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University of Jordan
Electrical Engineering Department

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Power System Analysis (I), EE 0903481. *Quiz 2016/2017*

Date: 17/11/2016 *Time: 30 minutes*

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Problem 1 (6 pts): The single line diagram of a three-phase power system is shown below, the ratings and parameters of all components are as follows

G: 40MVA, 10.5kV, X=0.2 p.u.

M: 10MVA, 3.3kV, X=0.25 p.u.

60 34

T_1: Three single phase units each rated 20MVA, 11/19.63kV, X=0.15 p.u.

T.L.: The line impedance of the Transmission Line (T.L.) is 0 + j2 Ω.

The static load at bus 4 is: 10 MW at 0.8 PF lagging at 11kV.

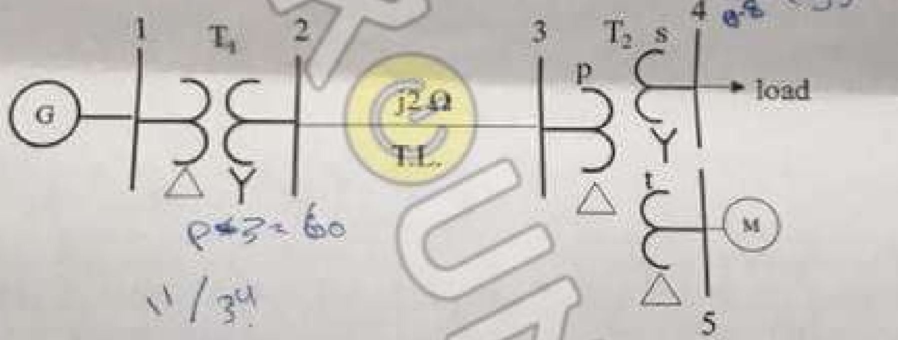
T_2: Three winding transformers rated as follows:

Primary (p): 34kV, Δ-connected, 50 MVA

Secondary (s): 11kV, Y-connected, 40 MVA

Tertiary (t): 3.3kV, Δ-connected, 20 MVA

11 kV.
10 MW
0.8 lagging



P*3=60

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Short circuit tests on T_2 gave the following leakage reactance in p.u. as follows:

Primary (p)	Secondary (s)	Tertiary (t)	Base
0.1	Short circuit	Open circuit	50 MVA and 34 kV
Open circuit	0.12	Short circuit	40 MVA and 11 kV
0.15	Open circuit	Short circuit	50 MVA and 34 kV

(a) Draw the equivalent impedance diagram. **Mark** the reactance/impedance of each component including the load in p.u., and use a **base of 11 kV, 100 MVA at the generation side** (Neglect transformer phase shifts)

(b) At a certain operating condition, the motor draws 8 MW at 0.8 lagging PF and the motor terminal voltage at bus 5 is 3kV. Use the p.u., system to calculate the terminal voltage at bus 1. (Assume that the impedance of static load remains constant as in (a), neglect transformer phase shifts)

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$y = \frac{1}{z}$

$\boxed{z = \frac{1}{y}}$

Problem 2 (12pts): The figure below shows a 2-bus power system. Its admittance matrix is:

$$\begin{array}{c|cc} & y_{11} & y_{12} \\ \hline y_{21} & -j10 & j3 \\ y_{22} & j3 & -j3 \end{array}$$

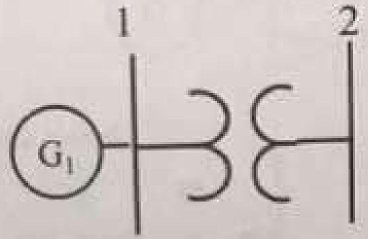
$0 = -7j + -3j$

$-7j$

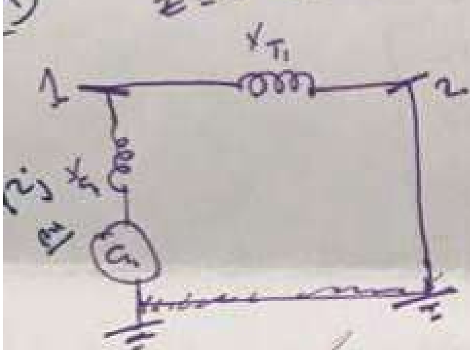
(a) Draw the reactance diagram with all reactances marked in per unit.

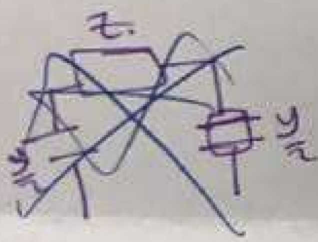
(b) A static load is connected at bus 2 with Z_L=1p.u. with 0.8 pf lagging. Find the three-phase fault current in p.u. at bus 2 by using the internal voltage method and assuming the prefault voltage at bus 2 is $1\angle 0$ p.u.

(c) If a capacitor bank with $|x_c|$=0.5 p.u. is connected to bus 2, determine the new admittance matrix.

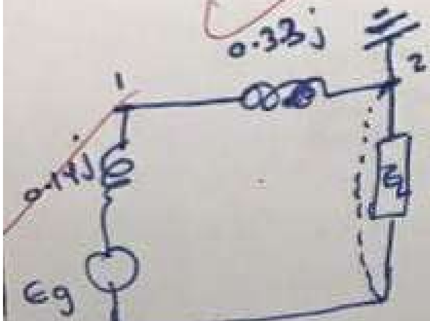


(1) $z = 0.33j$ pu





(4)



$V_f = 1 \angle 0.$

$I_f = I_g + \cancel{I_m}$ G.

$I_f = \frac{E_g}{(0.475j)} = \frac{1 + 0.475j}{0.475j}$

$E_g = V_f + I_L(0.475j)$

$\boxed{I_f = 1 - 2.1j \text{ pu.}}$

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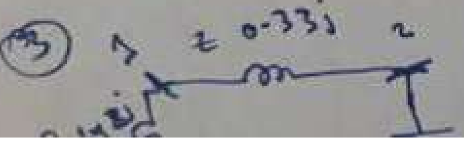
$I_L = \frac{V_f}{z} = \frac{1\angle 0}{1} = 1$ p.u.

$E_g = 1\angle 0 + 0.475j = 1 + 0.475j$

(3)



$x_c = 0.5j$ pu. $\longrightarrow Y = \begin{bmatrix} -j10 & j3 \\ j3 & j5 \end{bmatrix}$

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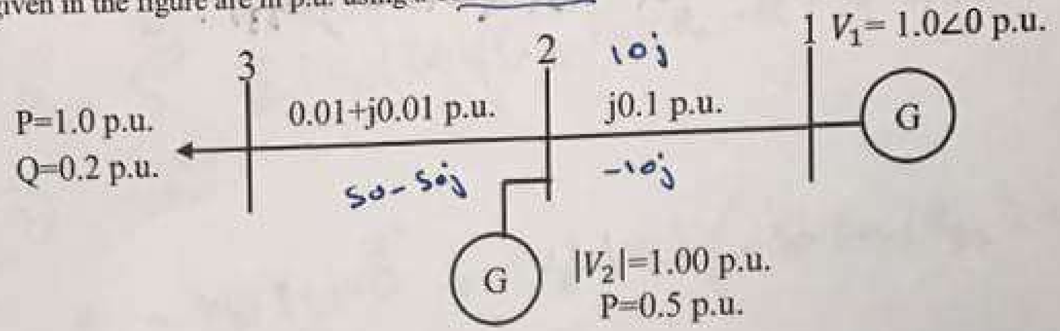
Problem 3 (20 pts): The figure below shows a 3-bus power system consisting of 2 generators (G_A and G_B) feeding a load through two line segments. All the quantities given in the figure are in p.u. using a common base.



(i) Write the admittance matrix

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$$\begin{bmatrix} -10j & 10j & 0 \\ 10j & 50-60j & -50+50j \\ 0 & -50+50j & 50-50j \end{bmatrix}$$

(ii) Determine the type of each bus

Bus 1 → Slack Bus.
Bus 2 → PV Bus (Generator Bus)
Bus 3 → PQ Bus (load Bus)

3

(iii) Evaluate the second row elements of the Jacobian matrix considering a flat start of the Newton-Raphson algorithm. Use the following structure for the Jacobian matrix

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$$\begin{bmatrix} \frac{\partial P_2}{\partial \theta_2} & \frac{\partial P_2}{\partial \theta_3} & \frac{\partial P_2}{\partial V_3} \\ \frac{\partial P_3}{\partial \theta_2} & \frac{\partial P_3}{\partial \theta_3} & \frac{\partial P_3}{\partial V_3} \\ \frac{\partial Q_3}{\partial \theta_2} & \frac{\partial Q_3}{\partial \theta_3} & \frac{\partial Q_3}{\partial V_3} \end{bmatrix}$$

$$\begin{bmatrix} \Delta\theta \\ \Delta V \end{bmatrix} = -J^{-1} \begin{bmatrix} P \\ Q \end{bmatrix}$$

(iv) Calculate the voltage magnitude and angle of bus 3 after the first iteration. The matrix below is the inverse of the Jacobian matrix at the first iteration.

$$\begin{bmatrix} 0.1 & 0.1 & 0 \\ 0.1 & 0.11 & -0.01 \\ 0 & 0.01 & 0.01 \end{bmatrix}$$

$$\begin{bmatrix} \Delta\theta_3 \\ \\ \Delta V_3 \end{bmatrix} = \begin{bmatrix} -0.1 & -0.1 & 0 \\ -0.1 & -0.11 & 0.01 \\ 0 & -0.01 & -0.01 \end{bmatrix} \begin{bmatrix} P_3(\theta, V). \\ \\ Q_3(\theta, V). \end{bmatrix}$$

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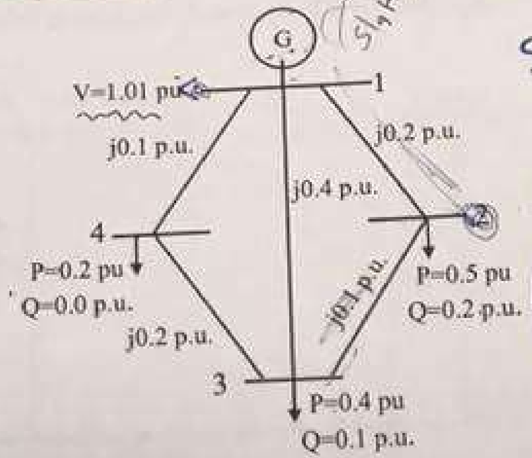
Problem 4 (12 pts): In the figure below, the reactance's of transmission lines and bus bar loads are given in per unit using a common base.



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$S_k = V_k^* \sum_{i=1}^{N} Y_{ki} V_i$

$S_1 = V_1^* [Y_{11} V_1 + Y_{12} V_2 + Y_{13} V_3 + Y_{14} \ldots$

$-0.5 + 0.2$

$\to 2 (1.01) [\,0\,]$

$S_1 = 0.$

Using bus bar 1 as the slack bus, carry out the first iteration of a Gauss Seidel power flow algorithm to determine the voltages at all bus bars. Assume the initial voltages of all bus bars to be 1.01 p.u. Use the following admittance matrix.

$V_1^{(0)} = 1.01 \angle 0.$

$$\begin{bmatrix} -j17.5 & j5 & j2.5 & j10 \\ j5 & -j15 & j10 & 0 \\ j2.5 & j10 & -j17.5 & j5 \\ j10 & 0 & j5 & -j15 \end{bmatrix}$$

$S_{injected} = S_G - \ldots$

$V_1^{(1)} = \frac{1}{y_{11}}\left(\frac{S_1^*}{V_1^*} - [\,y_{12} V_2^{(0)} + y_{13} V_3^{(0)} + y_{14} V_4^{(0)}\,]\right)$

$\frac{1}{-j17.5}\left(\frac{S_1^*}{1.01}\right.$

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$V_2^{(1)} = \frac{1}{y_{22}}\left(\frac{S_2^*}{V_2^*} - [\,y_{21} V_1 + y_{23} V_3 + y_{24} V_4\,]\right)$

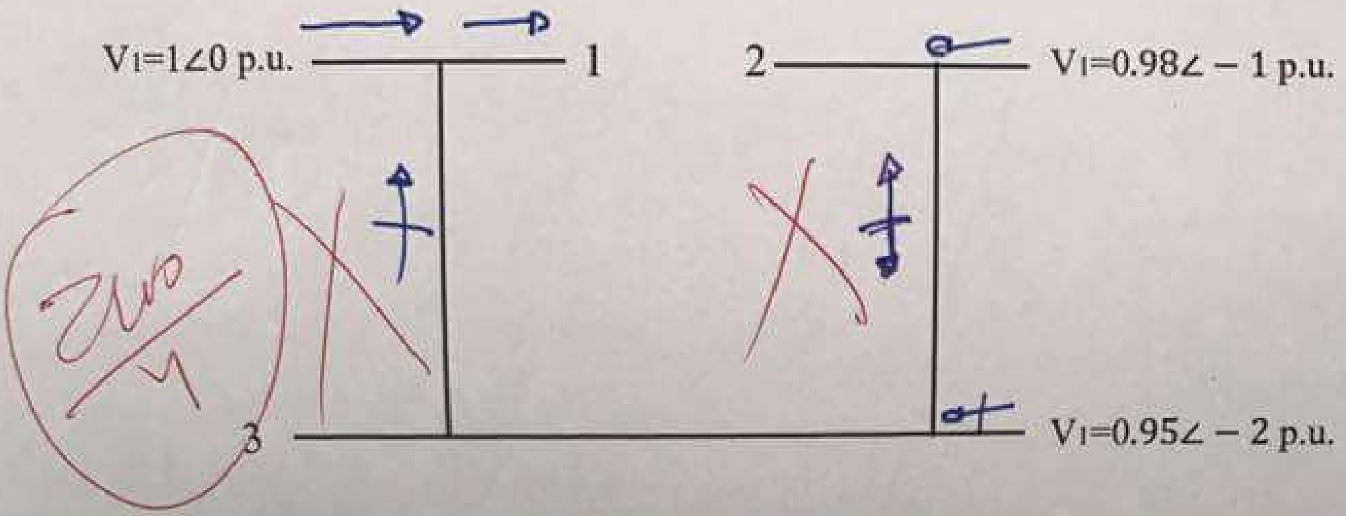
$= \frac{1}{-j15}\left(\frac{-0.5+0.2}{1.01} - (5j\, V_1^{(1)} + 10j \cdot 1.01 + 0)\right).$

$\frac{S_3^*}{V_3^*}$ ... $V_1 + y_{32} V$ ... $y_{34} V_4\,].$

2

$\frac{1}{10.1}$ ... 2

Problem 5 (4 pts): The figure below shows a 3-bus power system. **Mark on the graph** the real and reactive power flow directions throughout the transmission lines. Use ⟶ to indicate the direction of real power flow and ⇸ for the reactive power flow direction.



Motor