Load Flow Analysis For

Meshed Network Using Backward/Forward Sweep Method

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***Abstract*— This paper involves the development of a Matlab program which analyzes load flow in distribution system in mesh network with a defined number of nodes, real and reactive load power consumption at the nodes through the forward-backward load flow algorithm for IEEE 33 bus network.**

1. Introduction

Load flow analysis is the study of the flow of electrical power in a system of electrical buses. It is essential as it helps to plan the construction and expansion of the system. There are various numerical techniques to perform load flow analysis such as Gauss-Seidel, Newton-Raphson, fast decoupled method, Backward/Forward sweep, etc. Here we go for Backward/Forward sweep method for its simplicity and low computing cost amongst the others. IEEE has defined specific systems with fixed no of buses like 33, 69, etc. These test systems can be used to test the convergences of various load flow analysis algorithms. We make use of IEEE standard 33 bus system, which is the radial connected bus system to check the convergence of the Backward/Forward sweep method for the original system as well as for a modified weakly meshed network system.

A. Radial System

It is the most simple and commonly constructed network among the distributed system. Here all the buses are connected in series, which may be branched or unbranched. The variation in voltage profile for this type of system is a linear decrease across each of the buses, due to this voltage profile across the nodes away from the central source node has a drastic drop in their magnitude as compared to the source node voltage.

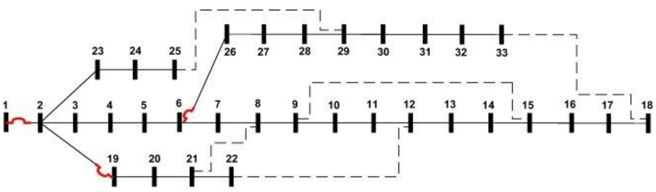


Fig 1. IEEE 33 bus system - Radial Network[5]

B. Meshed Network System

The problem faced by the radial system is the poor voltage profile faced by the nodes away from the source node the system. To improve the voltage profiles, we make use of interconnection between various nodes of the bus system. These interconnections allow the fraction of current across the bus with poor voltage profile through it, thus decreasing the effective drop in voltage across the impedance line increasing the voltage of the buses enclosed by the interconnections.

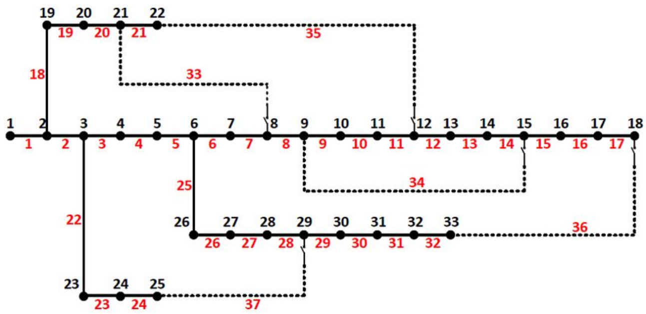


Fig 2. IEEE 33 bus system - Meshed Network[4]

I. Methodology

A. Backward/Forward sweep method

The first step of this method is to initialize all the bus voltages to 1 angle 0, i.e., flat start and the load current of each bus is calculated through the bus data provided.

- $L = \left(\frac{P}{Vs}\right)$

This is followed by the backward sweep, where all branch currents are sequentially calculated from all end nodes to the start node using KCL.

$$I_{ij} = I_j + \sum_k I_{jk}$$

where, I_{ij} is the current flowing the branch from i^{th} bus to j^{th} bus, and the second term is the sum of all branch currents flowing out of the j^{th} bus. Once, the branch currents for a given iteration have been calculated, the backward sweep ends. The next step is the forward sweep which sequentially calculates the bus voltages from the start bus to the end bus using KVL.

$$V_i = V_{i-1} - I_{i-1i} \cdot Z_{i-1i}$$

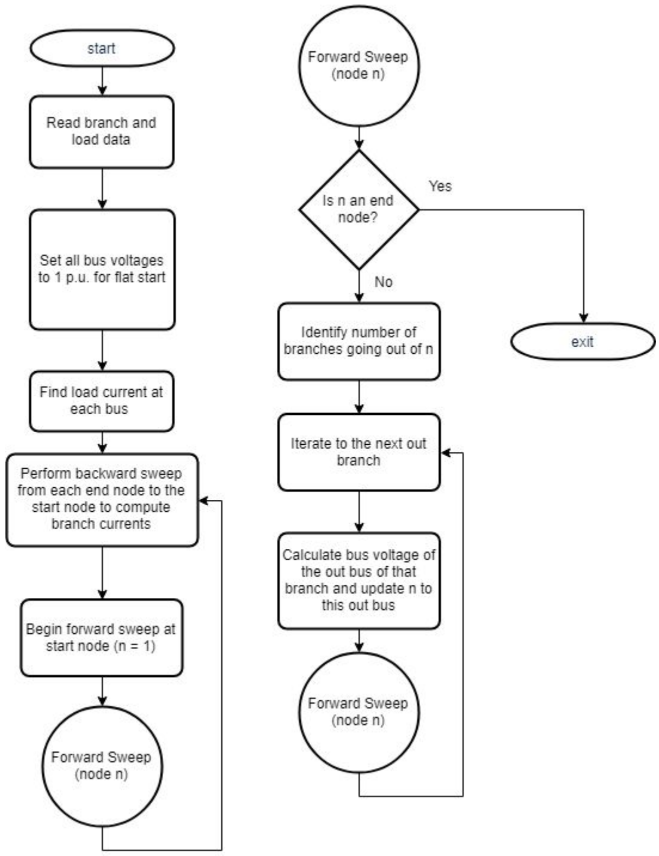
B. Weakly Meshed Network

The method is modified when the system is changed from a radial network to a weakly meshed network. Both backward and forward sweep steps are carried out the same way ignoring the newly added interconnections. After the updated voltage profiles are obtained from the forward sweep, these are used to update the value of interconnection branch current and the backward sweep equation has an extra term to take these connections into account.

$$I_{ij} = I_j + \sum_k I_{jk} - \sum_{l,\, l \neq i} I_{lj}$$

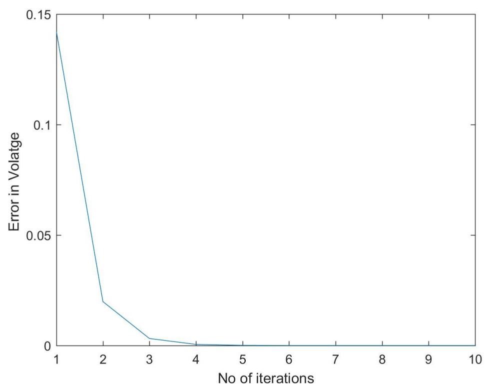
The extra term represents all the branch currents flowing into the j^{th} bus.

III. Algorithm

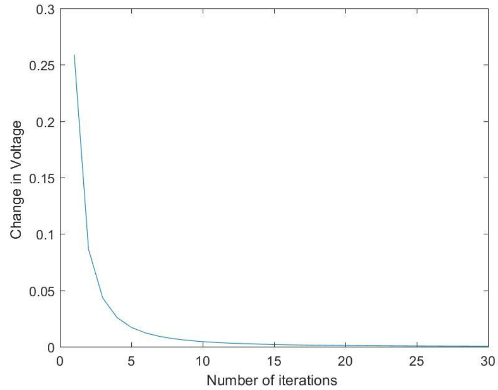


IV. Result

1. Convergence



The backward /forward sweep algorithm for the IEEE standard 33 bus radial system converges in 4 iterations as shown in the plot.



The algorithm converges in around 20 iterations for the IEEE standard 69 bus radial system.

2. Comparison between Radial System (IEEE 33 Standard Bus) and Weakly Meshed System

Bus No.	Voltage Magnitude (p.u.) Radial	Voltage Magnitude (p.u.) Weakly Meshed	Voltage Magnitude (p.u.) using non recursive method
1	1.0000	1.0000	1.0000
2	0.9860	0.9984	0.9974
3	0.9426	0.9930	0.9851
4	0.9242	0.9893	0.9782
5	0.9094	0.9857	0.9714
6	0.8818	0.9768	0.9548
7	0.8782	0.9768	0.9517
8	0.8642	0.9768	0.9469
9	0.8577	0.9768	0.9397
10	0.8517	0.9768	0.9334
11	0.8508	0.9768	0.9325
12	0.8492	0.9768	0.9308
13	0.8429	0.9768	0.9239
14	0.8406	0.9768	0.9213
15	0.8391	0.9768	0.9191
16	0.8377	0.9768	0.9174
17	0.8356	0.9768	0.9146
18	0.8349	0.9768	0.9136
19	0.9855	0.9979	0.9965
20	0.9821	0.9945	0.9917
21	0.9814	0.9939	0.9907
22	0.9808	0.9933	0.9894
23	0.9390	0.9930	0.9816
24	0.9324	0.9930	0.9762
25	0.9291	0.9930	0.9715
26	0.8798	0.9751	0.9529
27	0.8772	0.9728	0.9504
28	0.8655	0.9627	0.9392
29	0.8571	0.9930	0.9312
30	0.8534	0.9899	0.9275
31	0.8491	0.9862	0.9189
32	0.8482	0.9854	0.9177
33	0.8479	0.9852	0.9168

The voltage profiles were found for a basic 33 bus radial system and will be used as a reference to compare the voltage profiles with that obtained for the weakly meshed system. For the weakly meshed system, the following interconnections are taken:

8→21 (0.4 + 0.4j)
9 →15 (0.4 + 0.4j)
12→22 (0.4 + 0.4j)
18→33 (0.4 + 0.4j)
25→29 (0.4 + 0.4j)

On comparing the results, the average voltage profile across the system increases with interconnections.

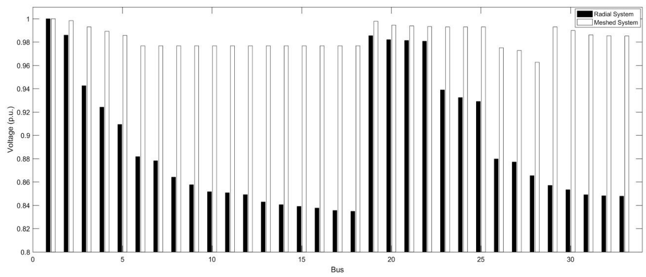


Fig 3. Comparison of voltage profiles of radial and meshed network systems

As we can see from the comparison plot, the voltage profile of the system improves when the buses are enclosed in the interconnections. Thus providing the meshed network a significant practical applicability when the compared to the latter system, thus resulting in the improvement in connectivity of various range of loads to the system.

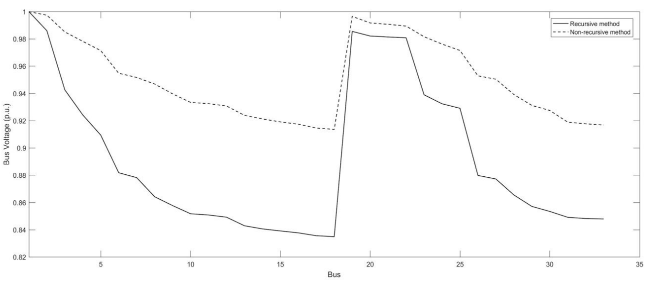


Fig 4. Comparison of data with non-recursive methods

The above plot is the comparison of the recursive technique for the backward-forward sweep method with the non-recursive iterative method. We can infer from the plot that the voltage profiles of the recursive method is more pessimistic while predicting the practical scenario compared the other techniques.

V. Conclusion

It is found that as we move away from the source node, the voltage profile decreases and the profile obtained for the recursive method used in this paper is found to be more pessimistic than other methods. The voltage profiles in a standard radial distribution system can be improved by adding interconnections between buses. Backward/Forward sweep method converges fast due to the lower computing cost associated with the method.

VII. References

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VIII. Appendix

1. Appendix 1-Branch Data For IEEE-33 Bus System

In Bus	Out Bus	Impedance $(R + Xj)\,\Omega$
1	2	0.0922 + 0.0477j
2	3	0.493 + 0.2511j
3	4	0.366 + 0.1864j
4	5	0.3811 + 0.194j
5	6	0.819 + 0.707j
6	7	0.1872 + 0.6188j
7	8	1.7114 + 1.2351j
8	9	1.03 + 0.74j
9	10	1.04 + 0.74j
10	11	0.1966 + 0.065j
11	12	0.3744 + 0.1238j
12	13	1.468 + 1.155j
13	14	0.5416 + 0.7129j
14	15	0.59 1+ 0.526j
15	16	0.7463 + 0.545j
16	17	1.289 + 1.721j
17	18	0.732 + 0.574j
2	19	0.164 + 0.1565j
19	20	1.5042 + 1.3554j
20	21	0.409 5+ 0.4784j
21	22	0.7089 + 0.9373j
3	23	0.4512 + 0.3083j
23	24	0.898 + 0.7091j
24	25	0.896 + 0.7011j
6	26	0.203 + 0.1034j
26	27	0.2842 + 0.1447j
27	28	1.059 + 0.9337j
28	29	0.8042 + 0.7006j
29	30	0.5075 + 0.2585j
30	31	0.9744 + 0.963j
31	32	0.3105 + 0.3619j
32	33	0.341 + 0.5302j