**KING FAHD UNIVERSITY OF PETROLEUM & MINERALS**

**ELECTRICAL ENGINEERING DEPARTMENT**

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**EE 463**

**MAJOR EXAM # 1**

**November 5th , 2007**

**7:30 - 9:00 pm**

**Key Solution**

**Section: 1**

**Student Name:**

**Student I.D.#**

**Serial #:**

| | |
|---|---|
| **Question # 1** | |
| **Question # 2** | |
| **Question # 3** | |
| **Total** | |

Q. 1) Prepare a per phase equivalent circuit of the system shown below and show all impedances in p.u. on a 100-MVA, 132-kV base in the transmission-line circuit. The necessary data for this system are as follows:

$G_1$: 50 MVA, 12.2 kV, $X$ = 0.15 p.u.

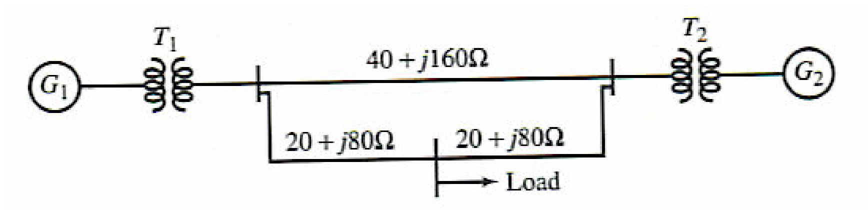
$G_2$: 20 MVA, 13.8 kV, $X$ = 0.15 p.u.

$T_1$: 80 MVA, 12.2/ 161 kV, $X$ = 0.10 p.u.

$T_2$: 40 MVA, 13.8/161 kV, $X$ = 0.10 p.u.

Load: 50 MVA, 0.80 PF lagging, operating at 154 kV

The load is modeled as a parallel combination of resistance and inductance




(40 Marks)

**Solution**

Convert all quantities to a common system base that has been specified in the transmission circuit

Base kV in the transmission line = 132 kV

$$\text{Base kV in the generator circuit } G_1 = 132 \times \frac{12.2}{161} = 10.002 \text{ kV}$$

$$\text{Base kV in the generator circuit } G_2 = 132 \times \frac{13.8}{161} = 11.31 \text{ kV}$$

We now proceed to convert all the parameter values to p.u. on the common base specified.

$$G_1\!: X = 0.15 \times \frac{100}{50} \times \left(\frac{12.2}{10.002}\right)^2 = 0.4463 \text{ p.u.}$$

$$G_2\!: X = 0.15 \times \frac{100}{20} \times \left(\frac{13.8}{11.31}\right)^2 = 1.1166 \text{ p.u.}$$

$$T_1\!: X = 0.1 \times \frac{100}{80} \times \left(\frac{12.2}{10.002}\right)^2 = 0.1 \times \frac{100}{80} \times \left(\frac{161}{132}\right)^2 = 0.18596 \text{ p.u.}$$

$$T_2\!: X = 0.1 \times \frac{100}{40} \times \left(\frac{13.8}{11.31}\right)^2 = 0.1 \times \frac{100}{40} \times \left(\frac{161}{132}\right)^2 = 0.3719 \text{ p.u.}$$

The base impedance in the transmission-line circuit $= \dfrac{(132)^2}{100} = 174.24\ \Omega$.

$$Z_{\text{Trans.line}} = \frac{40 + j160}{174.24} = 0.2296 + j0.9183 \text{ p.u.}$$

The p.u. impedance of the transmission lines connecting the load bus to the high-voltage buses is given by

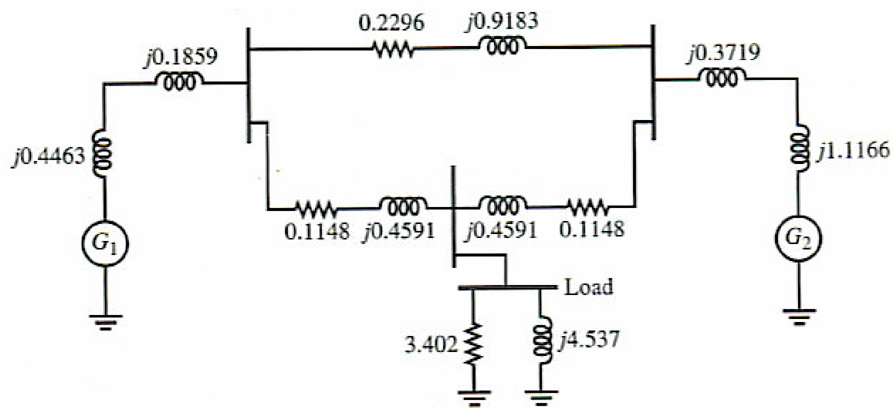
$$Z = \frac{20 + j80}{174.24} = 0.1148 + j0.4591 \text{ p.u.}$$

The base impedance in the load circuit is the same as the base impedance in the transmission-line circuit.

The load is specified as $50(0.8 + j0.6) = 40 + j30$ MVA.

$$R_{\text{Load}}^{\text{Parallel}} = \frac{(154)^2}{40} = 592.9\ \Omega = \frac{592.9}{174.24} = 3.402 \text{ p.u.}$$

$$R_{\text{Load}}^{\text{Parallel}} = \frac{(154)^2}{30} = 790.53\ \Omega = \frac{790.53}{174.24} = 4.537 \text{ p.u.}$$



Q. 2) Consider a 5-bus system with the following line data as indicated in the table below. The table provides information regarding the network topology of the system by giving the bus numbers to which the lines are connected. The table also provides the series reactance and the line charging susceptance for each line in per-unit on an appropriately chosen base. Consider the pi-equivalent model for the transmission lines.

| **Line Data** | **From Bus** | **To Bus** | **X (p.u.)** | **B (p.u.)** |
|---|---|---|---|---|
| Transformer | 1 | 2 | 0.05 | 0 |
| Transmission Line | 2 | 3 | 0.25 | 0.20 |
| Transmission Line | 2 | 5 | 0.40 | 0.20 |
| Transmission Line | 3 | 4 | 0.20 | 0.10 |
| Transformer | 4 | 5 | 0.04 | 0 |

- Determine the bus admittance matrix for this system.
- If a generator with a reactance of j1.25 p.u. is connected to bus 1, and a motor with a reactance of j1.25 p.u. is connected to bus 5, find the modified bus admittance matrix.

(30 Marks)

**Solution**

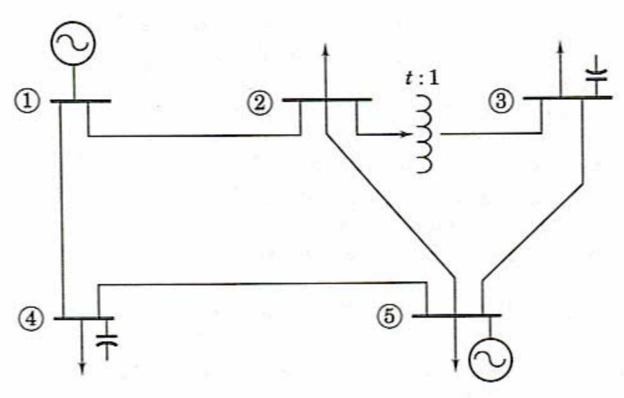
The bus admittance matrix is

$$Y_{BUS} = j\begin{bmatrix} -20.0 & 20.0 & 0 & 0 & 0 \\ 20.0 & -26.3 & 4.0 & 0 & 2.5 \\ 0 & 4.0 & -8.85 & 5.0 & 0 \\ 0 & 0 & 5.0 & -29.95 & 25.0 \\ 0 & 2.5 & 0 & 25.0 & -27.4 \end{bmatrix}$$

The modified bus admittance matrix is

$$Y_{BUS} = j\begin{bmatrix} -20.8 & 20.0 & 0 & 0 & 0 \\ 20.0 & -26.3 & 4.0 & 0 & 2.5 \\ 0 & 4.0 & -8.85 & 5.0 & 0 \\ 0 & 0 & 5.0 & -29.95 & 25.0 \\ 0 & 2.5 & 0 & 25.0 & -28.2 \end{bmatrix}$$

Q. 2) Apply the Newton-Raphson method to 5-bus system shown below to determine the mismatch equations in a matrix form (i.e., determine $\Delta P$ and $\Delta Q$ as a vector, the Jacobian partial derivatives as a matrix, and $\Delta\delta$ and $\Delta V$ as a vector. Consider bus1 as the slack bus; busses 2, 3, and 4 as PQ busses; bus 5 as PV bus.




(30 Marks)

**Solution**

$$
\begin{bmatrix} \Delta P_2 \\ \Delta P_3 \\ \Delta P_4 \\ \Delta P_5 \\ \Delta Q_2 \\ \Delta Q_3 \\ \Delta Q_4 \end{bmatrix}
=
\begin{bmatrix}
\frac{\partial P_2}{\partial \delta_2} & \frac{\partial P_2}{\partial \delta_3} & 0 & \frac{\partial P_2}{\partial \delta_5} & |V_2|\frac{\partial P_2}{\partial |V_2|} & |V_3|\frac{\partial P_2}{\partial |V_3|} & 0 \\
\frac{\partial P_3}{\partial \delta_2} & \frac{\partial P_3}{\partial \delta_3} & 0 & \frac{\partial P_3}{\partial \delta_5} & |V_2|\frac{\partial P_3}{\partial |V_2|} & |V_3|\frac{\partial P_3}{\partial |V_3|} & 0 \\
0 & 0 & \frac{\partial P_4}{\partial \delta_4} & \frac{\partial P_4}{\partial \delta_5} & 0 & 0 & |V_4|\frac{\partial P_4}{\partial |V_4|} \\
\frac{\partial P_5}{\partial \delta_2} & \frac{\partial P_5}{\partial \delta_3} & \frac{\partial P_5}{\partial \delta_4} & \frac{\partial P_5}{\partial \delta_5} & |V_2|\frac{\partial P_5}{\partial |V_2|} & |V_3|\frac{\partial P_5}{\partial |V_3|} & |V_4|\frac{\partial P_5}{\partial |V_4|} \\
\frac{\partial Q_2}{\partial \delta_2} & \frac{\partial Q_2}{\partial \delta_3} & 0 & \frac{\partial Q_2}{\partial \delta_5} & |V_2|\frac{\partial Q_2}{\partial |V_2|} & |V_3|\frac{\partial Q_2}{\partial |V_3|} & 0 \\
\frac{\partial Q_3}{\partial \delta_2} & \frac{\partial Q_3}{\partial \delta_3} & 0 & \frac{\partial Q_3}{\partial \delta_5} & |V_2|\frac{\partial Q_3}{\partial |V_2|} & |V_3|\frac{\partial Q_3}{\partial |V_3|} & 0 \\
0 & 0 & \frac{\partial Q_4}{\partial \delta_4} & \frac{\partial Q_4}{\partial \delta_5} & 0 & 0 & |V_4|\frac{\partial Q_4}{\partial |V_4|}
\end{bmatrix}
\begin{bmatrix} \Delta\delta_2 \\ \Delta\delta_3 \\ \Delta\delta_4 \\ \Delta\delta_5 \\ \frac{\Delta V_2}{|V_2|} \\ \frac{\Delta V_3}{|V_3|} \\ \frac{\Delta V_4}{|V_4|} \end{bmatrix}
$$