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Forward and Backward Sweep Algorithm for Distribution Power Flow Analysis and Comparison of Different Load Flow Methods

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Abstract: Power flow analysis is a very important and fundamental tool for the analysis of any electrical distribution system and is used in the operational as well as planning stages. Certain applications particularly in distribution automation and optimization of an electrical system require repeated load flow solutions. In these applications it is very important to solve the power flow problem as efficiently as possible. This paper describes a forward backward sweep method based approach for load flow analysis in radial distribution system and also includes comparison of different load flow methods. The effectiveness of the proposed forward and backward sweep algorithm will be tested on IEEE-33 bus system.
Keywords: Load flow analysis, Radial distribution system, Backward/forward sweep, Distributed Generation.

I. INTRODUCTION

In radial distribution systems, iterative techniques commonly used in power flow analysis for transmission networks are not suitable, because of their convergence and computational efficiency properties. In transmission systems Newton-Raphson (NR) and Gauss-Siedel (GS) methods are very popular.

However these are non-appropriate methods for distribution network due to high R/X ratio, the existence of unbalanced load. Therefore, due to these distribution network properties which most of the time caused the non-rapid convergence, special methods are needed to solve the load allocation problem rapidly.

Kersting in [1] exposes a forward and backward sweep (FBS) flow solution method for radial distribution systems, with no losses as initial condition. Then it determines voltages at end nodes and starts the backward sweep to calculate new voltages and currents. At the end of each iteration the difference between the calculated and specified values of voltage at source node is used as stopping criterion.

Electric energy that is contributed to the grid from many decentralized locations, such as from wind farms and solar panel installations, is known as Distributed Generation (DG). DG[7] resources have increased dramatically in India due to the policies related to interconnection e.g. new energy metering schemes, as well as due to the programs related to advancing the integration of green & clean energy.

II. FORWARD BACKWARD SWEEP METHOD

A. Variants of Forward Backward Sweep Method

Three variants of FBS method exist which differ on the basis of the electrical quantity being calculated during the iterations:

1) Current summation method: In this variant the currents flowing in the branches are calculated.
2) Power summation method: This variant basically calculates the power flow through branches.
3) Admittance summation method: In this variant driving point admittance for each and every node is calculated and then the current is calculated.

III. SYSTEM MODELLING

For the purposes of power flow studies, we model a radial distribution system as a network of buses connected by distribution lines, switches, or transformers to a voltage specified source bus. Each bus may also have a corresponding load, shunt capacitor or cogenerator connected to it. The model can be represented as shown in Figure 1.

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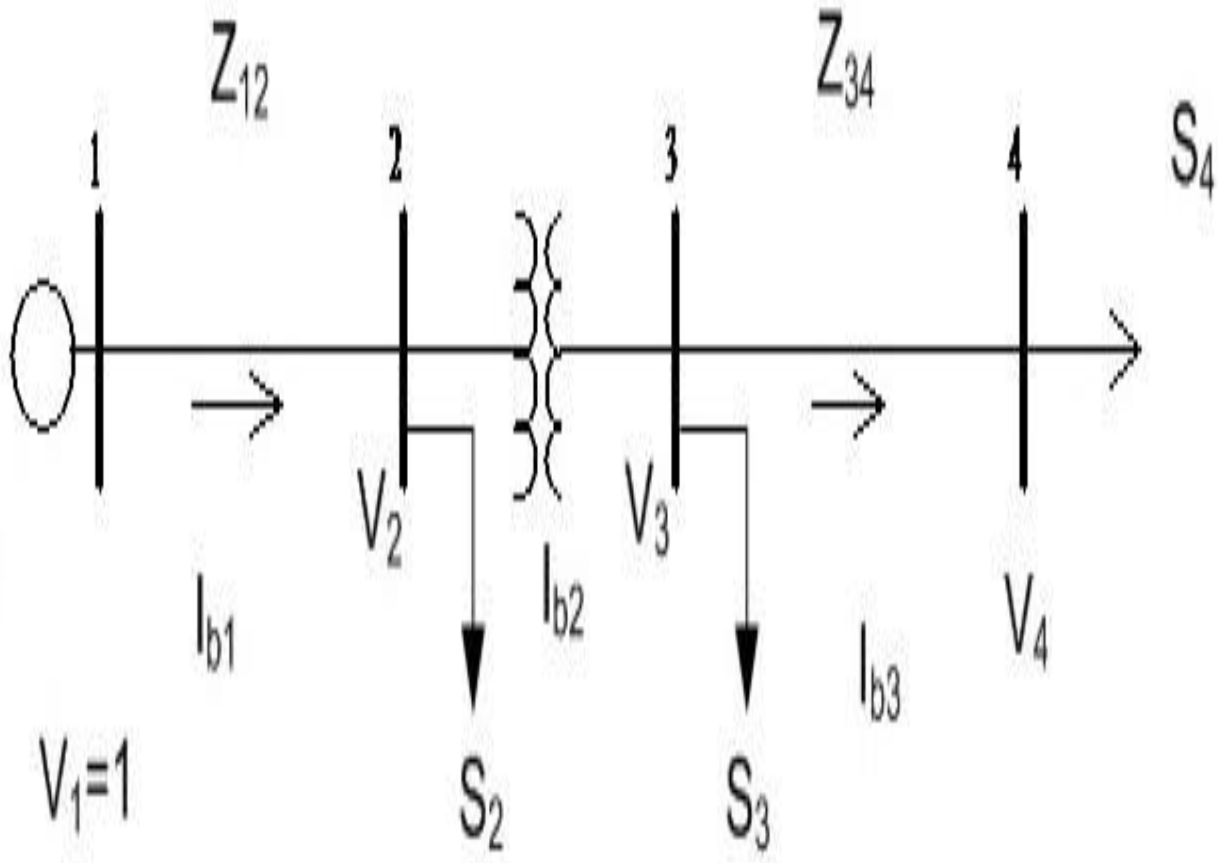


Forward → ← Backward

Fig. 1. Radial Distribution System

KERSTING METHOD (KM) [1] for radial distribution network, it is considered that the source voltage and all branch impedance and load impedances are known. To start up the system is considered without losses which mean that there are no load currents. Effective power flow in each branch is obtained in the backward sweep by considering 1 per unit (p.u.) voltage at the end node in first iteration and the end node's voltage is equal to the voltage calculated in forward sweep in further iterations. This indicates that the backward sweep starts at the end node and proceeds towards the source node.

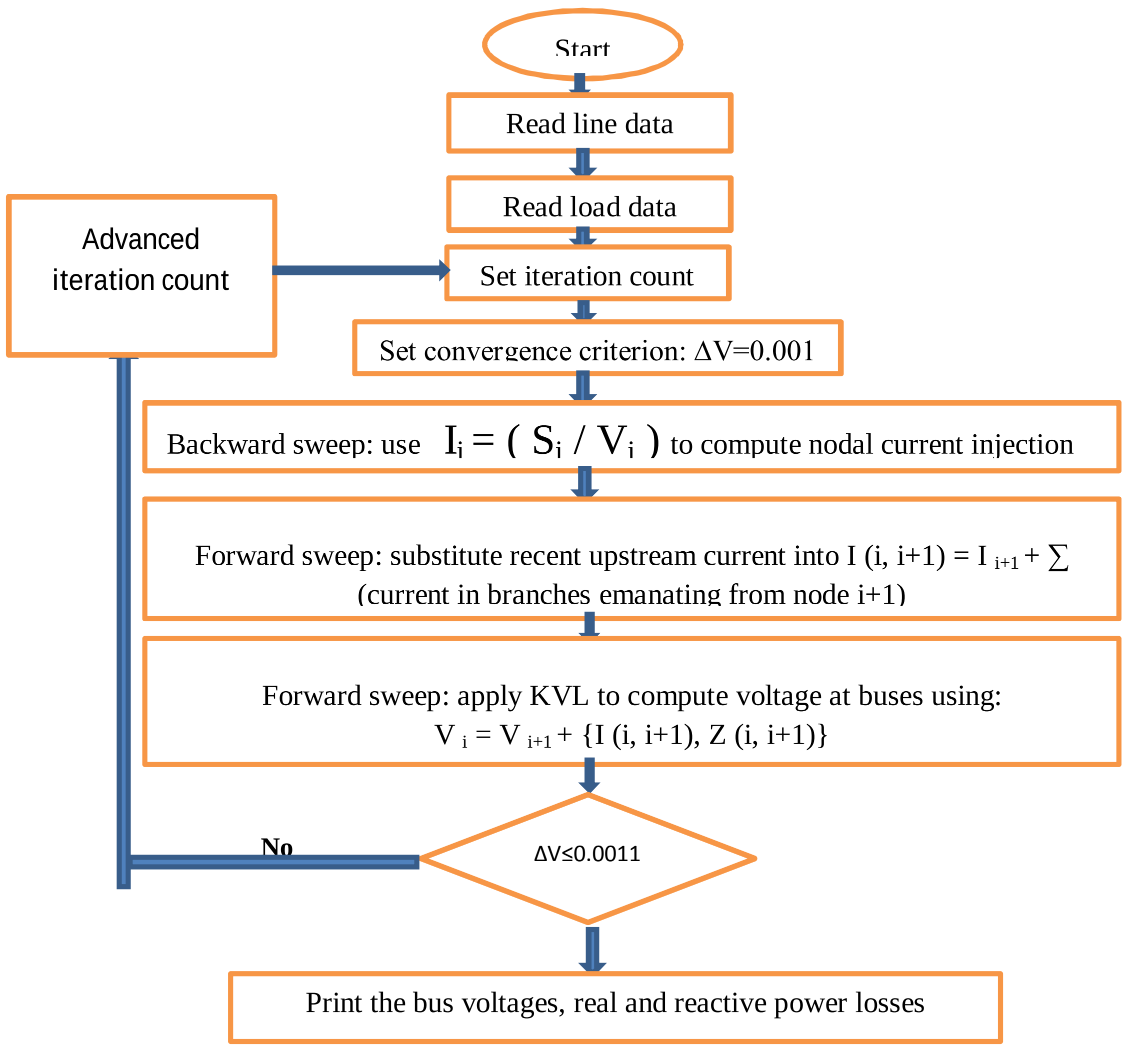
Input: substation voltage, load

Steps:

Initial current = 0, Initial voltage V = 1PU.
Compute node current In using Node model.
Backward: Compute branch current Ib using KCL.
Forward: Update Vk+1 = Vk based on Ib.
Check convergence (|dS|<Error Limit) stop or go to step 2.

Voltage obtained at the source node calculated in backward sweep is used to check the convergence. If voltage obtained at the source node in backward sweep has less difference than the convergence criterion then process stops there and if the voltage is not in convergence limit then forward sweep is started. The purpose of the forward sweep is to calculate the voltages at each node starting from the feeder source node. The feeder substation voltage is set at the value calculated in backward sweep. During forward sweep the effective power (i.e. the current calculated) in each branch is held same as the value obtained in backward sweep.

Flow Chart for the Solution Methodology:



IV. CLASSIFICATION & COMAPRISON

In the distribution network, because of the special structure, NR and many other traditional methods used for power flow analysis may fail to converge or use lot of time for calculation. Therefore, a lot of algorithms in the distribution network, such as FBS method, the loop circuit method, power distribution coefficient method, etc. have been proposed. The proposed method is compared with other load flow methods that are used for distribution systems.

Table 1: Classification and comparison

S.No	Parameters of comparison	Gauss Siedel	Newton Raphson	Fast Decoupled Load Flow
1.	Convergence	Linear	Quadratic	Geometric
2.	Arithmetic Operations	Least in number to complete one operation	Elements of Jacobian to be calculated in each iteration	Less than Newton Raphson
3.	No of Iterations	Large Number, increases with increase in buses	Very less (3 to 5 only) for large systems and is practically constant	Only 2 to 5 iterations for practical accuracies

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4.	Slack Bus Selection	Choice of slack bus affects convergence adversely	Sensitivity to this is minimal	Moderate
5.	Accuracy	Less accurate	More accurate	Moderate
6.	Memory	Less memory because of sparsity of matrix	Large memory even with compact storage scheme	Only 60% of memory when compared to NR
7.	Programming Logic	Easy	Very Difficult	Moderate
8.	Reliability	Only for small systems	Reliable even for large systems	More reliable than NR method.

A. NR & Fast Decoupled Load Flow (FDLF)

This method is not ideal for the distribution network, and these methods are based on good initial value without which it might diverge.

B. Newton-Downhill Algorithm

Down-hill algorithm [2] is usually used in the optimization problem. Generally speaking, NR method is local convergence. It is well established that in order to make the NR method convergence to the global, the initial iteration value must be very close to convergence value. Sometimes it is very difficult to choose the initial approximate value to meet the convergence conditions of NR method. The Down-hill algorithm can make NR method with a large-scale convergence. Hence to improve the convergence rate and to shorten the calculation time this method in the power flow calculation is relatively better because it can make many power flow calculations more robust this is the real need for power flow algorithm.

C. Genetic Algorithm Based

It is simple to implement and suitable for offline problems. However in complex network excessive computation time is needed and it is sensitive to controller parameters

D. Artificial Neural Network

It can handle large amount of data sets and suitable for online problems but the specified input range is limited and greater computational burden is also a disadvantage.

E. Backward/Forward sweep method

1) Advantages

a) Jacobian Matrix is not needed.

b) Not Depends on PV (Voltage Controlled Bus) and DG number for small networks.

c) Suitable for online and offline problems.

2) Disadvantages

a) Unsuccessful for Heavy Load.

b) Unsuccessful for large scale network.

V. CONCLUSION

The load flow analysis is primarily important for power systems operation and planning, contingency analysis, state estimation etc. The FBS method uses simple algebraic equations to calculate the outgoing power and voltage magnitudes at different nodes. The FBS algorithm is basically an iterative process, but use of simple equations make the FBS algorithm very robust and numerically efficient for convergence over the wide variations in the voltages of radial distribution system. DG is termed as decentralized generation because the energy generated and distributed using small scale technologies is closer to its end. India

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is facing high energy demand as the demand has always grown faster than generation capacity. Presently there are still so many rural areas where electricity has not reached yet and where grid connectivity is neither feasible nor cost effective. That's why the off grid or decentralized DG is a better option for electricity supply. The growing rate of DG also suggests that alternative energy based solutions will play an increasingly important role in the smart grid and modern utility.

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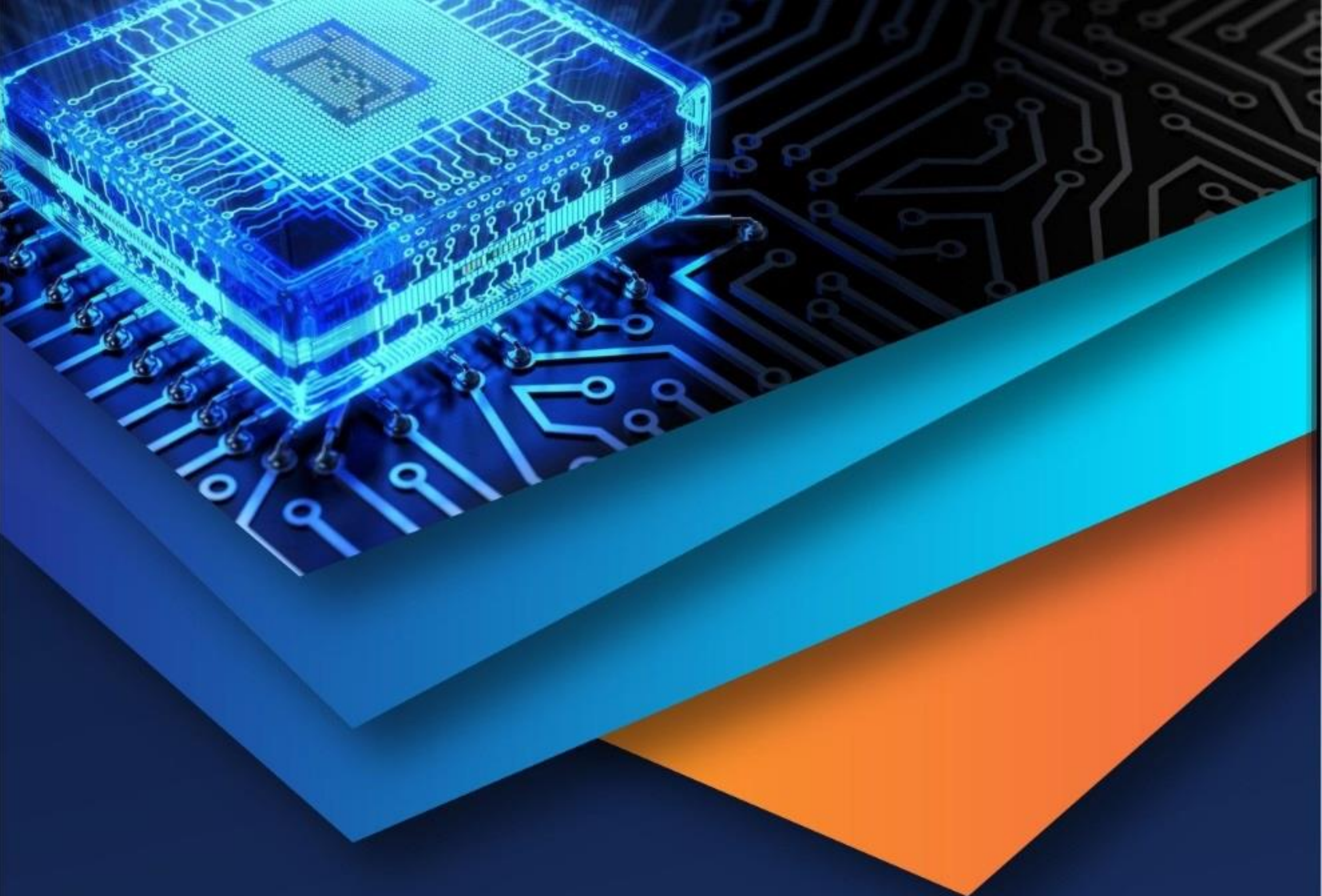

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