Load flow Analysis using Backward Forward Sweep Method

Bhavana Jangid
Department of Electrical and Instrumentation Engineering
Thapar University
Patiala-147004, Punjab

Smarajit Ghosh, PhD
Professor
Department of Electrical and Instrumentation Engineering
Thapar University
Patiala-147004, Punjab

ABSTRACT

The proposed method provides convergence approach which is fast and time efficient. The sequential numbering of the branches are not required in this methodology which makes it much easier from computation point of view. The backward forward sweep method for load flow analysis needed less memory as compared to conventional method. The computation is very simple and fast. Effectiveness of the following method is tested on IEEE 15 bus system.

General Terms

n is total number of nodes.

m is total number of branches.

Pl_j is the real power loss.

Ql_j is the reactive power loss.

P_n is Real power flow out of bus.

Q_n is Reactive power out of bus.

P_{Ln+1} is power loss at $(n+1)$ bus.

Q_{Ln+1} is reactive power loss at $(n+1)$.

$P_{loss}(n, n+1)$ is real power loss between n and $(n+1)$.

$Q_{loss}(n, n+1)$ is reactive power loss between n and

$(n+1)$buses.

Keywords

Radial distribution network, load flow analysis, forward-backward sweep.

1. INTRODUCTION

Due to changing power demand different problem arises like voltage unbalance, line overloading, power losses, power cogging/surplus etc. To cope up with the future power demand a large number of infrastructure and system restructuring required for generation, transmission and distribution to minimize the mismatch between generation and demand. But having new centralize generation every time is not a feasible way from both economical as well environmental point of view. A step towards decentralize generation leads us to pay attention towards the loss minimization and compensation. To determine losses and to improve voltage profile load flow can be used, the presented paper describes forward and backward sweep method for load flow analysis in radial distribution[1].

2. LOAD FLOW ANALYSIS

The load flow analysis is very important to determine the performance of power system operating under steady state. To determine the losses, the net power exchange, to improve voltage stability and for other evaluations load flow is required. There are different methods like Newton Raphson, Gauss Sidel method.

The distribution system due to some characteristics comes under poor conditioned system, which are [2]

- High R/X ratio.
- Meshed structure.
- Unbalanced loads.

The conventional methods like NR method and modified NR method or fast decoupled methods do not stand good in case of distribution systems. They are reliable only for transmission system where X/R ratio is high, they fail to converge in case of distribution network due to their ill conditioned meshed structure. So, an efficient load flow method is necessary for the analysis of distribution system

Tripathi *et.al* [3] proposed a method for ill conditioned power system. This method is Newton like method but could not be efficiently used for power system optimal analysis of power system. On the basis of a method introduced by Baran and Wu three algorithm presented by Chaiang[4]. These algorithms consist decoupled, fast decoupled and very fast decoupled method.

A compensation based method was introduced by shrimohmmadi *et.al*, this method [5] was robust but some advancements are needed for convergence of voltage. For transmission system NR methods were developed due to the meshed structure of transmission system with parallel lines and number of redundant paths from generating end to distribution.

NR method and fast decoupled are conventional methods. With some modification in these methods modified NR method was proposed by [6] which uses the jacobian matrix in upper triangular and diagonal matrix form. These methods replace the conventional steps with forward/backward sweep having equivalent impedances. But still the convergence time is large.

Jen-Hao Teng[7] proposed an approach which uses matrics-bus injection to branch current and branch current to bus voltage matrix. F.V. Gomes presented system reconfiguration method based upon optimal power flow[8].A. Augugliaro *et.*

al introduced an advance methodology which includes backward and decomposed forward sweep[9].

3. FORWARD-BACKWARD SWEEP

3.1 Distribution network

Distribution system delivers power from transmission line to the consumers. It is classified as primary distribution and secondary distribution system. Primary distribution delivers the power at medium voltage from transmission end to consumer premises. The power is further fed to the consumers via secondary distribution system at low voltages.

According to the connection scheme the distribution system is classified

a. Radial Distribution System.

b. Ring Main Distribution system

Ring main system stands more expensive than the radial distribution system. Moreover, when the generation is at low voltage radial system is preferred. The radial system structure have no loops *i.e.* every bus is connected to the source with exactly single path [10].

3.2 Problem formulation

The objective is to calculate real and reactive power losses occurring in the network. So to find the power flow

$$P_{n+1} = P_n - P_{loss,n} - P_{Ln+1} \qquad (1)$$

$$Q_{n+1} = Q_n - Q_{loss,n} - Q_{Ln+1} \qquad (2)$$

Here ,

$P_n = Real\ power\ flow\ out\ of\ bus,$

$Q_n = Reactive\ power\ out\ of\ bus,$

$P_{Ln+1} = power\ loss\ at\ n+1\ bus,$

$Q_{Ln+1} = reactive\ power\ loss\ at\ n+1,$

The real and reactive power loss between n and n+1 bus

$$P_{loss}(n, n+1) = R_n \frac{P_n^2 + Q_n^2}{V_n^2} \qquad (3)$$

$$Q_{loss}(n, n+1) = X_n \frac{P_n^2 + Q_n^2}{V_k^2} \qquad (4)$$

Here

$P_{loss}(n, n+1)\ is\ real\ power\ loss\ between\ n\ and\ (n+1),$

$Q_{loss}(n, n+1)\ is\ reactive\ power\ loss\ between\ n\ and\ (n+1)\ buses$

So the total power loss will be

$$P_{loss}(n, n+1) = \sum_{n=1}^{t} P_{loss}(n, n+1) \qquad (5)$$

$$Q_{loss}(n, n+1) = \sum_{n=1}^{t} Q_{loss}(n, n+1) \qquad (6)$$

3.3 Backward forward sweep method

There are two subsequent sweep forward sweep and backward [11] through which values of current are calculated and respective voltages are updated. There is no need of sequential numbering of branches. To compute current and power node branch identification scheme is required to analyze the number of next linked branches and connected node beyond a branch. Based on this scheme all the possible paths are computed.

Assumptions:

- Initial voltage is 1p.u.
- Initial power losses both real and reactive are zero.
- RDN is balanced in nature and can be represented by single line diagram.

Algorithm: { to find out different network matrices)

1. Start
2. Convert the resistance, reactance, voltages and power in per unit form.
3. Calculate matrix [A]:(Branch-Node incidence matrix)

   $$A_{i,j} = \begin{cases} -1\ if\ j = sending\ node \\ +1\ if\ j = receving\ node \end{cases}$$
4. Calculate number of possible paths by computing number of end nodes.
5. Find out the number of nodes on each possible path. Let the lateral have maximum 'm' number of branches, so the bus matrix [B] will be having dimensions (l×m).
6. To find out linked branches beyond a branch, form next- linked node matrix [C].

For load flow

1. Assume flat voltage start

   $V_i = 1 + 0j \quad ,for\ i = 1\ to\ n$

   $Pl_j = 0\ \ and\ Ql_j = 0\ ,for\ j = 1\ to\ b$

   Where,

   n= total number of nodes, m= Total number of branches, Pl_j and Ql_j are real and reactive power losses.
2. Set iteration count IT= 1 where IT= 1 to ITMAX
3. Calculate current from each branch

   $I_j = \left\{\frac{S_{i+1}}{V_{i+1}}\right\}^* \qquad for\ i = 1\ to\ b$

   Here, $S_{j+1} = (P_{i+1} + jQ_{i+1})$
4. Backward sweep : update current starting from the end nodes

   $I_k = \sum_j I_j \qquad for\ \ k = 1\ to\ b$

   $where\ j \in C_j$

   Here, C_j is the set of next linked node beyond k branch.
5. Forward sweep: from branch currents update the nodal voltages starting from source node.

   $V_{k+1} = V_k - (I_k * Z_k) \qquad for\ k = 1\ to\ n$
6. Calculate Real and Reactive power losses

   $Pl_j = Il_j * R_j$

   $Ql_j = Il_j * X_j$

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

   Total reactive power loss=$\sum_{j=1}^{b} Ql_j$
7. Check the deviation in values for real and reactive power losses from present and previous iteration.

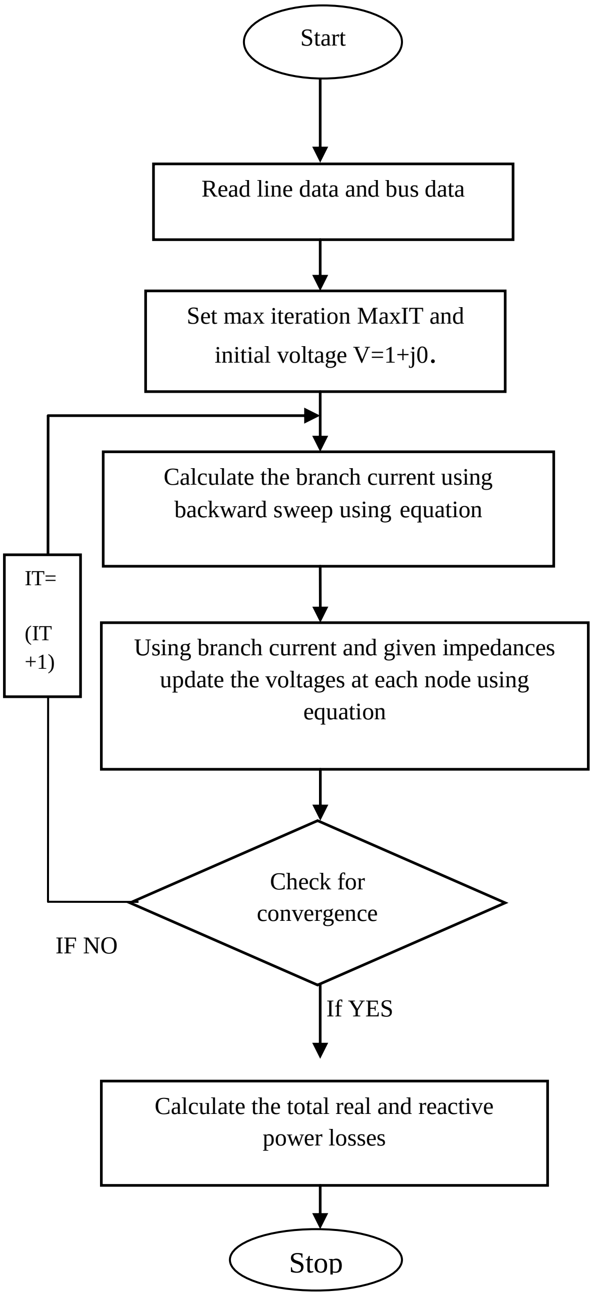
   If

   Deviation is small (∈) then go to step .

   $else$

   go to step 3.
8. IT=IT+1 until IT=ITMAX
9. Return Pl_j, Ql_j, IT, total real and reactive power losses.

3.4 Flow chart



4. RESULTS

To analyze the efficiency of the forward backward sweep method it is tested on the 15-bus system [12]. The single line diagram is shown in figure 1. The total real power loss kW and reactive power loss is kVAr. The base kV for system is 12.66kV and base MVA is 100.

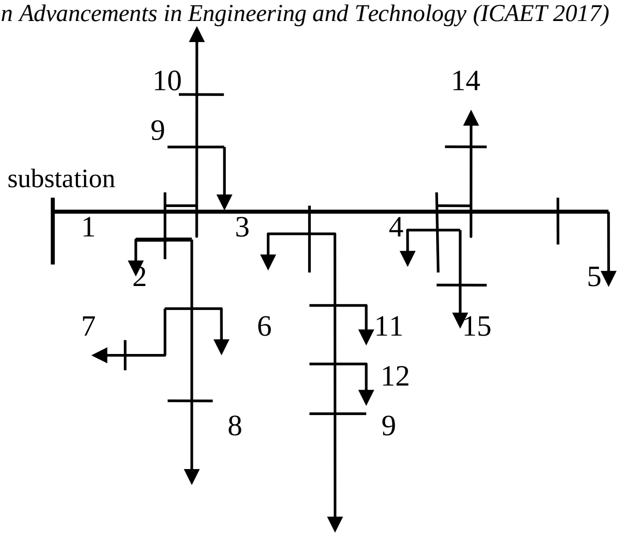


Figure 1: Single line diagram for IEEE 15-Bus system.

Table 1. Voltage magnitude of 15-bus system

Branch no.	Voltage magnitude (p.u.)
1	1
2	0.9713
3	0.9567
4	0.9509
5	0.9499
6	0.9582
7	0.9560
8	0.9570
9	0.9680
10	0.9669
11	0.9500
12	0.9458
13	0.9445
14	0.9486
15	0.9484

Table 2. Branch losses of 15- bus system

Bus connection	Real power loss (kW)	Reactive power loss (kVAr)
1-2	37.7002	36.8755
2-3	11.2890	11.0421
3-4	2.4438	2.3903
4-5	0.0554	0.0374
5-6	5.7677	3.8904
6-7	0.3936	0.2655
7-8	0.1129	0.0762
8-9	0.4722	0.3185

9-10	0.0592	0.0399
10-11	2.1762	1.4679
11-12	0.6016	0.4058
12-13	0.0740	0.0499
13-14	0.2049	0.1382
14-15	0.4399	0.2967
Total	61.7904kW	57.2940kVAR

Table 3. Performance analysis

Total real power losses (kW)	**Total reactive losses (kVAr)**	**Minimum voltage (p.u.)**
61.7904kW	**57.2940kVR**	**0.9445**

The results for the test system are analyzed using MATLAB.

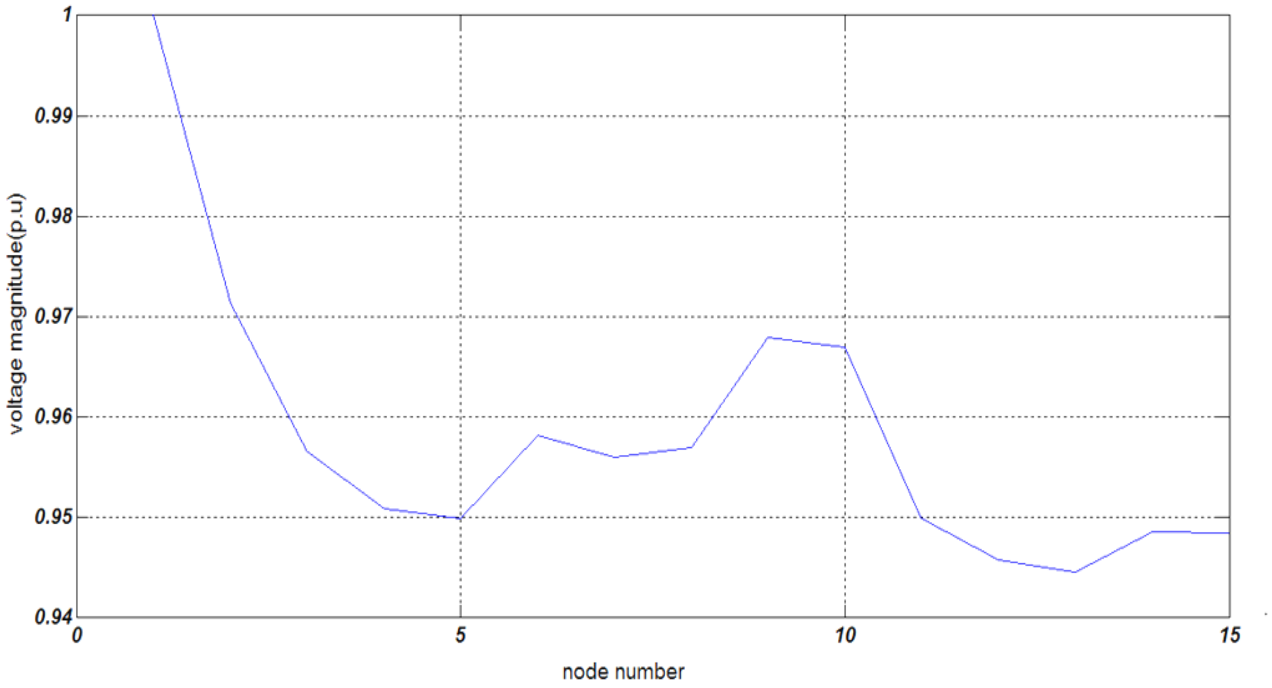


Fig 2: Voltage profile at different nodes for IEEE-15 bus system.

5. CONCLUSION

The realization of forward –backward sweep method is as shown above. The power flow is calculated using backward and forward propagation using iterations. The forward sweep will provide the voltage magnitudes whereas the backward propagation provides the power of each branch. The iterative method has fast convergence as compared to conventional methods. The results for IEEE 15 bus test system are calculated. It is concluded that the following load flow method is an efficient method for fast convergence tendency in radial distribution networks.

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