Modified

CBCS SCHEME

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15EE71

Seventh Semester B.E. Degree Examination, Dec.2018/Jan.2019
Power System Analysis – II

Time: 3 hrs. Max. Marks: 80

Note: Answer any FIVE full questions, choosing ONE full question from each module.

Module-1

1 a. With usual notations, prove that $Y_{bus} = A^T Y A$ using singular transformation. **(06 Marks)**

b. For the power system shown in Fig.Q1(b), obtain Y_{bus} using singular transformation. **(10 Marks)**

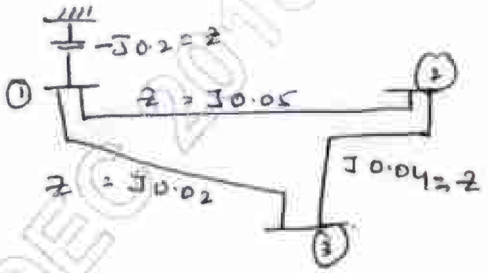


Fig.Q1(b)

OR

2 a. What is load flow analysis? Explain how buses are classified to carly out load flow analysis in power system. **(06 Marks)**

b. For the sample system of Fig.Q2(b), the generations are connected to all the 4-buses, while loads are at buses 2 and 3. Values of real and reactive powers are listed in Table Q2(b). All buses other than the slack bus are PQ type. **(10 Marks)**

Bus	P(pu)	Q(pu)	V(pu)	Type of bus
1	–	–	$1.04\angle 0$	Ref
2	0.5	– 0.2	–	PQ
3	– 1.0	0.5	–	PQ
4	0.3	– 0.1	–	PQ

Table Q2(b)

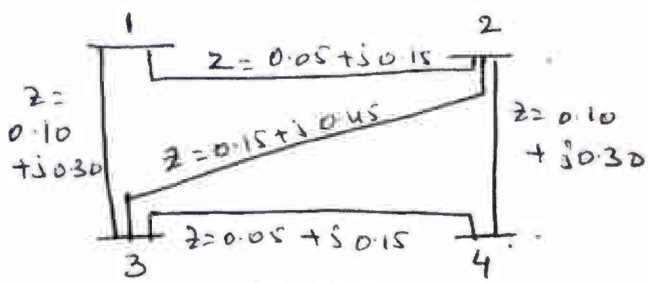


Fig.Q2(b)

Module-2

3 a. Draw the flow-chart of Newton-Raphson method of load flow analysis in polar co-ordinates. **(08 Marks)**

b. Derive expression for all elements of Jacobbian matrices on polar form. **(08 Marks)**

OR

4 a. Starting all assumptions, deduce the FDLF model and give the flow-chart. **(10 Marks)**

b. Compare Gauss-Seidal and Newton–Raphson methods of load flow analysis. **(06 Marks)**

Module-3

5 a. Deduce the condition for optimal load disipatch considering transmission losses in a system. **(06 Marks)**

b. The operating cost of C_1 and C_2 in Rs/hr of two generator units each of 100M watt rating of a Thermal plant are,

$C_1 = 0.2P_1^2 + 40P_1 + 120$ Rs/hr

$C_2 = 0.25P_2^2 + 30P_2 + 150$ Rs/hr.

i) Find optimal generation of 2-units for a total demand of 180MW and the corresponding total cost.

ii) Saving in Rs/hr in this case, as compare to equal sharing between the two machines. **(10 Marks)**

OR

6 a. With a usual notation, derive the generalized transmission loss formula and B–coefficients. **(08 Marks)**

b. Calculate the loss co-efficient in p.u and MW^{-1} on a base of SOMUA for the network of Fig.Q6(b) below.

$I_a = 1.2 - j0.4$; $I_b = 0.4 - j0.2$; $I_c = 0.8 - j0.1$;

$I_d = 0.8 - j0.2$; $I_e = 1.2 - j0.3$

$Z_a = 0.02 + j0.08$; $Z_b = 0.08 + j0.32$; $Z_c = 0.02 + j0.08$;

$Z_d = 0.03 + j0.12$; $Z_e = 0.03 + j0.12$,

$V_{ref} = 1\angle 0$. **(08 Marks)**

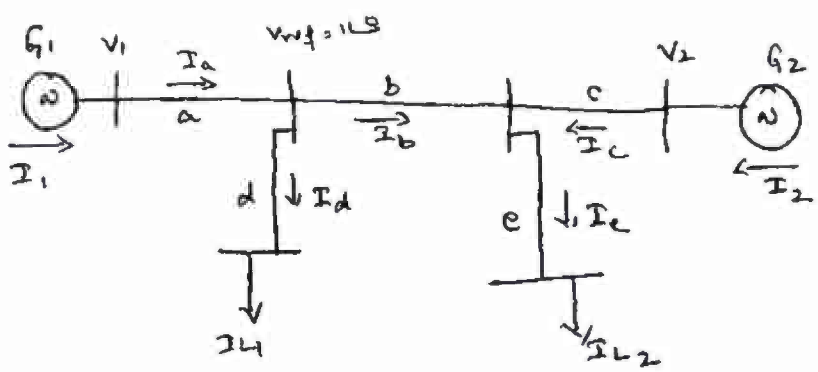


Fig.Q6(b)

Module-4

7 a. Discuss the problem formulation and solution procedure of optimal scheduling for hydro thermal plant. **(10 Marks)**

b. Draw the flow chart of optimal load flow solution. **(06 Marks)**

OR

8 a. Explain power system static security level classification. **(08 Marks)**

b. Define :

i) power system reliability

ii) power system security. **(08 Marks)**

Module-5

9 a. Derive the generalized algorithm for finding the elements of bus – impedance matrix Z_{bus} when a branch in added to the partial network. **(08 Marks)**

b. For the three-bus network shown in Fig.Q9(b) build Z_{bus}. **(08 Marks)**

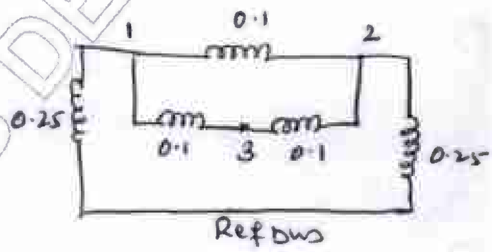


Fig. Q9(b)

OR

10 a. Explain the numerical solution of swing equation. **(08 Marks)**

b. Explain clearly the steps involved in solving power system stability solution of swing equation using Range-Kutta method. **(08 Marks)**

* * * * *

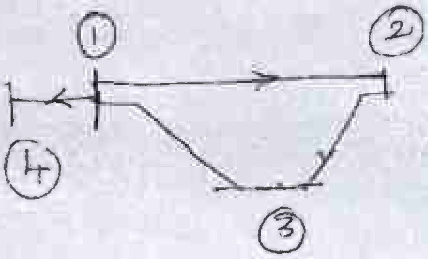
Scheme & Solution

Power System Analysis - 2 Subcode: 15EE71.

1. a.

Derivation of $Y_{Bus} = A^T y_{prim} A$ using singular Transformation (6 M)

1 b.



– (2 M)

$$A = \begin{array}{c} \begin{array}{ccc} 1 & 2 & 3 \end{array} \\ \begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ -1 & 0 & 1 \\ 1 & 0 & 0 \end{bmatrix} \end{array}$$ – (2 M)

$$y_{prim} = \begin{bmatrix} -j20 & 0 & 0 & 0 \\ 0 & -j25 & 0 & 0 \\ 0 & 0 & -j50 & 0 \\ 0 & 0 & 0 & +j5 \end{bmatrix}$$ – (2 M)

$$Y_{Bus} = A^T y_{prim} A = \begin{bmatrix} -j65 & +j20 & +j50 \\ +j20 & -j45 & +j25 \\ +j50 & +j25 & -j75 \end{bmatrix}$$ – 4M

2A. Load flow Analysis is the steady state Analysis of the system. At the end of load flow analysis we know the voltages at all the buses. We can solve for real & reactive power flow in the transmission lines, real and reactive power injection from Generator buses system losses etc... → (3 M)

Type of buses (3 M)

(i) PQ Bus
(ii) PV Bus
(iii) slack bus
(iv) Voltage controlled bus

2b.

$$Y_{Bus} = \begin{bmatrix} 3-j9 & -2+j6 & -1+j3 & 0 \\ -2+j6 & 3.66-j11 & -0.66+j2 & -1+j3 \\ -1+j3 & 0.66+j2 & 3.66-j11 & -2+j6 \\ 0 & -1+j3 & -2+j6 & 3-j9 \end{bmatrix} \text{ - 3M}$$

$$V_i^{(r+1)} = \frac{1}{Y_{ii}}\left[\frac{P_i - jQ_i}{(V_i^{r})^*} - \sum_{j=1}^{i-1} Y_{ij}V_j^{(r+1)} - \sum_{j=i+1}^{n} Y_{ij}\cdot V_j^{(r)}\right] \text{ - 1M}$$

$V_2^1 = 1.1019 + j0.046$ pu. – 2M.

$V_3^1 = 1.028 - j0.087$ pu – 2M

$V_4^1 = 1.025 - j0.0093$ pu 2M.

3A Module - 2.

Flow chart of Newton Raphson - Method 8M.

B

$$J = \begin{bmatrix} H & N \\ J & L \end{bmatrix}$$

$$H_{ii} = \frac{\partial P_i}{\partial \delta_i} = \sum_{\substack{k=1 \\ \neq i}}^{n} |V_i||V_j| Y_{ij} \sin(\theta_{ij} - \delta_i + \delta_j) \text{ — 1M}$$

$$\text{(or) } -Q_i - B_{ii}V_i^2$$

~~H_{ij} =~~

$$H_{ij} = \frac{\partial P_i}{\partial \delta_j} = -|V_i||V_j|Y_{ij} \sin(\theta_{ij} - \delta_i + \delta_j)$$

$$\frac{\partial P_i}{\partial \delta_j} = -|V_i||V_j||Y_{ij}| \sin(\theta_{ij} - \delta_i + \delta_j) \text{ - 1M}$$

$$N_{ii} = \frac{\partial P_i}{\partial V_i} = \frac{P_i + G_{ii}V_i^2}{V_i} \text{ (or)}$$

$$= \sum_{\substack{k=1 \\ \neq i}}^{n} V_j Y_{ij} \cos(\theta_{ij} - \delta_i + \delta_j) + 2V_i Y_{ii} \cos\theta_{ii} \text{ — 1M}$$

$$N_{ij} = \frac{\partial P_i}{\partial V_j} = |V_i||Y_{ij}| \cos(\theta_{ij} - \delta_i + \delta_j) \quad \text{— (1M)}$$

$$J_{ii} = \frac{\partial Q_i}{\partial \delta_i} = P_i - G_{ii} V_i^2$$

(or)

$$- \sum_{\substack{j=1 \\ \neq i}}^{n} |V_i||V_j||Y_{ij}| \cos(\theta_{ij} - \delta_i + \delta_j) \quad \text{— (1M)}$$

$$J_{ij} = \frac{\partial Q_i}{\partial \delta_j} = |V_i||Y_{ij}| \cos(\theta_{ij} - \delta_i + \delta_j) \quad \text{— (1M)}$$

$$L_{ii} = \frac{\partial Q_i}{\partial V_i} = \frac{Q_i - B_{ii}|V_i|^2}{|V_i|} \quad \text{(1M)}$$

or

$$\sum_{\substack{j=1 \\ \neq i}}^{n} |V_j||Y_{ij}| \sin(\theta_{ij} - \delta_i + \delta_j) + 2 V_i Y_{ii} \sin\theta_{ii}$$

$$L_{ij} = \frac{\partial Q_i}{\partial \delta_j} = V_i Y_{ij} \sin(\theta_{ij} - \delta_i + \delta_j) \quad \text{— (1M)}$$

4A. Assumption made in FDLF Method.

$\cos \delta_{ij} \simeq 1$ $\quad \sin \delta_{ij} \simeq 0$ $\quad Q_i << B_{ii} V_i^2$ (2M)

$G_{ij} \sin \delta_{ij} << B_{ij}$

~~Step by step~~ Flow chart with relevent equations — 8M.

4B Comparison of NRLF and GSLF (any 6 comparisons)

GS	NR
1) Works well with recangular co-ordinates	Works well with polar co-ordinates
2) Time taken per iteration is less	Time taken per iteration is more
3) No. of iteration increases with number of buses	Only 3 to 5 iterations, even for Large systems
(4) Linear convergence	Quadratic convergence
(5) Less accurate	More accurate
(6). Used for small size systems	Used for large systems, ill conditioned system.

6M.

Module 3.

5a. Derivation of optimal Loading of n plant system considering Losses

$$\frac{dC_1}{dP_1} L_1 = \frac{dC_2}{dP_2} L_2 = \cdots = \frac{dC_n}{dP_n} L_n = \lambda$$ 6M.

B. For optimal Loading

$$\frac{dC_1}{dP_1} = 0.4P_1 + 40 \qquad \frac{dC_2}{dP_2} = 0.5P_2 + 30.$$

$$\lambda = IC_1 = IC_2$$

$$0.4P_1 - 0.5P_2 = -10$$

$$P_1 + P_2 = 180$$

$\therefore P_1 = 88.88$ MW $\quad P_2 = 91.11$ MW (4M)

$C_1(88.88) + C_2(91.11) = 10213.68$ Rs/hr (2M)

$C_1(90) + C_2(90) = 10215$ Rs/hr. (2M)

Saving ~~total~~ in Rs/hr = 1.3 Rs/hr.

Annual saving = $1.3 \times 24 \times 365 = 11485.19$ – 2M

6.A Derivation for Transmission loss coefficients.

$$B_{ii} = \frac{\sum_p M_{pi}^2 R_p}{V_i^2 \cos^2 \phi_i} \quad (3)$$

$$B_{ij} = \frac{\sum_p M_{pi} M_{pj} R_p \cos(\sigma_i - \sigma_j)}{V_i V_j \cos \phi_i \cos \phi_j} \quad (3)$$

$$P_L = \sum_{i=1}^{n} \sum_{j=1}^{n} P_i B_{ij} P_j \quad — (2)$$

6B.

$M_{a1} = 0.6$; $M_{b1} = 0.6$; $M_{c1} = 0$; $M_{d1} = 0.4$; $M_{e1} = 0.6$
$M_{a2} = 0$; $M_{b2} = -0.4$; $M_{c2} = 1.0$ $M_{d2} = 0.4$
$M_{e2} = 0.6$ ———— (1M) —— $\cancel{(1M)}$

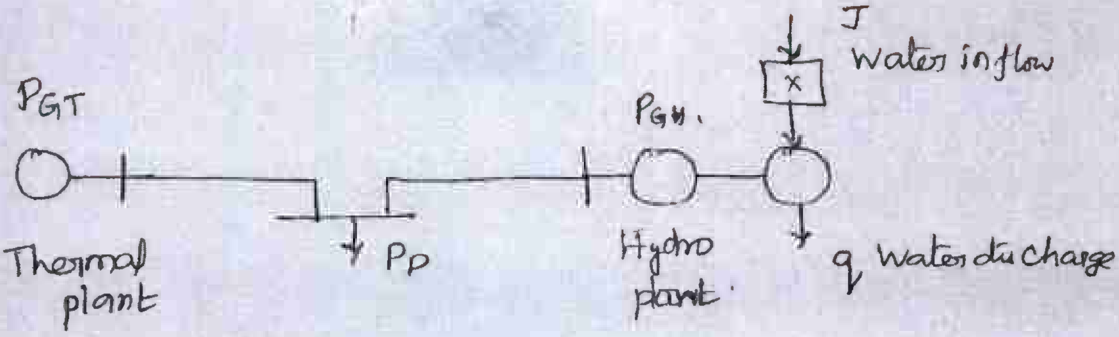
$$\left.\begin{aligned} V_1 &= V_{ref} + I_a Z_a = 1.06 \angle 4.78 \text{ pu.} \\ V_2 &= V_{ref} - I_b Z_b + I_c Z_c = 0.93 \angle -3.1 \text{ pu.} \end{aligned}\right\} 2M$$

$$\left.\begin{aligned} \sigma_1 &= \tan^{-1}\left(\frac{-0.4}{1.2}\right) = -18.43^\circ \\ \sigma_2 &= \tan^{-1}\left(\frac{-0.1}{0.8}\right) = -7.13^\circ. \end{aligned}\right\} 1M$$

$$\left.\begin{aligned} \phi_1 &= 23.21^\circ \quad \cos\phi_1 = 0.92. \\ \phi_2 &= 4.03^\circ \quad \cos\phi_2 = 0.998. \end{aligned}\right\} 1M$$

$B_{11} = 0.0677$ pu $= 0.1354 \times 10^{-2}$ MW^{-1} – 1M
$B_{22} = 0.056$ pu $= 0.112 \times 10^{-2}$ MW^{-1} – 1M
$B_{12} = -0.00389$ pu $= -0.0078 \times 10^{-2}$ MW^{-1}. – 1M

7a.



Problem Formulation

$$\text{Min} \quad C_T = \int_0^T c'(P_{GT}(t))\, dt. \qquad \text{— 2M.}$$

subject to the constraints.

(i) $P_{GT}(t) + P_{GH}(t) - P_L(t) - P_D(t) = 0$ Power balance eqn.

(ii) $x'(T) - x'(0) - \int_0^T J(t)\,dt + \int_0^T q(t)\,dt = 0$ water availability

(iii) $P_{GH}(t) = f(x'(t), q(t))$. Hydro generation.

2M

Discretizing the above eqn.

$$\min \sum_{m=1}^{M} C(P_{GT}^{m})$$

under the constraints.

$$P_{GT}^{m} + P_{GH}^{m} - P_L^{m} - P_D^{m} = 0$$

$$x'^{(m)} - x'^{(m-1)} - J^m \Delta T + q^m \Delta T = 0$$

$$\Rightarrow x^m - x^{m-1} - J^m + q^m = 0.$$

$$P_{GH}^{m} = h_0\{1 + 0.5e(x^m + x^{m-1})\}(q^m - e)$$

2M

Solution.

$$\mathcal{L} = \sum C(P_{GT}^{m}) - \lambda_1^{m}(P_{GT}^{m} + P_{GH}^{m} - P_L^{m} - P_D^{m}) + \lambda_2^{m}(x^m - x^{m-1} - J^m + q^m) + \lambda_3^{m}(P_{GH}^{m} - h_0(1 + 0.5e(x^m + x^{m-1}))(q^m - e))$$

$$\frac{\partial L}{\partial P_{GT}^{m}} = \frac{dC(P_{GT}^{m})}{\partial(P_{GT}^{m})} - \lambda_1^{m}\left(1 - \frac{\partial P_L^{m}}{\partial P_{GT}^{m}}\right) = 0$$

$$\frac{\partial L}{\partial P_{GH}^{m}} = \lambda_3^{m} - \lambda_1^{m}\left(1 - \frac{\partial P_L^{m}}{\partial P_{GH}^{m}}\right) = 0$$

4M.

$$\frac{\partial L}{\partial \lambda^{m}} = \lambda_2^{m} - \lambda_2^{m+1} - \lambda_3^{m}\{0.5\, h_0 e(q^{m} - \varrho)\} - \lambda_3^{m+1}\{0.5\, h_0 e(q^{m} - \varrho)\} = 0$$

$$\frac{\partial L}{\partial q^{1}} = \lambda_2^{1} - \lambda_3^{1} h_0\{1 + 0.5 e(2X_0 + J^{1} - 2q^{1} + \varrho)\} = 0$$

For optimal solution the gradient vector

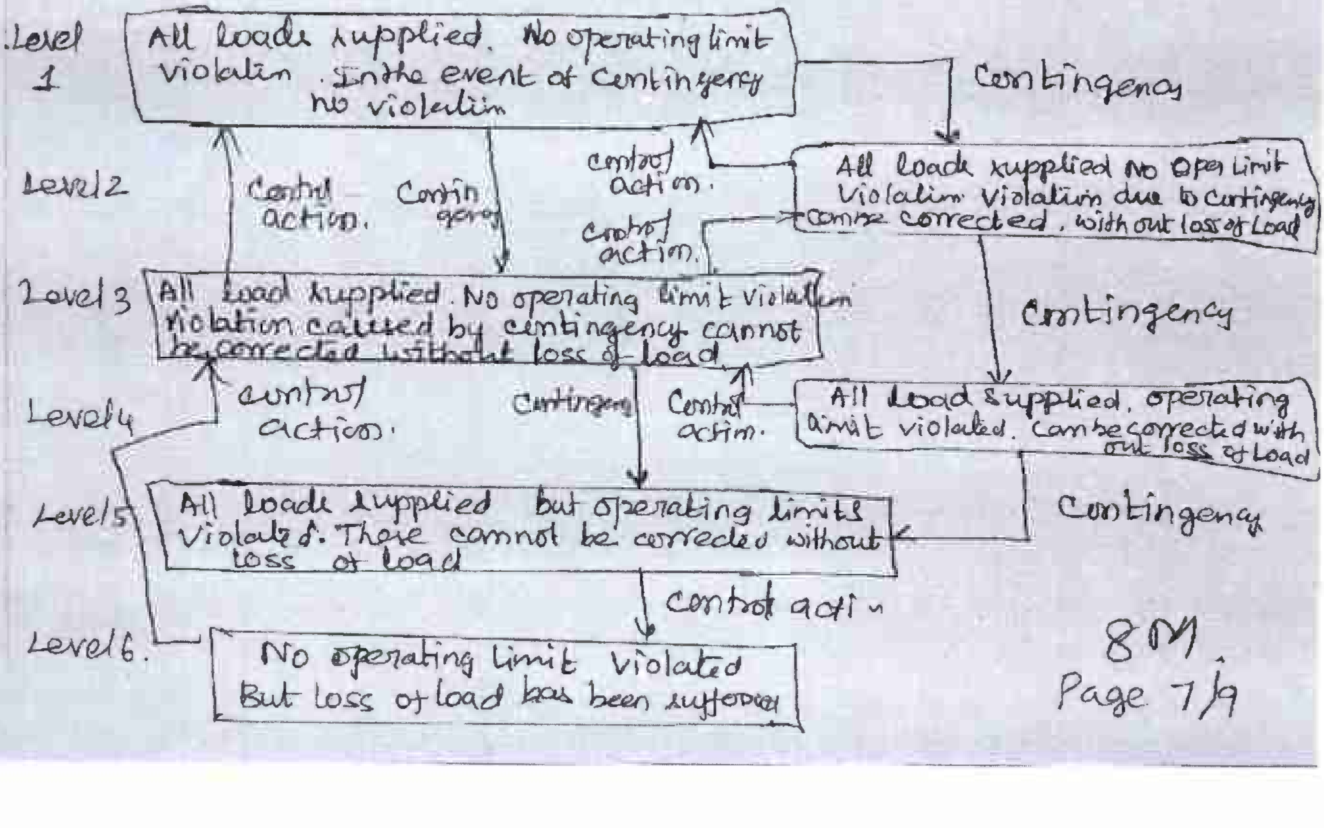
$$\left(\frac{\partial L}{\partial q^{m}}\right)_{m \neq 1} = \lambda_2^{m} - \lambda_3^{m} h_0\left(1 + 0.5 e(2X^{m+1} + J^{m} - 2q^{m} + \varrho)\right)$$

must be zero.

7B Flow chart of optimal Load Flow solution

6M.

8a

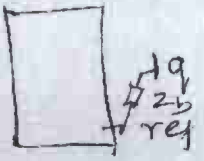


8M.

8B Definition of Power system reliability – 4M.
Definition of Power System security – 4M.

Module 5

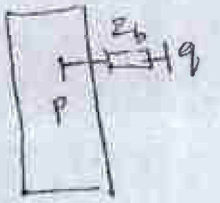
9.a. Derivation of Type 1 modification



$Z_{qi} = 0$ – 2M

$Z_{qq} = Z_b$ – 2M

Derivation of Type 2 modification



$Z_{qi} = Z_{pi}$ – 2M

$Z_{qq} = Z_{pp} + Z_b$ – 2M

9b (i) Adding element b/w 0 & 1.

Type 1 $\quad Z_{Bus} = [0.25]$ 1M

(ii) Add element b/w 1 & 2 $Z_b = 0.1$.

Type 2. $Z_{Bus} = \begin{bmatrix} 0.25 & 0.25 \\ 0.25 & 0.35 \end{bmatrix}$ 1M

(iii) Add element j0.1 b/w 1 & 3 $Z_b = 0.1$.

Type 2 $\quad Z_{Bus} = \begin{bmatrix} 0.25 & 0.25 & 0.25 \\ 0.25 & 0.35 & 0.25 \\ 0.25 & 0.25 & 0.35 \end{bmatrix}$ – 2M

(iv) Add element b/w 2 & 3 Type 3. with $Z_b = 0.25$.

$Z_{Bus} = \begin{bmatrix} 0.1458 & 0.1042 & 0.1458 \\ 0.1042 & 0.1458 & 0.1042 \\ 0.1458 & 0.1042 & 0.2458 \end{bmatrix}$ – 2M

(v) Add element b/w 2 & 3 Type 4] with $Z_b = 0.1$.

$Z_{Bus} = \begin{bmatrix} 0.1397 & 0.1103 & 0.1250 \\ 0.1103 & 0.1397 & 0.1250 \\ 0.1250 & 0.1250 & 0.1750 \end{bmatrix}$ – 2M.

10a. Any one numerical technique with relevent equations may be considered.

(i) Step by step method.
(ii) Runge-Kutta second order method. 8M.
(iii) Runge-Kutta forth order method.
(iv) Modified Euler's method ... etc

10b. Algorithm for Runge kutta second order / Forth order method with relevent equations 8M.

Bwalu 01/01/19

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