EECE458 Fall 2012 Solution Exercise 6

$$\text{Short-Circuit Ratio (SCR)} = \frac{\text{Field current for rated open-circuit voltage}}{\text{Field current for rated short-circuit current}}$$

We define $X_s = \frac{1}{SCR}$ (p.u.)

We don't need the generator reactance in this example

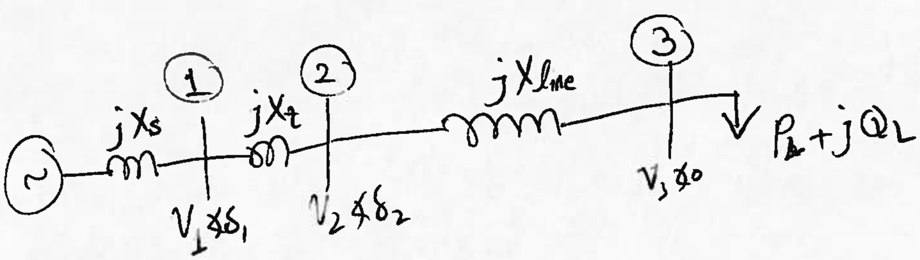
For the generator:

$$\left.\begin{aligned} X_s &= \frac{1}{1} = 1\ \text{p.u.} \\ Z_{base} &= \frac{13.8^2}{250} \end{aligned}\right\} \Rightarrow X_s = \frac{13.8^2}{250} = 0.76176\ \Omega$$

$$X_s = \frac{0.76176}{\left(\frac{13.8^2}{100}\right)} = 0.4\ \text{p.u.} \quad \text{in system base}$$

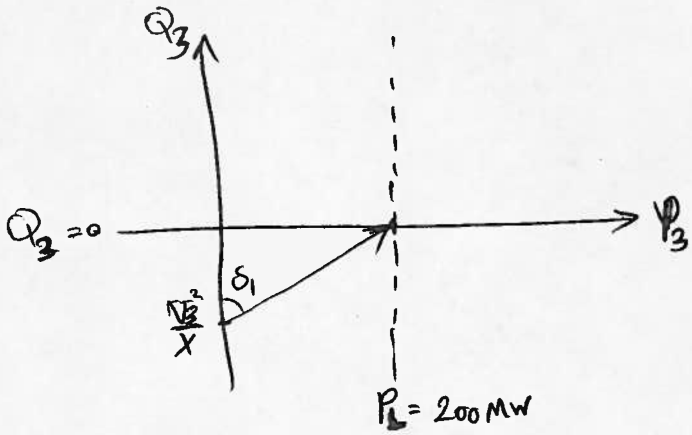
$$X_t = 0.1 \times \frac{100}{250} = 0.04\ \text{p.u.}$$

$$X_{line} = \frac{100\,(\text{km}) \times 0.5\,\left(\frac{\Omega}{\text{km}}\right)}{\frac{115^2}{100}} = 0.378\ \text{p.u}$$



$$P.F. = 1 \Rightarrow Q_2 = 0 \Rightarrow Q_L = -Q_C$$

$$|Q_C| = 200\ \text{MVAR} \Rightarrow Q_{ph} = \frac{200}{3}\ \text{MVAR} \Rightarrow C = \frac{Q_{ph}}{\omega V_{ph}^2} = \frac{200/3}{2\pi \times 60 \times \frac{115^2}{3}} = 40.11\mu$$



First, add X_t and X_{line} together.

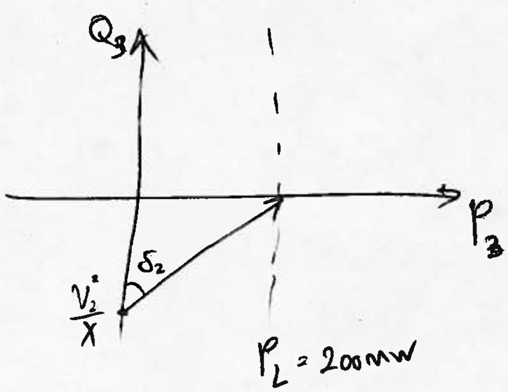
$$X = X_t + X_{line} = 0.418 \text{ p.u.}$$

$$\tan\delta_1 = \frac{P_L}{V_3^2/X} \Rightarrow \delta_1 = \tan^{-1}\left(\frac{P_L X}{V_3^2}\right)$$

$$\Rightarrow \delta_1 = 39.89^\circ$$

$$P_L = \frac{V_1 V_3}{X}\sin\delta_1 \Rightarrow V_1 = \frac{P_L X}{V_3 \sin\delta_1} = 1.303 \text{ p.u.}$$

Now, assume Bus 2 as the sending bus : $X = X_{line} = 0.378$ p.u.



$$\tan\delta_2 = \frac{P_L}{V_3^2/X} \Rightarrow \delta_2 = 37.09^\circ$$

$$P_3 = \frac{V_2 V_3}{X}\sin\delta_2 \Rightarrow V_2 = 1.2537 \text{ p.u}$$

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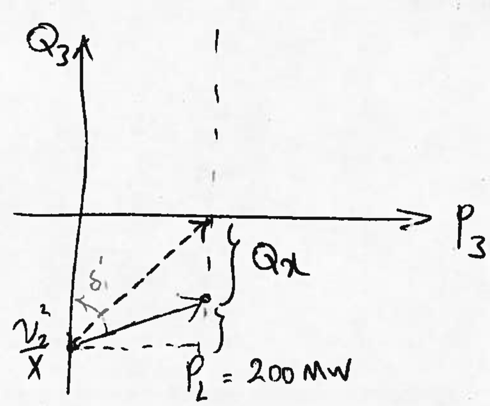

By injecting more reactive power at Bus 3, the Voltage angle at Bus 1 increases. Assume we are injecting Q_x value at Bus 3:

$$\tan\delta_1' = \frac{P_L}{V_3^2/X - Q_x} \Rightarrow \quad 0 < |Q_x| < \frac{V_3^2}{X}, \quad X = X_{line} + X_T$$

Let's calculate the voltage magnitude at Bus 1:

$$P_L^2 + \left(\frac{V_3^2}{X} - Q_x\right)^2 = \left(\frac{V_1 V_3}{X}\right)^2 \Rightarrow V_1^2 = \left(\frac{X P_L}{V_3}\right)^2 + \left(V_3 - \frac{X}{V_3} Q_x\right)^2$$

Substitute the known parameters:

$$V_1^2 = 0.6989 + (1 - 0.418\, Q_x)^2$$

we need $V_1 \leq 1.05 \Rightarrow \sqrt{0.6989 + (1-0.418 Q_x)^2} \leq 1.05$

$\Rightarrow |1 - 0.418 Q_x| \leq 0.6353$

$\Rightarrow Q_x \geq 0.8725$ p.u. and $Q_x \leq 3.912$ p.u.

For maintaining the stability limit ($\delta_1 < 90°$), we have to

Keep Q_x as: $0 \leq |Q_x| \leq 2.39$ p.u.

Therefore, the answer is "yes", we are able to have voltage magnitudes lower than 1.05 p.u. at Bus 1 by injecting sufficient reactive power at Bus 3 without violating the angle stability limit.