability in MW.
c) The full-load current at 0.92 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.

The ABCD parameters for the line are:

$\bar{A} = 0.814\angle 0.633°\ pu$ $Z' = \bar{B} = 150.14\angle 88.76°\ \Omega$ $\bar{C} = 0.0022\angle 88.76°\ \text{S}$ $\bar{D} = \bar{A}$

$$P_R = \frac{V_S V_R}{Z'}\cos(\theta_Z - \delta) - \frac{AV_R^2}{Z'}\cos(\theta_Z - \theta_A)$$

P2 (35): A three-phase power of 660 MW is to be transmitted to a load center located 345 km from the source of power. The following parameters are to be used for the design of the transmission line.

$V_S = 1.0\ pu$, $V_R = 0.94\ pu$, $\lambda = 5000$ km, $Z_C = 320\ \Omega$, $\delta = 38°$

a) Determine the rated voltage of the transmission line, based on the practical line loadability equation.
b) For the voltage level obtained in (a), determine the theoretical maximum power that can be transferred by the line.

$$P_R = V_{Spu}\, V_{Rpu}\, (SIL) \frac{\sin\delta}{\sin\left(\frac{2\pi l}{\lambda}\right)}$$

$$P_R = \frac{V_S\, V_R}{X'}\sin\delta$$

P3 (25): a) Draw the circuit model of a short line, **b)** obtain the ABCD parameters for the short line, **c)** show the effect of load power factor on voltage regulation using the circuit model and the phasor diagrams for the short line.

Duraion of the exam is 85 minutes.

1) : a)

$$P_R = \frac{V_S V_R}{Z'} \cos(\theta_Z - \delta) - \frac{A V_R^2}{Z'} \cos(\theta_Z - \theta_A)$$

$$= \frac{(765)(765)}{150.14} \cos(0°) - \frac{0.814(765)^2}{150.14} \cos(88.76° - 0.633°)$$

$$= 3897.9 - 103.7$$

$P_R = 3794.2$ MW → Theoretical steady-state stability limit

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b)

$$P_R = \frac{765(0.95 \times 765)}{150.14} \cos(88.76° - 35°) - \frac{0.814(0.95 \times 765)^2}{150.14} \cos(88.76° - 0.633°)$$

$$= 2189 - 93.6$$

$P_R = 2095.4$ MW → practical loadability

10

c)

$$\bar{I}_{RFL} = \frac{2095.4 \times 10^6}{\sqrt{3}(0.95 \times 765)(0.92)} \angle -\cos^{-1}(0.92)$$

$$= 1809.4 \angle -23.074° \quad A$$

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d)

$$\frac{765}{\sqrt{3}} \angle \delta° = (0.814 \angle 0.633°)(V_{RFL}) + (150.14 \angle 88.76°)(1.8094 \angle -23.074°)$$

$$441.7 \angle \delta° = (0.814)V_{RFL} + j0.009 V_{RFL} + 111.85 + j247.6$$

$$441.7 \angle \delta° = (0.814 V_{RFL} + 111.85) + j(0.009 V_{RFL} + 247.6)$$

$$= 0.6626 V_{RFL}^2 + 91 V_{RFL} + 12510.4$$

$$+ 8.1 \times 10^{-5} V_{RFL}^2 + 2.2284 V_{RFL} + 61305.76$$

$$441.7^2 = 0.662681 V_{RFL}^2 + 93.2284 V_{RFL} + 73816.16$$

$$0.662681 V_{RFL}^{2} + 93.2284 V_{RFL} - 121282.73 = 0$$

$$V_{RFL_{LN}} = 363.2 \quad kV_{LN}$$

(10)

$$V_{RFL_{LL}} = \sqrt{3}(363.2) = 629 \ kV_{LL}$$

e) $$\% VR = \frac{\frac{765}{0.814} - 629}{629} \times 100$$

$$\% VR = \frac{939.8 - 629}{629} \times 100$$

$$= 49\%$$

(5)

2) (3

a) $660\times10^6 = (1.0)(0.94)\dfrac{V_{rated}^2}{320}\dfrac{\sin 38^\circ}{\sin\left(\frac{360\times345}{5000}\right) = (0.42)}$

$660\times10^6 = 4.305087\times10^{-3}\,V_{rated}^2$

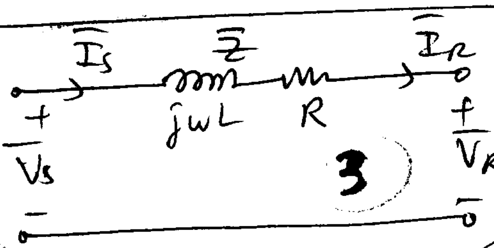
$V_{rated}^2 = 1.5337\times10^{11}$

20

$V_{rated} = 391614.4\ V_{LL} = 391.5\ kV_{LL}$

b) $P_{R_{max}} = (1.0)(1.0)\dfrac{(391.5)^2}{320}\dfrac{\sin(90)}{\sin\left(\frac{360\times345}{5000}\right)}$

$= 1140\ MW$ / 15

3) 

$\bar{Z} = \bar{z}.l$

$\bar{A} = \bar{D} = 1.0$ 3

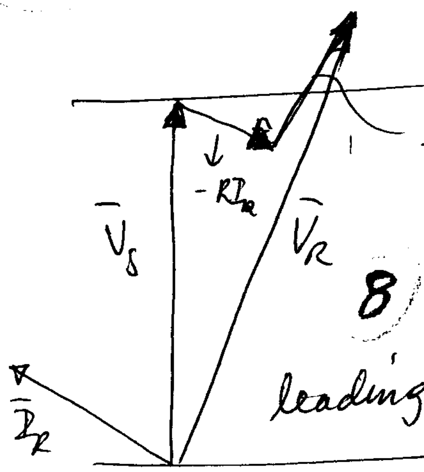
$\bar{B} = \bar{Z} \quad \bar{C} = 0$

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

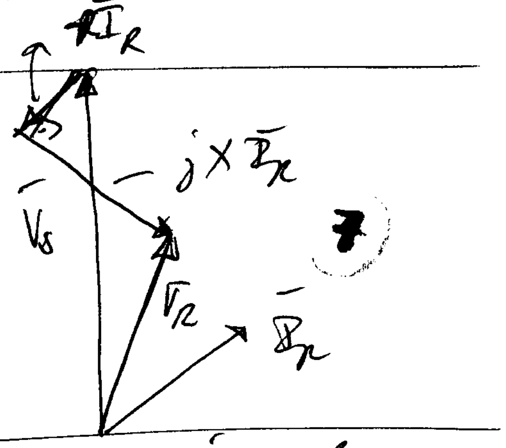
$\bar{V}_S = \bar{V}_R + \bar{Z}\,\bar{I}_R$ 2

$\bar{I}_S = \bar{C}\,\bar{V}_R + \bar{D}\bar{I}_R$

$\bar{I}_S = \bar{I}_R$ 2



leading pf



Lagging pf

$\bar{V}_R = \bar{V}_S - j\omega L\,\bar{I}_R - R\bar{I}_R \qquad V_R < V_S$