Loss Evaluation of Radial Distribution System

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Abstract: ***This paper gives the simple procedure for calculating the real and reactive power loss of balanced radial distribution system. It also examines the voltage profile of radial distribution systems. To find power loss in each branch and voltages at each bus, simple equations based on backward and forward method are used here. The load flows are evaluated based on current injection method. In this paper, two simple IEEE radial distribution systems have been taken to observe the proposed method. These two systems do not contain any laterals and sub-laterals. In this the loads are constant power loads. Load flow algorithm is given here based on apparent power mismatch.***

Keywords: Distribution system, Load flows, Power loss, Voltage profile, Current injection

1. Introduction

Power system contains power generation, transmission and distribution. The generated power in power stations can be supplied to distribution system where power consumers mostly exist by using transmission system. While the power is propagating from generating station to consumers with the help of transmission, the losses comes in to picture. The transmission contains less number of loads when compare to distribution system. The transmission system contains less resistance to reactance ratio where it is high for the distribution system. Because of high resistance to reactance ratio the power loss and voltage drops are more in distribution system. So the distribution system is known as ill-condition system. For these types of radial systems, the traditional load flow methods as Newton Rap son, Gauss, and Fast decoupled methods are not applicable. In literature number of load flow methods have been proposed for radial distribution systems.

Baran and Wu [1] used loadflow solution based on three iterative equations as real power, reactive power and voltage. Shirmohammadi [2] applied a new solution methodology based on KCL and KVL. This method is best suited for weakly meshed systems not for radial systems. Kersting [3] had given fastest loadflow solution but convergence problem occurs due to pure ladder network. Renato [4] given a solution methodology which gives an electrical equivalent for every node considering the power at one node is equivalent to summation of all loads fed through that node. A single line equivalent distribution system is implemented by Jasmon and Lee [5]. Direct solution method is executed by Goswami and Basu [6]. It cannot be used for the system having a node more than three branches. Das [7] proposed a load flow method based on total active and reactive power fed through any node.

This paper presents backward and forward sweep method based on apparent power mismatch criteria. This method executes simple manner and calculation part will be reduced. Memory usage is less. The time taken to execute process is less.

2. Problem Formulation

The computation of loss and voltage profile is the basic problem in radial distribution system. It is done in a simple way here.

Objective: Total real power loss

$$P_{totalloss} = \sum_{k=1}^{nb} \left| I_{branch}(k) \right|^2 \times R_{branch}(k)$$

3. Current injection based Backward and Forward Method

In any radial distribution system, the electrical model of a branch which is connected between node-1 and node-2 having impedance Z_1 is given in Fig.1

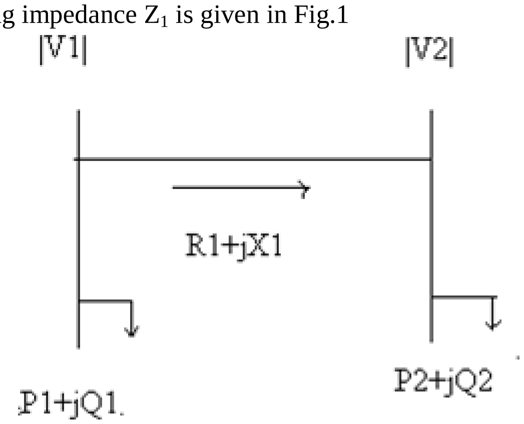

Figure 1: Single line diagram of a branch

From given load data and line data find load current at each bus using equation (1).

$$I_{Load}(k) = \left(\frac{s(k)}{v(k)} \right)^* \tag{1}$$

Where k=1, 2, 3 …N

Calculate branch currents from last node to first node in backward manner using below shown equation (2).

$$I_{branch}(a) = I_{branch}(a+1) + I_{Load}(a+1) \tag{2}$$

Where a=1,2…nb

Calculate bus voltages in forward manner using below shown equation (3).

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$$v(k) = v(k-1) - I_{branch}(k-1) * Z_{branch}(k-1) \quad (3)$$

Where N=number of nodes, nb=number of branches.
Finally from the branch currents calculate real and reactive power losses using below given equation (4).
Total real power loss is given by

$$P_{totalloss} = \sum_{k=1}^{nb} |I_{branch}(k)|^2 \times R_{branch}(k) \quad (4)$$

Total reactive power loss is given by

$$Q_{totalloss} = \sum_{k=1}^{nb} |I_{branch}(k)|^2 \times X_{branch}(k) \quad (5)$$

3.1. Algorithm Ffor Load Flow Solution

1. Read line and load data
2. Arrange voltage value as 1 per unit for all nodes.
3. Compute load currents using equation (1)
4. Compute apparent poweras $S_{old} = V_k * I_{load}$.
   Where V_k is node voltage
5. Compute branch currents using backward Propagation from equation (2).
6. Update node voltages using forward propagation from equation (3).
7. Compute apparent power at each node using
   $S_{new} = V_{knew} * I_{load}$
   Where V_{knew} is updated new voltage of kthnode.
8. Compute Sdel= max(|Snew-Sold|)
9. If the difference of apparent power magnitude is less than 0.0001, stop the iteration.
10. Otherwise, go to step (3)
11. Compute branch power losses, total system losses using equations (4) and (5).

3.2 Flow chart for load flow solution

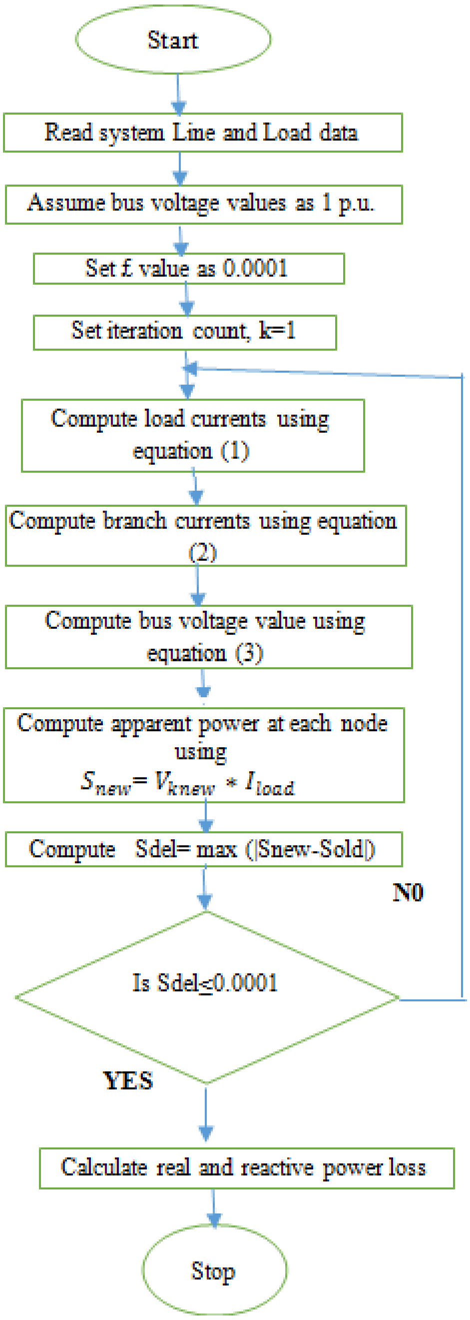

Figure 2: Flow chart for load flows

4. Results analysis

IEEE-10 bus and IEEE-12 bus radial distribution systems are considered to evaluate the proposed method [7-8].

a) IEEE-10 bus radial distribution system

The BASEMVA and BASEKV for this system are 100 and 23.

Table 1: The branch results of 10-bus radial distribution system.

Branch number	Branch currents (p.u.)	Branch loss (p.u.)
1	0.1315	0.0005
2	0.1130	0.0000
3	0.1032	0.0018
4	0.0848	0.0011
5	0.0689	0.0019
6	0.0518	0.0005
7	0.0433	0.0008
8	0.0304	0.0009
9	0.0192	0.0004

Table 2: The bus results of 10-bus radial distribution system

Bus number	Bus currents (p.u.)	Bus voltages (p.u.)
1	0	1.0000
2	0.0185	0.9929
3	0.0098	0.9874
4	0.0184	0.9634
5	0.0159	0.9480
6	0.0171	0.9172
7	0.0085	0.9072
8	0.0128	0.8889
9	0.0112	0.8587
10	0.0192	0.8375

The total real power loss = 783.8064 kW.
The total reactive power loss = 1.0369e+03 kVAr.
The minimum voltage value in p.u. =0.8375
The bus number having minimum voltage = 10.

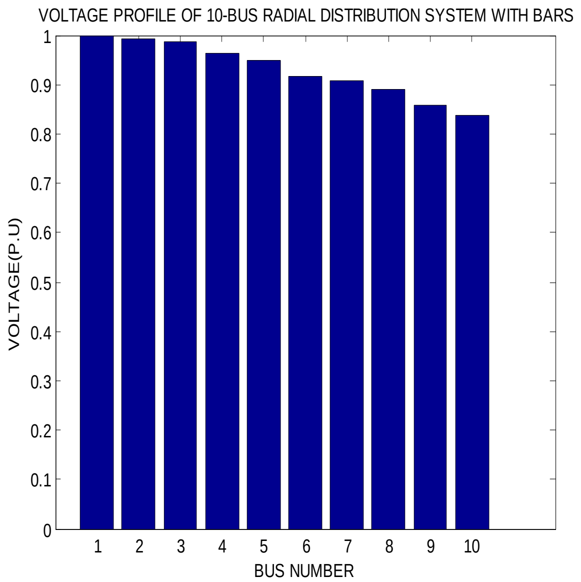

Figure 3: Voltage profile of 10-bus radial distribution system with bars

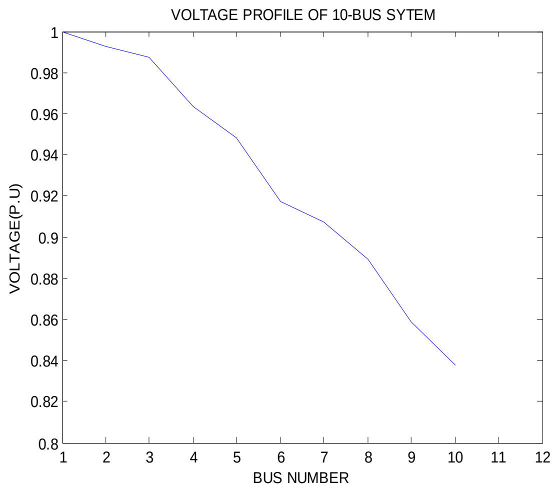

Figure 4: Voltage profile of 10-bus radial distribution system

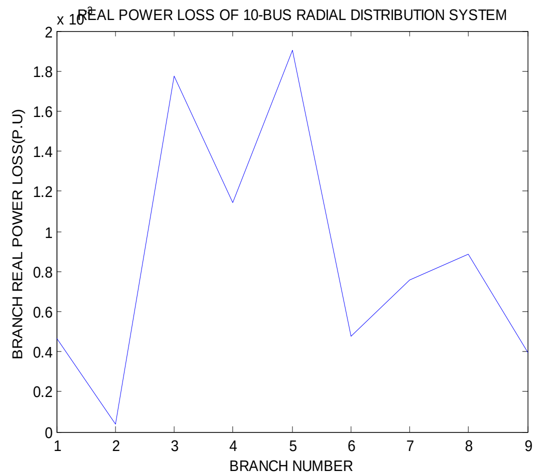

Figure 5: Real power loss of 10-bus radial distribution system

b) IEEE-12 bus Radial Distribution System

The BASEMVA and BASEKV for this system are 10 and 11. The voltage mismatch based convergence criteria is used.

Table 3: The branch results of 12-bus radial distribution system.

Branch number	Branch currents (p.u.)	Branch real power loss (p.u.)*10^-3
1	0.0456	0.3417
2	0.0395	0.2747
3	0.0355	0.3980
4	0.0298	0.4220
5	0.0267	0.1148
6	0.0246	0.0906
7	0.0188	0.2277
8	0.0140	0.1573
9	0.0097	0.0368
10	0.0059	0.0071
11	0.0016	0.0005

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Table 4: The bus results of 12-bus radial distribution system.

Bus number	Bus(load) currents (p.u.)	Bus voltages (p.u.)
1	0.0615	1.0000
2	0.0615	0.9943
3	0.0530	0.9890
4	0.0479	0.9806
5	0.0400	0.9698
6	0.0357	0.9665
7	0.0331	0.9638
8	0.0250	0.9553
9	0.0184	0.9473
10	0.0124	0.9445
11	0.0075	0.9436
12	0.0022	0.9435

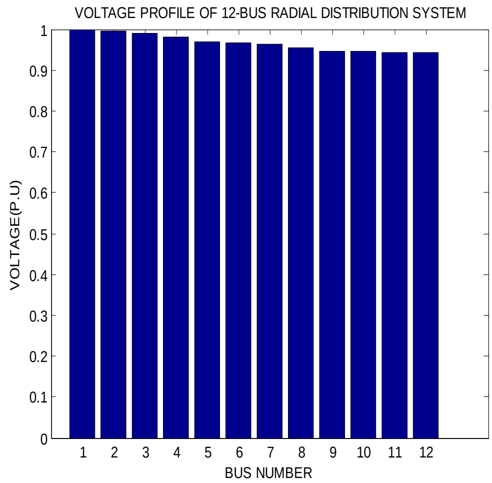

Figure 6: Voltage profile of 12-bus radial distribution system with bars

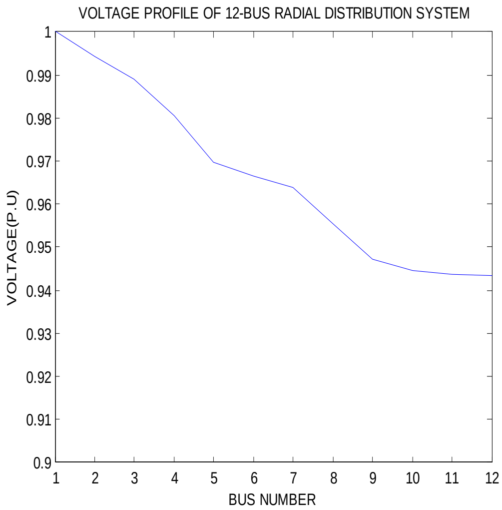

Figure 7: Voltage profile of 12-bus radial distribution system

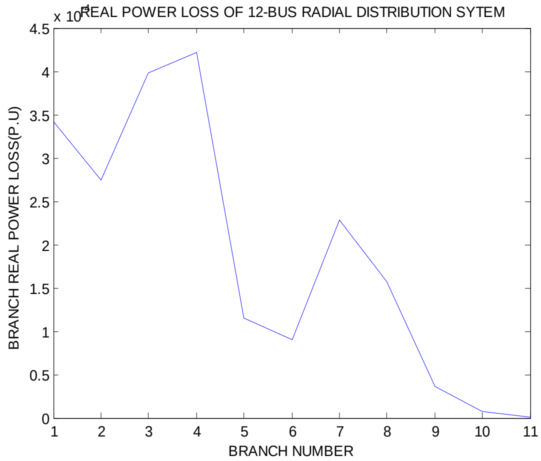

Figure 7: Real power loss of 12-bus radial distribution system

The total real power loss =20.7120 kW.
The total reactive power loss = 8.0405 kVAr.
The minimum voltage value in p.u.= 0.9435.
The bus number having minimum voltage = 12.

5. Conclusion

In this paper, load flows are done with the help of apparent power mismatch. The basic thing used here is backward and forward method. To analyze the effectiveness of this method two test systems namely 10-bus and 12-bus radial distribution have taken. This methods gives simple equations for radial distribution system. The radial distribution systems taken here are having only radial structure. They do not have laterals and sub laterals.

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