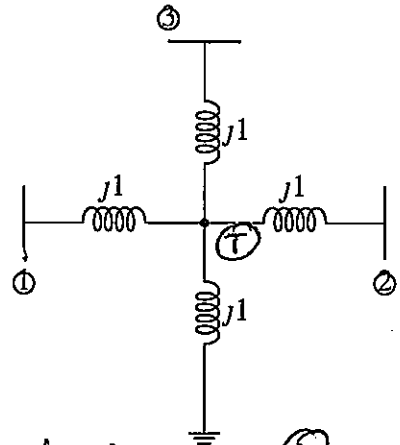
Indian Institute of Technology Patna
Department of Electrical Engineering
EE3202 - Power Systems-II
Spring - 2026
Mid Semester Exam — Solution.
February 26, 2026

Total Marks : 25 — Time: 2 Hours

Section - A

Each question carries two (2) marks.

1. Form the Y_{bus} matrix of the 3-bus network shown below. All the reactances are in per unit.



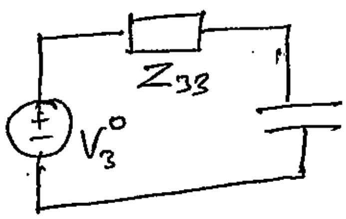
Let (T) be the temporary node.

$$Y_{bus} = \begin{array}{c} \\ \\ \\ \\ \end{array}\begin{array}{cccc} 1 & 2 & 3 & T \end{array}$$
$$Y_{bus} = \begin{bmatrix} -j & 0 & 0 & j \\ 0 & -j & 0 & j \\ 0 & 0 & -j & j \\ j & j & j & -4j \end{bmatrix}$$

By node elimination,

$$Y_{bus} = \begin{array}{c|ccc} & 1 & 2 & 3 \\ \hline 1 & -\frac{3}{4}j & \frac{1}{4}j & \frac{1}{4}j \\ 2 & \frac{1}{4}j & -\frac{3}{4}j & \frac{1}{4}j \\ 3 & \frac{1}{4}j & \frac{1}{4}j & -\frac{3}{4}j \end{array}$$

2. For a power system network with 3 nodes, Z_{33} of its bus impedance matrix is $j0.5$ per unit. The voltage at node 3 is $1.3\angle{-10^\circ}$ per unit. If a capacitor having reactance of $-j3.5$ per unit is now added to the network between node 3 and the reference node, the voltage at node 3 is



$$V_3' = V_3^0 \times \frac{-j3.5}{-j3.5 + j0.5}$$
$$= 1.4936 - j0.2634$$
$$\underline{V_3' = 1.52\angle{-10^\circ}\ \text{p.u.}}$$

3. A 10-bus power system consists of four generator buses indexed as G_1, G_2, G_3 and G_4 and six load buses indexed as L_1, L_2, L_3, L_4, L_5 and L_6. The generator bus G_1 is considered as slack bus, and the load buses L_3 and L_4 are voltage controlled buses. The generator at bus G_2 cannot supply the required reactive power demand, and hence it is operating at its maximum reactive power limit. Find the number of non-linear equations required and the size of the jacobian matrix for solving the load flow problem using the Newton-Raphson method.

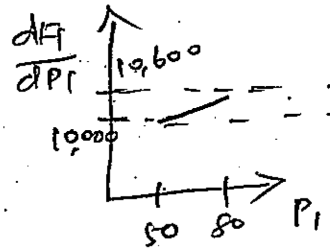
Number of P equation = 9

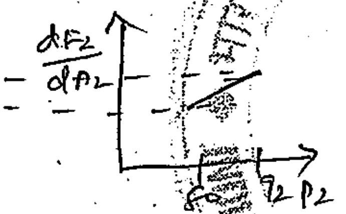
Number of Q equation = 5

Total number of equation = $\underline{14}$

Size of J = $\underline{14 \times 14}$

4. Two units, rated at 100 MW and 150 MW, are enabled for economic load dispatch. When the overall incremental cost is 10,000 Rs./MWh, the units are dispatched to 50 MW and 80 MW respectively. At an overall incremental cost of 10,600 Rs./MWh, the power output of the units are 80 MW and 92 MW, respectively. Find the total plant MW output (without overloading any unit) at an overall incremental cost of 11,800 Rs./MWh.





$\frac{dF_2}{dP_2} = 50P_2 + 6000$ Rs/MWhr.

The equation is $\frac{dF_1}{dP_1} = 20P_1 + 9000$ Rs/MWhr

At $\lambda = 11,800$,

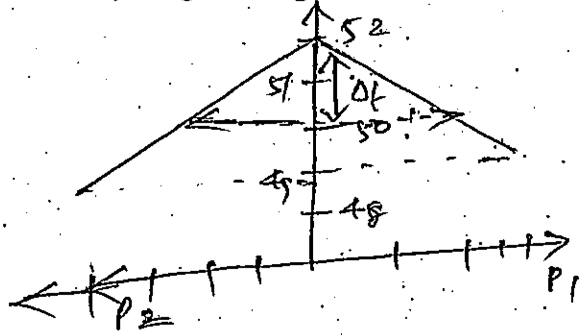
$P_1 = 140$ MW

$P_2 = 116$ MW.

Since $P_1 > 100$, $P_1 = 100$, $P_2 = 116$

$\boxed{P_T = P_1 + P_2 = 216 \text{ MW}}$

5. Two generating units rated for 250 MW and 400 MW have governor speed regulations of 6% and 6.4%, respectively, from no load to full load. Both the generating units are operating in parallel to share a load of 500 MW. Assuming free governor action, find the load shared in MW, by the generating units.



Let x be the load shared by P_{G_1}

$\frac{x}{250} = \frac{\Delta f}{3}$ — (1)

$\frac{500 - x}{400} = \frac{\Delta f}{3.2}$ — (2)

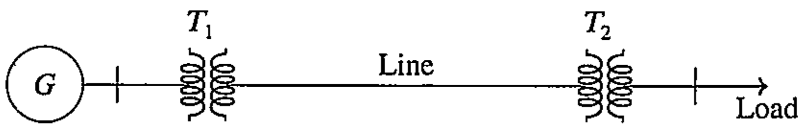
From (1) and (2),

$\boxed{\begin{array}{l} P_{G_1} = 200 \text{ MW} \\ P_{G_2} = 300 \text{ MW} \end{array}}$

Section - B

Each question carries five (5) marks.

1. The schematic diagram of a radial transmission system is shown below.

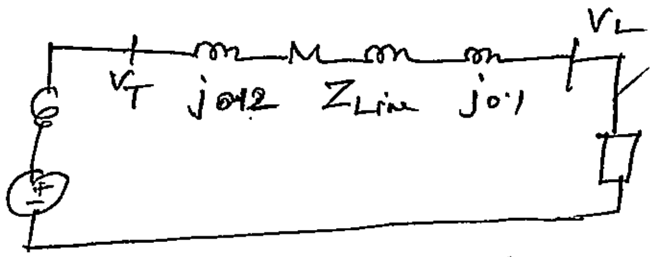


T_1: 100 MVA, 11/220 kV. X = 12 %
T_2: 100 MVA, 220/66 kV. X = 10 %
Line: $30 + j100\ \Omega$.
Load: 60 MW at 0.9 pf lagging .
If the load voltage is to be maintained at 60 kV, what will be the terminal voltage in kV and the real power supplied in MW of the generator?

Base MVA = 100 Base kV on Transmission line = 220 kV

Base kV on Load Side = 66 kV, Base kV on G Side = 11 kV.

$$Z_{Line} = (30 + j100) \times \frac{100}{(220)^2} = \underline{0.062 + j0.2066}$$



$P = 1$ pu
$pf = 0.9$ lagging

2

$$V_L = \frac{60}{66} = 0.91 \text{ p.u}$$

$$I_L = 0.73 \angle -25.84^\circ \text{ p.u}$$

$$V_T = V_L + I_L (j0.12 + 0.062 + j0.2066 + j0.1)$$

$$V_T = 1.12 \angle 13.55^\circ \text{ p.u}$$

2

$$V_T \text{ in kV} = \underline{12.32 \text{ kV}}$$

$$P_G = \text{Real} \{ V_T I_L^* \} = 0.6333$$

1

$$\underline{P_G \text{ in MW} = 63.33 \text{ MW}}$$

2. For a simple three bus system, the admittances are given below:

Bus Code	Admittance (p.u.)
1-2	1 - j4
1-3	1 - j4
2-3	1 - j4

The schedule of active and reactive power in p.u.. is given below:

Bus	P_d	Q_d	$\lvert V \rvert$	Type
1	-	-	1.04	Slack
2	0.5	0.2	-	PQ
3	0.4	0.3	-	PQ

Assuming a flat voltage start, determine the voltage at the end of the first iteration using Gauss-Seidal method. Take $\alpha = 1.6$.

$$Y_{Bus} = \begin{bmatrix} 2-j8 & -1+j4 & -1+j4 \\ -1+j4 & 2-j8 & -1+j4 \\ -1+j4 & -1+j4 & 2-j8 \end{bmatrix}$$

1

$V_2^0 = 1 + j0$

$V_3^0 = 1 + j0$

$P_2 = -0.5 \quad Q_2 = -0.2$

$P_3 = -0.4 \quad Q_3 = -0.3$

$$V_2^1 = \frac{1}{Y_{22}}\left[\frac{P_2 - jQ_2}{(V_2^0)^*} - Y_{21}V_1 - Y_{23}V_3^0\right]$$

2

$$V_2^1 = 0.9818 - j0.053$$

$$V_{2\,acc}^1 = 0.9708 - j0.0847 = 0.9745\angle -4.99^\circ$$

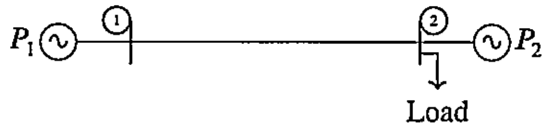
$$V_3^1 = \frac{1}{Y_{33}}\left[\frac{P_3 - jQ_3}{(V_3^0)^*} - Y_{31}V_1 - Y_{32}V_{2\,acc}^1\right]$$

$$V_3^1 = 0.9584 - j0.086$$

2

$$V_{3\,acc}^1 = 0.9334 - j0.1285 = 0.9422\angle -7.87^\circ$$

3. Consider a two bus system shown below. If a power 125 MW of power is transmitted from plant 1 to load, a power loss of 15.625 MW will occur. Find the generation schedule and load demand if the cost of received power is 24 Rs./MWhr.



The incremental production costs are

$$\frac{dF_1}{dP_1} = 0.025P_1 + 15 \text{ Rs/MWHr}$$

$$\frac{dF_2}{dP_2} = 0.05P_2 + 20 \text{ Rs/MWHr}$$

$$P_L = 0.001\, P_1^2$$

$$L_1 = \frac{1}{1-\frac{\partial P_L}{\partial P_1}} = \frac{1}{1-0.002P_1}$$

$$L_2 = \frac{1}{1-\frac{\partial P_L}{\partial P_2}} = 1$$

$$L_1 \frac{dF_1}{dP_1} = L_2 \frac{dF_2}{dP_2} = \lambda$$

$$\frac{1}{1-0.002P_1}\; 0.025+15 = 24 \quad \text{— (1)}$$

$$0.05P_2 + 20 = 24 \quad \text{— (2)}$$

From (1) and (2)

$$\boxed{\begin{array}{l} P_1 = 123.28 \text{ MW} \\ P_2 = 80 \text{ MW} \end{array}}$$

$$P_L = 15.2 \text{ MW}$$

$$P_D = 188.1 \text{ MW}$$