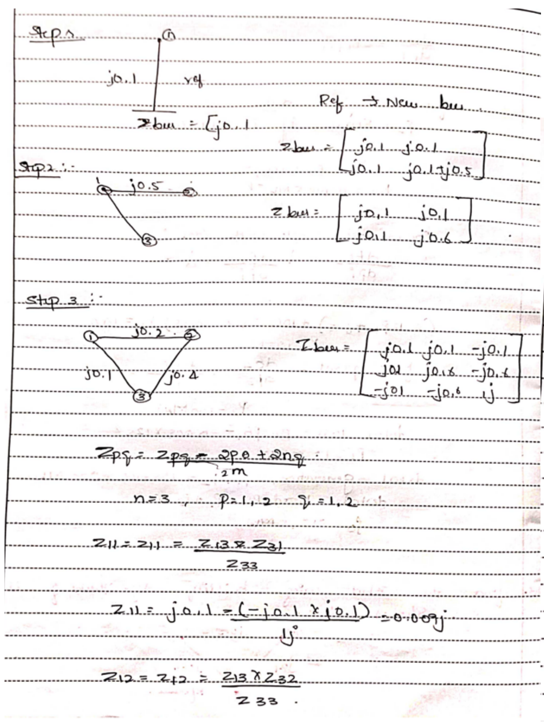
CMR INSTITUTE OF TECHNOLOGY	USN										

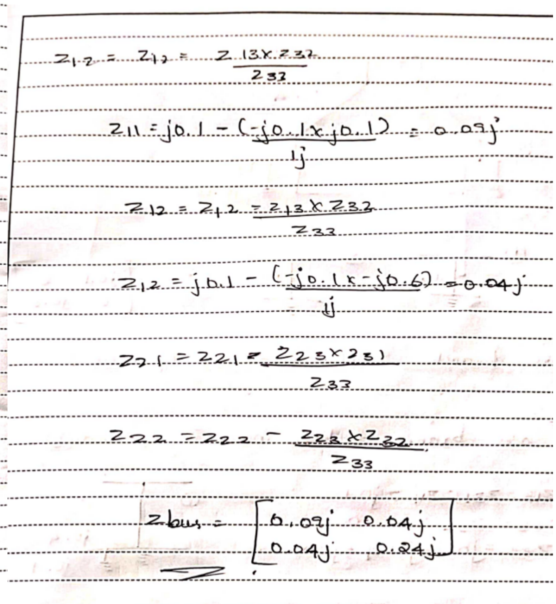
Internal Assesment Test III – December - 2023

Sub:	Power System Analysis - II						Code:	18EE71
Date:	3/1/2024	Duration:	90 Min	Max Marks:	50	Sem:	7	Section:	A & B

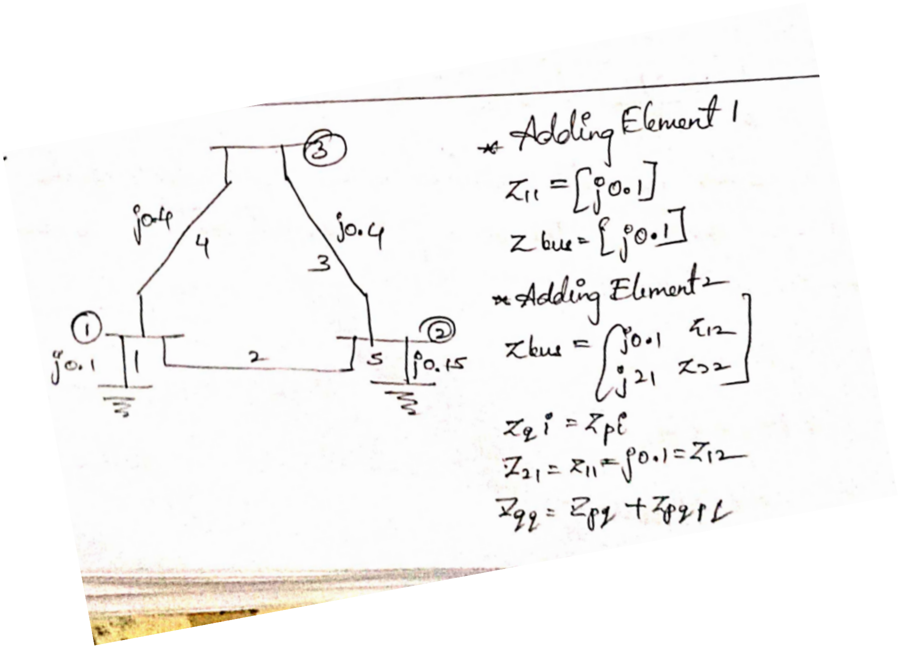
Note: Answer any **FIVE FULL** Questions & Sketch Neat Figures Wherever Necessary.

<table>
<tr><th></th><th></th><th>Mark</th><th>OBE CO</th><th>OBE RBT</th></tr>
<tr><td>1</td><td>Form the Zbus using building Algorithm of the system shown below.





</td><td>[10]</td><td>CO5</td><td>L3</td></tr>
<tr><td>2</td><td>Construct the bus impedance matrix for the network shown below. Impedance values are in P.u. Add the elements in the given order {1,2,3,4,5}



</td><td>[10]</td><td>CO5</td><td>L3</td></tr>
</table>

(11)

$$Z_{22} = Z_{12} + Z_{1212} = j0.7$$

Adding Element 3

$$Z_{bus} = \begin{bmatrix} j0.1 & Z_{12} \\ Z_{21} & Z_{22} \end{bmatrix}$$

$$Z_{qi} = Z_{pi}$$

$$Z_{21} = Z_{11} = j0.1 = Z_{12}$$

$$Z_{qq} = Z_{pq} + Z_{pqpq}$$

$$Z_{22} = Z_{12} + Z_{1212} = j0.7$$

* Adding element 3

$$Z_{bus} = \begin{bmatrix} j0.1 & j0.1 & Z_{13} \\ j0.1 & j0.7 & Z_{23} \\ Z_{31} & Z_{32} & Z_{33} \end{bmatrix}$$

$$Z_{qi} = Z_{pi}$$

$$Z_{31} = Z_{21} = j0.1 = Z_{13}$$

$$Z_{32} = Z_{22} = j0.7 = Z_{23}$$

$$Z_{qq} = Z_{pq} + Z_{pqpq}$$

$$Z_{33} = Z_{23} + Z_{2323} = j0.7 + j0.4 = j1.1$$

$$Z_{bus} = \begin{bmatrix} j0.1 & j0.1 & j0.1 \\ j0.1 & j0.7 & j0.7 \\ j0.1 & j0.7 & j1.1 \end{bmatrix}$$

Adding Element 4

$$Z_{bus} = \begin{bmatrix} j0.1 & j0.1 & j0.1 & Z_{1l} \\ j0.1 & j0.7 & j0.7 & Z_{2l} \\ j0.1 & j0.7 & j1.1 & Z_{3l} \\ Z_{l1} & Z_{l2} & Z_{l3} & Z_{ll} \end{bmatrix}$$

$$Z_{li} = Z_{pi} - Z_{qi}$$

$$Z_{l1} = Z_{31} - Z_{11} = 0 = Z_{1l}$$

$$Z_{l2} = Z_{32} - Z_{12} = j0.6 = Z_{2l}$$

$$Z_{l3} = Z_{33} - Z_{13} = j1 = Z_{3l}$$

$$Z_{ll} = Z_{pl} - Z_{ql} + Z_{pqpq}$$

$$= Z_{3l} - Z_{1l} + Z_{3131}$$

$$Z_{ll} = j1.4$$

$$Z_{bus\,new} = Z_{bus\,old} - \frac{Z_{il} Z_{lj}}{Z_{ll}}$$

$$Z_{bus} = \begin{bmatrix} j0.1 & j0.1 & j0.1 \\ j0.1 & j0.44 & j0.27 \\ j0.1 & j0.27 & j0.38 \end{bmatrix}$$

Adding Element 5.

$$Z_{li} = Z_{qi}$$

$$Z_{l1} = -Z_{21} = -j0.1 = Z_{1l}$$

$$Z_{l2} = -Z_{22} = -j0.44 = Z_{2l}$$

$$Z_{l3} = -Z_{23} = -j0.27 = Z_{3l}$$

$$Z_{ll} = -Z_{ql} + Z_{pqpq}$$

$$= -Z_{2l} + Z_{2022} = j0.59$$

$$Z_{bus\,new} = Z_{bus\,old} - \frac{Z_{il} \times Z_{lj}}{Z_{ll}}$$

$$Z_{bus} = \begin{bmatrix} j0.083 & j0.025 & j0.05 \\ j0.025 & j0.111 & j0.068 \\ j0.05 & j0.068 & j0.025 \end{bmatrix}$$

3	Explain Point by Point method for solving Swing Equation and Explain Runge Kutta Method for the solution of Swing Equation for transient stability analysis	[10]	CO5	L2

R-K method

$$\frac{dx}{dt} = f_x(x, y, t), \quad \frac{dy}{dt} = f_y(x, y, t)$$

$$x_1 = x_0 + \tfrac{1}{6}(K_1 + 2K_2 + 2K_3 + K_4)$$

$$y_1 = y_0 + \tfrac{1}{6}(I_1 + 2I_2 + 2I_3 + I_4)$$

$$K_1 = f_x(x_0, y_0, t_0)h$$

$$K_2 = f_x\left(x_0 + \frac{K_1}{2}, y_0 + \frac{I_1}{2}, t_0 + \frac{h}{2}\right)h$$

$$K_3 = f_x\left(x_0 + \frac{K_2}{2}, y_0 + \frac{I_2}{2}, t_0 + \frac{h}{2}\right)h$$

$$K_4 = f_x(x_0 + x_3, y_0 + I_3, t_0 + h)h$$

$$I_1 = f_y(x_0, y_0, t_0)h$$

$$I_2 = f_y\left(x_0 + \frac{K_1}{2}, y_0 + \frac{I_1}{2}, t_0 + \frac{h}{2}\right)h$$

$$I_3 = f_y\left(x_0 + \frac{K_2}{2}, y_0 + \frac{I_2}{2}, t_0 + \frac{h}{2}\right)h$$

$$I_4 = f_y\left(x_0 + K_3, y_0 + \frac{I_3}{2}, t_0 + \frac{h}{2}\right)h$$

$\frac{d\delta}{dt} = \omega$ ← 1st order diff. eqn to be solved

$$\frac{d\omega}{dt} = \frac{P_a}{M} = \frac{P_m - P_{max}\sin\delta}{M}$$

for initial value

$$K_1 = \omega_0 \Delta t$$

$$K_2 = \left(\omega_0 + \frac{I_1}{2}\right)\Delta t$$

$$K_3 = \left(\omega_0 + \frac{I_2}{2}\right)\Delta t$$

$$K_4 = (\omega_0 + I_3)\Delta t$$

$$I_1 = \left(\frac{P_m - P_{max}\sin\delta_0}{M}\right)\Delta t$$

$$I_2 = \left[\frac{P_m - P_{max}\sin\left(\delta_0 + \frac{K_1}{2}\right)}{M}\right]\Delta t$$

$$I_3 = \left[\frac{P_m - P_{max}\left(\delta_0 + \frac{K_2}{2}\right)}{M}\right]\Delta t$$

$$\delta_1 = \delta_0 + \tfrac{1}{6}\left[K_1 + 2K_2 + 2K_3 + K_4\right]$$

$$\omega_1 = \omega_0 + \tfrac{1}{6} + \left[I_1 + 2I_2 + 2I_3 + I_4\right]$$

Swing E_q^n :

$$T_a \propto \frac{d^2\theta_m}{dt^2}$$

$$T_a = \frac{J d^2\theta_m}{dt^2} \longrightarrow 1$$

$$\frac{J d^2\theta_m}{dt^2} = T_m - T_e \longrightarrow 2$$

$$\theta_m = \omega_{sm} t + \delta_m \longrightarrow 3$$

diff wrt t

$$\frac{d}{dt}\theta_m = \omega_{sm} + \frac{d}{dt}\delta_m \longrightarrow 4$$

$$\frac{d^2\theta_m}{dt^2} = \frac{d^2\delta_m}{dt^2} \longrightarrow 5$$

E_q^n 3 . in 2 .

~~put~~ $P = \omega T \longrightarrow 7$

$$T_m = \frac{P_{mout}}{\omega_m} \longrightarrow 8 \qquad T_e = \frac{P_{eout}}{\omega_{sm}} \longrightarrow 9$$

E_q^n (8) & (9) in E_q^n (10)

$$\frac{J d^2\delta_m}{dt^2} = \frac{P_{m\,out}}{\omega_m} - \frac{P_{e\,out}}{\omega_{sm}}$$

$$J\omega_{sm} = \frac{2H_s}{\omega_{smd}} \longrightarrow 12$$

E_q^n (2) in (10)

$$\frac{2H_s}{\omega_{sm}}\frac{d^2\delta_m}{dt^2} = P_{mat} - P_{eat} \longrightarrow 13$$

$$\frac{2H_s}{\omega_{sm}}\frac{d^2\delta}{dt^2} = P_{mant} - P_{eat} \longrightarrow 14$$

$$\frac{H}{\pi f}\frac{d^2\delta}{dt^2} = P_m - P_e \longrightarrow 15$$

4

Define unit commitment and explain how the dynamic programming is applied to obtain unit commitment. Also Deduce the condition for optimal load dispatch considering losses in a system.

[10] CO4 L2

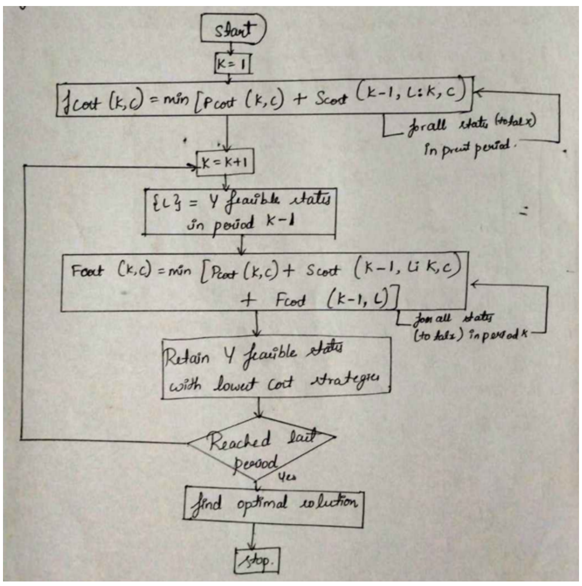
Unit Commitment:

Unit commitment is a crucial optimization problem in power system operation that determines the on/off status of generating units over a specific time horizon to meet the electricity demand at minimum cost while satisfying various operational constraints.

Dynamic Programming for Unit Commitment:

Dynamic programming is a mathematical optimization technique used to solve the unit commitment problem. The problem involves selecting the optimal combination of committed and decommitted generating units to minimize the total cost, considering factors such as fuel costs, start-up costs, and operational constraints.

The dynamic programming approach involves breaking down the decision-making process into smaller subproblems and solving them recursively. By considering the optimal solution for each subproblem, the algorithm builds up to the optimal solution for the entire unit commitment problem.



5	A system consists of two plants connected to a transmission line; the load is located at plant – 2. The power transfer of 100MW from station 1 to the load results in a loss of 8MW. Find the required generation at each station and the power received by the load when the system is operating with λ = Rs 100MWh. The incremental fuel cost of two plants are $dC_1 / dP_1 = 0.12 P_1 + 65$Rs/MWh and $dC_2 / dP_2 = 0.25P_2 + 75$Rs/MWh. 1. From the first equation: $0.24P_1 + 65 - \lambda = 0$ $0.24P_1 = \lambda - 65$ 2. From the second equation: $0.5P_2 + 75 - \lambda = 0$ $0.5P_2 = \lambda - 75$ 3. Substitute $\lambda - 65$ for $0.24P_1$ and $\lambda - 75$ for $0.5P_2$ into the power balance equation: $\lambda - 65 + \lambda - 75 = P_{\text{load}} + 8$ $2\lambda - 140 = P_{\text{load}} + 8$ $2\lambda = P_{\text{load}} + 148$ $\lambda = \frac{P_{\text{load}}}{2} + 74$ 4. Substitute λ back into the first and second equations to find P_1 and P_2: $0.24P_1 = \frac{P_{\text{load}}}{2} + 74 - 65$ $0.24P_1 = \frac{P_{\text{load}}}{2} + 9$ $P_1 = \frac{2}{0.24}\left(\frac{P_{\text{load}}}{2} + 9\right)$ $0.5P_2 = \frac{P_{\text{load}}}{2} + 74 - 75$ $0.5P_2 = \frac{P_{\text{load}}}{2} - 1$ $P_2 = \frac{2}{0.5}\left(\frac{P_{\text{load}}}{2} - 1\right)$ 5. Substitute the values of P_1, P_2, and λ back into the power balance equation to find P_{load}: $P_{\text{load}} = 2\lambda - 148$	[10]	CO4	L3
6	The operating cost of F_1 and F_2 in Rs/h of two generating units each of 100 MW are $F_1 = 0.2PG_1^2+40PG_1+120$; $F_2=0.25PG_2^2+30PG_2+150$. Find the optimal generation of two units for a total demand of 180MW and the corresponding total cost. Also compute savings in Rs/h in this case as compared to equal sharing between two generators. $\frac{dF_1}{dPG_1} = 0.4P_1 + 40$ $\frac{dF_2}{dPG_2} = 0.5P_2 + 30$ for economic generation $\frac{dF_1}{dPG_1} = \frac{dF_2}{dPG_2} = 0.4P_1 + 40 = 0.5P_2 + 30$ $P_1 + P_2 = 180$ $P_2 = 180 - P_1$ $0.4P_1 + 40 = 0.5(180 - P_1) + 30$ $P_1 = 88.88$ MW $P_2 = 180 - 88.88 = 91.12$ MW $F_1 = 0.2(88.88)^2 + 40(88.88) + 120 = 5855.13$ Rs/hr $F_2 = 0.25(91.12)^2 + 30(91.12) + 150 = 4559.31$ Rs/hr total cost = 10214.44 Rs/hr with equal load sharing $P_1 = P_2 = \frac{180}{2} = 90$ MW $F_1 = 0.2(90)^2 + 40(90) + 120 = 5340$ Rs/hr $F_2 = 0.25(90)^2 + 30(90) + 150 = 4875$/hr total cost = 10215 Rs/hr Saving = 10215 − 10214 = 0.5Y Rs/hr	[10]	CO4	L3

****** ALL THE BEST ******

Signature of Paper Setter(s)   Signature of CCI   HOD – EEE