LOAD FLOW SOLUTION FOR MESHED DISTRIBUTION NETWORKS

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Bachelor of Technology in "Electrical Engineering"

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CERTIFICATE

This is to certify that the thesis entitled "**Load Flow Solution For Meshed Distribution Networks**", submitted by **Durgit Kumar (Roll. No. 109EE0275) and Shwetank Agrawal (Roll. No. 109EE0248)** in partial fulfilment of the requirements for the award of **Bachelor of Technology** in **Electrical Engineering** during session 2012-2013 at National Institute of Technology, Rourkela. A bonafide record of research work carried out by them under my supervision and guidance.

The candidates have fulfilled all the prescribed requirements.

The Thesis which is based on candidates' own work, have not submitted elsewhere for a degree/diploma.

In my opinion, the thesis is of standard required for the award of a bachelor of technology degree in Electrical Engineering.

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ABSTRACT

Power flow is a useful tool in operation, planning and optimisation of a system. Distribution systems, generally, refers to the power system network connected to loads at lower operating voltage**.** In this thesis an efficient power flow method for solving meshed distribution networks by using current injection method and basic formulations of Kirchhoff's laws has been acknowledged. This method has excellent convergence characteristics and thus is more efficient than Newton-Raphson and Fast Decoupled Method. This method can be applied to the solution of both the three-phase (unbalanced) and single-phase (balanced) representation of the network. The main objective of this thesis to study the Forward-Backward Sweep and to derive the inference that how much efficient it is in solving the load flow problem of the meshed distribution networks.

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CHAPTER **1**

Introduction

1.1. LITERATURE AND REVIEW:

Delivery of electricity to end users is the final stage in the electricity distribution. A distribution system network carries electricity from the transmission system and delivers it to the consumers. Distribution networks are typically of two types:-

i). Radial distribution network

ii). Mesh distribution network.

A radial network leaves the station and passes through the network area with no normal connection to any other supply. This is typical in long rural lines with isolated load areas. An interconnected or meshed network is generally found in urban areas and will have multiple connections to other points of supply.

The distribution system is entirely different, in both its operation and characteristics, from the transmission system. The Newton-Raphson and Fast decoupled Methods have efficiently solved the well behaved power system for the last two decades but they failed in case of:-

i). Ill-conditioned or poorly initialized

ii). Special applications or special network structure, e.g. Meshed networks**.[1,2,3]**

The Gauss-Seidel power flow technique has also shown to be extremely inefficient in solving large power systems **[4].**

Distribution networks, due to their wide ranging resistance and reactance values and radial structure, fall into the category of ill-conditioned power systems for the generic Newton-Raphson **[5, 6]** and fast decoupled power flow algorithms **[7].** Even though with some advancements in the Newton-Raphson Methods the robustness of the program is obtained but still the computational time is large enough **[8].** Thus to solve the distribution load flow problems an algorithm is required which is having the following characteristics:

i). Capable of solving radial and meshed distribution network with several thousand line sections (branches) and nodes (buses).

ii). Robust and efficient.

iii). Requires less computational time.

The efficiency of such a power system is of at most importance as each optimization study requires numerous power flow runs. Efficient power flow algorithm for solving single and three phase radial distribution network has been extensively used by electric distribution engineers. However these algorithms are not designed to solve meshed network **[9, 10].**

In this thesis, we worked on the method proposed by D. Shirmoharmnadi, H. W. Hong, A. Semlyen and G. X. Luo for the solution of weakly meshed network **[11]**. In this method if the network is meshed, the interconnected grid is first broken at a number of points (breakpoints) in order to convert it into one radial network **[11]**. The radial network is solved efficiently by the direct application of Kirchhoff's voltage and current laws (KVL and KCL).The power flows at the breakpoints is then accounted for by injecting currents at their two end nodes. The breakpoint currents are calculated using the multi-port compensation methods **[11].** In the presence of constant P Q loads, the network becomes nonlinear and causes the compensation process to become iterative **[11].** The solution of the radial network with the additional current injections completes the solution of the meshed network.

The numerical efficiency of the proposed compensation-based power flow method diminishes as the number of breakpoints required to convert the meshed network to the radial configuration increases **[11].**

CHAPTER 2

LOAD FLOW TECHNIQUES FOR DISTRIBUTION NETWORKS

2.1. RADIAL DISTRIBUTION NETWORK TECHNIQUE:

Radial distribution is the type of power distribution where the power is delivered from the main branch to the sub branches then it split out from the sub-branches again as seen in **Figure 2.1** where the power is transferred from root node and then it is split at L1. It is the cheapest but the least reliable network configuration. In this configuration electrical service is interrupted when any piece of service equipment is de-energised to perform routine maintenance and service. A radial network leaves the station and passes through the network area with no normal connection to any other supply. This is typical in long rural lines with isolated load areas. In general, radial distribution network has more power failures than meshed distribution network.

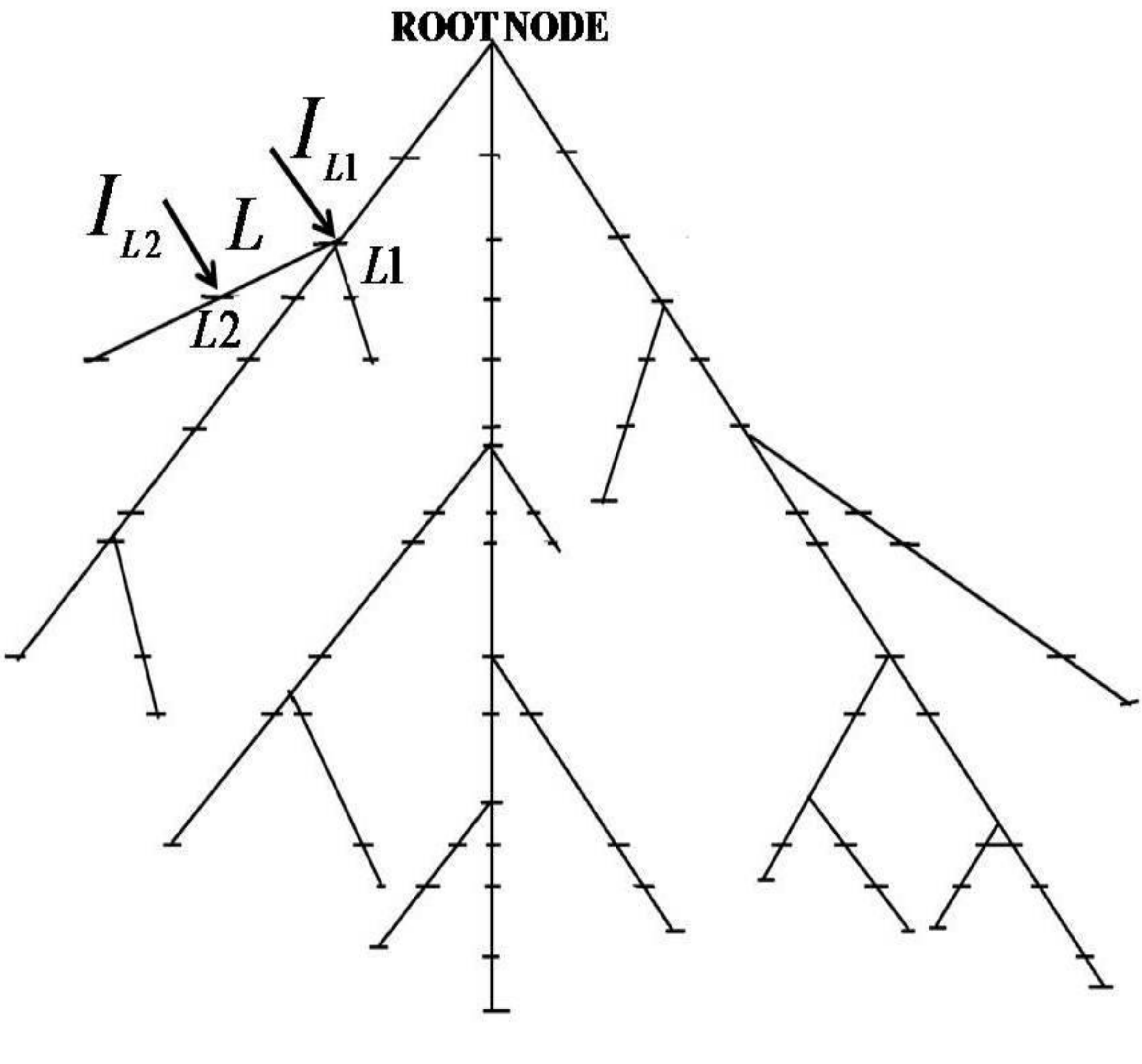


Fig 2.1.A typical Radial Distribution Network.

2.1.1 SOLUTION METHODOLOGIES:

The methods involved in solving the radial distribution network take advantage of the special feature of the radial network that there is a unique path from any given bus to the source. The general algorithm consists of three basic steps **[11]**:-

i). Nodal Current Calculation:-

Given the load power at any bus the current injection at that node can be calculated as:

$$I_i^{(k)} = \left(S_i \big/ V_i^{(k-1)} \right)^* - Y_i V_i^{(k-1)} \tag{2.1}$$

i= 1, 2, 3 …n

Where $I_i^{(k)}$ = current at the i^{th} node in k^{th} iteration.

S_i = power at the i^{th} node.

$V_i^{(k-1)}$= voltage at the i^{th} node in $(k-1)^{th}$ iteration

Y_i = admittance at the i^{th} node.

ii). Backward Sweep:

The backward sweep is basically a current or power flow solution with possible voltage updates. At iteration k, starting from the branches in the last layer and moving towards the branches connected to the root node network the current in branch L shown in **Fig 2.1** J_L is calculated as:

$$J_L^{(k)} = -I_{L2} + \sum \begin{matrix} (currents \\ in\ branch \\ emanating \\ from\ L2) \end{matrix} \tag{2.2}$$

L2=b, b-1........1

Where I_{l2}^{k} = current injecting at node L2.

$J_L^{(k)}$ = current in branch L at the k^{th} iteration.

iii). Forward Sweep:

The forward sweep is basically a voltage drop calculation with possible current or power flow updates. Nodal voltages are updated in a forward sweep starting from branches in the first layer toward those in the last. For each branch, L shown in **Fig 2.1**, the voltage at node L2 is calculated using the updated voltage at node L1 and the branch current calculated in the preceding backward sweep:

$$V_{L2}^{(k)} = V_{L1}^{(k)} - Z_L\, J_L^{(k)} \tag{2.3}$$

Where Z_L = series impedance of branch L. L=1, 2 ...b

iv). Convergence criteria:

The voltages at each node are first calculated using forward sweep. The maximum mismatch at each node is found out and compared with each other. The maximum mismatch thus obtained is if less than the estimated mismatch **€** then the program is terminated. If the program is not terminated by the mismatch calculation then it is made to terminate by the maximum number of iterations.

$$€ \leq \left|V_i^{k+1} - V_i^{k}\right| \quad \text{for i=1, 2, 3..........n} \tag{2.4}$$

2.2. MESHED DISTRIBUTION NETWORK TECHNIQUE:

An interconnected or meshed network is generally found in urban areas and will have multiple connections to other points of supply.

The advantages of using meshed networks are:-

i. Identification and isolation of fault is easy

ii. Highly reliable

2.2.1 SOLUTION METHODOLOGIES:

The meshed network is first converted to the radial network by taking proper breakpoints at the suitable places and then injecting currents of opposite polarity at the two ends of the breakpoint without affecting the network operating condition **[11].** The resulting radial network can now be solved using radial network technique. **Fig 2.2** shows a weakly meshed distribution network with three breakpoints and **Fig 2.3**.shows the injection of current $-J_j and\, J_j$ at the two nodes j1 and j2 of the break-point j.

Thus current at the j^{th} node for i^{th} iteration is given by:

$$I_{j1}^{(k)} = -J_j^{(k)} \tag{2.5}$$

$$I_{j2}^{(k)} = J_j^{(k)} \qquad \text{j=1, 2... p}$$

Where p=no.of breakpoints.

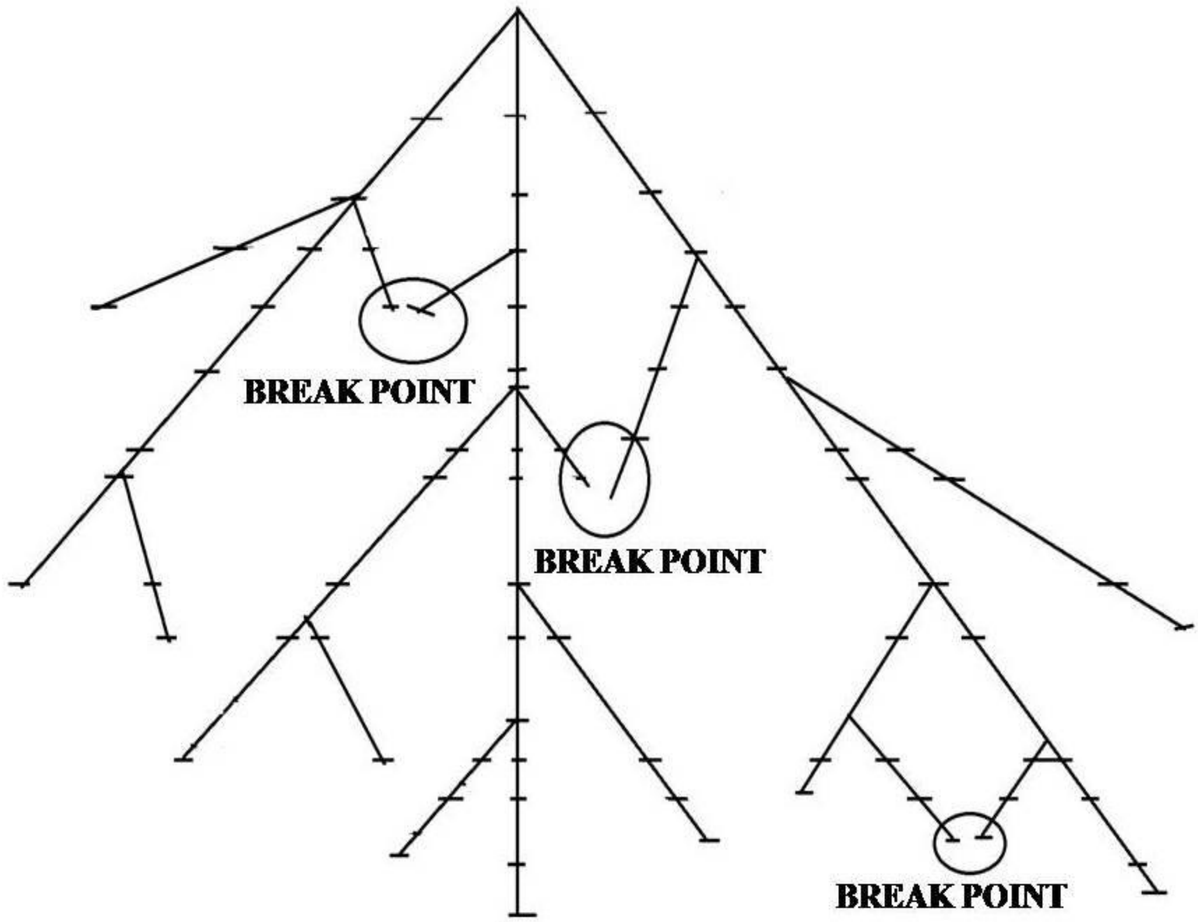


Fig 2.2 A meshed distribution network.

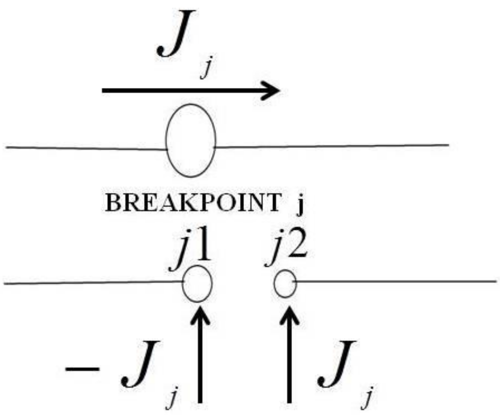


Fig 2.3.Breakpoint representation using Nodal current Injection.

i). Calculation of breakpoint current using compensation method:

Breakpoint current can be calculated using multiport compensation technique **[12]. Figure 2.4** shows the concept used in this approach. In this figure radial network resulting from the opening of breakpoints is shown as a multi-port circuit with the breakpoint nodes forming the ports of the circuit. For a linear network, this multi-port equivalent can be the thevnin equivalent circuit of the radial network seen from the open ports created by the breakpoints. **Figure 2.5** shows the thevnin equivalent of the open port network where V represents the Thevnin Voltage, [Z] represents the thevnin impedance and J the current flowing through the load.

$$V = [Z]\,J \tag{2.6}$$

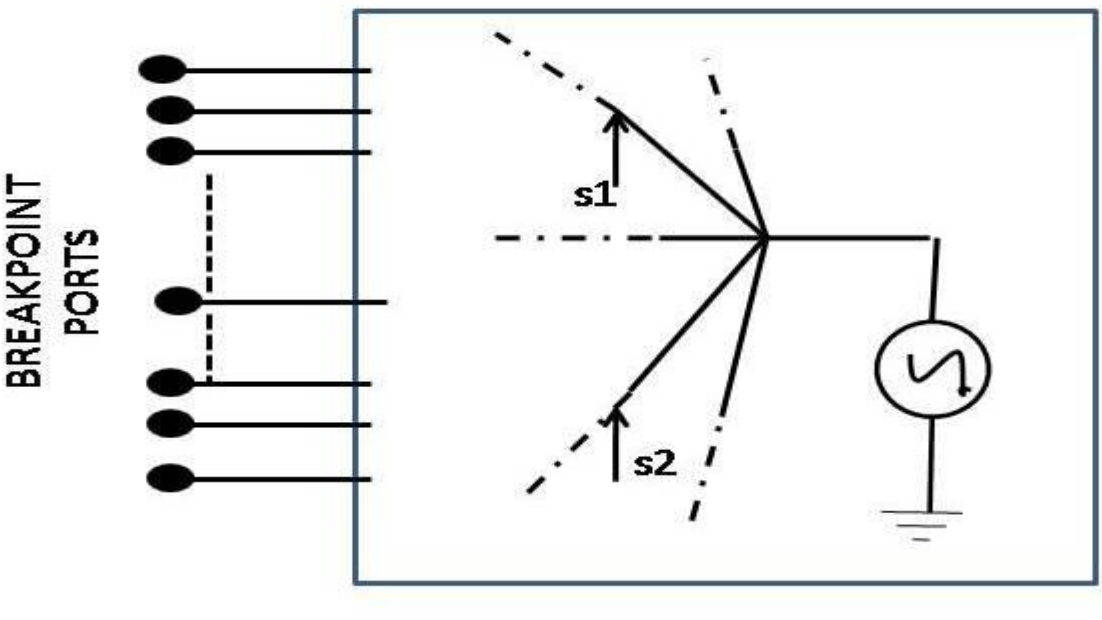


Fig 2.4.Multiport equivalent of the network as seen from the breakpoint ports

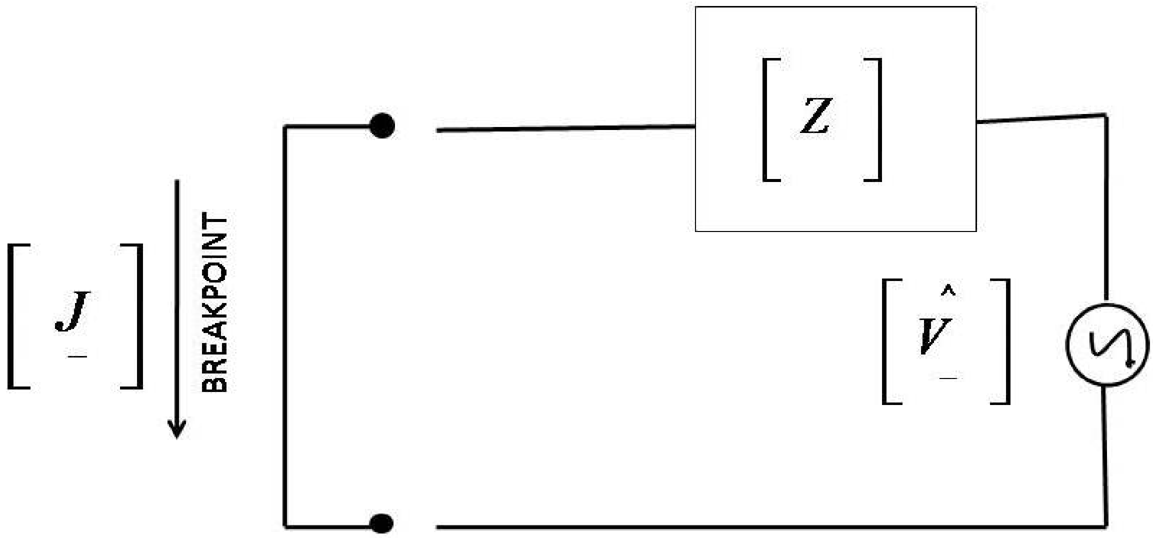


Fig 2.5. Thevnin equivalent circuit of the network as seen from the breakpoint ports.

ii). Calculation of breakpoint impedance matrix:

The breakpoint impedance matrix (thevnin equivalent impedance) can be calculated determined using the following method **[11]**. The thevnin equivalent equation can be written as:

$$\begin{bmatrix} V_1 \\ \vdots \\ V_J \\ \vdots \\ V_P \end{bmatrix} = \begin{bmatrix} Z_{11} & \cdots & Z_{1J} & \cdots & Z_{1P} \\ \vdots & & \vdots & & \vdots \\ Z_{J1} & \cdots & Z_{JJ} & \cdots & Z_{JP} \\ \vdots & & \vdots & & \vdots \\ Z_{P1} & \cdots & Z_{PJ} & \cdots & Z_{PP} \end{bmatrix} \begin{bmatrix} J_1 \\ \vdots \\ J_J \\ \vdots \\ J_P \end{bmatrix} \quad (2.7)$$

- Put J_J=1 p.u. and $J_i = 0$, i=1, 2 ...p and i≠j which is equivalent to injecting 1 p.u current of opposite polarity at the two end nodes of the breakpoint j.
- Each of the breakpoint voltages can be obtained by subtracting the voltages at the two end nodes of the breakpoint.

iii). Iterative compensation process:

The iterative compensation process for calculating the breakpoint currents, using the thevenin equivalent circuit of **fig 2.5** is described below **[11]**:

STEP 1. Calculate the thevenin equivalent impedance and maintain it constant throughout the compensation process.

STEP 2. Calculate the thevenin equivalent voltage of the radial network including the breakpoint currents calculated from the previous iteration of the compensation process assuming initial values of the breakpoint currents to be 0.

STEP 3. Calculate the incremental change in the breakpoint currents using the Thevenin equivalent circuit. At iteration m of the compensation process

$$\Delta J^{(m)} = [Z]^{-1} V^{(m)} \tag{2.8}$$

STEP 4. Update the breakpoint currents. At iteration m:

$$J^{(m)} = J^{(m-1)} + \Delta J^{(m)} \tag{2.9}$$

STEP 5. Repeat equations 2, 3 and 4 until convergence is reached (the maximum breakpoint voltage calculated at step 3 is within prescribed limits).

iv). Steps to solve meshed network:

The different steps involved in solving meshed distribution network are **[11]**:

STEP 1. First the bus and line data are read.

STEP 2. The meshed network is then converted to the radial network.

STEP 3. Branch numbering is done and the breakpoints are opened.

STEP 4. Breakpoint impedance matrix is then calculated.

STEP 5. Set iteration count to m=1 and solve the radial network load flow using Forward Backward Sweep.

STEP 6. If the maximum voltage mismatch is less than the specified voltage mismatch the exit the loop and print the result.

STEP 7. Else calculate the breakpoint currents and add them to nodal current.

STEP 8. If the maximum iteration is reached and still specified voltage mismatch is not obtained then stop the process and print the result.

STEP 9. Else increase the iteration number by 1 and go to step 6 and repeat the process till convergence point or the maximum iteration is reached.

v). FLOW CHART

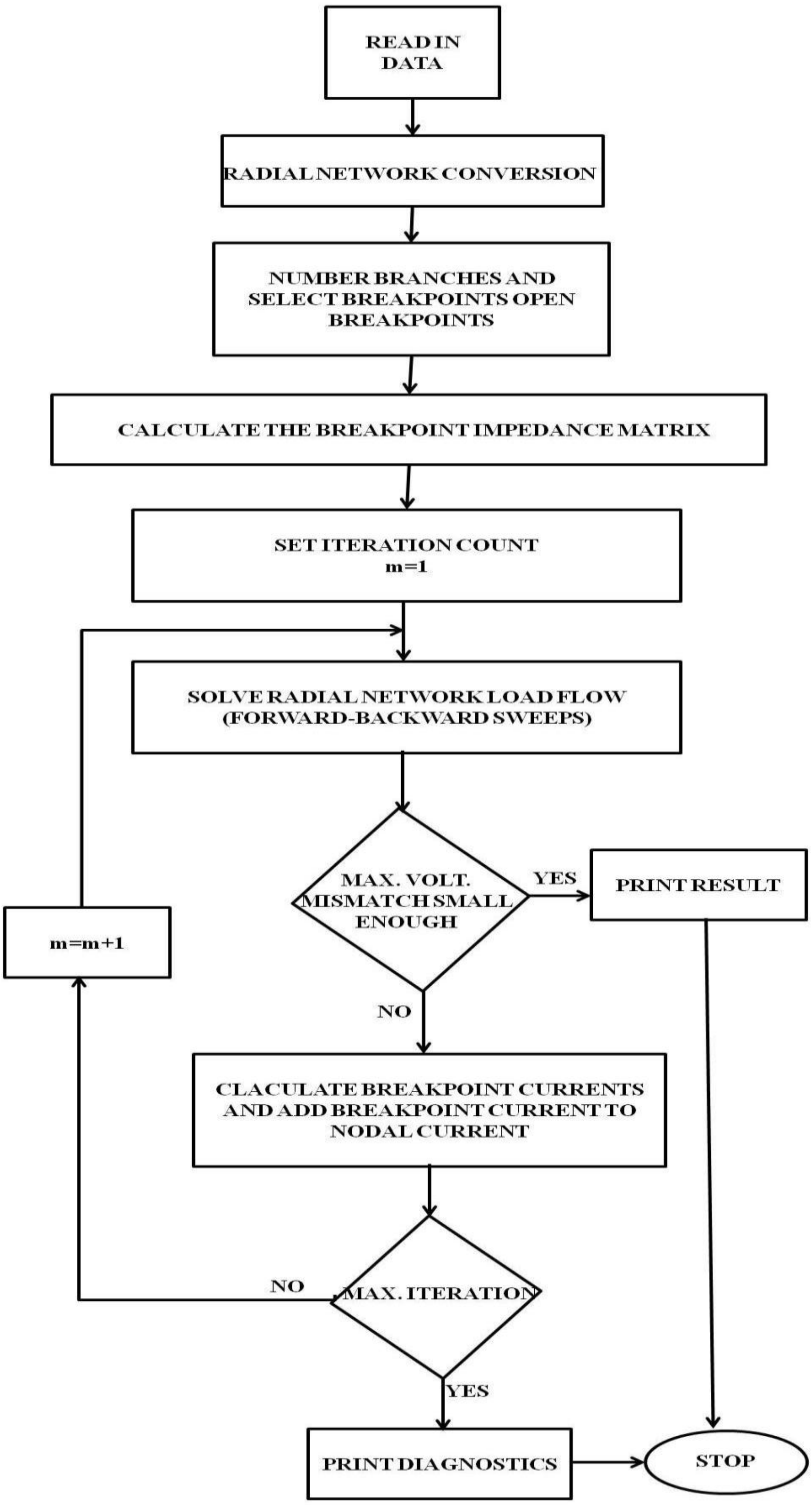


Fig2.6 Computation flow chart of the method.

CHAPTER 3

MESH DISTRIBUTION SYSTEM LOAD FLOW TECHNIQUE VS NEWTON-RAPHSON TECHNIQUE

3.2. CONPARISON BETWEEN MESH DISTRIBUTION SYSTEM LOAD FLOW VS NEWTON-RAPHSON TECHNIQUE

The main purpose of the load flow solution is to evaluate the individual voltages at all bus bars/buses connected to the network corresponding to the specified system conditions. Researchers have found out that for solving Meshed Distribution Networks, Newton-Raphson is less effective as compared to the Meshed Method. Some of the points highlighting the comparison between the two are:

i). Radial or weakly meshed topology:

In distribution system most of the networks are either radial or weakly meshed. The increase in the reliability and the outgoing distribution generation constraints has made the distribution systems more complex. Therefore the power flow analysis in such system by Newton-Raphson method has become more difficult **[13].**

ii). Time of computation:

It is very essential to keep track of the computational time while doing power flow analysis. The time taken for each iteration as well as the total time taken by the Meshed Method for computation is much less than that of the Newton-Raphson method.

iii). Effect on increasing R/X ratio:

In distribution system the R/X ratio is high ranging from 0.5 to 7. In this situation, the N-R method diverges whereas Meshed method still converges. Also on increasing R/X ratio, the computational time for N-R method increases linearly whereas for Meshed method it almost remains constant.

iv). Effect on increasing load power:

On increasing the active and reactive power of the load bus equally the N-R method diverges whereas the Meshed method converges.

v). Number of iteration:

Meshed method takes more iteration in solving the same network as compared to the Newton-Raphson method.

CHAPTER **4**

SIMULATION RESULTS AND DISCUSSIONS

4.1. For IEEE 33-BUS SYSTEM

Table-4.1: Voltage and angle profile for nominal R/X ratio for IEEE-33 BUS SYSTEM:

Bus No.	Bus Code	By Newton-Raphson Method		By Mesh Distribution Method	
		Voltage Mag.	Angle Degree	Voltage Mag.	Angle Degree
1	1	1.000	0.000	1.0000	0
2	0	0.997	0.014	0.9971	0.0142
3	0	0.986	0.053	0.9870	0.0455
4	0	0.983	0.057	0.9838	0.0463
5	0	0.979	0.060	0.9808	0.0445
6	0	0.971	-0.051	0.9740	-0.0588
7	0	0.970	-0.146	0.9734	-0.1360
8	0	0.969	-0.165	0.9728	-0.1630
9	0	0.966	-0.194	0.9683	-0.1869
10	0	0.965	-0.218	0.9689	-0.2043
11	0	0.965	-0.220	0.9690	-0.2085
12	0	0.965	-0.227	0.9695	-0.2187
13	0	0.962	-0.226	0.9681	-0.2059
14	0	0.961	-0.241	0.9678	-0.2006
15	0	0.960	-0.236	0.9683	-0.1870
16	0	0.959	-0.215	0.9659	-0.1648
17	0	0.955	-0.212	0.9611	-0.1815
18	0	0.954	-0.179	0.9594	-0.1486
19	0	0.995	-0.000	0.9950	-0.0025
20	0	0.981	-0.082	0.9778	-0.1013
21	0	0.977	-0.132	0.9729	-0.1633
22	0	0.973	-0.192	0.9695	-0.2190
23	0	0.981	0.044	0.9817	0.0368
24	0	0.970	-0.012	0.9713	-0.0200
25	0	0.963	-0.023	0.9643	-0.0308
26	0	0.970	-0.040	0.9731	-0.0493
27	0	0.969	-0.024	0.9719	-0.0353
28	0	0.964	-0.029	0.9673	-0.0387
29	0	0.960	-0.020	0.9642	-0.0301
30	0	0.957	0.049	0.9614	0.0342
31	0	0.954	-0.085	0.9591	-0.0931
32	0	0.953	-0.124	0.9589	-0.1285
33	0	0.954	-0.151	0.9595	-0.1476

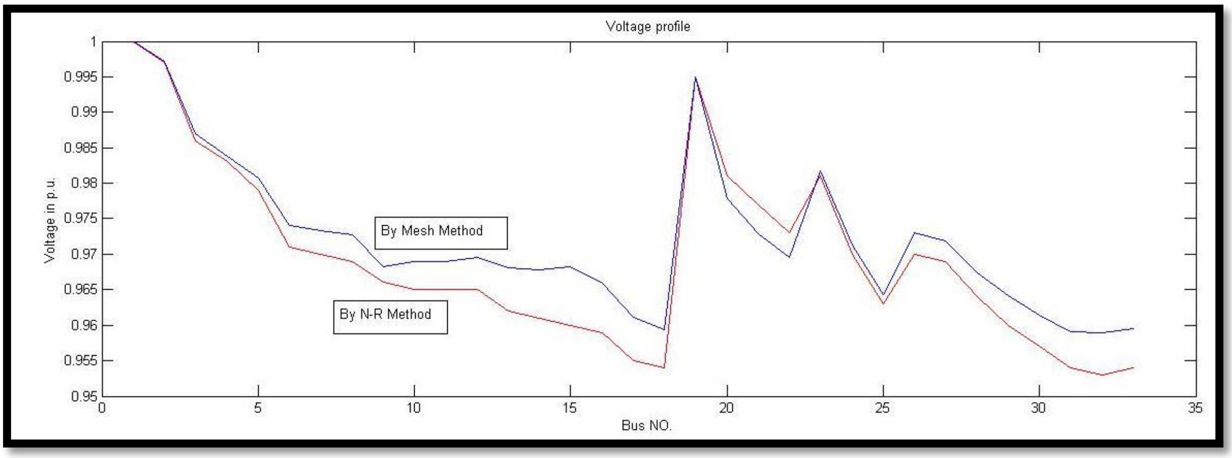


Figure 4.1 voltage profile for N-R method and Meshed method

Table 4.1 and Figure 4.1 show the voltage profile comparison between the Meshed distribution method and N-R method. From this figure it is clear that the Mesh Distribution Method gives approximately the same result as Newton-Raphson Method. Hence now we discuss how much less time did Mesh Distribution Method will take than Newton-Raphson Method. Hence we change the R/X ratio and studied how less time did Mesh Distribution Method takes. Here R/X ratio are changed in two different manner

a) Individual Lines taken once at a time.
b) A set of five lines taken once.

Table-4.2: Total time taken (in sec) to compute while changing the R/X ratio of individual lines for IEEE-33 BUS SYSTEM.

LINE NO.	R/X=1		2		4		8	
	N-R Method	Mesh Method	N-R Method	Mesh method	N-R method	Mesh Method	N-R Method	Mesh Method
1	0.158007	0.047426	0.132450	0.051498	0.122661	0.047161	0.122599	0.049509
2	0.142165	0.047742	0.117906	0.049646	0.123213	0.056503	0.133768	0.055164
3	0.195849	0.052439	0.135040	0.052906	0.126658	0.050225	0.130399	0.054289
4	0.133182	0.048827	0.131179	0.052315	0.124773	0.050289	0.129783	0.053436
5	0.136799	0.048072	0.144066	0.055120	0.136139	0.051280	0.126113	0.058902

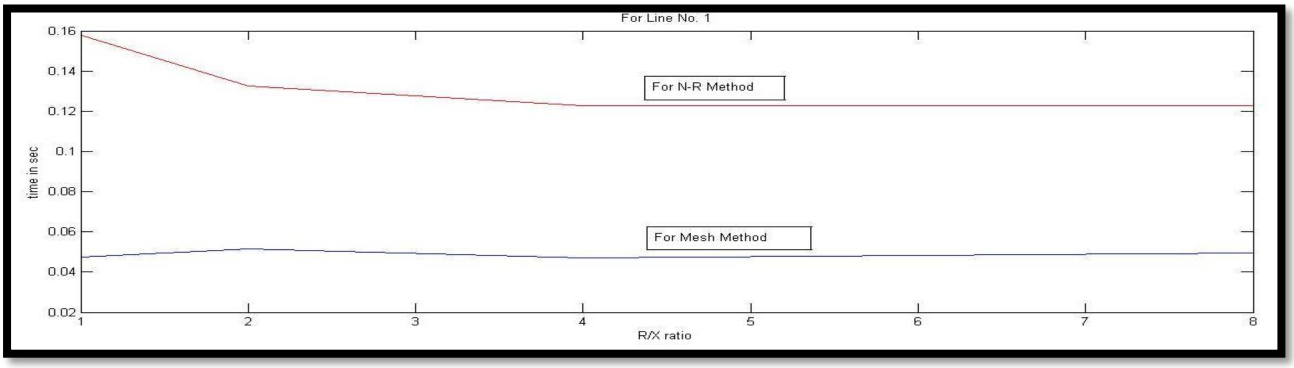
6	0.119161	0.048903	0.153004	0.050038	0.117025	0.050645	0.131599	0.055657
7	0.121727	0.050449	0.126498	0.056054	0.120485	0.050046	0.127316	0.050373
8	0.138421	0.052142	0.118063	0.050539	0.139648	0.053213	0.131502	0.050943
9	0.115803	0.055442	0.115849	0.056747	0.122540	0.048681	0.144225	0.052280
10	0.121304	0.059784	0.114104	0.051520	0.145841	0.051898	0.134438	0.054278
11	0.131014	0.049766	0.129898	0.053146	0.115980	0.056429	0.139236	0.054645
12	0.122093	0.048466	0.120469	0.054563	0.126955	0.049176	0.136090	0.048136
13	0.112440	0.047614	0.141720	0.054878	0.117316	0.049380	0.135016	0.047602
14	0.112375	0.055612	0.130636	0.047963	0.139820	0.045089	0.136717	0.050912
15	0.128611	0.049919	0.142369	0.049266	0.133752	0.050847	0.140366	0.052243
16	0.130025	0.041063	0.142271	0.049293	0.128864	0.050213	0.140431	0.049199
17	0.134714	0.056709	0.135304	0.056371	0.139808	0.054851	0.118282	0.050980
18	0.124498	0.052286	0.127370	0.050001	0.136653	0.052776	0.134885	0.054948
19	0.122897	0.041590	0.122146	0.050846	0.137027	0.048403	0.123587	0.048365
20	0.141110	0.048143	0.136021	0.051147	0.139681	0.055527	0.127326	0.051845
21	0.143887	0.049338	0.129244	0.053375	0.131127	0.050411	0.137488	0.051777
22	0.129525	0.057604	0.127991	0.049134	0.145772	0.051318	0.134373	0.053801
23	0.119621	0.051604	0.133143	0.049407	0.127084	0.055923	0.126039	0.045340
24	0.121869	0.054638	0.121869	0.050886	0.125035	0.047913	0.125649	0.050037
25	0.144721	0.054888	0.127201	0.054505	0.122721	0.058173	0.116709	0.049481
26	0.134926	0.048686	0.165013	0.051213	0.155983	0.053510	0.122268	0.047814
27	0.121615	0.041597	0.117843	0.051162	0.117843	0.050568	0.139563	0.049510
28	0.115769	0.050785	0.117968	0.053667	0.141485	0.047859	0.113032	0.049817
29	0.117414	0.057733	0.117633	0.051238	0.117633	0.051308	0.127600	0.053991
30	0.118076	0.055238	0.123940	0.046787	0.123524	0.048609	0.122280	0.050774
31	0.130374	0.056084	0.140205	0.057368	0.148857	0.059207	0.146826	0.052355
32	0.128475	0.051924	0.124401	0.051347	0.140229	0.047995	0.121780	0.053967

Table-4.3: Total time taken (in sec) to compute while changing the R/X ratio of five lines at once for IEEE-33 BUS SYSTEM.

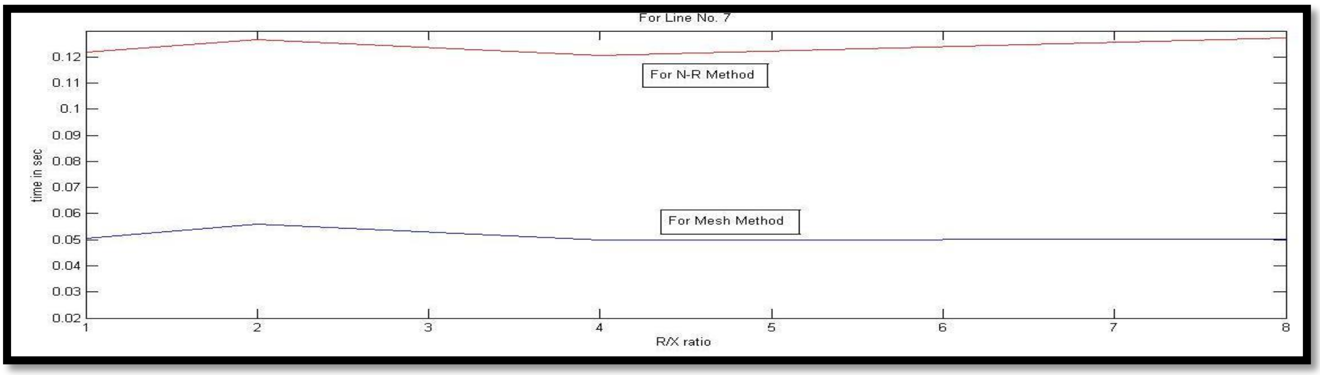
SET NO.	R/X=1		2		4		8	
	N-R Method	Mesh Method	N-R Method	Mesh method	N-R method	Mesh Method	N-R Method	Mesh Method
1	0.128082	0.045388	0.122347	0.051872	0.128248	0.050721	0.138833	0.052760
2	0.111066	0.054062	0.139027	0.056423	0.140607	0.048765	0.141308	0.050312
3	0.119139	0.054931	0.119216	0.048071	0.121475	0.055238	0.157311	0.056368
4	0.114721	0.048573	0.136092	0.048528	0.117189	0.047311	0.125704	0.054812
5	0.137468	0.054510	0.134497	0.046777	0.139603	0.052825	0.133209	0.053936
6	0.117739	0.048729	0.122269	0.050348	0.114022	0.048168	0.152080	0.053243

Fig 4.2: Total time vs. R/X ratio for individual lines for IEEE-33 BUS SYSTEM:

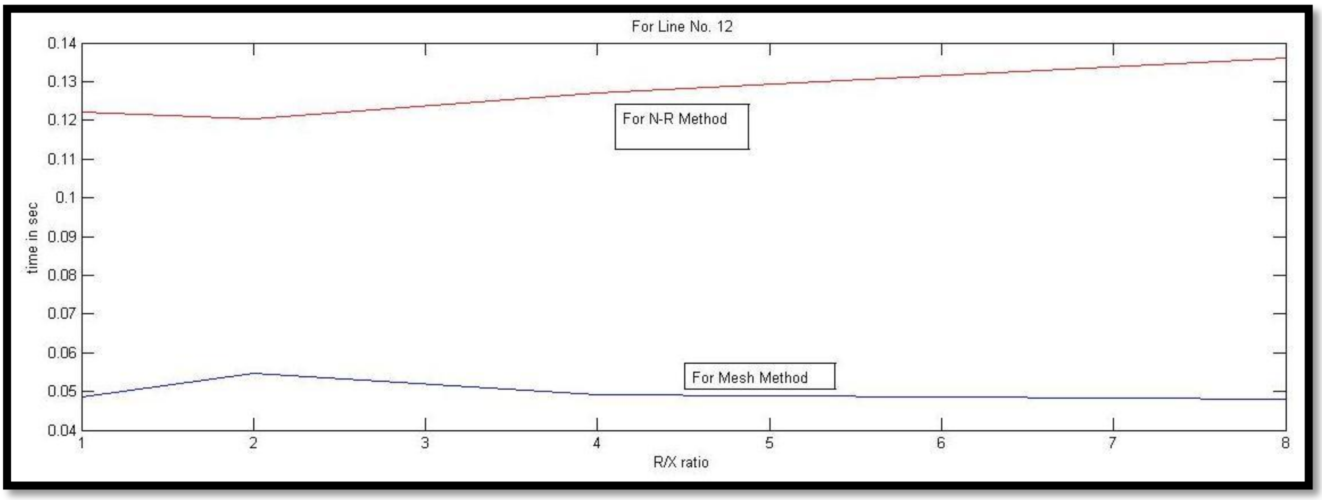
a) **For line no.1**



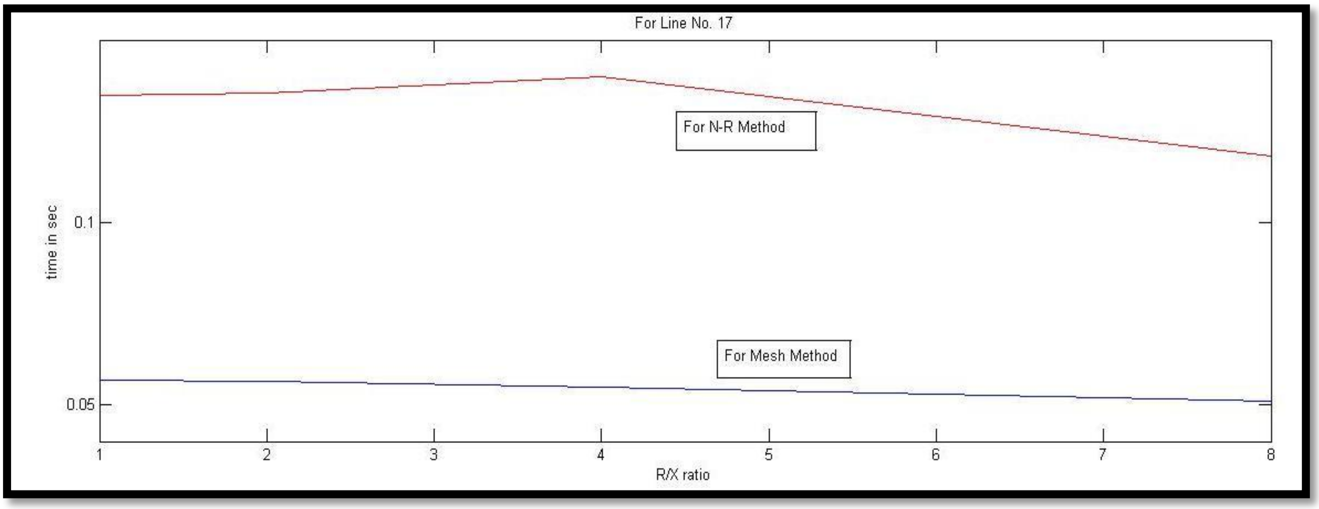
b) **For line no.7**



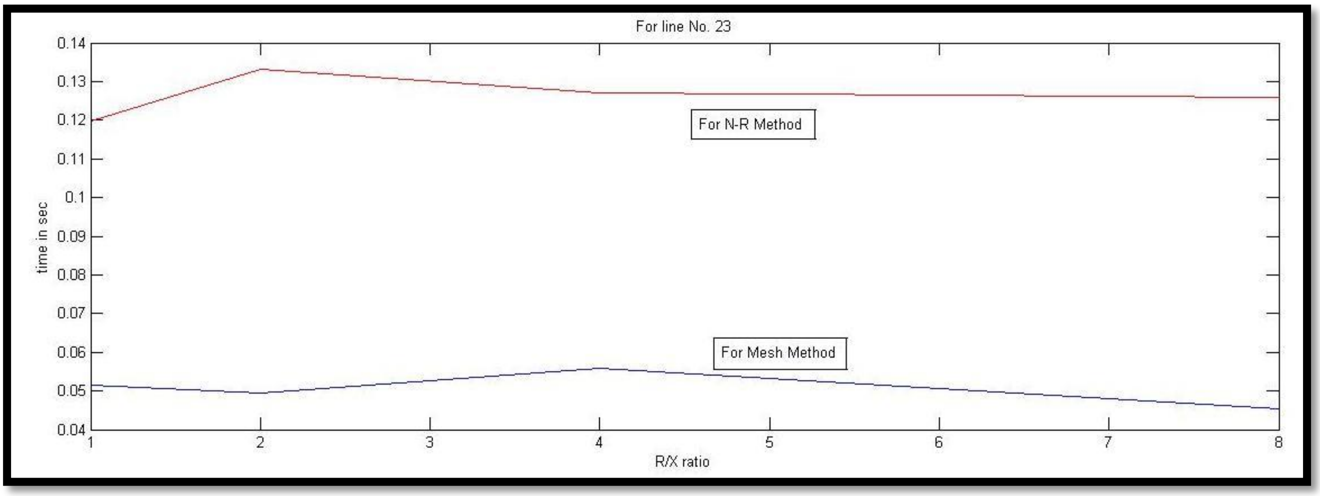
c) For line no.12



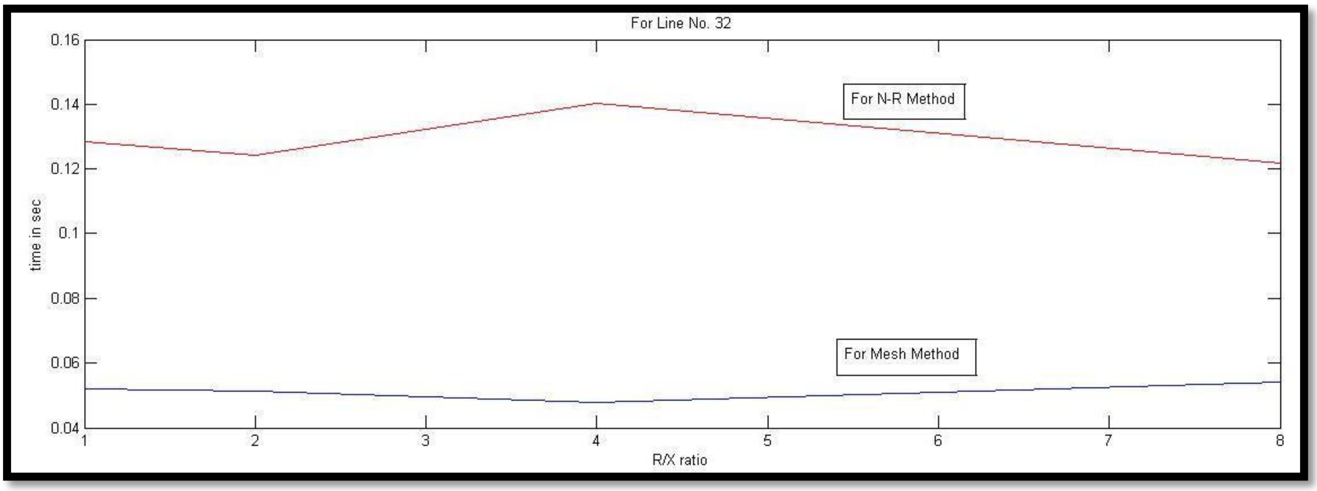
d) For line no.17



e) For line no 23



f) For line no 32



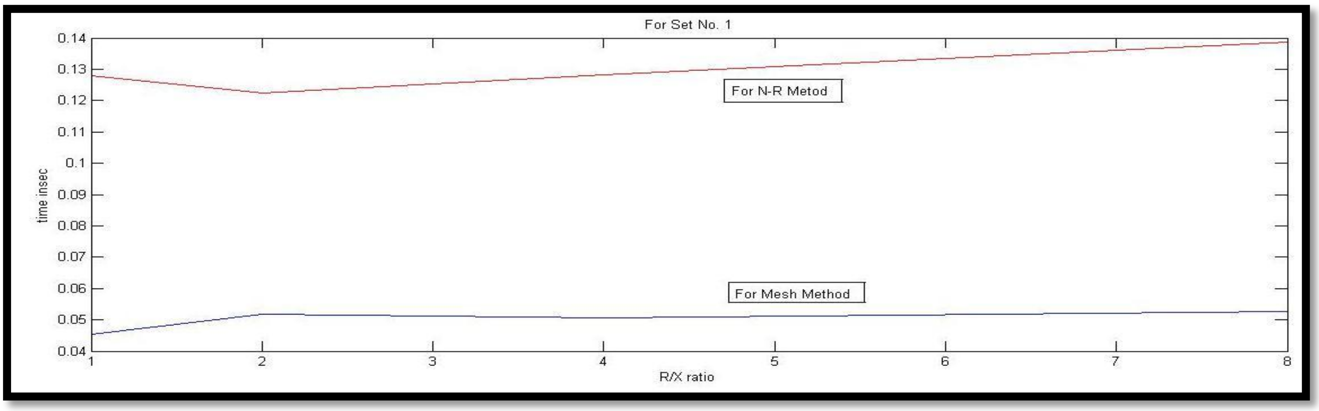
From the above graphs it is clear that total time taken by Meshed distribution method is much less than Newton-Raphson Method. In a nutshell we can say that N-R method diverges on increasing the R/X ratio whereas Meshed method doesn't. Also increasing R/X ratio in a similar manner for both the methods, for different lines, will have different effects on the time taken.

- For line no.1 the time taken by N-R method first decreases greatly and then slightly and then it becomes constant whereas for Meshed method, it first increases slightly and then becomes constant.
- For line no.7 the time taken by N-R method fluctuates between 0.115s to 0.13s whereas for Meshed method it first increases and then slightly decreases and then becomes constant.
- For line no.12, for N-R method, it first decreases slightly and then increases linearly whereas for Meshed method, it first increases, then decreases slightly and then becomes constant.
- For line no.17, for N-R method, initially it is constant and then decreases linearly whereas for Meshed method it remains constant throughout.
- For line no.23, for N-R method, it first increases greatly then slightly decreases and then becomes constant whereas for Meshed method, it fluctuates between 0.049s and 0.055s.

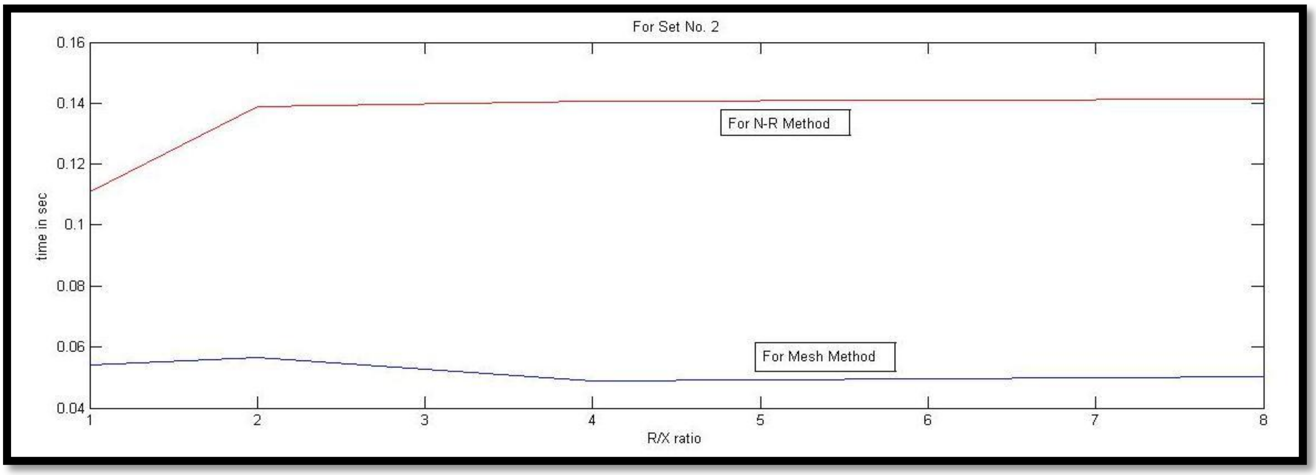
- For line no.32, for N-R method, it fluctuates between 0.12s and 0.14s whereas for Meshed method it almost remains constant.

Fig 4.3: Total time vs R/X ratio for set of 5 lines for IEEE-33 BUS SYSTEM.

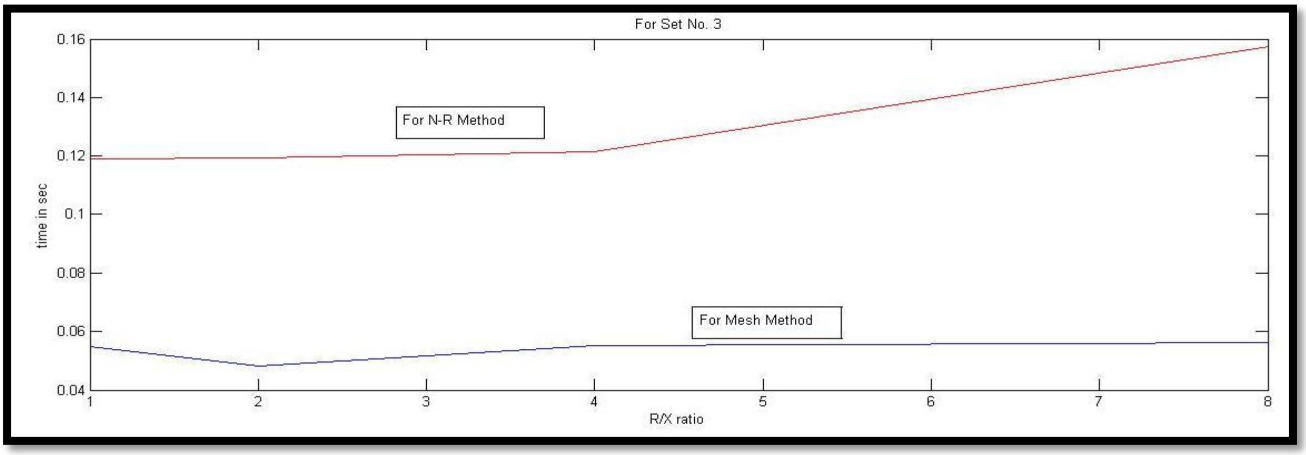
a) For set no.1 (line 1-5)



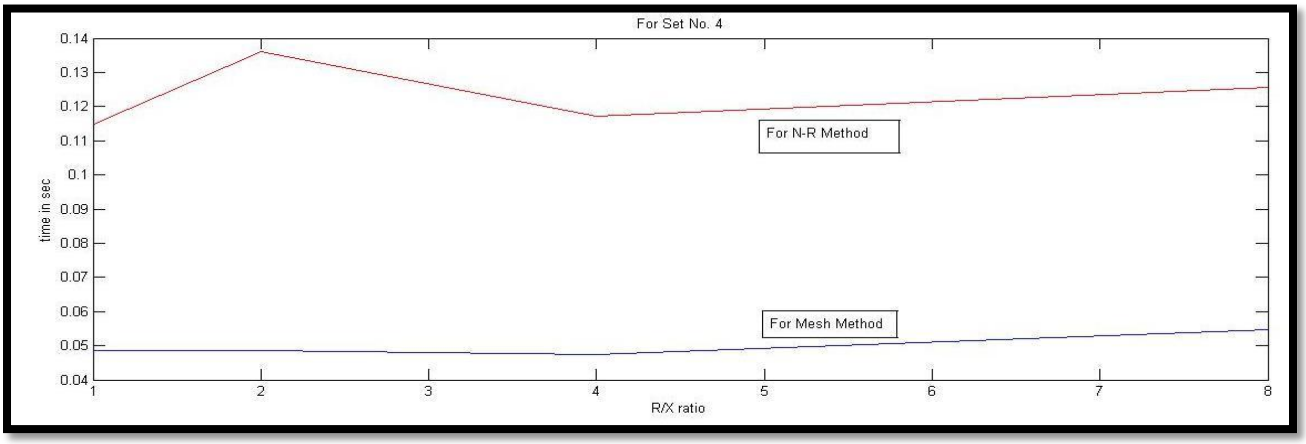
b) For set no.2 (line 6-10)



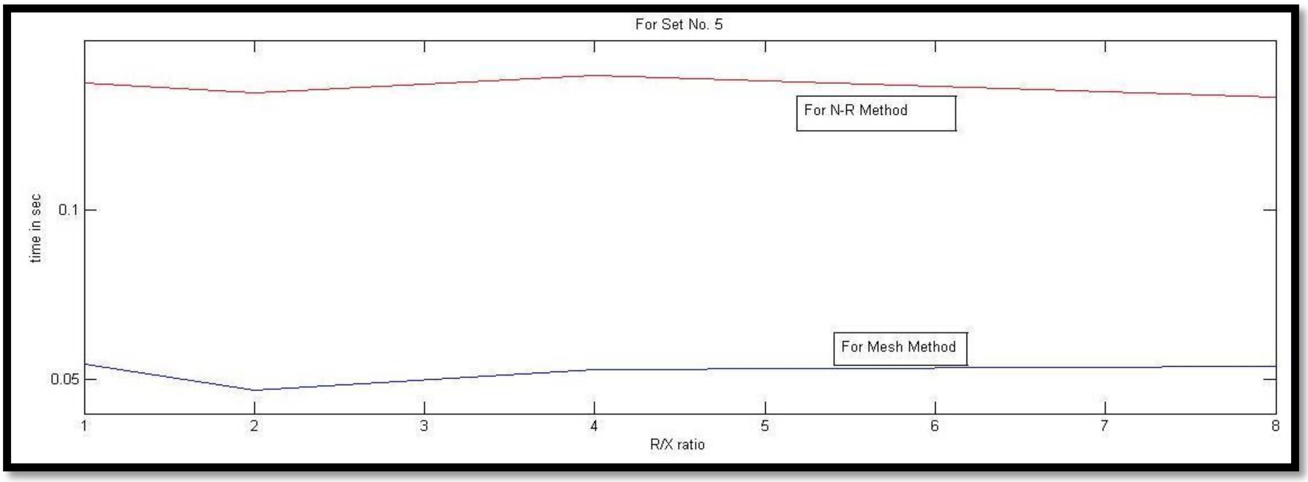
c) For set no.3 (line 11-15)



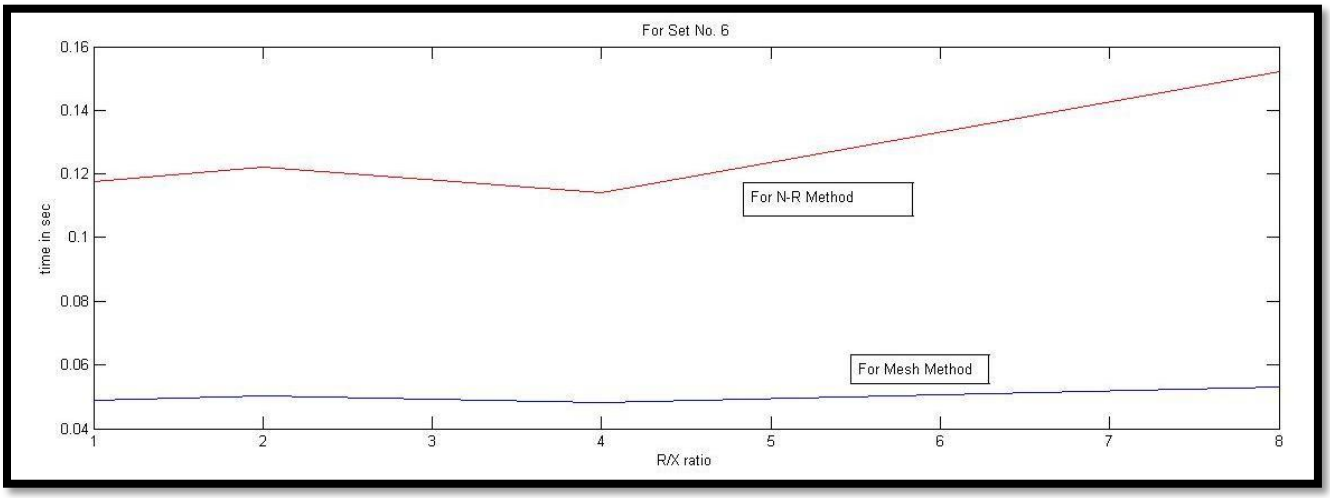
d) For set no.4 (line 16-20)



e) For set no.5 (line 21-25)



f) For set no.6 (line 26-30)



From the above graphs it is clear that when R/X ratio is increased from 1 to 8 in a set of five lines simultaneously then the time of computation for N-R method increases greatly whereas those for Meshed method remains constant. Thus the N-R method diverges on increasing the R/X ratio whereas Meshed method doesn't.

4.2. For IEEE 69-BUS SYSTEM

Table-4.4: Voltage and Angle profile for nominal R/X ratio for IEEE-69 BUS SYSTEM.

Bus No.	Bus Code	By Newton-Raphson Method		By Mesh Distribution Method	
		Voltage Mag.	Angle Degree	Voltage Mag.	Angle Degree
1	1	1.000	0.000	1.0000	0
2	0	1.000	-0.000	1.0000	-0.0012
3	0	1.000	-0.000	0.9999	-0.0024
4	0	1.000	-0.000	0.9999	-0.0039
5	0	1.000	-0.001	0.9997	-0.0082
6	0	1.000	-0.000	0.9975	-0.0049
7	0	0.999	0.000	0.9951	-0.0015
8	0	0.999	0.000	0.9946	-0.0010
9	0	0.999	0.001	0.9941	0.0032
10	0	0.999	0.007	0.9912	0.0545
11	0	0.999	0.008	0.9906	0.0645
12	0	0.999	0.012	0.9893	0.0886
13	0	0.999	0.016	0.9870	0.1255
14	0	0.998	0.019	0.9849	0.1619
15	0	0.998	0.023	0.9827	0.1978
16	0	0.998	0.023	0.9823	0.2045
17	0	0.998	0.024	0.9817	0.2152
18	0	0.998	0.025	0.9817	0.2153
19	0	0.998	0.025	0.9814	0.2210
20	0	0.998	0.025	0.9813	0.2246
21	0	0.998	0.026	0.9810	0.2305
22	0	0.998	0.026	0.9811	0.2285
23	0	0.998	0.024	0.9823	0.2063
24	0	0.998	0.020	0.9850	0.1580
25	0	0.999	0.011	0.9910	0.0615
26	0	0.999	0.012	0.9903	0.0720
27	0	0.999	0.012	0.9903	0.0724
28	0	1.000	-0.001	0.9998	-0.0059
29	0	1.000	-0.005	0.9985	-0.0568
30	0	1.000	-0.000	0.9949	0.0005
31	0	0.999	0.001	0.9942	0.0106

32	0	0.999	0.005	0.9910	0.0616
33	0	0.999	0.003	0.9915	0.0369
34	0	0.999	-0.001	0.9928	-0.0170
35	0	0.999	-0.005	0.9942	-0.0673
36	0	1.000	-0.000	0.9998	-0.0048
37	0	1.000	-0.004	0.9986	-0.0394
38	0	1.000	-0.005	0.9974	-0.0496
39	0	1.000	-0.005	0.9970	-0.0525
40	0	1.000	-0.005	0.9970	-0.0527
41	0	1.000	-0.006	0.9951	-0.0626
42	0	0.999	-0.006	0.9943	-0.0668
43	0	0.999	-0.006	0.9942	-0.0673
44	0	0.999	-0.006	0.9942	-0.0675
45	0	0.999	-0.007	0.9941	-0.0693
46	0	0.999	-0.007	0.9941	-0.0693
47	0	1.000	-0.001	0.9998	-0.0057
48	0	1.000	-0.005	0.9986	-0.0505
49	0	0.999	-0.019	0.9948	-0.1896
50	0	0.999	-0.021	0.9942	-0.2094
51	0	0.999	-0.001	0.9952	-0.0090
52	0	1.000	-0.005	0.9970	-0.0528
53	0	0.999	0.002	0.9929	0.0120
54	0	0.999	0.003	0.9915	0.0221
55	0	0.999	0.005	0.9896	0.0359
56	0	0.999	0.006	0.9878	0.0489
57	0	0.998	0.023	0.9786	0.2005
58	0	0.997	0.031	0.9740	0.2763
59	0	0.997	0.034	0.9722	0.3063
60	0	0.997	0.037	0.9703	0.3414
61	0	0.997	0.040	0.9675	0.3625
62	0	0.997	0.039	0.9681	0.3571
63	0	0.997	0.039	0.9689	0.3487
64	0	0.997	0.035	0.9730	0.3077
65	0	0.998	0.029	0.9810	0.2304
66	0	0.999	0.009	0.9905	0.0656
67	0	0.999	0.009	0.9905	0.0656
68	0	0.999	0.011	0.9903	0.0721
69	0	0.999	0.011	0.9903	0.0720

Now we discuss how much less time did Mesh Distribution Method will take than Newton-Raphson Method. To study total time taken by the methods we took two different manners:

a) Changing R/X ratio of five lines at once.
b) Changing the Power of five Load buses at once.

Table-4.5: Total time (in sec) taken to compute while changing the R/X ratio of five lines at once for IEEE-69 BUS SYSTEM.

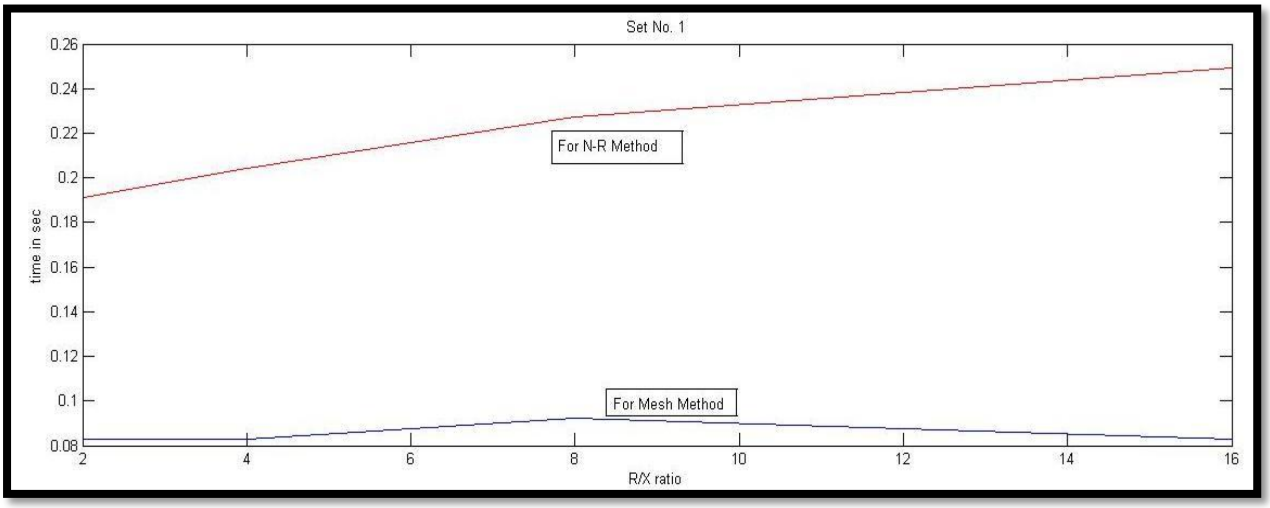
SET NO.	R/X=2		4		8		16	
	N-R Method	Mesh Method	N-R Method	Mesh method	N-R method	Mesh Method	N-R Method	Mesh Method
1	0.191315	0.082884	0.204226	0.083095	0.227400	0.092185	0.249453	0.083053
2	0.198459	0.083148	0.200684	0.085162	0.225401	0.103103	0.200346	0.093534
3	0.183155	0.084742	0.184590	0.083256	0.223939	0.085721	0.172118	0.087939
4	0.208913	0.074182	0.189558	0.083089	0.214374	0.089534	0.180204	0.082853
5	0.210722	0.074375	0.204536	0.067485	0.209578	0.059511	0.199912	0.054363
6	0.173345	0.040568	0.224387	0.047197	0.215165	0.048366	0.220798	0.048561
7	0.197211	0.043281	0.186231	0.045530	0.227414	0.041071	0.219500	0.042629
8	0.245344	0.043417	0.211828	0.040051	0.192780	0.040773	0.202190	0.040857
9	0.189873	0.047498	0.198760	0.041259	0.208192	0.043722	0.215507	0.040082
10	0.220206	0.044262	0.182212	0.047692	0.205264	0.046852	0.194254	0.042468
11	0.211942	0.041966	0.218101	0.042411	0.208143	0.051056	0.169888	0.040409
12	0.228290	0.048802	0.194604	0.045671	0.219145	0.046603	0.220452	0.066441
13	0.221375	0.043988	0.207755	0.040656	0.225350	0.043840	0.214058	0.040368

Table-4.6: Total time (in sec) taken to compute while changing the power of five lines at once for IEEE-69 BUS SYSTEM.

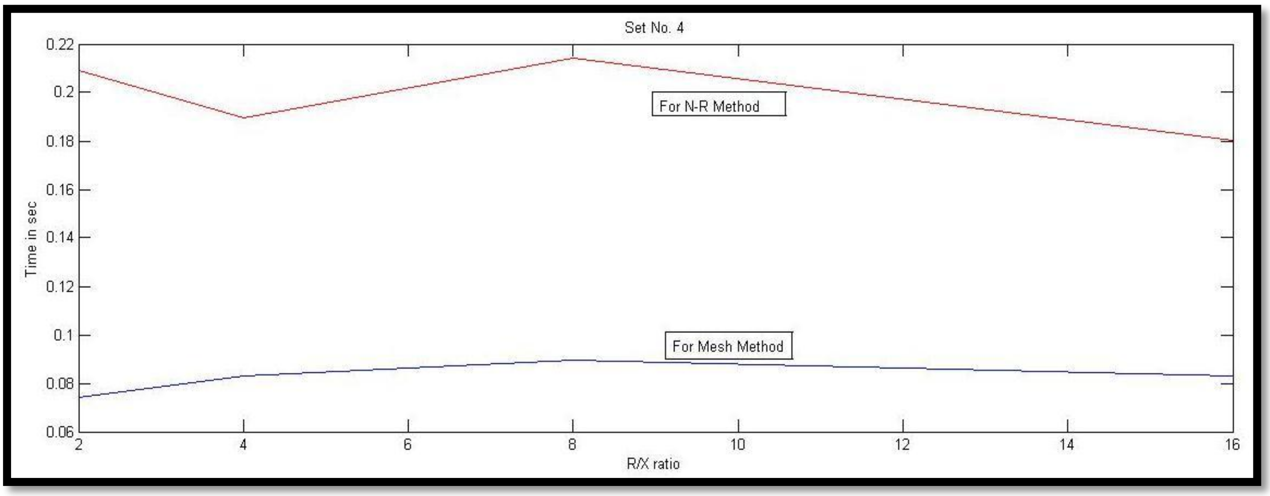
SET NO.	power=1		2		3		4	
	N-R Method	Mesh Method	N-R Method	Mesh method	N-R method	Mesh Method	N-R Method	Mesh Method
1	0.578627	0.019939	0.609720	0.037340	0.690562	0.033494	0.735758	0.032089
2	0.849123	0.039306	0.831179	0.042808	0.999576	0.041317	1.030857	0.032746
3	1.146236	0.034376	1.098494	0.034056	1.164698	0.034150	1.171764	0.020048
4	0.751279	0.039010	0.383544	0.032632	0.417087	0.039976	0.422163	0.039749
5	0.372857	0.033745	0.350412	0.038427	0.407381	0.035114	0.325519	0.020050
6	0.373572	0.040183	0.376116	0.032928	0.320398	0.035257	0.390612	0.035833
7	0.364762	0.032968	0.357430	0.036224	0.388944	0.032784	0.380487	0.037641
8	0.401101	0.035681	0.354247	0.045982	0.331277	0.036515	0.367340	0.037505
9	0.345391	0.040454	0.405056	0.039614	0.367607	0.035012	0.424614	0.034637
10	0.398731	0.033322	0.449099	0.032080	0.390107	0.039863	0.406366	0.038581
11	0.373012	0.037412	0.370566	0.040137	0.391461	0.042083	0.360203	0.039582
12	0.369312	0.031508	0.378593	0.042303	0.351107	0.034374	0.347927	0.038322
13	0.342214	0.036781	0.376357	0.022117	0.428254	0.041919	0.401938	0.045680

Fig 4.4 Total time vs R/X ratio for five lines taken at once for IEEE-69 BUS SYSTEM.

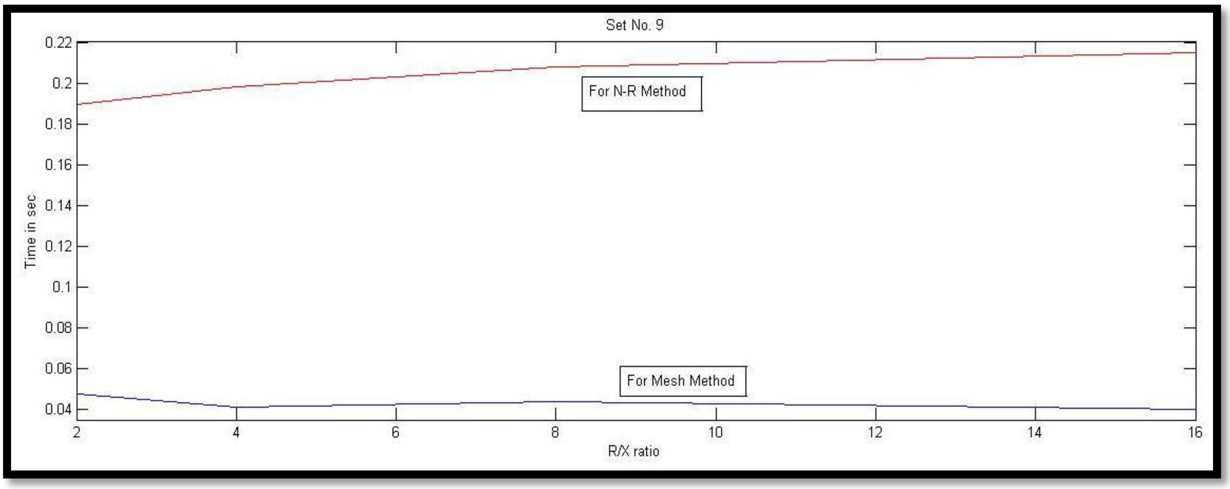
a) For set no.1 (line 1-5)



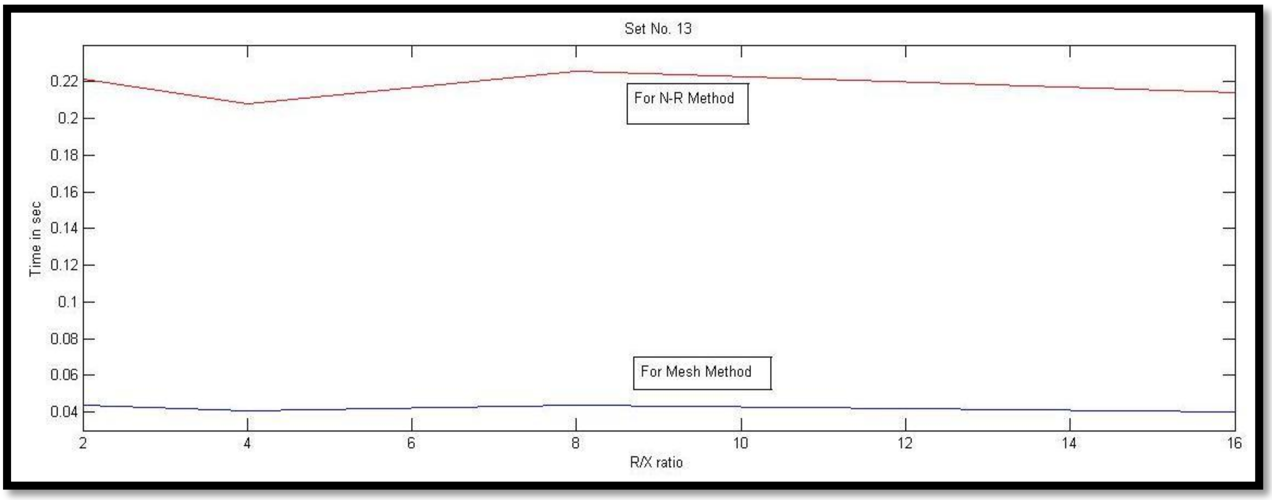
b) For set no.4 (line 16-20)



c) For set no.9 (line 41-45)



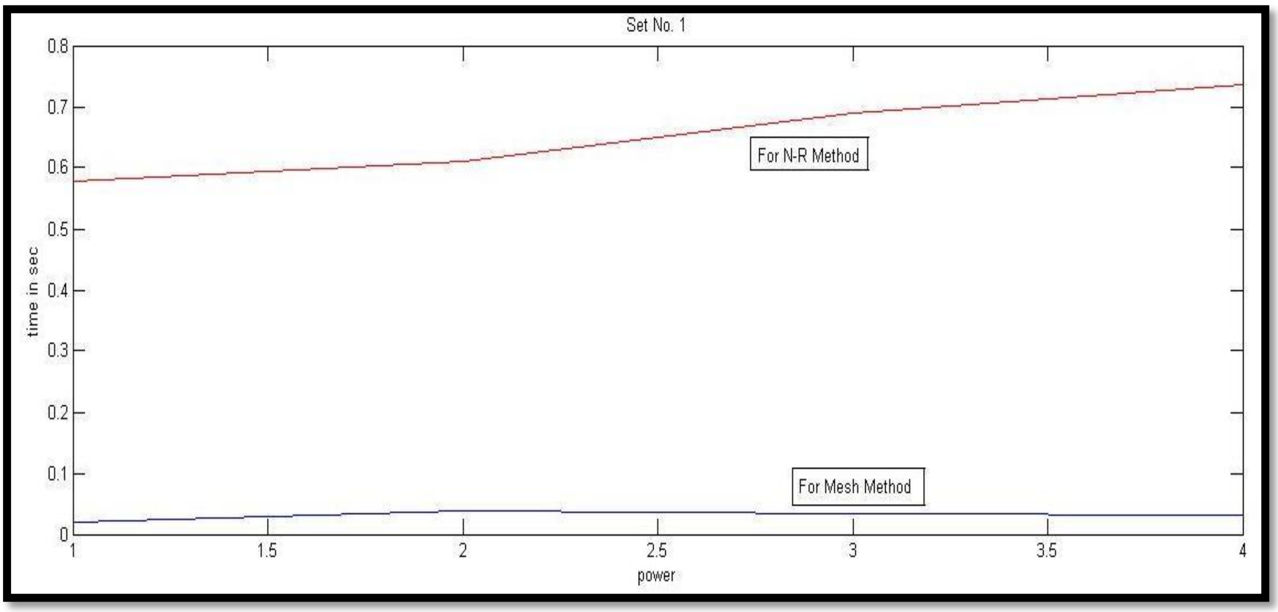
d) For set no.13 (line 61-65)



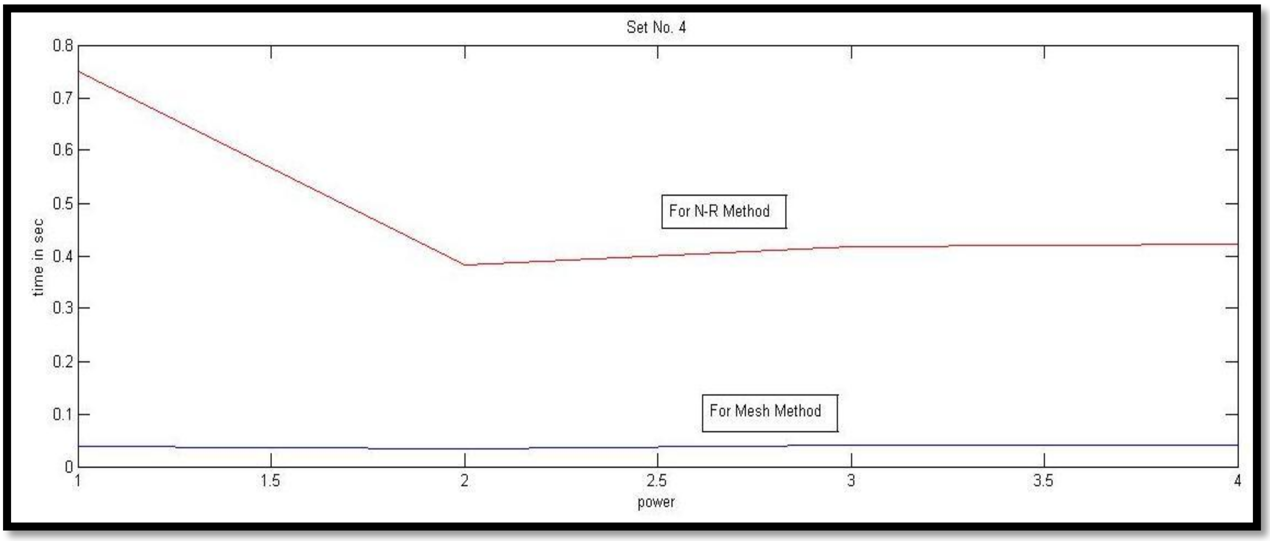
From fig.4.6 it is clear that the computational time for N-R Method is higher than that of the Meshed method. On increasing the R/X ratio the computational time generally increases for N-R method but for Meshed method it fluctuates very slightly and remains almost constant. Thus we can also infer here that N-R method diverges on increasing the R/X ratio whereas the Meshed Method doesn't.

Fig 4.7 Total time vs Total power increased of five lines taken at once for IEEE-69 BUS SYSTEM.

a) For set no.1 (line 1-5)



b) For set no.4 (line 16-20)



c) For set no.8 (line 36-40)

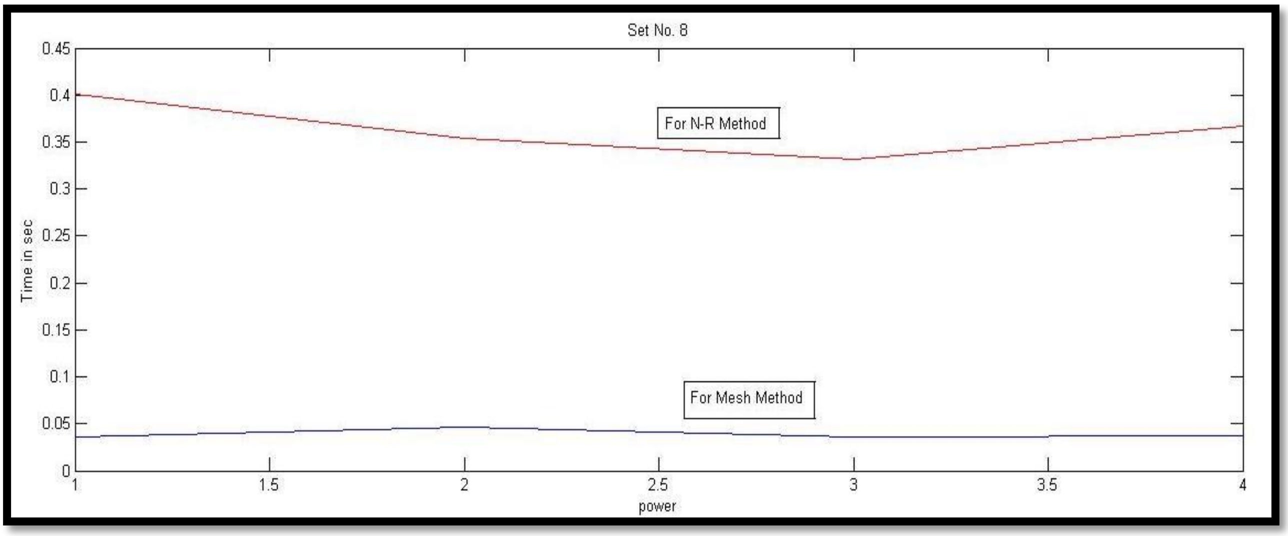


Figure 4.7 shows that the computational time for N-R method is much more than the Meshed Method for the same rise in load power. Also the computational time in case of N-R method varies unevenly by increasing the load power of a set of five lines simultaneously. In some cases it is found that the time decreases on increasing the load power whereas in other cases it increases on increasing the load power. But in case of Meshed method the computational time remains almost constant with the simultaneous increase in power of a set of any five buses

CHAPTER **6**

Conclusion

6.1 CONCLUSION:

The voltage and angle profile for the IEEE-33 BUS SYSTEM and IEEE-69 BUS SYSTEM in the meshed distribution network is analysed using both Newton-Raphson method as well as Meshed Distribution method. In both the cases the profile is almost same. The overall computational time for N-R method is more than that of the Meshed method. Even though the number of iteration taken by Meshed method is more than that of the N-R method but still the time per iteration is lesser in case of Meshed method. It is also found out that on increasing the R/X ratio the computational time for N-R method increases but for Meshed method it remains almost constant. Also if R/X ratio is increased to a very high value then the N-R method got diverged but the Meshed method is still converging. The computational time also varies with the rise in load power. It is observed that in case of N-R method it varies unevenly i.e. sometime it raises but sometime it dips, whereas in case of meshed method the computational time varies very slightly with the increase in load power.

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APPENDIX

Table-6.1: Bus Data for IEEE-33 Bus System

BASE KV= 12.66, BASE MVA= 100

Bus NO.	Bus Code	-------------------Load------------------	
		In Kw	In Kvar
1	1	SLACK BUS	
2	0	100	60
3	0	90	40
4	0	120	80
5	0	60	30
6	0	60	20
7	0	200	100
8	0	200	100
9	0	60	20
10	0	60	20
11	0	45	30
12	0	60	35
13	0	60	35
14	0	120	80
15	0	60	10
16	0	60	20
17	0	60	20
18	0	90	40
19	0	90	40
20	0	90	40
21	0	90	40
22	0	90	40
23	0	90	50
24	0	420	200
25	0	420	200
26	0	60	25
27	0	60	25
28	0	60	20
29	0	120	70
30	0	200	600
31	0	150	70
32	0	210	100
33	0	60	40

Table-6.2: Line Data for IEEE-33 Bus System

Sending Bus	Receiving Bus	R(in ohm)	X(in ohm)
1	2	0.09220	0.04700
2	3	0.49300	0.25110
3	4	0.36600	0.18640
4	5	0.38110	0.19410
5	6	0.81900	0.70700
6	7	0.01872	0.61880
7	8	0.71140	0.23510
8	9	1.03000	0.74000
9	10	1.04400	0.74000
10	11	0.19660	0.06500
11	12	0.37440	0.12380
12	13	1.46800	1.15500
13	14	0.54160	0.71290
14	15	0.59100	0.52600
15	16	0.74630	.054500
16	17	1.28900	1.72100
17	18	0.73200	0.57400
2	19	0.16400	0.15650
19	20	1.50420	1.35540
20	21	0.40950	0.47840
21	22	0.70890	0.93730
3	23	.045120	0.30830
23	24	0.89800	0.70910
24	25	0.89600	0.70110
6	26	0.20300	0.10340
26	27	0.20420	0.14470
27	28	1.05900	0.93370
28	29	0.80420	0.70060
29	30	0.50750	0.25850
30	31	0.97440	0.96300
31	32	0.31050	0.36190
32	33	0.34100	0.53020

Table-6.3: Mesh Data for IEEE-33 Bus System

Sending Bus	Receiving Bus	R(in ohm)	X(in ohm)
8	21	2	2
9	15	2	2
12	22	2	2
18	33	.5	.5
25	29	.5	.5

Table-6.4: Bus Data for IEEE-69 Bus System

BASE KV= 12.66, BASE MVA= 10

Bus NO.	Bus Code	-------------------Load------------------	
		In Kw	In Kvar
1	1	SLACK BUS	
2	0	0	0
3	0	0	0
4	0	0	0
5	0	0	0
6	0	2.6	2.2
7	0	40.4	30
8	0	75	54
9	0	30	22
10	0	28	19
11	0	145	104
12	0	145	104
13	0	8	5.5
14	0	8	5.5
15	0	0	0
16	0	45.5	30
17	0	60	35
18	0	60	35
19	0	0	0
20	0	1	0.6
21	0	114	81
22	0	5.3	3.5
23	0	0	0
24	0	28	20
25	0	0	0
26	0	14	10
27	0	14	10
28	0	26	18.6
29	0	26	18.6
30	0	0	0
31	0	0	0
32	0	0	0
33	0	14	10
34	0	19.5	14
35	0	6	4
36	0	26	18.55
37	0	26	18.55
38	0	0	0
39	0	24	17
40	0	24	17
41	0	1.2	1
42	0	0	0
43	0	6	4.3
44	0	0	0

45	0	39.22	26.3
46	0	39.22	26.3
47	0	0	0
48	0	79	56.4
49	0	384.7	274.5
50	0	384.7	274.5
51	0	40.5	28.3
52	0	3.6	2.7
53	0	4.35	3.5
54	0	26.4	19
55	0	24	17.2
56	0	0	0
57	0	0	0
58	0	0	0
59	0	100	72
60	0	0	0
61	0	1244	888
62	0	32	23
63	0	0	0
64	0	227	162
65	0	59	42
66	0	18	13
67	0	18	13
68	0	28	20
69	0	28	20

Table-6.5: Line Data for IEEE-69 Bus System

Sending Bus	Receiving Bus	R(in ohm)	X(in ohm)
1	2	0.0005	0.0012
2	3	0.0005	0.0012
3	4	0.0015	0.0036
4	5	0.0251	0.0294
5	6	0.366	0.1864
6	7	0.3811	0.1941
7	8	0.0922	0.047
8	9	0.0493	0.0251
9	10	0.819	0.2707
10	11	0.1872	0.0691
11	12	0.7114	0.2351
12	13	1.03	0.34
13	14	1.044	0.345
14	15	1.058	0.3496
15	16	0.1966	0.065

16	17	0.3744	0.1238
17	18	0.0047	0.0016
18	19	0.3276	0.1083
19	20	0.2106	0.0696
20	21	0.3416	0.1129
21	22	0.014	0.0046
22	23	0.1591	0.0526
23	24	0.3463	0.1145
24	25	0.7488	0.2745
25	26	0.3089	0.1021
26	27	0.1732	0.0572
3	28	0.0044	0.0108
28	29	0.064	0.1565
29	30	0.3978	0.1315
30	31	0.0702	0.0232
31	32	0.351	0.116
32	33	0.839	0.2816
33	34	1.708	0.5646
34	35	1.474	0.4873
3	36	0.0044	0.0108
36	37	0.064	0.1565
37	38	0.1053	0.123
38	39	0.0304	0.0355
39	40	0.0018	0.0021
40	41	0.7283	0.8509
41	42	0.31	0.3623
42	43	0.041	0.0478
43	44	0.0092	0.0116
44	45	0.1089	0.1373
45	46	0.0009	0.0012
4	47	0.0034	0.0084
47	48	0.0851	0.2083
48	49	0.2898	0.7091
49	50	0.0822	0.2011
8	51	0.0928	0.0473
51	52	0.3319	0.1114
9	53	0.174	0.0886
53	54	0.203	0.1034
54	55	0.2842	0.1447
55	56	0.2813	0.1433
56	57	1.59	0.5337
57	58	0.7837	0.263
58	59	0.3042	0.1006

59	60	0.3861	0.1172
60	61	0.5075	0.2585
61	62	0.0974	0.0496
62	63	0.145	0.0738
63	64	0.7105	0.3619
64	65	1.041	0.5302
11	66	0.2012	0.0611
66	67	0.0047	0.0014
12	68	0.7394	0.2444
68	69	0.0047	0.0016

Table-6.3: Mesh Data for IEEE-69 Bus System

Sending Bus	Receiving Bus	R(in ohm)	X(in ohm)
21	65	0.2012	0.0611
25	32	0.3861	0.1172
26	69	0.1089	0.1373
35	43	0.3744	0.1238
52	40	0.0015	0.0036