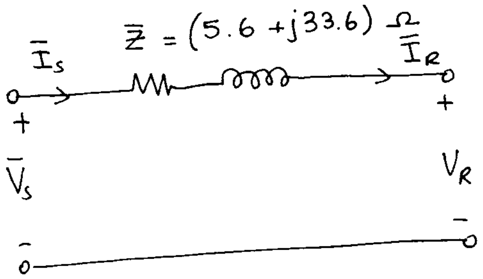
Power System Analysis I * Midterm II ***Fall**** December 17, 2010**

SOLUTIONS

1(35): A 70-km, 230-kV, 60Hz three-phase overhead transmission line has a positive-sequence series impedance of $\bar{z} = 0.08 + j0.48\ \Omega/\text{km}$ and 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 short line model, calculate the following:

a) ABCD parameters of the line
b) The sending-end voltage and current
c) The percent voltage regulation
d) The sending-end real power and reactive power
e) The real and reactive power lost in the line.



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

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

a) $\bar{A} = \bar{D} = 1.0 \quad \bar{C} = 0 \quad \bar{B} = \bar{Z} = 34\angle 80.54^\circ\ \Omega$

b) $\bar{V}_s = (1.0)\left(\frac{220}{\sqrt{3}}\angle 0^\circ\right) + (34\angle 80.54^\circ)\ \bar{I}_R$

let's find $\bar{I}_R$:

$$\bar{I}_R = \frac{250\times10^6}{\sqrt{3}(220000)\times(0.99)} \angle -\cos^{-1}(0.99) = 663\angle -8.11\ \text{A}$$

$\bar{V}_s = 127^{\text{kV}} + (34\angle 80.54^\circ)(0.663\angle -8.11^\circ)$

$\bar{V}_s = 127 + 22.542\angle 72.43^\circ$

$\bar{V}_s = 135.52\angle 9.1^\circ\ \text{kV}_{LN}$

$\bar{I}_s = \bar{I}_R = 0.663\angle -8.11^\circ$

c) $V_{RNL} = \frac{V_s}{A} = \frac{135.52}{1.0} = 135.52\ \text{kV}_{LN}$

$V_{RFL} = \frac{220}{\sqrt{3}} = 127\ \text{kV}_{LN}$

$$\% VR = \frac{V_{RNL} - V_{RFL}}{V_{RFL}} = \frac{135.52 - 127}{127} \times 100$$

$\% VR = 6.7\%$

d) $\bar{S}_s = 3\bar{V}_s\bar{I}_s^*$

$= 3(135.52\angle 9.1^\circ)(0.663\angle 8.11^\circ)$

$= 269.55\angle 17.21^\circ$

$= 257.5 + j79.8$

$P_s = 257.5$ MW

$Q_s = 79.8$ MVar

e) $P_R = 250$ MW

$P_{Lost} = P_S - P_R = 257.5 - 250$

$= 7.5$ MW

$Q_R = 250\tan(8.11^\circ) = 35.62$ MVar

$Q_{Lost} = 79.8 - 35.62$

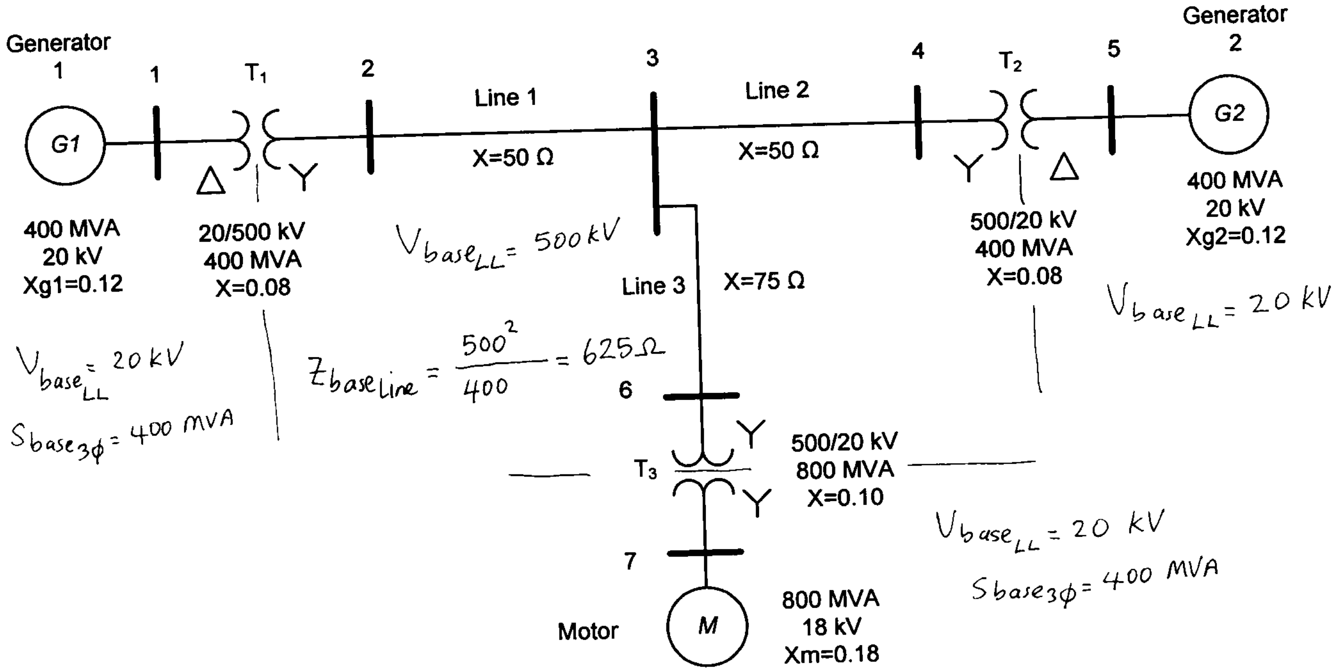
$= 44.18$ MVar

Duration of the exam is 80 minutes

2(35): The figure below shows the one-line diagram of a three-phase power system.

a) Draw the per-unit impedance diagram of the system including the transformer phase shifts. Use the ratings of the generator 1 as the base values.

b) The motor is drawing 700 MVA from the system at the rated terminal voltage and at 0.8 power factor lagging. Determine the voltages at bus 1 and bus 5 in per-unit and also in kV. Assume that generators 1 and 2 supply equal real powers and equal reactive powers.



$V_{base_{LL}} = 20\,kV$

$S_{base3\phi} = 400\,MVA$

$V_{base_{LL}} = 500\,kV$

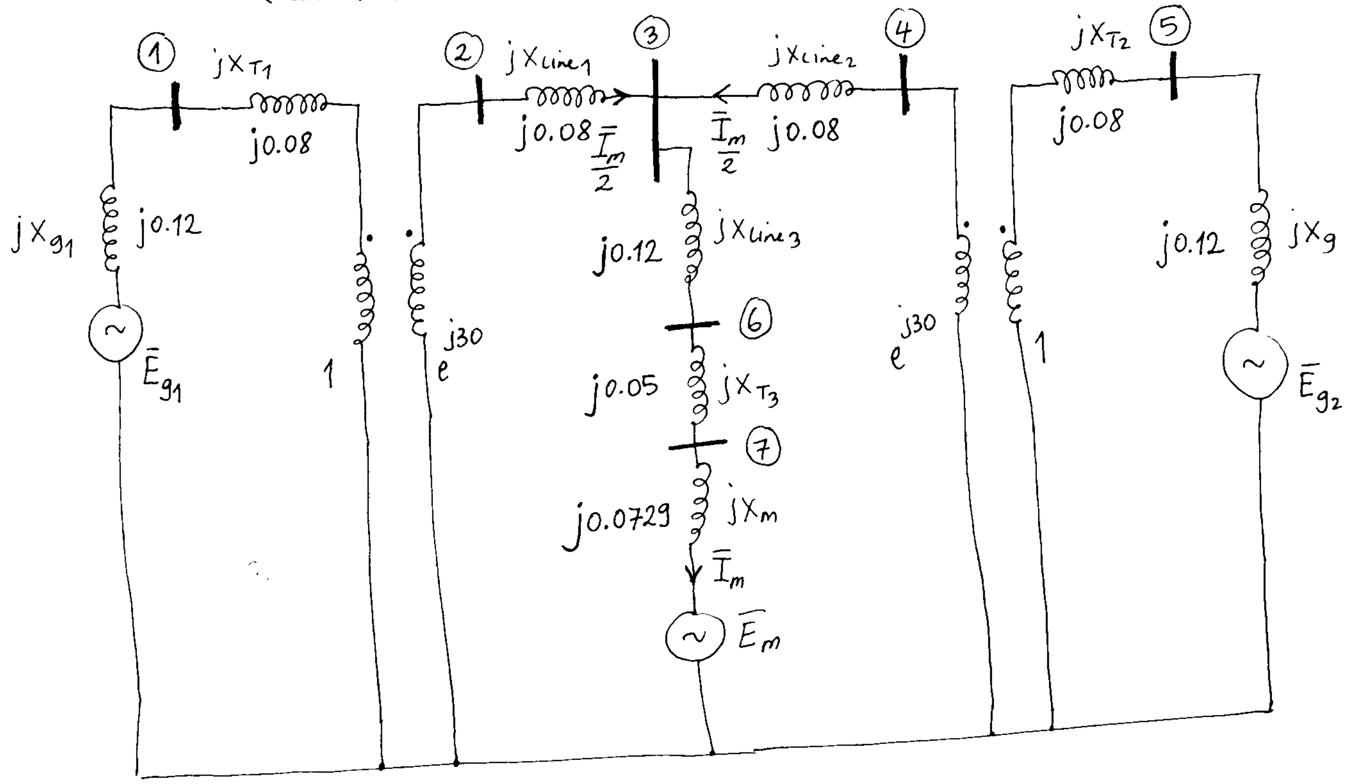
$Z_{baseLine} = \frac{500^2}{400} = 625\Omega$

$V_{base_{LL}} = 20\,kV$

$V_{base_{LL}} = 20\,kV$

$S_{base3\phi} = 400\,MVA$

$$Z_{new} = Z_{old}\left(\frac{V_{baseold}}{V_{basenew}}\right)^2\left(\frac{S_{basenew}}{S_{baseold}}\right) \qquad I_{base} = \frac{S_{base1\phi}}{V_{baseLN}} = \frac{S_{base3\phi}}{\sqrt{3}V_{baseLL}} \qquad Z_{base} = \frac{V_{baseLN}}{I_{base}} = \frac{V^2_{baseLN}}{S_{base1\phi}} = \frac{V^2_{baseLL}}{S_{base3\phi}}$$



b) let's first find the per-unit motor current

$$\bar{I}_m = \frac{700 \times 10^6}{\sqrt{3}\,(18000)} \angle -\cos^{-1}(0.8) = 22452 \angle -36.87^\circ \quad A$$

$$I_{base} = \frac{400 \times 10^6}{\sqrt{3}\,(20000)} = 11547 \ A$$

$$\bar{I}_{mpu} = 1.9444 \angle -36.87^\circ \quad pu$$

$$\bar{V}_7 = 1.0 \ pu$$

$$\bar{V}_3 = \bar{V}_7 + \bar{I}_m \left(\bar{X}_{T_3} + \bar{X}_{Line_3} \right) = 1.0 + \left(1.9444 \angle -36.87^\circ\right)\left(0.17 \angle 90^\circ\right)$$

$$\bar{V}_3 = 1 + 0.33 \angle 53.13^\circ = 1.2272 \angle 12.444^\circ$$

$$\bar{V}_4 = 1.2272 \angle 12.444^\circ + \left(\frac{1.9444 \angle -36.87^\circ}{2} \right) \times \left(0.08 \angle 90^\circ \right)$$

$$\bar{V}_4 = 1.2272 \angle 12.444^\circ + 0.0778 \angle 53.13^\circ$$

$$\bar{V}_4 = 1.2872 \angle 14.7^\circ \quad pu$$

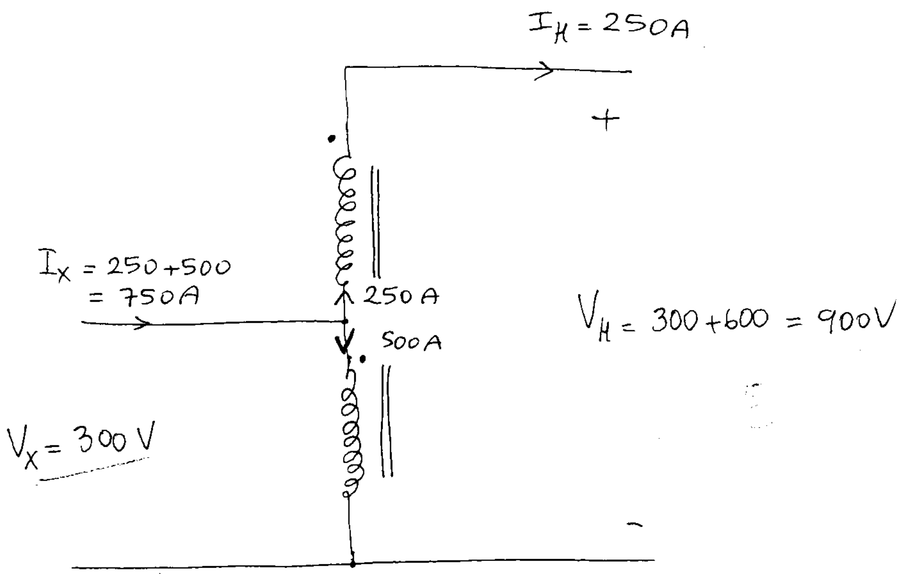
$$\bar{V}_5 = 1.2872 \angle -15.3^\circ \qquad \bar{V}_5 = 25744 \angle -15.3^\circ \quad Volt$$

$\bar{V}_1$ is also equal to $\bar{V}_5$

3(30): A single-phase two-winding transformer has the following ratings:
150 kVA, 300 V/600 V, and a total series leakage reactance of 8.4%.
If the given transformer is connected as a step-up autotransformer,

a) Determine the voltage and power rating as an autotransformer
b) Draw the circuit schematic of the autotransformer.
c) Find the per-unit leakage reactance for the high voltage terminal as an autotransformer.

a)



$S_X = S_H = 750 \times 300 = 250 \times 900$

$S_X = S_H = 225\ kVA$

b) ↗

c) let's first find the actual leakage reactance of the single-phase two-winding transformer.

$$Z_{base\,old} = \frac{600^2}{150\,000} = 2.4\ \Omega \qquad X_{eq} = (0.084)(2.4) = 0.2016\ \Omega$$

$$Z_{base_H} = \frac{900^2}{225\,000} = 3.6\ \Omega$$

$$X_{eq} = \frac{(0.2016\ \Omega)}{3.6\ \Omega} = 0.056 = 5.6\ \%$$ after (as an auto transformer)