II Jai Sri Gurudev II

Sri Adichunchanagiri Shikshana Trust®

SJB Institute of Technology

(Affiliated to Visvesvaraya Technological University, Belagavi and Approved by AICTE and Accredited by NAAC with 'A' Grade, CGPA-3.22 - New Delhi)

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Website : www.sjbit.edu.in

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INTERNAL ASSESSMENT BOOK

Student Name : YAMUNA R.K

Semester & Section : 7th sec USN : 1JB18EE032

Subject: Power System analysis-2 Subject Code: 18EE71 Branch: EEE

Name of Faculty in charge : Mr. Kubera U

Q No.	Internal Assessment Test - I, Date : 18/11/2021, Max. Marks : 50				Q No.	Internal Assessment Test - II, Date : 27/12/2021, Max. Marks : 50				Q No.	Internal Assessment Test - III, Date : 27/01/2022, Max. Marks : 50			
	PART - A					PART - A					PART - A			
	A	B	C	Total		A	B	C	Total		A	B	C	Total
1	8	7	10	25	1	12	7	6	25	1				
2					2					2	12	8	5	25
	PART - B					PART - B					PART - B			
3	7	8	10	25	3	7	8	10	25	3	9	8	8	25
4					4	7	8	10	25	4				
I Test IA Marks Total				50	II Test IA Marks Total				50	III Test IA Marks Total				50
Quiz 1/Assignment etc.,				10	Quiz 2/Assignment etc.,				10	Quiz 3/Assignment etc.,				09
Student Signature : Yamuna R.K					Student Signature : Yamuna R.K					Student Signature : Yamuna R.K				
Signature of Invigilator					Signature of Invigilator					Signature of Invigilator				
Signature of Faculty in charge 20/11/21					Signature of Faculty in charge 28/12/21					Signature of Faculty in charge 22/1/22				

Avg. IA Marks for 30 (A) : 30 Assignment /Quiz etc., for 5+5 (B) : 10 Total IA Marks for 40 (A+B): 40

HOD

Principal

Department of EEE

Dept. Vision:

One among the best department in Engineering & research area through professional faculty and state of art laboratories and to make the students sucessful engineerin with good Ethics.

Dept. Mission:

M1 - to provide learner centric Environment through quality Education and training. M2 - To lay the foundation for research by fortifying peers & Establishing incubation centre M3 - To develop the overall personality of the students to face the challenges of the real world

About Anti - Ragging

SJBIT has zero tolerance policy for ragging. The Institute views ragging, is an uncivilized, and inhuman practice. We do not subscribe to the view that one could wait till something happens in order to initiate stringent action. Any rigorous action in such cases may damage a young career. So we repose faith in averting such eventualities. For this, the Institute has proactive policy.

Punishments for Ragging

1. Cancellation of admission.
2. Suspension from attending classes.
3. Withholding/withdrawing scholarship/fellowship and other benefits.
4. Debarring from appearing in any test/examination or other evaluation process.
5. Withholding results.
6. Debarring from representing the University in any regional, national or international meet, tournament, youth festival etc.
7. Suspensions/expulsion from the hostel.
8. Rustication from the college and University for period varying from 1 to 4 years.
9. Expulsion from the college and consequent debarring from admission to any other college.
10. Rigorous imprisonment of three years and/or a fine of upto Rs.25,000.
11. Collective punishment: When the persons committing or abetting the crime or ragging are not identified, the institution has resort to collective punishment as a deterrent to ensure community pressure on the potential raggers.

I Internal test

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1. [b] = 4
2. [c] e x (n-1)
3. [a] Link
4. [c] n-1
5. [b] n x n
6. [c] Twigs
7. [c] voltage magnitude, phase angle
8. [a] P and Q
9. [d] Q and δ
10. [c] Reactive power goes beyond limit

$n = 4$
$e = 7$
$l = e - b$
$= e - n + 1$
$= 7 - 4 + 1$
$= 4$

$\frac{10}{10}$

20/11/21

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PART-A

1.

A)

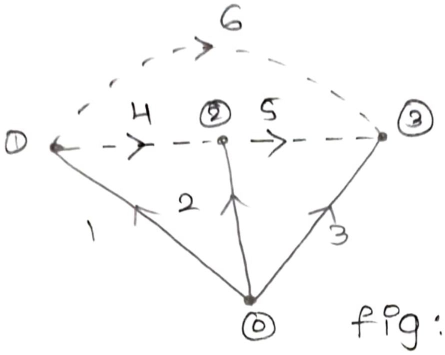


fig: G

(i) Tree :- It is a subgraph containing all nodes of the Graph G but does not form any loop

→ Elements of tree are called twigs / branches

T(1,4,6), T(1,2,3), T(3,5,6), T(6,5,2), T(6,4,2) Etc.

(ii) co-tree :- It is a set of branches of the original Graph G but not included in tree is called co-tree → Elements of co-tree are called links

→ In co-tree loops can be formed.

T(1,2,4), T(1,3,6) T(4,5,6) T(2,3,5)

(iii) Basic loop :- when a link is added to the tree it form a closed Basic loop.

→ Elements of basic loop is called ~~twigs~~

→ no of basic loops = no of links.

no of links = e-b

Basic loops = l = e-b = 6-3 = 3

→ The loop which contain only one link and remaining are branches.

→ b(1,2,4), b(2,5,3), b(1,6,3)

(iv) Basic cutset :- The loop which contain only one branch and remaining are links

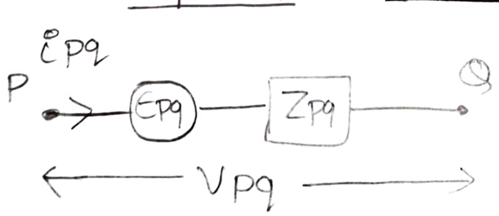
→ no of basic cutset = number of branches.

Basic cutset = b = n-1 = 3

C(1, 4, 6), C(3, 5, 6), C(4, 2, 5) are the basic cut sets.

[B] primitive network : These matrices contain a complete information about network connectivity, loops and cut set, but these matrices has no information on the nature of elements which form interconnected network. This information can be obtained by knowing the knowledge of individual elements behaviour along with incidence matrix.

Impedance form



In impedance form voltage is the source

$$V = IZ$$

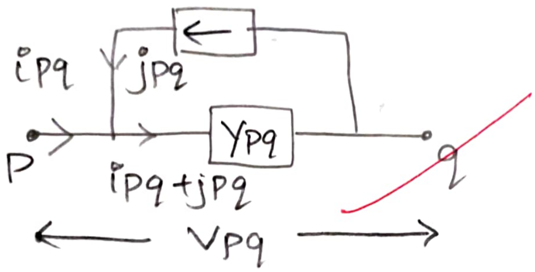
$$V_{pq} + E_{pq} = i_{pq} Z_{pq}$$

$$i_{pq} = \frac{V_{pq}}{Z_{pq}} + \frac{E_{pq}}{Z_{pq}}$$

$$Y_{pq} = \frac{1}{Z_{pq}}$$

$i_{pq} = Y_{pq} \epsilon_{pq} + Y_{pq} V_{pq} \rightarrow ①$

admittance form



In admittance form current is the source

$i_{pq} + j_{pq} = Y_{pq} V_{pq} \rightarrow ②$

From eqn ①

$i_{pq} - Y_{pq} \epsilon_{pq} = Y_{pq} V_{pq} \rightarrow ③$

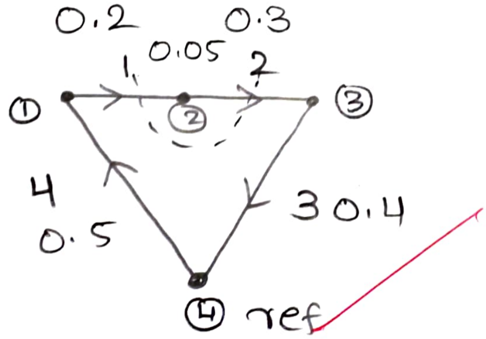
comparing ② & ③

$j_{pq} = -Y_{pq} \epsilon_{pq}$

$\bar{V} + \bar{e} = [Z] I$

$i + j = [Y] V$

$[Z] = [Y]^{-1}$



$$A = \begin{array}{c|ccc} e|n & ① & ② & ③ \\ \hline 1 & 1 & -1 & 0 \\ 2 & 0 & 1 & -1 \\ 3 & 0 & 0 & 1 \\ 4 & -1 & 0 & 0 \end{array}$$

$$A^T = \begin{bmatrix} 1 & 0 & 0 & -1 \\ -1 & 1 & 0 & 0 \\ 0 & -1 & 1 & 0 \end{bmatrix}$$

$$[Z] = \begin{array}{c} \quad Z_1 \qquad\qquad\qquad Z_2 \\ \left[\begin{array}{cc|cc} 0.2 & 0.05 & 0 & 0 \\ 0.05 & 0.3 & 0 & 0 \\ \hline 0 & 0 & 0.4 & 0 \\ 0 & 0 & 0 & 0.5 \end{array}\right] \\ \quad Z_3 \qquad\qquad\qquad Z_4 \end{array}$$

$$Z_1 = \begin{bmatrix} 0.2 & 0.05 \\ 0.05 & 0.3 \end{bmatrix}$$

$$|A| = 0.0575$$

$$\text{Adj } A = \begin{bmatrix} 0.3 & -0.05 \\ -0.05 & 0.2 \end{bmatrix}$$

$$Z_1^{-1} = \frac{\begin{bmatrix} 0.3 & -0.05 \\ -0.05 & 0.2 \end{bmatrix}}{0.0575} = \begin{bmatrix} 5.217 & -0.869 \\ -0.869 & 3.478 \end{bmatrix}$$

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$$[Y] = \begin{bmatrix} 5.217 & -0.869 & 0 & 0 \\ -0.869 & 3.478 & 0 & 0 \\ 0 & 0 & 2.5 & 0 \\ 0 & 0 & 0 & 2 \end{bmatrix}_{4\times4}$$

$$A^T[Y] = \begin{bmatrix} 1 & 0 & 0 & -1 \\ -1 & 1 & 0 & 0 \\ 0 & -1 & 1 & 0 \end{bmatrix}_{3\times4} \begin{bmatrix} 5.217 & -0.869 & 0 & 0 \\ -0.869 & 3.478 & 0 & 0 \\ 0 & 0 & 2.5 & 0 \\ 0 & 0 & 0 & 2 \end{bmatrix}$$

$$A^T[Y]A = \begin{bmatrix} 5.217 & -0.869 & 0 & -2 \\ -6.086 & 4.347 & 0 & 0 \\ 0.869 & -3.478 & 2.5 & 0 \end{bmatrix}_{3\times4} \begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ 0 & 0 & 1 \\ -1 & 0 & 0 \end{bmatrix}_{4\times3}$$

$$Y_{bus} = \begin{bmatrix} 7.217 & -6.086 & 0.869 \\ -6.086 & 10.433 & -4.347 \\ 0.869 & -4.347 & 5.978 \end{bmatrix}$$

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3.

[A] Buses are classified in load flow analysis is

Bus type	Quantity specified	Quantity to be find
load bus	P Q	V, δ
Generation bus	P V	Q, δ
Slack bus	V, δ	P V

Load bus :- The real and reactive components of power are specified for bus. The load flow Equation is solved to find magnitude of voltage and phase of bus voltage.

Generation bus :- The real power and magnitude of voltage for bus is specified. The load flow Equation is solved to find reactive power and phase of bus voltage

Slack bus :- The magnitude of voltage and phase of bus voltage is specified for bus.

→ Slack bus is taken as a reference bus.

→ slack bus is used to determine the real and reactive power of bus for the transmission line losses.

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[B] algorithm

1. prepare a ~~data~~ data for given system required.
2. formulate the bus admittance matrix Ybus by using inspection method.
3. Assume initial voltage at all bodes 2,3---n-1 In ~~parttical~~ practical power system the voltage at all buses is closer to 1.0pu. hence the complex voltage is given as $1\angle 0^\circ$ which is called a flat ~~slack~~ Start solution.
4. Depute the voltages at any $(r+1)^{th}$ iteration the voltage is given by

$$V_K^{(r+1)} = \frac{1}{Y_{KK}}\left[\frac{P_K - jQ_K}{V_K^{*(r)}} - \sum_{\substack{i=1 \\ i\neq K}}^{n} Y_{Ki}V_i\right]$$

continue the iterations till

$$\Delta V_K^{r+1} = \left| V_K^{r+1} - V_K^{r} \right| < \varepsilon$$

$$\varepsilon = 0.0003\,pu$$

5. compute the slack power when the voltage converged

$$S_K^* = P_K - jQ_K = V_K^* \sum_{i=1}^{n} Y_{Ki}V_i$$

6. compute all the flow of lines.
7. The complex power of lines is given as $S_{Ki} + S_{iK}$

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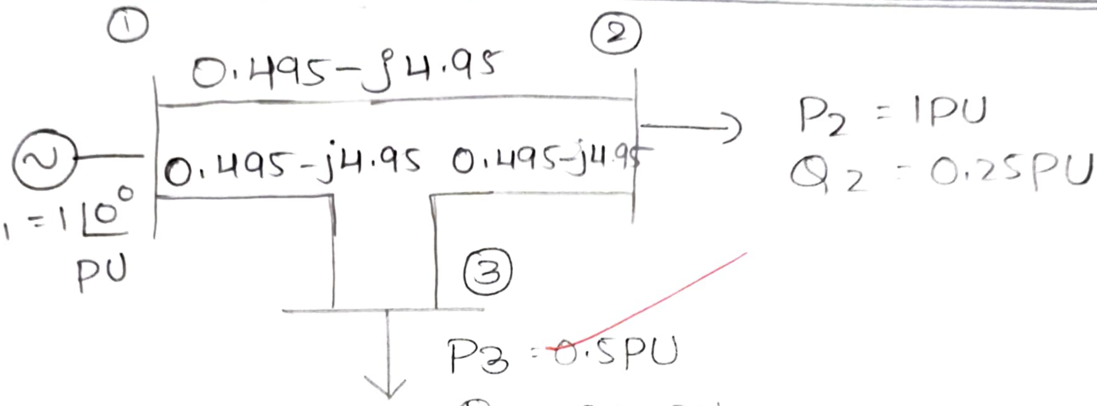
The total power of lines can be obtained by summing the individual powers of lines.

[C]



Impedance	admittance
$0.02+j0.2$	$0.495-j4.95$

$$Y_{bus} = \begin{bmatrix} Y_{11} & Y_{12} & Y_{13} \\ Y_{21} & Y_{22} & Y_{23} \\ Y_{31} & Y_{33} & Y_{31} \end{bmatrix}$$

$$= \begin{bmatrix} 0.99-j9.9 & -0.495+j4.95 & -0.495+j4.95 \\ -0.495+j495 & 0.99-j9.9 & -0.495+j4.95 \\ -0.495+j4.95 & -0.495+j4.95 & 0.99-j9.9 \end{bmatrix}$$

$$V_k^{(r+1)} = \frac{1}{Y_{KK}}\left[\frac{P_K - jQ_K}{V_K^{*(r)}} - \sum_{\substack{i=1 \\ i\neq K}}^{n} Y_{Ki}V_i\right]$$

Use the other General Formula

$$V_2^{(1)} = \frac{1}{Y_{22}}\left[\frac{P_2 - jQ_2}{U_2^{*(0)}} - [Y_{21}V_1 + Y_{23}V_3]\right]$$

$$= \frac{1}{0.99-j9.9}\left[\frac{1-j0.25}{1\angle 0} - \left[(-0.495+j4.95)(1\angle 0^\circ) + (-0.495+j4.95)(1\angle 0^\circ)\right]\right]$$

$$= 1.03500+0.0975i$$

$$\boxed{V_2^{(1)} = 1.0395\angle 5.382}$$

$$V_3^{(1)} = \frac{1}{Y_{33}}\left[\frac{P_3-jQ_3}{V_3^{*(0)}} - \left[Y_{31}V_1 + Y_{32}V_2\right]\right]$$

$$= \frac{1}{0.99-j9.9}\left[\frac{0.5-j0.25}{1\angle 0^\circ} - \left[(-0.495+j4.95)(1\angle 0^\circ) + (-0.495+j4.95)(1.03500+0.0975i)\right]\right]$$

$$= \cancel{0.9974+0.1012i} \quad 1.0475+0.0962i$$

$$= \cancel{1.0026\angle 5.796} \quad 1.0519\angle 5.2501$$

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$V_2 = 1.0395$ $\qquad$ $V_3 = \cancel{1.0026}\ \cancel{1.0475}\ 1.0519$

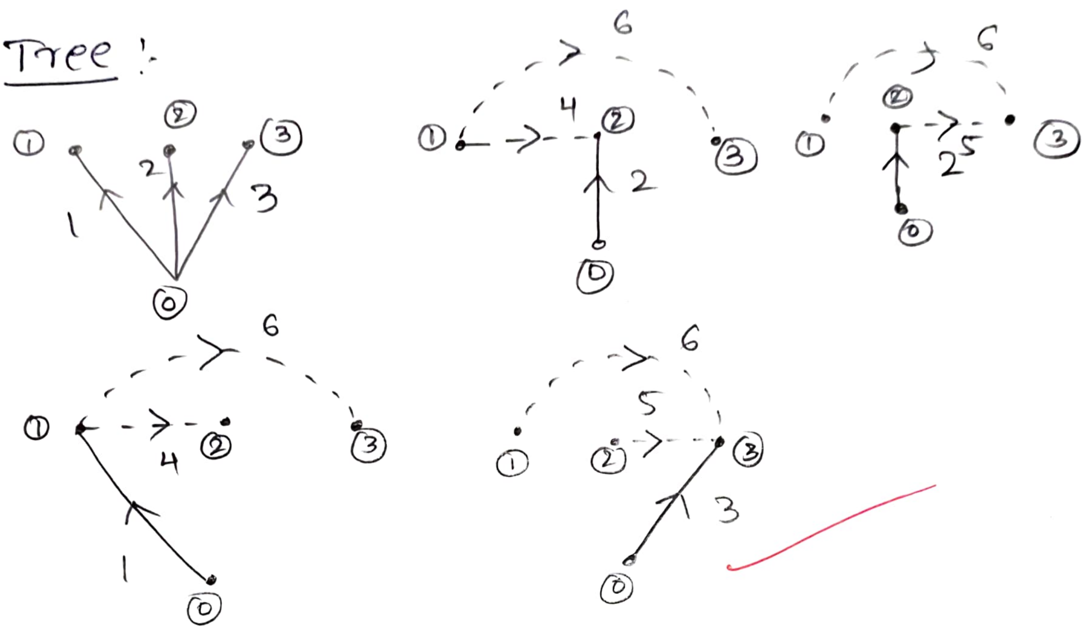
$\delta_2 = 5.382$ $\qquad$ $\delta_3 = \cancel{5.796}\ \cancel{\text{to}}\ 5.2501$

$V_3 = 1.0519$

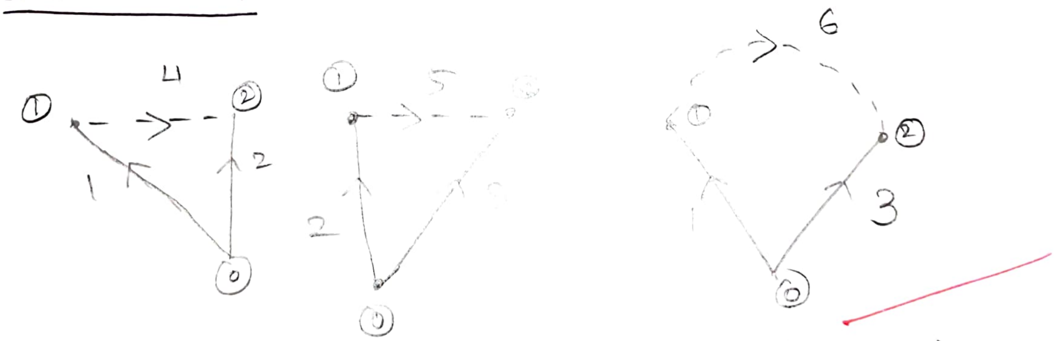
$\delta_3 = 5.2501$

1.

A) Tree :-

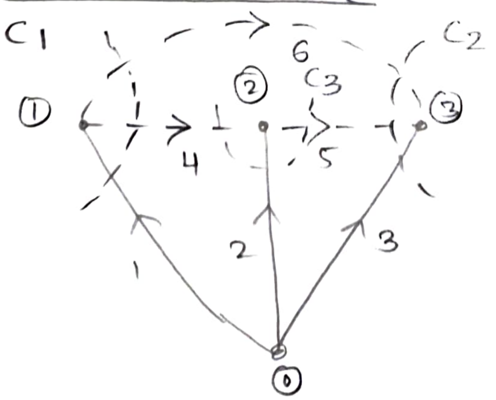


B) Basic loops :-



b(1, 4, 2)   b(2, 5, 3)   b(1, 6, 3)

Basic cut sets

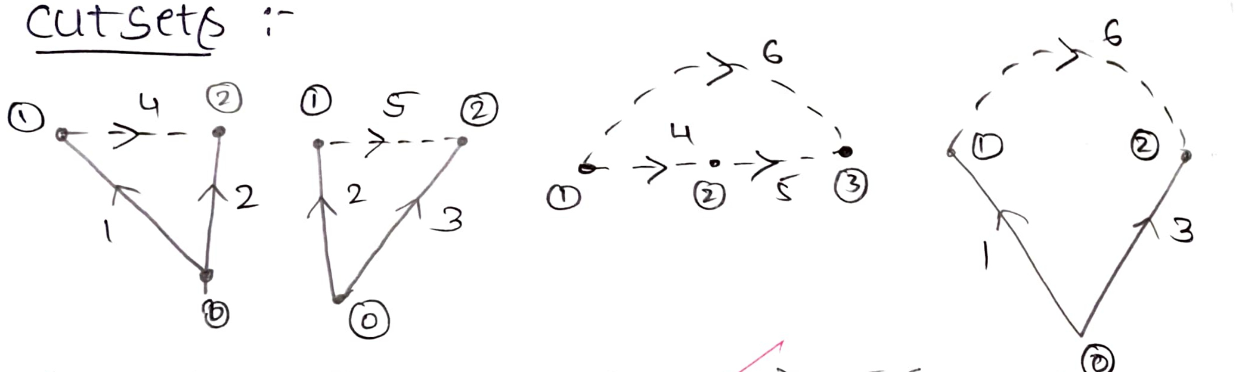


C(1, 4, 6)

C(3, 5, 6)

C(4, 5, 2)

Cutsets :-



T(1, 4, 2) T(2, 5, 3) ~~T(4, 5, 6)~~, T(1, 3, 6) are the cutsets.

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IInd internal test.

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Quiz :

1. a calculation time for each iteration is less.
2. [a] Ybus matrix.
3. [b] N-R method
4. [b] Remains constant
5. [d] Both a and b
6. [d] 1.6 to 2.0
7. a) Increases.
8. a) Heat rate.
9. c) The incremental cost
10. a) Rs/mwh

10/10

Kus 28/12/21

1. Expression for Jacobian Elements in polar form in N-R method of load flow analysis.

From Static Load flow Equations

$$P_K = |V_K|^2 G_{KK} + \sum_{\substack{i=1 \\ i \neq K}}^{n} |V_K||V_i| \left(G_{Ki}\cos(\delta_K - \delta_i) + B_{Ki}\sin(\delta_K - \delta_i) \right) \rightarrow (1)$$

$$Q_K = -|V_K|^2 B_{KK} + \sum_{\substack{i=1 \\ i \neq K}}^{n} |V_K||V_i| \left(G_{Ki}\sin(\delta_K - \delta_i) - B_{Ki}\cos(\delta_K - \delta_i) \right) \rightarrow (2)$$

J1 Elements

diagonal Elements $= \dfrac{\partial P_K}{\partial \delta_K}$

$$\frac{\partial P_K}{\partial \delta_K} = 0 + \sum_{\substack{i=1 \\ i \neq K}}^{n} |V_K||V_i| \left(-G_{Ki}\sin(\delta_K - \delta_i) + B_{Ki}\cos(\delta_K - \delta_i) \right)$$

$$= -\sum_{\substack{i=1 \\ i \neq K}}^{n} |V_K||V_i| \left(G_{Ki}\sin(\delta_K - \delta_i) - B_{Ki}\cos(\delta_K - \delta_i) \right)$$

$$\frac{\partial P_K}{\partial \delta_K} = -\left(Q_K + B_{KK}|V_K|^2 \right) \rightarrow (3)$$

offdiagonal Element $= \dfrac{\partial P_K}{\partial \delta_i}$

$$\frac{\partial P_K}{\partial \delta_i} = 0 + |V_K||V_i| \left(-G_{Ki}\sin(\delta_K - \delta_i)(-1) + (B_{Ki}\cos(\delta_K - \delta_i)(-1)) \right)$$

$$= |V_K||V_i| \left(G_{Ki}\sin(\delta_K - \delta_i) + B_{Ki}\cos(\delta_K - \delta_i) \right) \rightarrow (4)$$

$$\frac{\partial P_K}{\partial \delta_i} = |V_K||V_i| \left(G_{Ki}\sin(\delta_K - \delta_i) - B_{Ki}\cos(\delta_K - \delta_i) \right)$$

J_3 Elements

diagonal Elements $= \dfrac{\partial Q_K}{\partial \delta_K}$

$$\frac{\partial Q_K}{\partial \delta_K} = 0 + \sum_{\substack{i=1\\ i\neq K}}^{n} |V_K||V_i|\left(G_{Ki}\cos(\delta_K-\delta_i) + B_{Ki}\sin(\delta_K-\delta_i)\right)$$

$$= \sum_{\substack{i=1\\ i\neq K}}^{n} |V_K||V_i|\left[\left(G_{Ki}\cos(\delta_K-\delta_i) + B_{Ki}\sin(\delta_K-\delta_i)\right)\right]$$

$$\frac{\partial Q_K}{\partial \delta_K} = \left(P_K - |V_K|^2 G_{KK}\right) \rightarrow (5)$$

offdiagonal Elements: $\dfrac{\partial Q_K}{\partial \delta_i}$

$$\frac{\partial Q_K}{\partial \delta_i} = 0 + |V_K||V_i|\left(G_{Ki}\cos(\delta_K-\delta_i)(-1) + B_{Ki}\,\cancel{\cos}\,\sin(\delta_K-\delta_i)(-1)\right)$$

$$\frac{\partial Q_K}{\partial \delta_i} = -|V_K||V_i|\left(G_{Ki}\cos(\delta_K-\delta_i) + B_{Ki}\sin(\delta_K-\delta_i)\right) \rightarrow (6)$$

J_2 Elements

diagonal Elements $= \dfrac{\partial P_K}{\partial |V_K|}$

$$\frac{\partial P_K}{\partial |V_K|} = 2|V_K|G_{KK} + \sum_{\substack{i=1\\ i\neq K}}^{n} |V_i|\left(G_{Ki}\cos(\delta_K-\delta_i) + B_{Ki}\sin(\delta_K-\delta_i)\right)$$

multiply $|V_K|$ on both sides

$$|V_K|\frac{\partial P_K}{\partial |V_K|} = 2|V_K|^2 G_{KK} + \sum_{\substack{i=1\\ i\neq K}}^{n} |V_K||V_i|\left(G_{Ki}\cos(\delta_K-\delta_i) + B_{Ki}\sin(\delta_K-\delta_i)\right)$$

$$|V_K|\frac{\partial P_K}{\partial |V_K|} = |V_K|^2 G_{KK} + P_K \rightarrow (7)$$

Offdiagonal Elements $= \frac{\partial P_K}{\partial |V_i|}$

$$\frac{\partial P_K}{\partial |V_i|} = 0 + |V_K| \left(G_{Ki}\cos(\delta_K - \delta_i) + B_{Ki}\sin(\delta_K - \delta_i) \right)$$

$$\frac{\partial P_K}{\partial |V_i|} = |V_K| \left(G_{Ki}\cos(\delta_K - \delta_i) + B_{Ki}\sin(\delta_K - \delta_i) \right) \rightarrow (8)$$

J4 Elements

diagonal Elements $= \frac{\partial Q_K}{\partial |V_K|}$

$$\frac{\partial Q_K}{\partial |V_K|} = -2|V_K|B_{KK} + \sum_{\substack{i=1 \\ i \neq K}}^{n} |V_i| \left(G_{Ki}\sin(\delta_K - \delta_i) - B_{Ki}\cos(\delta_K - \delta_i) \right)$$

$$|V_K| \frac{\partial Q_K}{\partial |V_K|} = -2|V_K|^2 B_{KK} + \sum_{\substack{i=1 \\ i \neq K}}^{n} |V_K||V_i| \left(G_{Ki}\sin(\delta_K - \delta_i) - B_{Ki}\cos(\delta_K - \delta_i) \right)$$

$$|V_K| \frac{\partial Q_K}{\partial |V_K|} = \left(-|V_K|^2 B_{KK} + Q_K \right) \rightarrow (9)$$

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Off diagonal Elements $= \frac{\partial Q_K}{\partial |V_i|}$

$$\frac{\partial Q_K}{\partial |V_i|} = \sum_{\substack{\cancel{i=1} \\ i \neq K}} |V_K| \left(G_{Ki}\sin(\delta_K - \delta_i) - B_{Ki}\cos(\delta_K - \delta_i) \right)$$

$$\frac{\partial Q_K}{\partial |V_i|} = |V_K| \left[\left(G_{Ki}\sin(\delta_K - \delta_i) - B_{Ki}\cos(\delta_K - \delta_i) \right) \right] \rightarrow (10)$$

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$$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_1 & J_2 \\ J_3 & J_4 \end{bmatrix} \begin{bmatrix} \Delta \delta \\ \frac{\Delta |V|}{|V|} \end{bmatrix} = \begin{bmatrix} \frac{\partial P}{\partial \delta} & \frac{\partial P}{\partial |V|}|V| \\ \frac{\partial Q}{\partial \delta} & \frac{\partial Q}{\partial |V|}|V| \end{bmatrix} \begin{bmatrix} \Delta \delta \\ \frac{\Delta |V|}{|V|} \end{bmatrix}$$

[B] The advantages and limitations of G-S method.

advantages:

(1) G-S method is very useful for smaller systems

(2) It is easily adoptable

(3) very efficient ~~to~~ the system have less no of buses

Limitations:

fails to converge in following cases.

i) system having large number of buses.

ii) system with heavily loaded lines.

iii) system with short and long transmission lines terminating on same bus

iv) system with negative value of transfer admittance in large system.

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[C] Given:-

$$F_1 = 1.5 + 20P_{G1} + 0.1P_{G1}^2$$

$$F_2 = 1.9 + 30P_{G2} + 0.1P_{G2}^2$$

$$P_{G1} + P_{G2} = P_D = 200\,MW$$

$$\lambda = \frac{dF_1}{dP_{G1}} = 20 + 0.2P_{G1}$$

$$\lambda = \frac{dF_2}{dP_{G2}} = 30 + 0.2P_{G2}$$

$$\frac{dF_1}{dP_{G1}} = \frac{dF_2}{dP_{G2}}$$

$$20 + 0.2P_{G1} = 30 + 0.2P_{G2}$$

$$P_{G1} = 200 - P_{G2}$$

$$20 + 0.2(200 - P_{G2}) = 30 + 0.2P_{G2}$$

$$20 + 40 - 0.2P_{G2} = 30 + 0.2P_{G2}$$

$$30 = 0.4P_{G2}$$

$$P_{G2} = \frac{30}{0.4}$$

$$\boxed{P_{G2} = 75\ mw}$$

6

$$P_{G1} = 200 - P_{G2}$$

$$= 200 - 75$$

$$\boxed{P_{G1} = 125\ mw}$$

$$\lambda = 30 + 0.2P_{G2}$$

$$= 30 + 0.2(75)$$

$$\boxed{\lambda = 45\ \cancel{\$}\ Rs/mwh}$$

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4

A)

Gauss-Seidal method	Newton-Raphson method.
1. Time taken to perform 1st iteration is less	1. Time taken to perform 1st iteration is more.
2. Number of iteration required to reach desired value is more	2. Number of iterations required to reach desired value is less.
3. Interations increases with size of the system	4. Interations are carried 3 to 5 irrespective of size of the system.
4. programming is easy	4 programming is difficult
5. It is applicable for the smaller system	5. It is applicable for the large system.
6. Linear convergence and hence rate of convergence is slow	6. Quadratic convergence and hence rate of convergence is fast.

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B) The iterative algorithm for N-R method in polar coordinates

1. Formulate Y bus
2. Assume initial voltage value $1\angle 0°$ for PQ and $|V_{specified}| \angle \delta°$, $\delta° = 0°$ for PV
3. At $(r+1)$th interation calculate $P_K^{(r+1)}$ for all PV and PQ buses and $Q_K^{(r+1)}$ for all PQ buses using voltage values from previous iteration formulas are.

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$$P_{K(calcu)}^{(r+1)} = |V_K|^2 G_{KK} + \sum_{\substack{i=1 \\ i \neq K}}^{n} |V_K||V_i| \left(G_{Ki}\cos(\delta_K - \delta_i) + B_{Ki}\sin(\delta_K - \delta_i)\right)$$

$$Q_{K(calcu)}^{(r+1)} = -|V_K|^2 B_{KK} + \sum_{\substack{i=1 \\ i \neq K}}^{n} |V_K||V_i| \left(G_{Ki}\sin(\delta_K - \delta_i) - B_{Ki}\cos(\delta_K - \delta_i)\right)$$

4. calculate the power mismatch

$$\Delta P_K^{(r)} = P_K(\text{specified}) - P_K^{(r+1)}(\text{calculated})$$

$$\Delta Q_K^{(r)} = Q_K(\text{specified}) - Q_K^{(r+1)}(\text{calculated})$$

5. calculate Jaccobian matrix

6. compute

$$\begin{bmatrix} \Delta\delta^{(r)} \\ \dfrac{\Delta|V|^{(r)}}{|V|} \end{bmatrix} = [J]^{-1} \begin{bmatrix} \Delta P^{(r)} \\ \Delta Q^{(r)} \end{bmatrix}$$

7 update the variables as follows

$$\delta_K^{(r+1)} = \delta_K^{(r)} + \Delta\delta_K^{(r)}$$

$$|V_K|^{(r+1)} = |V_K|^{(r)} + \Delta|V_K|^{(r)}$$

8. Go to step 3. continue the steps still the power mismatch values are within the Expected tolerance value.

8

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[C] Given :- $F_1 = 400 + 6.0P_{G1} + 0.004P_{G1}^2$ $F_2 = 500 + b_2P_{G2} + C_2 P_{G2}^2$

(i) $\lambda = 8\ \$/mwh$

$P_D = 550\ mw$

$$P_{G1} = \frac{\lambda - b_1}{2C_1}$$

$$= \frac{8 - 6.0}{2(0.004)}$$

$$\boxed{P_{G1} = 250\ mw}$$

$P_{G1} + P_{G2} = 550$

$P_{G2} = 550 - 250$

$$\boxed{P_{G2} = 300\ mw}$$

(ii) $\lambda = 10\ \$/mwh$

$P_D = P_{G1} + P_{G2} = 1300\ mw$

$$P_{G1} = \frac{\lambda - b_1}{2C_1} = \frac{10-6}{2(0.004)} = 500\ MW$$

$P_{G2} = 1300 - P_{G1}$

$= 1300 - 500$

$$\boxed{P_{G2} = 800\ mw}$$

(iii) For $P_{G2} = 300\ mw$

$$P_{G2} = \frac{\lambda - b_2}{2C_2}$$

$300 \times 2C_2 = \lambda - b_2$

$600C_2 = 8 - b_2$

$b_2 + 600C_2 = 8 \rightarrow ①$

For $P_{G2} = 800$ MW

$$P_{G2} = \frac{\lambda - b_2}{2C_2}$$

$$800 \times 2C_2 = \lambda - b_2$$

$$1600C_2 + b_2 = 10 \rightarrow ②$$

$$\cancel{b_2} + 600C_2 = 8$$

$$(-)\ \cancel{b_2} \underset{(-)}{+} 1600C_2 = \underset{(-)}{10}$$

$$+1000C_2 = +2$$

$$C_2 = \frac{2}{1000}$$

$$\boxed{C_2 = 0.002}$$

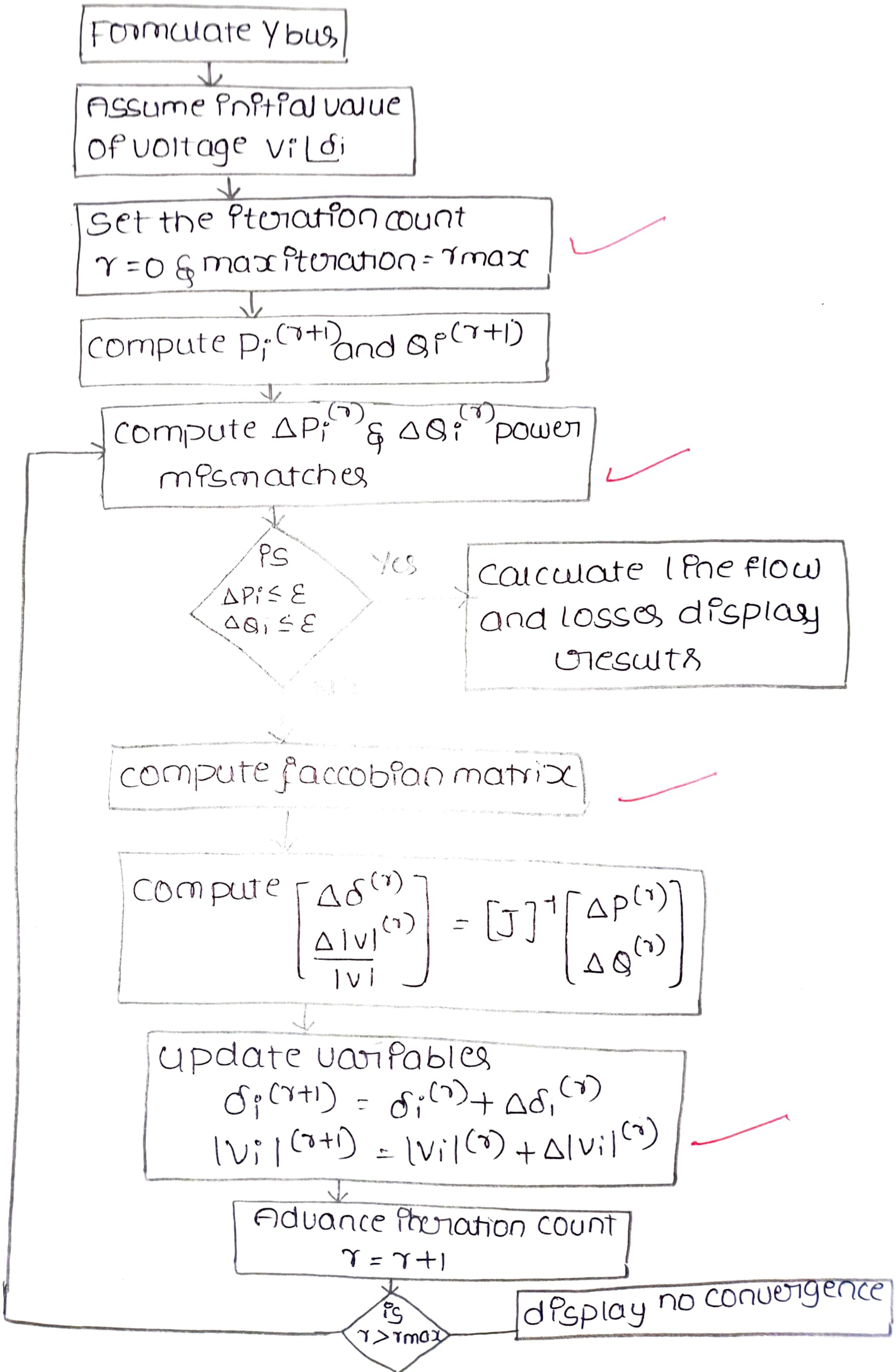
$$b_2 = 10 - 1600(0.002)$$

$$\boxed{b_2 = 6.8}$$

-10-

3.

A) Flowchart of N-R method in polar coordinates.



7

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[B] optimal generation scheduling neglecting transmission losses and generator limits

To minimize the cost of the plant

Such that $\sum_{i=1}^{ng} P_{Gi} = P_D \rightarrow (1)$

where, P_{Gi} = Generation power in plant i

P_D = load demand.

$$F_T = \sum_{i=1}^{ng} F_i$$

where, F_T = Total cost

F_i = cost of the plant i

It is a constrained optimization problem and can be solved by lagranges method

$$\mathcal{L} = F_t + \lambda\left[P_D - \sum_{i=1}^{ng} P_{Gi}\right]$$

minimum is obtained at the condition

$$\frac{\partial \mathcal{L}}{\partial P_{Gi}} = 0 \quad \text{and} \quad \frac{\partial \mathcal{L}}{\partial \lambda} = 0$$

$$\frac{\partial \mathcal{L}}{\partial P_{Gi}} = \frac{\partial F_t}{\partial P_{Gi}} + \lambda[0-1]$$

$$0 = \frac{\partial F_t}{\partial P_{Gi}} - \lambda$$

$$\frac{\partial F_t}{\partial P_{Gi}} = \lambda$$

$$\frac{\partial f}{\partial \lambda} = 0 + P - \sum_{i=1}^{ng} P_{Gi}$$

$$P = \sum_{i=1}^{ng} P_{Gi}$$

$$\frac{\partial F_t}{\partial P_{Gi}} = \frac{\partial F_i}{\partial P_{Gi}} = \lambda$$

$$\frac{\partial F_t}{\partial P_{Gi}} = \frac{dF_i}{dP_{Gi}} = \lambda$$

$$F_i = a_i + b_i P_{Gi} + c_i P_{Gi}^2$$

$$\frac{dF_i}{dP_{Gi}} = b_i + 2c_i P_{Gi}$$

$$\sum_{i=1}^{ng} P_{Gi} = P_D$$

-8-

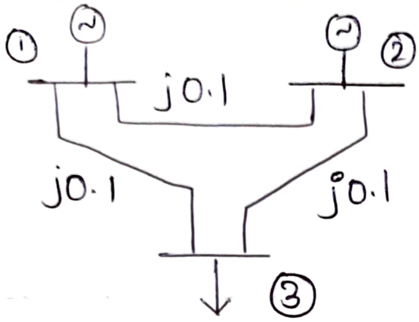
$$P_{Gi} = \frac{\lambda - b_i}{2c_i}$$

$$\sum_{i=1}^{ng} \frac{\lambda - b_i}{2c_i} = P_D$$

$$\sum_{i=1}^{ng} \frac{\lambda}{2c_i} - \sum_{i=1}^{ng} \frac{b_i}{2c_i} = P_D$$

$$\boxed{\lambda = \frac{P_D + \sum_{i=1}^{ng} \frac{b_i}{2c_i}}{\sum_{i=1}^{ng} \frac{1}{2c_i}}}$$

[C]



$Y_{11} = -20i$

$Y_{22} = Y_{33} = -20i$

$Y_{12} = Y_{21} = Y_{31} = Y_{32} = Y_{13} = Y_{23} = -10i$

$$Y_{bus} = \begin{bmatrix} Y_{11} & -Y_{12} & -Y_{13} \\ -Y_{21} & Y_{22} & -Y_{23} \\ -Y_{31} & -Y_{32} & Y_{33} \end{bmatrix}$$

$$= \begin{bmatrix} -j20 & j10 & j10 \\ j10 & -j20 & j10 \\ j10 & j10 & -j20 \end{bmatrix}$$

$$V_3^{(1)} = \frac{1}{Y_{33}} \left[\frac{P_3 - jQ_3}{V_3^{*(r)}} - [Y_{31}V_1 + Y_{32}V_2] \right]$$

$$= \frac{1}{-j20} \left[\frac{0.5 - j0.2}{1\angle 0^\circ} - [j10(1) + j10(1)] \right]$$

$$= 1.01 + 0.025i$$

$$\boxed{V_3^{(1)} = 1.010309 \angle 1.4179^\circ}$$

$$V_{3(\text{accelerated})}^{(1)} = V_3^{(0)} + \alpha \left[V_3^{(1)} - V_3^{(0)} \right]$$

$$= 1.0 + 1.6 [1.01 + 0.025i - 1]$$

$$= 1.016 + 0.04i$$

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$$\boxed{V_3^{(1)}(\text{accelerated}) = 1.01678\angle 2.254^\circ}$$

-10-

Kus 29/12/21

50/50

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IA-3

1. c) Equal loads.

2. d) All of the above

3. c) penalty factor.

4. c) fuel Efficiency

5. b) lagrange's

6. c) (m+1) x (m+1)

7. b) Remains unchanged.

8. a) fuel cost

9. d) 1.25

10. b) point by point method.

08/10

27/1/22

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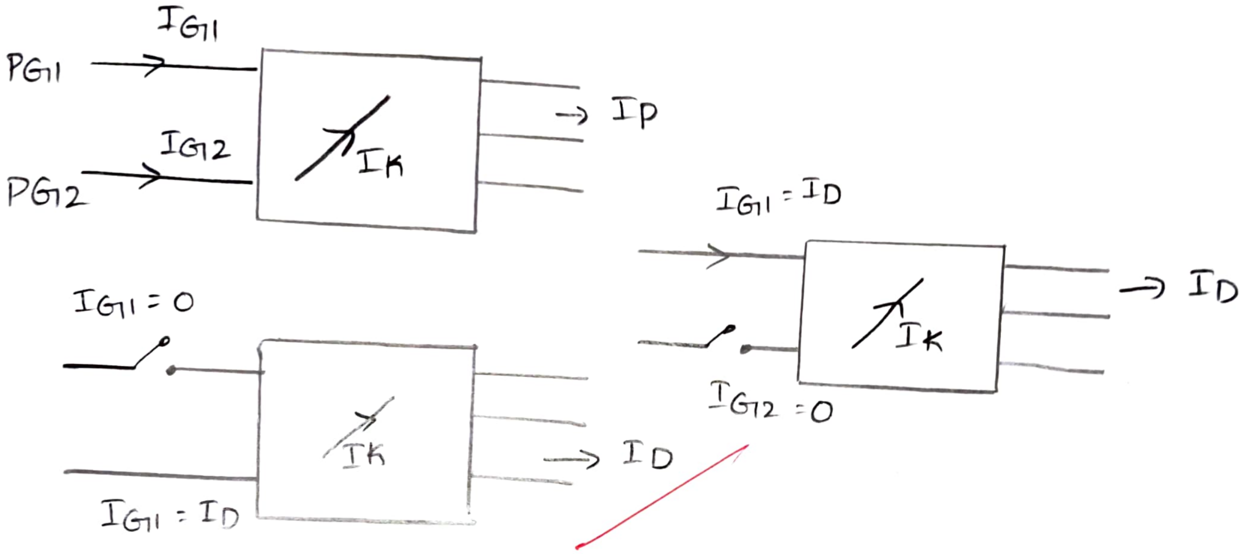
2)

a)



The current distribution factors

$$N_{K1} = \frac{I_{K1}}{I_D} = \frac{I_{K1}}{I_{G1}}$$

$$N_{K2} = \frac{I_{K2}}{I_D} = \frac{I_{K2}}{I_{G2}}$$

The total current in the system by using superposition theorem

$$I_K = I_{K1} + I_{K2}$$

$$= N_{K1} I_{G1} + N_{K2} I_{G2}$$

$$I_{G1} = |I_{G1}| \angle \sigma_1$$

$$I_{G2} = |I_{G2}| \angle \sigma_2$$

$$I_{G1} = |I_{G1}| \cos\sigma_1 + j \sin\sigma_1 |I_{G1}|$$

$$I_{G2} = |I_{G2}| \cos\sigma_2 + j |I_{G2}| \sin\sigma_2$$

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$$I_K = N_{K1}(|I_{G1}|\cos\sigma_1 + j|I_{G1}|\sin\sigma_1) + N_{K2}($$
$$(|I_{G2}|\cos\sigma_2 + j|I_{G2}|\sin\sigma_2)$$

$$I_K = (N_{K1}|I_{G1}|\cos\sigma_1 + N_{K2}|I_{G2}|\cos\sigma_2) + j($$
$$N_{K1}|I_{G1}|\sin\sigma_1 + N_{K2}|I_{G2}|\sin\sigma_2)$$

$$I_K^2 = N_{K1}^2|I_{G1}|^2 + N_{K2}^2|I_{G2}|^2 + 2N_{K1}N_{K2}|I_{G1}|$$
$$|I_{G2}|(\cos\sigma_1\cos\sigma_2 + \sin\sigma_1\sin\sigma_2)$$

$$I_K^2 = N_{K1}^2|I_{G1}|^2 + N_{K2}^2|I_{G2}|^2 + 2N_{K1}N_{K2}|I_{G1}||I_{G2}|$$
$$\cos(\sigma_1 - \sigma_2)$$

$$P_{G1} = \sqrt{3}V_1 I_{G1}\cos\phi_1$$
$$P_{G2} = \sqrt{3}V_2 I_{G2}\cos\phi_2$$

$$I_{G1} = \frac{P_{G1}}{\sqrt{3}V_1\cos\phi_1} \qquad I_{G2} = \frac{P_{G2}}{\sqrt{3}V_2\cos\phi_2}$$

$$P_L = \sum_K 3|I_K|^2 R_K$$

$$I_K^2 = N_{K1}^2\left[\frac{P_{G1}^2}{3V_1^2\cos^2\phi_1}\right] + N_{K2}^2\left[\frac{P_{G2}^2}{3V_2^2\cos^2\phi_2}\right] + 2N_{K1}N_{K2}$$
$$\frac{P_{G1}P_{G2}}{3V_1V_2\cos\phi_1\cos\phi_2}\cos(\sigma_1 - \sigma_2)$$

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$$P_L = \frac{P_{G1}^2}{V_1^2\cos^2\phi_1}\sum_K N_{K1}^2 R_K + \frac{P_{G2}^2}{V_2^2\cos^2\phi_2}\sum_K N_{K2}^2 R_K + 2\frac{P_{G1}P_{G2}\cos(\sigma_1-\sigma_2)}{V_1V_2\cos\phi_1\cos\phi_2}\sum_K N_{K1}N_{K2}R_K$$

$$\boxed{P_L = P_{G1}^2 B_{11} + P_{G2}^2 B_{22} + 2P_{G1}P_{G2}B_{12}}$$

where,
$$B_{11} = \frac{1}{V_1^2\cos^2\phi_1}\sum_K N_{K1}^2 R_K$$

$$B_{22} = \frac{1}{V_2^2\cos^2\phi_2}\sum_K N_{K2}^2 R_K$$

$$B_{12} = \frac{\cos(\sigma_1-\sigma_2)}{V_1V_2\cos\phi_1\cos\phi_2}\sum_K N_{K1}N_{K2}R_K.$$

For 'n' number of plants

$$P_L = P_{G1}^2 B_{11} + P_{G2}^2 B_{22} + \cdots + P_{Gn}^2 B_{nn} + 2\sum_{\substack{p=1\\q=1\\p\neq q}}^{n} P_{Gp}P_{Gq}B_{pq}$$

$$P_L = \sum_{p=1}^{n}\sum_{q=1}^{n} P_{Gp}P_{Gq}B_{pq}$$

$$B_{pq} = \frac{\cos(\sigma_1-\sigma_2)}{V_1V_2\cos\phi_1\cos\phi_2}\sum_K N_{K1}N_{K2}R_K$$

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b) Priority list method

It is the simplest unit commitment solution which create a priority list

Full load average production cost = net heat rate at full load x fuel.

Cost consumption:

* No load cost is zero
* Unit Input and output characteristics are linear between zero output and full load.
* Startup cost are fixed amount
* ignore minimum startup and maximum down time.

Steps to be followed.

1. determine the full load average production cost of all the unit
2. form the priority order based on the average production
3. Commit the number of solutions corresponding to priority list
4. Calculate P_{G1}, P_{G2}, P_{Gn} from Economic dispatch problem for only feasiable combinations.
5. For the load curve, Assume load is dropping. determine whether dropping the next unit will supply generation and spinning reserve. if not continue as it is if yes go to next step.

6. calculate the number of hours H before the unit is needed again.

7. check H < maximum shutdown if not go to last bus if yes go to next step.

8. calculate the two cost one is sum of hourly production for next H hours with up unit and second is recalculating the same unit with down + startup for cooling or banking.

9. repeat the procedure till the priority.

merits :

* ignore minimum up and down time.
* complications are reduced.
* Take only one constraint
* No need go for N combinations.

8

demerits :-

* Start up cost are fixed amount
* No load cost are not considered.

[c] **Given :-**

$$\frac{\partial F_1}{\partial P_{G1}} = 0.01 P_{G1} + 20$$

$$\frac{\partial F_2}{\partial P_{G2}} = 0.015 P_{G2} + 22.5$$

$$P_{G1} = P_{G2} = 100 \, MW$$

$$\frac{\partial P_L}{\partial P_{G2}} = 0.2$$

$$\lambda = \frac{dF_1}{dP_{G1}}\left[\frac{1}{1-\frac{\partial P_L}{\partial P_{G1}}}\right]$$

$$\lambda = \frac{dF_2}{dP_{G2}}\left[\frac{1}{1-\frac{\partial P_L}{P_{G2}}}\right]$$

$$= 0.015(100)+22.5\left[\frac{1}{1-0.2}\right]$$

$$= \frac{0.015(100)+22.5\,(1.25)}{\cancel{1.25}}$$

$$\boxed{\lambda = \cancel{19.2}\quad 30}$$

$$\lambda = \frac{dF_1}{P_{G1}}\,L_1$$

$$L_1 = \frac{\cancel{19.2}\ 30}{0.01(100)+20}$$

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$$\boxed{L_1 = \cancel{0.9142}\ \cancel{1.4925}\ 1.4285}$$

$$L_1 = \frac{1}{1-\frac{\partial P_L}{\partial P_{G1}}}$$

$$\frac{\partial P_L}{\partial P_{G1}} = 1-\frac{1}{L_1} = \cancel{1-\frac{1}{0.9142}}$$

$$= 1-\frac{1}{1.4285}$$

$$= 0.29996 \simeq 0.3$$

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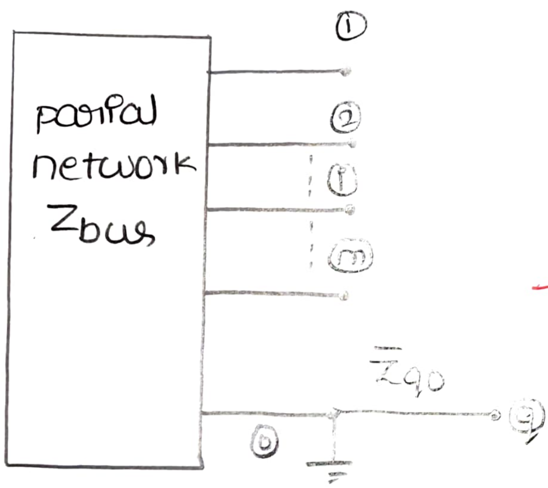
$$\boxed{\frac{\partial P_L}{\partial P_{G1}} = 0.3}$$

3.

A) The building algorithm for finding the Elements of Zbus

case1 : when a branch is added between the newnode and reference node.

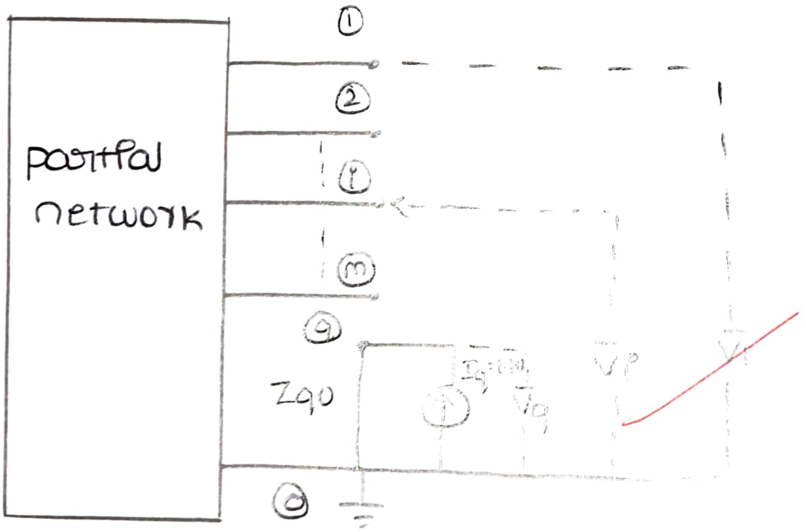


when a branch is added between the new node 'q' and reference node '0'. adding a new node to the partial network changes size of original matrix $\bar{Z}_{bus}$ to $(m+1)\times(m+1)$ with new row and new column corresponding to 'q' bus node.

The current source $\bar{I}_q = 1.0$ pu connected to 'q' node with all other bus open circuited the voltage is $\bar{V}_q$

$$\bar{V}_q = \bar{Z}_{q0}\bar{I}_q$$

$$
\begin{bmatrix} \bar{V}_1 \\ \bar{V}_2 \\ \vdots \\ \bar{V}_p \\ \vdots \\ \bar{V}_m \\ \hline \bar{V}_q \end{bmatrix}
=
\left[\begin{array}{ccccccc|c}
\bar{Z}_{11} & \bar{Z}_{12} & \cdots & \bar{Z}_{1p} & \cdots & Z_{1m} & & \bar{Z}_{1q} \\
\bar{Z}_{21} & \bar{Z}_{22} & \cdots & \bar{Z}_{2p} & \cdots & \bar{Z}_{2m} & & \bar{Z}_{2q} \\
\vdots & \vdots & & \vdots & & \vdots & & \vdots \\
\bar{Z}_{p1} & \bar{Z}_{p2} & \cdots & \bar{Z}_{pp} & \cdots & \bar{Z}_{pm} & & \bar{Z}_{pq} \\
\vdots & \vdots & & \vdots & & \vdots & & \vdots \\
\bar{Z}_{m1} & \bar{Z}_{m2} & \cdots & \bar{Z}_{mp} & & \bar{Z}_{mm} & & \bar{Z}_{mq} \\
\hline
\bar{Z}_{q1} & \bar{Z}_{q2} & \cdots & \bar{Z}_{qp} & \cdots & \bar{Z}_{qm} & & \bar{Z}_{qq}
\end{array}\right]
\begin{bmatrix} \bar{I}_1 \\ \bar{I}_2 \\ \bar{I}_p \\ \vdots \\ \bar{I}_m \\ \hline \bar{I}_q \end{bmatrix}
$$



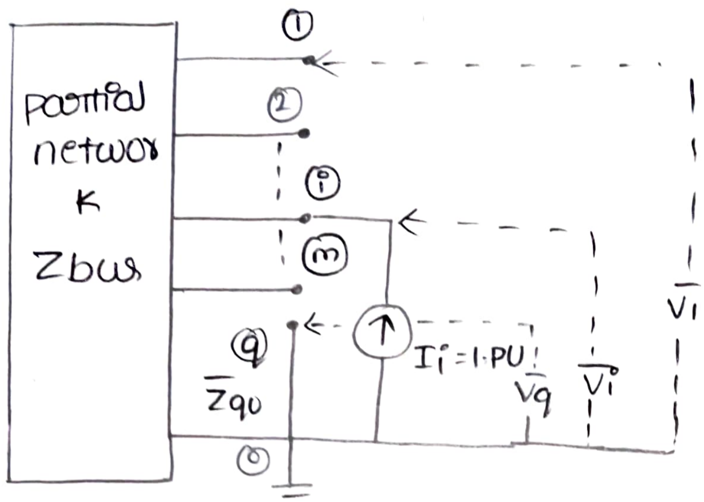
For calculating $\bar{Z}_{qq}$:

$$\bar{Z}_{qq} = \frac{\bar{V}_q}{\bar{I}_q} \Bigg|_{\bar{I}_k = 0 \ \forall\ k = 1, 2 \ldots m}$$

$$\boxed{\bar{Z}_{qq} = \bar{Z}_{q0}}$$

For calculating $\bar{Z}_{qi}$:

$$Z_{qi} = \frac{\bar{V}_q}{\bar{I}_i} \Bigg|_{\bar{I}_k = 0 \ \forall\ k = 1, 2, \ldots m}$$



The current source $I_i = 1 \cdot PU$ connected to the ith bus voltage $\bar{V}_q = 0$

$$\boxed{\bar{Z}_{qi} = 0}$$

it implied that the offdiagonal elements $\bar{Z}_{1q}, \bar{Z}_{2q}, \bar{Z}_{pq}, \bar{Z}_{mq}$ and $\bar{Z}_{q1}, \bar{Z}_{q2}, \bar{Z}_{qp}, \bar{Z}_{qm}$ are equal to zero

The modified Z bus is

$$Z_{bus} = \left[\begin{array}{cccc|c} \bar{Z}_{11} & \bar{Z}_{12} \cdots \bar{Z}_{1p} & \cdots & \bar{Z}_{1m} & 0 \\ \bar{Z}_{21} & \bar{Z}_{22} \cdots \bar{Z}_{2p} & \cdots & \bar{Z}_{2m} & 0 \\ \bar{Z}_{p1} & \bar{Z}_{p2} \cdots \bar{Z}_{pp} & \cdots & \bar{Z}_{pm} & 0 \\ \bar{Z}_{m1} & \bar{Z}_{m2} \cdots \bar{Z}_{mp} & \cdots & \bar{Z}_{mm} & 0 \\ \hline 0 & 0 & 0 & 0 & \bar{Z}_{q0} \end{array}\right]$$

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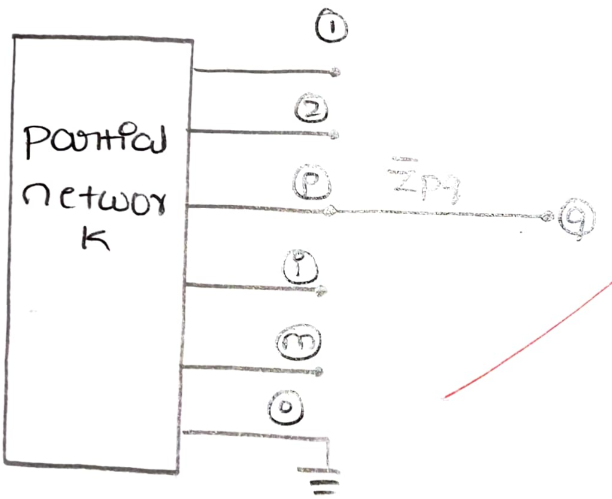
Case 2 :- Addition of branch b/w new node and Existing node.

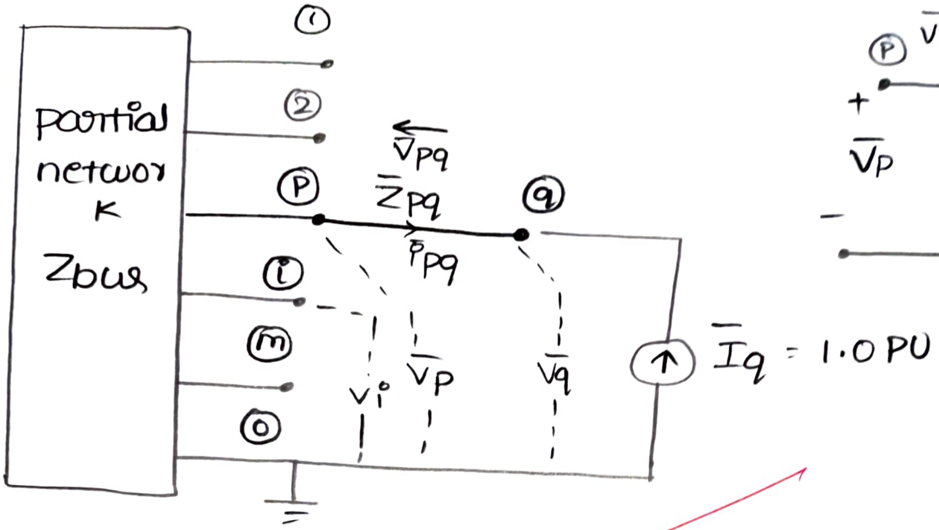
Adding a branch with impedance $\bar{Z}_{pq}$ between Existing node 'p' and new node 'q'. Addition of new node to the partial network changes the size of Z_{bus} to $(m+1) \times (m+1)$ with new row and new column corresponding to 'q' node.

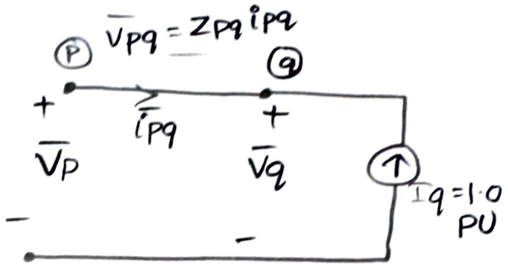


For calculating $\bar{Z}_{qq}$

$$\begin{bmatrix} \bar{V}_1 \\ \bar{V}_2 \\ \vdots \\ \bar{V}_p \\ \vdots \\ \bar{V}_m \\ \hline \bar{V}_q \end{bmatrix} = \left[\begin{array}{ccccccc|c} \bar{Z}_{11} & \bar{Z}_{12} & \cdots & \bar{Z}_{1p} & \cdots & \bar{Z}_{1m} & & \bar{Z}_{1q} \\ \bar{Z}_{21} & \bar{Z}_{22} & \cdots & \bar{Z}_{2p} & \cdots & \bar{Z}_{2m} & & \bar{Z}_{2q} \\ \vdots & \vdots & & \vdots & & \vdots & & \\ \bar{Z}_{p1} & \bar{Z}_{p2} & \cdots & \bar{Z}_{pp} & \cdots & \bar{Z}_{pm} & & \bar{Z}_{pq} \\ \vdots & \vdots & & \vdots & & \vdots & & \\ \bar{Z}_{m1} & \bar{Z}_{m2} & \cdots & \bar{Z}_{mp} & \cdots & \bar{Z}_{mm} & & \bar{Z}_{mq} \\ \hline \bar{Z}_{q1} & \bar{Z}_{q2} & \cdots & \bar{Z}_{qp} & \cdots & \bar{Z}_{qm} & & \bar{Z}_{qq} \end{array}\right] \begin{bmatrix} \bar{I}_1 \\ \bar{I}_2 \\ \vdots \\ \bar{I}_p \\ \vdots \\ \bar{I}_m \\ \hline \bar{I}_q \end{bmatrix}$$

$$\bar{V}_p - \bar{V}_q = \bar{Z}_{pq}\, \bar{i}_{pq}$$





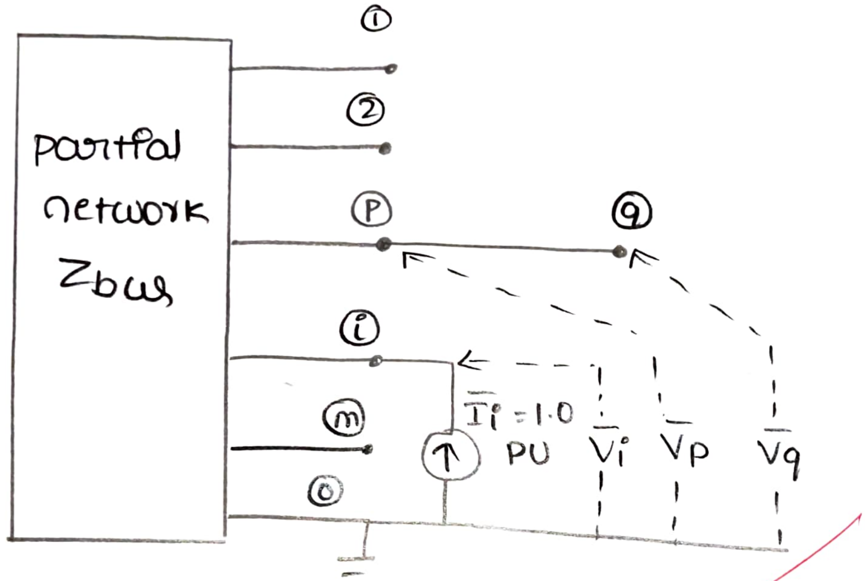
The current source $\bar I_q = 1.0$ pu connected to 'q' node with all other buses open circuited. the voltage $\bar V_q$ computed is

$$\bar V_1 = \bar Z_{1q} \bar I_q = \bar Z_{1q}$$
$$\bar V_2 = \bar Z_{2q} \bar I_q = \bar Z_{2q}$$
$$\bar V_p = \bar Z_{pq} \bar I_q = \bar Z_{pq}$$
$$\bar V_q = \bar Z_{qq} \bar I_q = \bar Z_{qq}$$
$$\bar V_m = \bar Z_{mq} \bar I_q = \bar Z_{mq}$$

$$\bar V_p - \bar V_q = \bar Z_{pq} i_{pq} \qquad i_{pq} = -\bar I_q = -1\,P.U$$
$$V_q = \bar V_p + \bar Z_{pq} \bar I_q$$
$$V_q = \bar Z_{pq} + \bar Z_{pq}$$
$$\boxed{\bar Z_{qq} = \bar Z_{pq} + \bar Z_{pq}}$$

The current source $\bar I_i = 1.0$ pu connected to i^{th} bus with all other buses open circuited. $\bar V_q$ is computed.

For calculating Z_{qi}



$$\bar{Z}_{qi} = \left.\frac{\bar{V}_q}{\bar{I}_i}\right|_{\bar{I}_k = 0 \quad k = 1, 2, \ldots m}$$

$$\bar{V}_1 = \bar{Z}_{1i}\bar{I}_i = \bar{Z}_{1i}$$

$$\bar{V}_2 = \bar{Z}_{2i}\bar{I}_i = \bar{Z}_{2i}$$

$$\bar{V}_B = \bar{Z}_{pi}\bar{I}_i = \bar{Z}_{pi}$$

$$\bar{V}_q = \bar{Z}_{qi}\bar{I}_i = \bar{Z}_{qi}$$

$$\bar{V}_m = Z_{mi}I_i = \bar{Z}_{mi}$$

$$\bar{V}_p = \bar{V}_q$$

$$\boxed{Z_{qi} = Z_{pi}}$$

The modified Z bus is

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$$Z_{bus} = \left[\begin{array}{cccccc|c} \bar{Z}_{11} & \bar{Z}_{12} & \cdots & \bar{Z}_{1p} & \cdots & \bar{Z}_{1m} & \bar{Z}_{1p} \\ \bar{Z}_{21} & \bar{Z}_{22} & \cdots & \bar{Z}_{2p} & \cdots & \bar{Z}_{2m} & \bar{Z}_{2p} \\ \bar{Z}_{p1} & \bar{Z}_{p2} & \cdots & \bar{Z}_{pp} & \cdots & \bar{Z}_{pm} & \bar{Z}_{pp} \\ \bar{Z}_{m1} & \bar{Z}_{m2} & \cdots & \bar{Z}_{mp} & \cdots & \bar{Z}_{mm} & \bar{Z}_{mp} \\ \hline \bar{Z}_{p1} & \bar{Z}_{p2} & \cdots & \bar{Z}_{pp} & \cdots & \bar{Z}_{pm} & \bar{Z}_{pq}+\bar{Z}_{pq} \end{array}\right]$$

[B] The formula for Runge-Kutta method for fourth order approximation for two simultaneous differential equation.

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

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

Starting with initial conditions x_0, y_0, t_0 with step size h

$$x_1 = x_0 + \frac{1}{6}[k_1 + 2k_2 + 2k_3 + k_4]$$

$$y_1 = y_0 + \frac{1}{6}[k_1 + 2k_2 + 2k_3 + k_4]$$

$$k_1 = f_x(x_0, y_0, t_0)h$$

$$k_2 = f_x\left(x_0 + \frac{k_1}{2}, y_0 + \frac{l_1}{2}, t_0 + \frac{h}{2}\right)h$$

$$k_3 = f_x\left(x_0 + \frac{k_2}{2}, y_0 + \frac{l_2}{2}, t_0 + \frac{h}{2}\right)h$$

$$k_4 = f_x(x_0 + k_3, y_0 + l_3, t_0 + h)h$$

$$l_1 = f_y(x_0, y_0, t_0)h$$

$$l_2 = f_y\left(x_0 + \frac{K_1}{2}, y_0 + \frac{l_1}{2}, t_0 + \frac{h}{2}\right)h$$

$$l_3 = f_y\left(x_0 + \frac{K_2}{2}, y_0 + \frac{l_2}{2}, t_0 + \frac{h}{2}\right)h$$

$$l_4 = f_y(x_0 + K_3, y_0 + l_3, t_0 + h)h.$$

The first order solution can be solved by Solution of Swing Equation.

$$\frac{d\delta}{dt} = \omega$$

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

Starting with initial conditions ω_0, δ_0, t_0 with Step size Δt

$$K_1 = \omega_0 \Delta t$$

$$K_2 = \left(\omega_0 + \frac{l_1}{2}\right)\Delta t$$

$$K_3 = \left(\omega_0 + \frac{l_2}{2}\right)\Delta t$$

$$K_4 = (\omega_0 + K_3)\Delta t$$

$$l_1 = \left[\frac{P_m - P_{max}\sin\delta_0}{M}\right]\Delta t$$

$$l_2 = \left[\frac{P_m - P_{max}\sin\left(\delta_0 + \frac{K_1}{2}\right)}{M}\right]\Delta t$$

$$k_3 = \left[\frac{P_m - P_{max}\sin\left(\delta_0 + \frac{k_2}{2}\right)}{M}\right]\Delta t$$

$$k_4 = \left[\frac{P_m - P_{max}\sin(\delta_0 + k_3)}{M}\right]\Delta t$$

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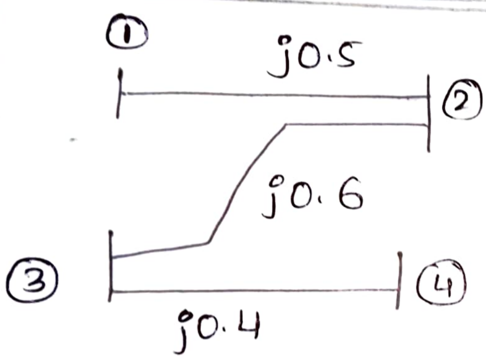
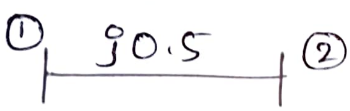
$$\delta_1 = \delta_0 + \frac{1}{6}(k_1 + 2k_2 + 2k_3 + k_4)$$

$$\omega_q = \omega_0 + \frac{1}{6}(k_1 + 2k_2 + 2k_3 + k_4)$$

[C]

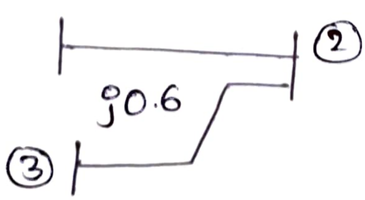


Step ①



$$Z_{bus}^{new} = [j0.5]$$

Step ②



$p = 2,\ q = 3,\ i = 2$

$$Z_{bus}^{new} = \begin{bmatrix} j0.5 & Z_{2q} \\ Z_{q2} & Z_{qq} \end{bmatrix}$$

$$Z_{2q} = Z_{q2}$$

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

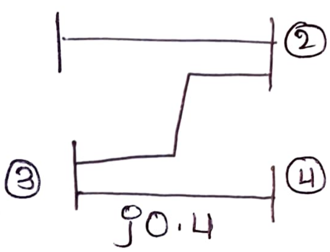
$$Z_{q2} = Z_{p2}$$

$$Z_{32} = Z_{22} = j0.5$$

$$Z_{qq} = \bar{Z}_{pq} + z_{pq}$$
$$= Z_{23} + z_{pq}$$
$$= j0.5 + j0.6$$
$$= j1.1$$

$$Z_{bus}^{new} = \begin{array}{c} \\ 2 \\ 3 \end{array}\begin{array}{c} \begin{array}{cc} 2 & \quad 3 \end{array} \\ \begin{bmatrix} j0.5 & j0.5 \\ j0.5 & j1.1 \end{bmatrix} \end{array}$$

Step 3



$p = 3,\ q = 4 \quad i = 2, 3$

$$Z_{bus}^{new} = \begin{bmatrix} j0.5 & j0.5 & \bar{Z}_{2q} \\ j0.5 & j1.1 & \bar{Z}_{3q} \\ \bar{Z}_{q2} & \bar{Z}_{q3} & Z_{qq} \end{bmatrix}$$

$$Z_{qi} = Z_{pi}$$
$$Z_{q2} = Z_{p2}$$
$$Z_{42} = Z_{32} = j0.5$$

$$Z_{q3} = Z_{p3}$$
$$Z_{43} = Z_{33} = j1.1$$

$$Z_{qq} = Z_{pq} + z_{pq}$$
$$= Z_{34} + j0.4$$
$$= j1.1 + j0.4$$
$$= j1.5$$

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$$Z_{bus}^{new} = \begin{bmatrix} j0.5 & j0.5 & j0.5 \\ j0.5 & j1.1 & j1.1 \\ j0.5 & j1.1 & j1.5 \end{bmatrix}$$

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50/50

27/1/22