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Formation of Thevenin's Equivalent Network for Radial Distribution System

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ABSTRACT: Distribution system is the network which connects the large amount of power consumers. This distribution system can be modeled in to single Thevenin's network across a node which contains a branch having sending end and receiving end. This paper presents a solution methodology for a radial distribution network to form an equivalent Thevenin's network based on load flows. Here backward and forward sweep based load flows method has used. To form Thevenin's equivalent network, 10-bus and 15-bus radial distribution systems have considered. Here 10-bus radial distribution system is analyzed for constant current loads and 15-bus radial distribution system is analyzed for constant power loads.

KEYWORDS: Thevenin's equivalent network, Load flows, constant current loads, bus voltages.

I. INTRODUCTION

Thevenin's network can be formed by using load flows. Hence load flows are necessary for getting Thevenin's network. In order to evaluate bus voltages, bus currents, branch currents, branch power losses and total power loss of the radial distribution system, number of authors proposed number of load flow methods. Das et al. [1] proposed a load flow method. In this author implemented a method to find branch and node number in order to find real and reactive power losses. In this method data will be stored in vector form so that computer memory can be saved. Haque et al. [2] developed recursive iterations based load flow solution for real and reactive power losses. Here various load models also considered. Mok et al. [3] analyzed the voltage and load relation using load flows. Das et al. [4] calculated nodes beyond a branch, charging currents. After this author calculated bus currents and branch currents.

II. PROBLEM FORMULATION

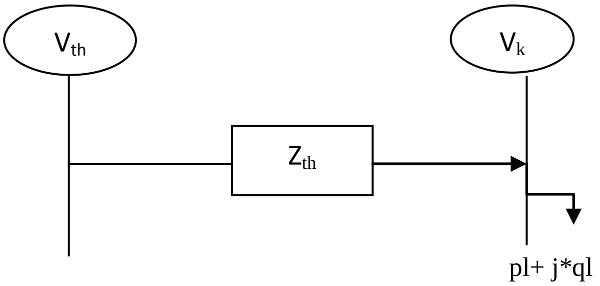

Figure 1: Thevenin's Network for radial distribution system

Where,
Z_{th} is Thevenin impedance
V_{th} is Thevenin voltage

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V_k is voltage at k^{th} node.

1. To find Thevenin voltage, V_{th}
2. To find thevenin impedance, Z_{th}

III. SOLUTION METHODOLOGY

Here the backward and forward sweep based load flow method has considered to find bus voltages and bus currents. The bus currents, branch currents and bus voltages can be calculated by using below shown equations.

1. Bus currents

$$L_i = \frac{pl(i)-ql(i)}{v_i*} \quad (1)$$

2. Branch currents

$$L(se(i)) = L(se(i)) + L(re(i)) \quad (2)$$

3. Bus voltages

$$v(re(i)) = v(se(i)) - z(i) * L(i) \quad (3)$$

4. Total real power loss

$$TPL = sum(L(i)^2 * R(i)) \quad (4)$$

5. Total reactive power loss

$$TQL = sum(L(i)^2 * X(i)) \quad (5)$$

Algorithm for finding V_{th} and Z_{th}

1. Run bus currents using equation (1).
2. Run branch currents using equation (2)
3. Run bus voltages using equation (3)
4. From load flows identify the minimum bus voltage V_k
5. Equate that bus current to zero
6. Run load flows again and calculate that bus voltage (V_{th}).
7. Calculate Thevenin impedance (Z_{th})

$$Z_{th} = \frac{V_{th}-V_k}{L_k}$$

IV. RESULTS AND ANALYSIS

Here 10-bus 15-bus radial distribution systems have taken to evaluate the proposed method.

Test system-1: 10- bus radial distribution system

The basemva is 100 and basekv is 23 [15].

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

Bus Number	Bus Voltages (per unit)
1	1.0000
2	0.9983
3	0.9973
4	0.9940
5	0.9924
6	0.9904

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7	0.9899
8	0.9891
9	0.9881
10	**0.9875**

The above table-2 shows the the bus voltages of 10-bus radial distribution system. Here the maximum voltage is 1.0000 at bus-1 and minimum voltage is 0.9875 at 10-bus. Here it is observed that the bus voltages are decreasing as moving from bus-1 (slack bus) to 10-bus.

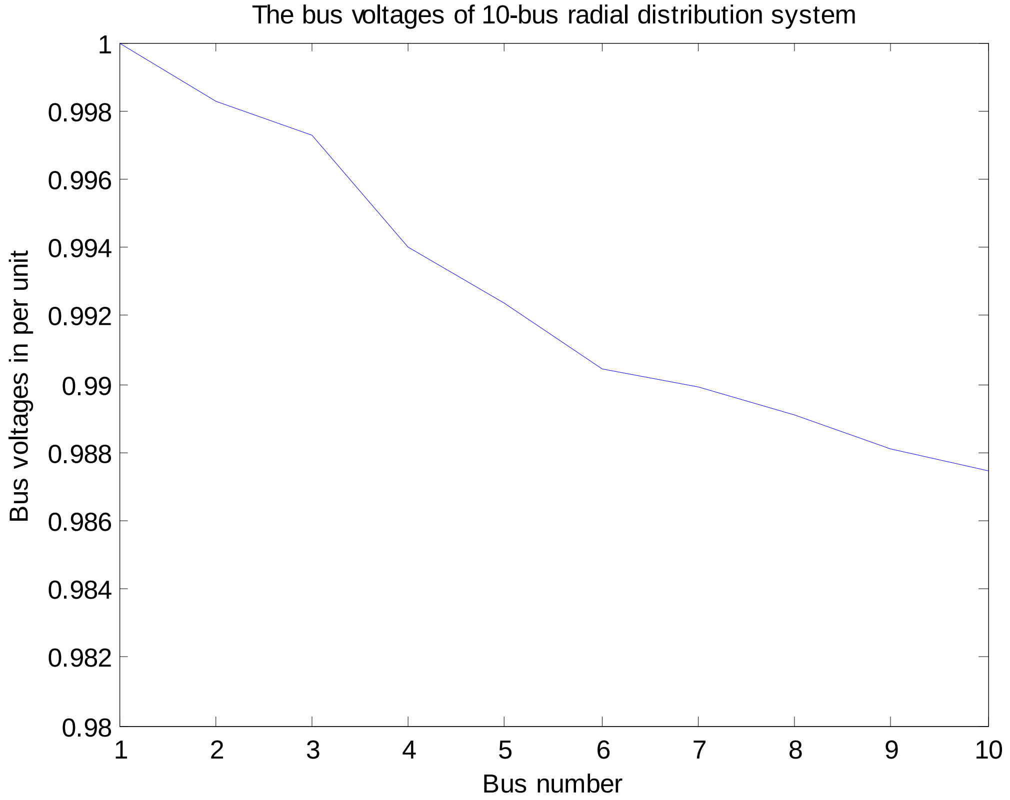

Figure 3: The bus voltages of 10-bus radial distribution system

The above figure 3 shows the bus voltage profile of 10-bus radial distribution system. By observing figure 3 it is clear that the bus-10 has minimum voltage.

Hence by observing table-2 and figure 3, the bus-10 has minimum voltage 0.9875. Hence the bus which is having minimum bus voltage is known as weak bus.

The minimum bus voltage 0.9875 is denoted as V_k .

In order to form Thevenin's network for 10-bus radial distribution system, the bus current at weak bus will be equated to zero. The voltage will be calculated again running load flows. This voltage is represented as V_{th} known as Thevenin's voltage.

The Thevenin's voltage V_{th} is 0.9882.

The Thevenin's impedance Z_{th} is 1.3529 per unit.

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Test system-2: 15-bus radial distribution system

The basemva is 100 and the basekv is 11 for 15-bus radial distribution system [1].

Table-1: The bus voltages of 15-bus radial distribution system

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

Table 1 shows the bus voltages of 15-bus radial distribution system. The minimum bus voltage is 0.9446. the minimum bus voltage exist at 13-bus. Hence 13-bus is known as weakest bus.

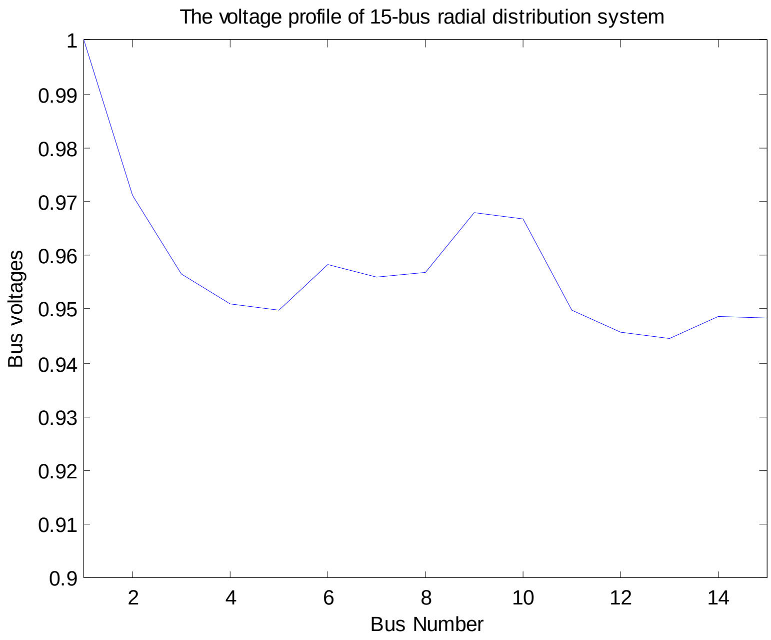

Figure 2: The bus voltages of 15-bus radial distribution system

The figure 2 shows the bus voltages of 15-bus radial distribution system. The minimum voltage occurred at bus-13. From table 1 and figure 1 it is clear that the minimum voltage is 0.9446. This value occurred at 13-bus. This value is represented as V_k Hence this bus is called as weak bus for 15-bus radial distribution system. At this weak bus current is

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equated to zero and again load flows are evaluated. The bus voltage (V_{th}) at 13-bus is again calculated. It's value is obtained as 0.9507
From load flows we got V_k, and V_{th}
Hence V_{th} is 0.9507 and V_k is 0.9446.

The load current L_k is 0.000666
Thevenin impedance is 9.2973 per unit.

V. CONCLUSION

Any radial distribution system can be transformed into equivalent Thevenin's network by using proposed procedure. This method gives simple analysis of any radial distribution system. Here 10-bus and 15-bus radial distribution systems are taken to analyze the proposed method. Here 10-bus radial distribution system is used with constant current loads and 15-bus radial system is used with constant power loads. This can be further extended to different load modeling conditions. Here the weak bus is directly evaluated by considering minimum voltage. But weak bus can be evaluated by taking indices based on voltage (or) power loss.

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BIOGRAPHY

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