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Network Topology Based Back/Forward Sweeping for Load Flow of Radial Distribution Systems

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ABSTRACT: This paper presents a simple network topology based back/forward sweeping method for radial distribution systems. This method uses networktopology based matrices and KCL , KVL based equations. The data are stored in matrix form, then the memory requirement is very less.The current and voltage values have been updated in two subsequent sweeps (Backward and Forward). The requirement of sequential branch numbering has been averted. This method has been tested to IEEE 33 and 69 test systems and time required and accuracy has been found satisfying.

KEYWORDS: Radial distribution system, load flow, Network topology, Back/forward sweep.

I.INTRODUCTION

Referable to the high R/X ratio and ill conditioned radial structure of distribution systems, conventional methods that has been utilized for load flow of transmission systems fail to converge in distribution network.However modified NR method can be employed for the design, but the size of the Jacobian of a real distribution would be largely sparse for the role.A set of methods has been previously suggested in literature for load flow of the radial distribution network as analysis of distributed systems is very necessary as the connection between power system and consumer.

II.RELATED WORKS

The conventional methods of load flow presented in[1] and [2] were later found to be very complex and time consuming.Kersting and Mendive[3] and kersting [4] proposed load flow of radial distribution system by using ladder-network theory but stevens [5] showed that the proposed method become fastest but does not converge in five out of twelve cases it studied.Shirmohammadi [6]presented a new method by using KCL and KVL laws and proposed a new branch numbering scheme, but the memory requirement became very high. Baran and Wu [7] prepared a load flow method by iterating fundamental equations for real, reactive and voltage magnitude. Goswami and Basu[8] proposed a new method but with conditions of no branch is a junction of more than three branches. Das*et.al* [9] proposed a method of coding at each lateral and sub laterals but with larger systems the coding became more complex.Ghosh and Dash [10] solved load flow equations by considering nodes beyond a node, they have alsoincorporated charging admittances.Aravindhababu [11] has proposed a method based on branch-node power flow (BNPF) but it also added complexity. Ranjan*et.al*[12] proposed a technique by calculating the voltage at each bus by forward sweeping but it required calculation of real and reactive load at the receiving end node and all branch losses and loads beyond the receiving node.

The main objective of this paper is to solve load flow problems for radial systems by using simple KVL and KCL equations with no trigonometric functions used. This method requires a branch and node identification scheme beyond a node, which is required to find out branch current flows and power losses. Based on the topology of the network, the number of laterals (paths) is found out.

Initial voltage of 1p.u across the network assumed and initial power losses in the branches are assumed to be zero.Again, it is assumed that the three phase radial distribution system is balanced and represented by the single line diagram. Charging capacitances are neglected at distribution levels.

III.METHODOLOGY

The following are steps are to be studied to find out some network based matrices:

Step-1: The system data like branch impedance, load real and reactive power are converted to p.u.

Step-2: Matrix **A** (*Branch-node incidence matrix*) is formed by considering branches as rows and nodes as columns, hence the dimensions of the matrix would be $(n - 1 \times n)$, where n is the no of nodes of the matrix.

For *i* th node

$$A_{ij} = \begin{cases} -1, \text{if jth node is sending node.} \\ +1, \text{if jth node is receiving node.} \end{cases}$$

Step-3: The number of laterals or the possible paths (l) are found out by calculating the number of end nodes.

Step-4: The next step would be to get the nodes on each lateral. The lateral having maximum number of nodes say (m) is found. Then the matrix say **B** is supposed to have dimensions of $(l \times m)$.

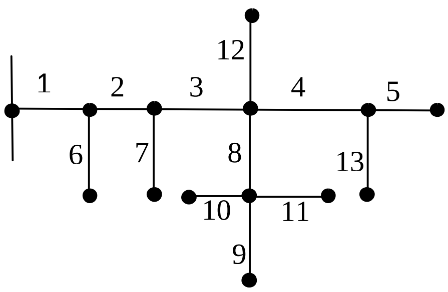

Figure.1 Example of a radial system with only branches numbered

Step-5: In a radial distribution system, itfinds necessary the branches beyond a branch. Hence a *next-linked branch matrix* (**C**) is formed. In the above lateral the number of possible paths is8. Hence the size of **C** would be13×8.However, to reduce memory space up to 4 columnsin this case has to be considered as no branch is connected to more than 3 branches. Here the row number shows the branch number and column denotes the connected branches.

$$C_{13\times 4} = \begin{bmatrix} 2 & 6 & 0 & 0 \\ 3 & 7 & 0 & 0 \\ 8 & 12 & 0 & 0 \\ 5 & 13 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 9 & 10 & 11 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix}$$

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The following steps are then to be considered for load flow calculations:

Step 1: Assume a flat voltage(1 p.u) across the network and system losses are considered to be zero.

$$v_i = 1p.u \quad \text{for } i = 1 \; to \; n,$$

$$LP_j, LQ_j = 0 \quad \text{for } j = 1 \; to \; b.$$

n= total number of nodes.

b=total number of branches.

Step 2: Set the maximum number of iteration.

Step-3: Start Iteration count IT=1.

Step-4: calculate the branch currents as

$I_i = (S_{i+1}|V_{i+1})^*$ ……..(1)

Where, i is 1 to$b$.

Step-5: Backward sweep:

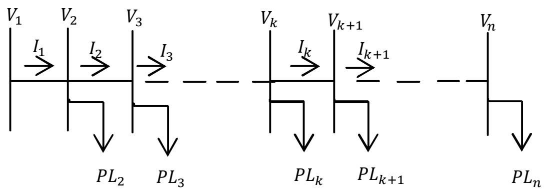

Figure.2 Example showing current flow

In the backward sweeping method, the current values are to be updated starting from the endnode.
For the $k\;th$ branch,

$$I_k = \sum_{j \in C_j} IL_j \;;\; k \text{ is from 1 to } b \qquad \text{……….. (2)}$$

Where C_jIs the set of all nodes beyond the branch$k$. It is to be found out from the C matrix, for updating the values ofI_kIt is then checked for the connected branches of k.

Step-6: Forward sweep:

After finding out the branch currents, the nodal voltages are updated, starting from the source node (i.e. substation).

$V_{k+1} = V_k - I_k . Z_k$; k is from 1 to n. ………… (3)

Step-7: Calculate the branch real and reactive power losses.

$$Pl_j = I_j^2 . R_j$$

$$Ql_j = I_j^2 . X_j \qquad \text{…..……..} \qquad (4)$$

Total real power loss: $TPl_{IT} = \sum_{j=1}^{b} Pl_j$

Total reactive power loss: $TQl_{IT} = \sum_{j=1}^{b} Ql_j$ ………… (5)

Step-8: Check for difference between TPl_j,$TQl_j$for the current iteration with the previous iterations.If difference is sufficiently small(∈) then go to step 9, otherwise go to step 4.

$TPl_{IT} - TPl_{IT-1} \leq \in$

and $TQl_{IT} - TQl_{IT-1} \leq \in$ ………… (6)

Step-9: check for iteration count. If it is less than the maximum number of iterations the go to step 10, otherwise increment iteration count by 1 and go to step 4.

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Step-10: Display Results.

The detailed flow chart of the procedure is shown in APPENDIX.

IV.EXAMPLES

The algorithm is tested on two IEEE test systems. For IEEE 33 bus system data are obtained from [13] and for IEEE 69 bus system data are obtained from [7].Base KV for the systems are 12.66 and base MVA is 100.

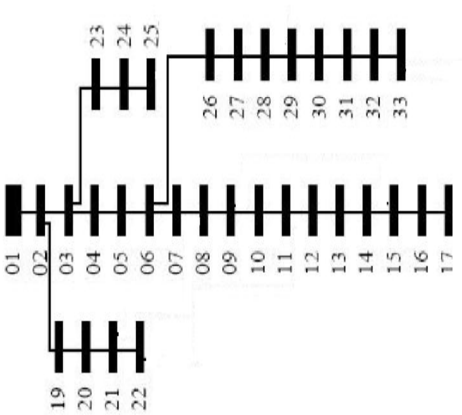

Figure.3 IEEE 33 bus test system[13]

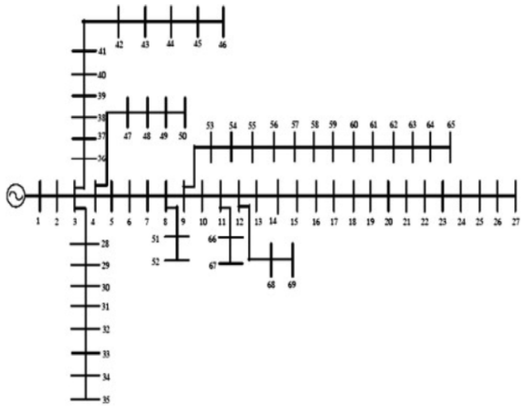

Figure.4 IEEE 69 bus test system[7]

For the IEEE 33 bus system total real power load is 3715 KW and total reactive power is 2300 KVAR. Voltage profile across the network is shown in table.1.

Table.1 (Voltage profile)

Node	Voltage(PU)	Voltage(KV)
1	1	12.66
2	0.99703	12.622
3	0.98294	12.444
4	0.97546	12.349
5	0.96806	12.256
6	0.94966	12.023
7	0.94617	11.979
8	0.94133	11.917
9	0.93506	11.838
10	0.92924	11.764
11	0.92838	11.753
12	0.92688	11.734
13	0.92077	11.657
14	0.9185	11.628
15	0.91709	11.61
16	0.91572	11.593
17	0.9137	11.567
18	0.91309	11.56
19	0.9965	12.616
20	0.99293	12.57
21	0.99222	12.562
22	0.99158	12.553
23	0.97935	12.399
24	0.97268	12.314
25	0.96936	12.272
26	0.94773	11.998
27	0.94517	11.966
28	0.93373	11.821
29	0.92551	11.717
30	0.92195	11.672
31	0.91779	11.619
32	0.91687	11.608
33	0.91659	11.604

Total real power loss is found out to be **202.68 KW** and total reactive power loss is **135.14 KVAR**.

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For IEEE 69 bus system total real power load 3801.9 KW and total reactive power load is 2694.1 KVAR. Voltage profile across the network is shown in table. 2.

Table.2(Voltage profile)

Node	Voltage(PU)	Voltage(KV)
1	1	12.66
2	0.99997	12.66
3	0.99993	12.659
4	0.99984	12.658
5	0.99902	12.648
6	0.99009	12.534
7	0.9808	12.417
8	0.97858	12.389
9	0.97745	12.374
10	0.97245	12.311
11	0.97135	12.297
12	0.96819	12.257
13	0.96527	12.22
14	0.96237	12.184
15	0.9595	12.147
16	0.95897	12.141
17	0.95809	12.129
18	0.95808	12.129
19	0.95762	12.123
20	0.95732	12.12
21	0.95684	12.114
22	0.95683	12.113
23	0.95676	12.113
24	0.9566	12.111
25	0.95643	12.108
26	0.95636	12.108
27	0.95634	12.107
28	0.99993	12.659
29	0.99985	12.658
30	0.99973	12.657
31	0.99971	12.656
32	0.99961	12.655
33	0.99935	12.652
34	0.99901	12.648
35	0.99895	12.647
36	0.99992	12.659
37	0.99975	12.657
38	0.99959	12.655
39	0.99954	12.654
40	0.99954	12.654
41	0.99884	12.645
42	0.99855	12.642
43	0.99851	12.641
44	0.9985	12.641
45	0.99841	12.64
46	0.9984	12.64
47	0.99979	12.657
48	0.99854	12.642
49	0.9947	12.593
50	0.99415	12.586
51	0.97854	12.388
52	0.97854	12.388
53	0.97466	12.339
54	0.97142	12.298
55	0.96694	12.242
56	0.96258	12.186
57	0.9401	11.902
58	0.92904	11.762
59	0.92476	11.708
60	11.644	11.644
61	0.91234	11.55
62	0.91205	11.547
63	0.91167	11.542
64	0.90977	11.518
65	0.90919	11.51
66	0.97129	12.297
67	0.97129	12.297
68	0.96786	12.253
69	0.96786	12.253

Total real power loss is found out to be **224.95 KW** and total reactive power loss is **102.15 KVAR**.

V.CONCLUSION

This paper, presents a network topology based load flow for radial distribution system.The data are stored in matrix form, hence the memory requirement is very low.The numbering pattern for the elements is not a concern, for the

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algorithm. However, the proposed algorithm takes zero initial loss approximation and flat voltage profile across the network. The efficiency of the method tests with satisfying results.

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VIII.BIOGRAPHY

Soumitri Jena obtained B.Tech. from D.R.I.E.M.S, Cuttack in the year 2011. Presently, he is continuing M.Tech. in Power System Engineering from National Institute of Technology, Hamirpur. His area of interest include Power Distribution Systems, Computer analysis of Power system problemsand application of Artificial Intelligence in Power System.

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VII.APPENDIX: *PROCESS FLOW*