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Thevenin's Network Analysis for Radial Distribution System with Load Models

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Abstract: ***This paper presents thevenin's network formation for radial distribution system. Here backward and forward sweep method has been used for load flow solution. Here load flows have to run twice. First time, normal load flows has to be executed. Second time, load flows can be executed by equating sensitive bus power to zero. The main objectives of this paper have given below.***
(1) To find thevenin's voltage
(2) To find thevenin's impedance
For radial distribution system with load models
a) Constant power loads
b) Constant current loads
c) Constant impedance loads.
Here 10-bus and 15-bus radial distribution systems have been used for evaluating proposed objectives.

Keywords: Radial Distribution System, Load Models, Sensitive node, Thevenin's Voltage and Thevenin's Impedance

1. Introduction

Distribution system planning plays main role to expand radial distribution system in future. To analyze radial distribution system and mesh distribution system Goswami and Basu presented a direct method [1]. Here there is no convergence problem but it cannot work properly for node having more than three branches. With three iterative basic equations of real power, reactive power and voltage, Chiang analyzed loadflows [2]. Das implemented a load flow technique which calculates total real and reactive power fed through any node [3]. Here the data will be stored in vector format. Haque analyzed power flow solution for voltage dependent loads [4]. Ghosh and Das proposed a method initially considering all bus voltages as 1 per unit [5].

2. Problem Formation

Thevenin's network formation:
1) To find Thevenin's voltage
2) To find Thevenin's impedance
For 10-bus and 12-bus radial distribution system

Load modeling:
The load modeling equation has given below [3].
$P = P_0 * |V_i|^n$
$Q = Q_0 * |V_i|^n$ (1)
Where,
P_0 is the nominal bus real power. i.e., given load real power
Q_0 is the bus nominal reactive power. i.e., given load reactive power
V_i is the bus voltage
n is the load coefficient.
n=0 for constant power loads
n=1 for constant current loads
n=2 for constant impedance loads

3. Proposed Algorithm

1) Run basic backward and forward load flows.
2) Find the minimum voltage at which bus existed.
3) Assign this bus as sensitive bus.
4) Assign sensitive bus current to zero. i.e., open circuit the sensitive bus
5) Run load flows again.
6) The voltage obtained at sensitive bus after open circuiting the system is known as Thevenin's voltage (V_{oc}).
7) Assign the sensitive bus voltage, before open circuiting the system as V_j.
8) Assign the sensitive bus current, before open circuiting the system as I_j.
9) Execute Z_{oc} by using $Z_{oc} = \frac{V_{oc} - V_j}{I_j}$ (2)
10) Execute above procedure for load models.

4. Results and Discussions

Here 10-bus and 13-bus radial distribution systems have used for analysis.
Test system-1: 10-bus radial distribution system:
The bus data and line data have taken from reference [6]. The BASEMVA is 100 and The BASEKV is 23.

Table 1: The bus voltages for constant power loads of 10-bus radial distribution system (RDS)

Bus Number	*Bus voltage (per unit)*
1	1.000
2	0.9935
3	0.9887
4	0.9658
5	0.9508
6	0.9208
7	0.9110
8	0.8931
9	0.8632
10	**0.8422**

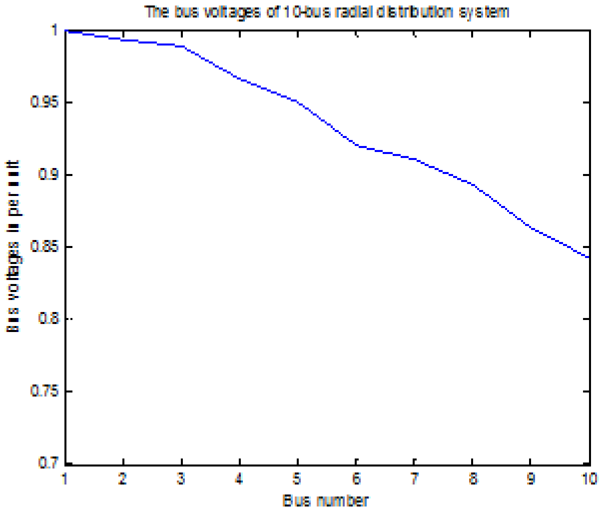

Figure 1: The voltage profile of 10-bus RDS for constant power loads

The above table-1 and figure 1 indicates the bus voltages of 10-bus radial distribution system with constant power loads. Here the minimum voltage is 0.8422 at 10-bus. Hence bus-10 is the 'sensitive node'.

Table 2: The voltage profile of 10-bus radial distribution system for constant current loads

Bus Number	*Bus Voltages (per unit)*
1	1.0000
2	0.9983
3	0.9973
4	0.9940
5	0.9924
6	0.9904
7	0.9899
8	0.9891
9	0.9881
10	**0.9875**

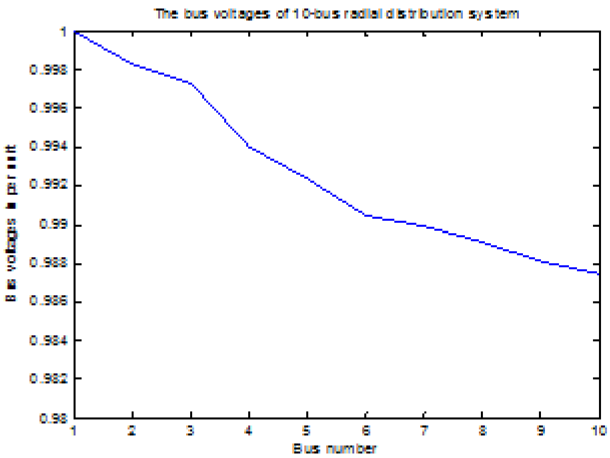

Figure 2: The voltage profile of 10-bus radial distribution system for constant current loads

The above table 2 and figure 2 shows the voltage profile of 10-bus radial distribution system with constant current loads. The minimum voltage is 0.9875 at 10-bus. So the 10-bus has becoming as 'sensitive node'.

Table 3: The bus voltages of 10-bus RDS for constant impedance loads

Bus Number	*Bus Voltages (per unit)*
1	1.0000
2	0.9988
3	0.9982
4	0.9963
5	0.9955
6	0.9946
7	0.9944
8	0.9941
9	0.9937
10	**0.9934**

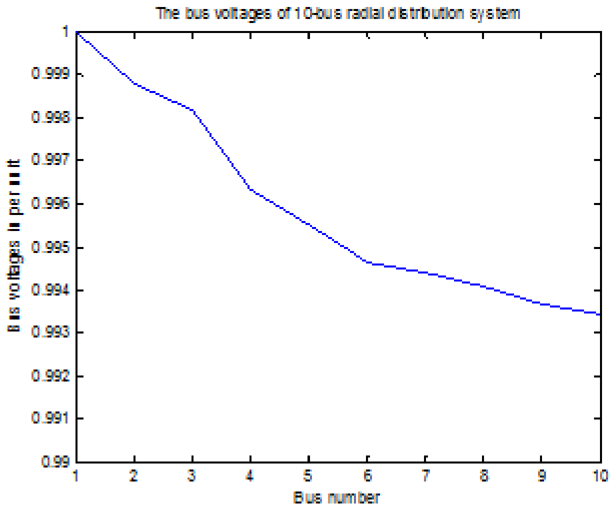

Figure 3: The voltage profile of 10-bus RDS for constant impedance loads

The above table 3 and figure 3 shows the bus voltage profile of 10-bus radial distribution system with constant impedance loads. The minimum bus voltage is 0.9934 at 10-bus. Hence 10-bus is 'sensitive node'.

Table 4: Bus voltage and current for 10-bus RDS before open circuit

	Constant P	*Constant I*	*Constant Z*
V_i	0.8422	0.9875	0.9934
I_i	0.0196	0.00051	0.00018

Table 5: Thevenin's voltage and Thevenin's impedance for 10-bus RDS

	Constant P	*Constant I*	*Constant Z*
V_{oc} (per unit)	0.91125	0.98816	0.99362
Z_{oc} (per unit)	3.52	1.37	1.0591

Test system-2: 15-bus radial distribution system

The bus and line data has taken from reference [3]. The BASEMVA is 100 and BASEKV is 11.

Table 6: The Bus voltages of 15-bus RDS for constant power loads

Bus Number	*Bus Voltages (per unit)*
1	1.0000
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	0.9459
13	**0.9446**
14	0.9486
15	0.9485

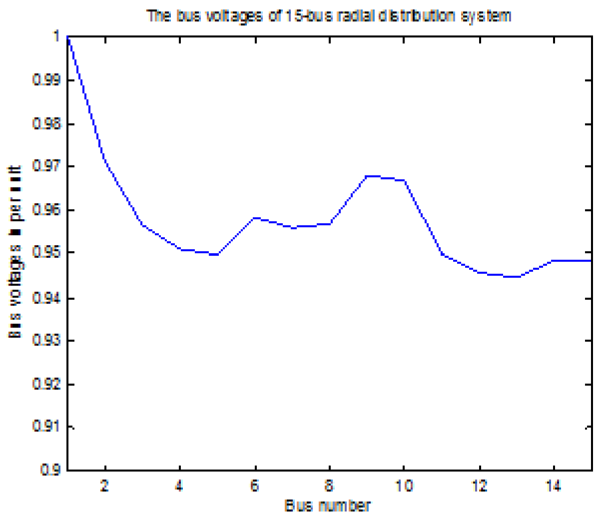

Figure 4: The voltage profile of 15-bus RDS for constant power loads

The above figure 4 and table 6 shows the voltage profile of 15-bus radial distribution system for constant power loads. The minimum voltage is 0.9446 at 13-bus. Hence bus-13 is the 'sensitive node' for constant power loads.

Table 7: The bus voltages of 15-bus RDS for constant current loads

Bus Number	*Bus Voltages (per unit)*
1	1.0000
2	0.9944
3	0.9920
4	0.9910
5	0.9907
6	0.9919
7	0.9914
8	0.9916
9	0.9934
10	0.9931
11	0.9909
12	0.9902
13	**0.9900**
14	0.9905
15	0.9905

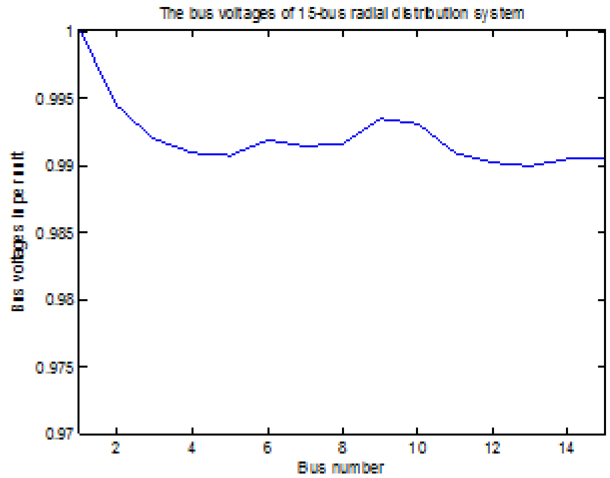

Figure 5: The voltage profile of 15-bus RDS for constant current loads

The figure 5 and table 7 shows the voltage profile of 15-bus radial distribution system for constant loads. The minimum bus voltage is 0.9900 at 13-bus. Hence 13-bus is the 'sensitive bus' for constant current loads.

Table 8: The bus voltages of 15-bus RDS for constant impedance loads

Bus Number	*Bus Voltages (per unit)*
1	1.0000
2	0.9961
3	0.9944
4	0.9937
5	0.9935
6	0.9944
7	0.9940
8	0.9941
9	0.9953
10	0.9951
11	0.9937
12	0.9932
13	**0.9930**
14	0.9934
15	0.9934

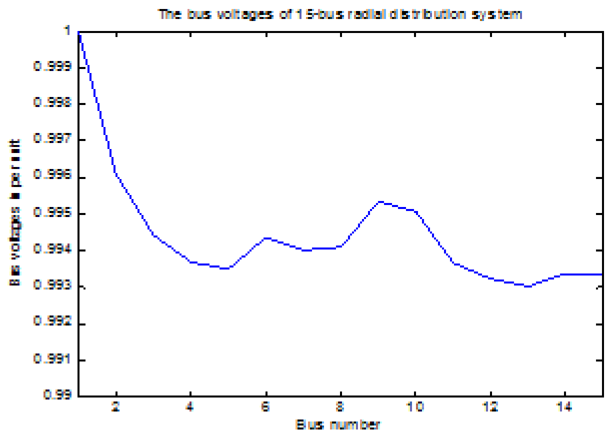

Figure 6: The voltage profile of 15-bus RDS for constant impedance loads

The above figure 6 and table 8 shows the voltage profile of 15-bus RDS for constant impedance loads. The minimum voltage is 0.9930 at bus-13. Hence the bus-13 is 'sensitive bus' for constant impedance loads.

Table 9: Bus voltage and current for 15-bus RDS before open circuit

	Constant P	*Constant I*	*Constant Z*
V_i (per unit)	0.94457	0.98997	0.99302
I_i (per unit)	0.00065	0.00018	0.00014

Table-10: Thevenin's voltage and Thevenin's impedance for 15-bus RDS

	Constant P	*Constant I*	*Constant Z*
V_{oc} (per unit)	0.95052	0.99005	0.99308
Z_{oc} (per unit)	8.9224	0.83048	0.92991

5. Conclusion

This paper presented a network reduction technique for radial distribution system. Thevenin's voltage and Thevenin's impedance have analyzed for two test systems namely 10-bus and 15-bus radial distribution systems. Here for each test system, constant power, constant current and constant impedance load models also have considered. Here the sensitive node has evaluated based on minimum voltage in the voltage profile. In future it can be done by assuming suitable index as on voltage or power basis.

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Author Profile

Gundugallu Peddanna was born in Ananthapuramu, A. P., India on June 03, 1989. He received B. Tech Degree in Electrical and Electronics Engineering from JNTUA College of Engineering, Pulivendula, A. P. India in 2010. He completed M. Tech in Electrical Engineering with specialization in Electrical Power Systems from JNTUA College of Engineering, Ananthapuramu, A. P., India in 2014. Currently, he is Assistant Professor, at Department of Electrical & Electronics Engineering, Srinivasa Ramanujan Institute of Technology, Ananthapuramu, A. P, India. His area of interest includes Electrical Distribution Systems, Analysis of Distributed Generation, Optimization Techniques and Renewable Energy Sources.