

Power flow methods for loss allocation in radial distribution networks with DG's

N.SUBHASHINI¹, A.HEMA SEKHAR²

¹ (ELECTRICAL AND ELECTRONICS ENGINEERING, SVPCET, INDIA)

² (ELECTRICAL AND ELECTRONICS ENGINEERING, SVPCET, INDIA)

ABSTRACT: This paper proposes an LA method that can be applied to radial medium voltage distribution systems with DGs. The method starts by assigning zero power losses to a specific group of nodes. Then, the power loss allocated to other nodes is calculated based on the power loss of the lines connecting the zero assigned nodes and these nodes. Since this method results in over-recovery of total loss, normalization is executed at the end to compensate. The method is simple and is based on the results of power flow.

I. INTRODUCTION

The increase in deployment of distributed generation (DG) and the shift of distribution loads from customer mode to pro-summers have altered distribution systems from passive to active mode. As a result, some of the transmission networks issues have been generalized to distribution systems as well. One of these issues is loss allocation (LA), which specifies the fraction of total distribution loss that each load or DG is responsible for. Although there are many transmission LA methods in the literature, distribution LA is still a new topic and most of the distribution system operators still do not have a standard policy.

Most of the methods implemented for distribution LA, have been mainly proposed This paper proposes an LOSS ALLOCATION method that can be applied to radial medium voltage distribution systems with DGs. The method starts by assigning zero power losses to a specific group of nodes. Then the power loss allocated to other nodes is calculated based on the power loss of the lines connecting the zero assigned nodes and these nodes. Since this method results in over-recovery of total loss, normalization is executed at the end to compensate. The method is simple and is based on results on the results of power flow. This paper organized as follows: the next section explains the bases of the method, which is proceeded by the formulation of the method presented in section 5. in section 6, the proposed method and five other methods are applied to a rural distribution feeder in order to compare the results. Finally the last section presents the concluding remarks.

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III. INDENTATIONS AND EQUATIONS

I. PROPOSED METHOD

The distribution loss allocated to the node connecting the distribution and transmission network is set to zero.

- 1) Consider the node depicted in Fig.1 In case $(P_{G1}+P_{G2}+.....) > (P_{D1}+P_{D2}+.....)$, the proposed method allocates zero losses to all loads connected to this node, since it means that the loads are locally fed by the DGs and, hence, do not result in any power loss.

In case $(P_{G1}+P_{G2}+.....) < (P_{D1}+P_{D2}+.....)$, the method allocates zero losses to the DGs connected to the node.

- 1) The proposed method does not allocate negative losses to the loads and DGs.
- 2) The distribution system is assumed to be a radial system, in which the loads and DGs have private owners.
- 3) Consider the circuit depicted in Fig.5 which shows two nodes of a system. The power loss of the line connecting nodes 1 and 2 can be written as

$$P_{\text{Loss } 1,2} = r_{1,2} \frac{P_{1,2}^2 + Q_{1,2}^2}{|V_1|^2} = k(P_{1,2}^2 + Q_{1,2}^2) \quad (1)$$

Where $r_{1,2}$ is the resistance of the line; $P_{1,2}$ and $Q_{1,2}$ are the active and Reactive power through the line; and V_1 is the voltage of node 1. As it is seen $P_{\text{Loss } 1,2}$ is Composed of two terms. The first term, which is $kP_{1,2}^2$, is due to the active flows through the line and the second term, which is $kQ_{1,2}^2$, is due to the reactive flows. Let us denote these two terms, respectively, as $P_{\text{Loss } 1,2}^P$ and $P_{\text{Loss } 1,2}^Q$. Consequently, (1) can be written as

$$P_{LOSS\ 1,2} = P_{LOSS\ 1,2}^p + P_{LOSS\ 1,2}^q \quad (2)$$

As $P_{1,2} = P_{D21} + P_{D22} + P_{LOSS\ 1,2}$, $P_{LOSS\ 1,2}^p$ can be written as

$$P_{LOSS\ 1,2}^p = kP_{1,2}^2 = k(P_{D21} + P_{D22} + P_{LOSS\ 1,2})^2 \quad (3)$$

Which is hence, can be ignored. Based on the Shapley value, which is for calculating the contribution of a player in a game played by a number of players, the contribution of load P_{D21} in $P_{LOSS\ 1,2}^p$ is equal to $k(P_{D21} + P_{D22})^2$, since $P_{LOSS\ 1,2}$ is usually small compared to P_{D21} and P_{D22} and, to

$$k(P_{D21}^2 + P_{D21}P_{D22}) \quad (4)$$

And that of load P_{D22} is $k(P_{D22}^2 + P_{D21}P_{D22})$. A similar formulation can be derived case the number of loads or lines connected to node 2 increases. Moreover, the same approach is applicable if we want to allocate $P_{LOSS\ 1,2}^q$ to Q_{D21} and Q_{D22} . These formulae are the basis for the proposed LA method, which is presented in the following section.

A. Calculating the Loss Allocated to the Loads

1) Loss Allocated to Loads Due to Active Flows:

In this step, first the loss assigned to any of the nodes due to active flows is calculated and then distributed between the loads connected to it.

The procedure is based on the fact that the loss assigned to node k is dependent on the loss assigned to all nodes that are adjacent to this node and send active power to it. Let branch $b_{n,k}$ connect node n to node k and $P_{n,k}^s$, which is the active power flow at sending node n of this branch, be positive. Presume that the loss allocated to node n due to active flows is denoted as L^p and is known. We want to distribute among: 1) all the loads that are connected to node n and 2) the branches connected to this node whose active power flow from this node is positive. Based on the Shapley value method results given in (4), the contribution of $P_{n,k}^s$ in L^p_n is proportional to

$$\left\{ (P_{n,k}^s)^2 + P_{n,k}^s \left(\sum_{m \in A_{n+1}, m \neq k} P_{n,m}^s + \sum_{D_m \in D_n} P_{D_m} \right) \right\} \quad (5)$$

Where $P_{n,m}^s$ is the active power flow at the sending point of branch $b_{n,m}$, which is a positive value; P_{D_m} is the active power demand of load D_m ; A_{n+1} is the set of nodes receiving active power from node n and connected to this node with branch $b_{n,m}$ and D_n is the set of loads connected to node n.

Since the contribution of all loads and active power sending branches connected to node n should add up to L^p_n , the following term is assigned to $P_{n,k}^s$:

$$L_n^p \frac{(P_{n,k}^s)^2 + P_{n,k}^s \left(\sum_{m \in A_{n+1}, m \neq k} P_{n,m}^s + \sum_{D_m \in D_n} P_{D_m} \right)}{\left(\sum_{m \in A_{n+1}} P_{n,m}^s + \sum_{D_m \in D_n} P_{D_m} \right)^2} \quad (6)$$

Node k is not only responsible for a fraction of the loss assigned to node n, but also the power loss of branch $b_{n,k}$ due to active power flows. As a result, L^p_k can be calculated as shown in (7), at the bottom of the next page, where A_{k-1} is the set of nodes that send active power to node k and are connected to this node with branch $b_{n,k}$; and $P_{LOSS\ n,k}^p$ is the power loss of branch $b_{n,k}$ due to active power flows. As (7) shows, a fraction of the loss assigned to node n is assigned to node k.

In this step, the loss assigned to the active source nodes, that is, the nodes whose active generation is greater than their active load, is considered to be zero, since all of the loads connected to these nodes are supplied locally by the DGs connected to these nodes. While the node connecting the transmission and distribution systems should not be allocated any loss, the loss assigned to this node is set to zero, as well.

Based on (7), the procedure to calculate L^p_k 's is as follows.

Step 1) Assign zero L^p_k to each of the active source nodes, as well as the connection Node of the transmission and distribution systems.

Step 2) Loop over all nodes whose L^p_k is not obtained yet. If the loss assigned to all the nodes sending active power to this node was previously calculated, then obtain the loss assigned to this node using (7).

Step 3) If there is a node whose L^p_k is not obtained yet, go back to Step 2); otherwise, stop the procedure.

For the proof of why L^p_k can be determined for all nodes using the proposed method, imagine node n_1 is a node, whose L^p_k cannot be determined. This should be due to the impossibility of determining the loss due to active flows allocated to one, or some, of its adjacent nodes, that send(s) active power to node n_1 , say node n_2 . Likewise, the impossibility of determining the loss due to active flows allocated to node n_2 should be because the loss due to active flows allocated to node n_3 , which is adjacent to n_2 , cannot be calculated, as shown in Fig. 3. Since the system is assumed to be radial and the number of nodes is finite, there would be a node, say n_n , that either does not receive active power from any other node or is the connection between the distribution and

transmission systems. Thus, the loss allocated to node n_n due to active flows should be zero, which contradicts the fact that it is impossible to determine the loss allocated to node n_3, n_2 , and n_1 . As a result, the proposed method can always calculate L^p_k for all nodes.

The same explanation can be used to demonstrate that it is always possible to calculate L^q_k, L^p_k and L^q_k for all nodes, which are later introduced.

Furthermore, note that L^p_k is not the actual loss allocated to node k , rather it is the loss assigned to this node for calculating the loss allocated to the loads (and not the DGs) connected to this node. This fact will become more clear, when we define L^p_k in the following step, which is used to calculate the loss allocated to the DGs connected to node k . Similar to (6), the loss allocated to load D_i connected to node k , which has the active power demand of P_{Di} , is calculated as

$$L^p_k = \sum_{n \in A_{k-1}} \left[L^n_p \frac{(P_{n,k}^s)^2 + P_{n,k}^s \left(\sum_{m \neq k} P_{n,m}^s + \sum_{D_m \in D_n} P_{D_m} \right)}{\left(\sum_{m \in A_{n+1}} P_{n,m}^s + \sum_{D_m \in D_n} P_{D_m} \right)^2} + P_{Loss_{n,k}}^p \right] - (7)$$

$$L^p_{Di} = L^p_k \frac{(P_{Di})^2 + P_{Di} \left(\sum_{n \neq i} P_{Dn} + \sum_{n \in A_{k+1}} P_{k,n}^s \right)}{\left(\sum_{D_k \in D_k} P_{Dn} + \sum_{n \in A_{k+1}} P_{k,n}^s \right)^2} - (8)$$

Similar to (7), shown at the bottom of the page, (8) is based on the fact that the loss assigned to a node should be distributed between all of the loads that are connected to it and the nodes receiving active power from it. As (8) shows, L^p_{Di} is dependent on L^p_k , which has term $P_{Loss_{n,k}}^p$ in it. As a result, the loss allocated to the loads is based on the power loss of the lines from which the loads are fed. Hence, the loss allocated to the loads connected to heavily loaded feeders will be greater, compared to the ones attached to lightly loaded feeders. This ensures that the LA results are fair and equitable.

Imagine the distribution system shown in Fig.4. The following equations show how the loss allocated to the loads of this system are calculated First, the loss assigned to the slack node is set to zero ($L^p_0=0$) Since node 2 is a source node, the loss assigned to this node is zero as well ($L^p_2=0$).

Now using (7), the loss assigned to nodes 1, 3, and 4 is calculated as

$$L^p_1 = P_{Loss_{0,1}}^p + P_{Loss_{2,1}}^p$$

$$L^p_3 = P_{Loss_{2,3}}^p$$

$$L^p_4 = L^p_1 + P_{Loss_{1,4}}^p - (9)$$

After finding the loss assigned to the nodes due to active flows, the loss allocated to the loads can be obtained by using (8) as

$$L^p_{D1} = 0, L^p_{D2} = 0, L^p_{D3} = L^p_3,$$

$$L^p_{D4} = L^p_4 - (10)$$

1) Loss Allocated to Loads Due to Reactive Flows:

After calculating the loss allocated to the loads due to active Flows the loss allocated to them due to reactive flows is calculated.

The procedure to do this is very similar to the previous section. First, the reactive source nodes, that is, the nodes whose reactive generation is more than their reactive load, are assigned zero reactive losses. Then, is calculated as shown in (11) at the bottom of the page,

Where R_{k-1} Set of nodes that send reactive power to node k and are connected to this Node with Branch $b_{n,k}$; $Q^s_{n,k}$ Reactive power flow at the sending point of branch $b_{n,k}$, which is a Positive value; $Q^s_{n,m}$ Reactive power flow at the sending point of branch $b_{n,m}$, which is a Positive value; $P^q_{lossn,k}$ Power loss of branch $b_{n,k}$ due to reactive flows; R_{n+1} Set of nodes receiving reactive power from node n and connected to this Node n and connected to this node with branch $b_{n,m}$; D_n Set of loads connected to node n ; Q_{Dm} Reactive power demand of load D_m ; L^q_n Loss allocated to node n due to reactive flows.

Similar to the previous section, the procedure could be applied to calculate the loss assigned to all nodes due to reactive flows. As a result, the loss allocated to load D_i is calculated similar to (8) as

$$L^q_k = \sum_{n \in R_{k-1}} \left[L^n_q \frac{(Q_{n,k}^s)^2 + Q_{n,k}^s \left(\sum_{m \neq k} Q_{n,m}^s + \sum_{D_m \in D_n} Q_{D_m} \right)}{\left(\sum_{m \in R_{n+1}} Q_{n,m}^s + \sum_{D_m \in D_n} Q_{D_m} \right)^2} + P^q_{Loss_{n,k}} \right] - (11)$$

$$L_{D_i}^q = L_k^q \frac{(Q_{D_i})^2 + Q_{D_i} \left(\sum_{\substack{n \in D_k \\ n \neq i}} Q_{D_n} + \sum_{n \in R_{k+1}} Q_{k,n}^s \right)}{\left(\sum_{n \in D_k} Q_{D_n} + \sum_{n \in R_{k+1}} Q_{k,n}^s \right)^2} - (12)$$

2) Total Loss Allocated to Loads:

The total loss allocated to load D_i is obtained by adding (8) and (12) as

$$L_{D_i} = L_{D_i}^p + L_{D_i}^q - (13)$$

Calculating the Loss Allocated to the DGs

Likewise, in order to calculate the loss allocated to DG G_i , which is connected to node k , first L'_k is obtained. L'_k is the loss assigned to node k , which is calculated using the loss allocated to all nodes that receive active power from this node. L'_k is composed of L'^p_k and L'^q_k , whose formulations are presented in the following sections.

1) Loss Allocated to the DGs Due to Active Flows:

The loss allocated to node k due to active flows is calculated as shown in (14), at the bottom of the page, where A_{k+1} Set of nodes receiving active power from node k and are connected to this Node With branch $b_{k,n}$; $P^r_{k,n}$ Active power flow at the receiving point of branch $b_{k,n}$, which is a positive Value; $P^r_{m,n}$ Active power flow at the receiving point of branch $b_{m,n}$, which is a positive Value; $P^p_{lossk,n}$ Loss of branch $b_{k,n}$ due to active flows; A_{n-1} Set of nodes sending active power to node n and connected to this node With branch $b_{m,n}$; G_n Set of DG's connected to node n ; P_{G_m} Active power output of DG G_m ; L'^p_n Loss allocated to node n due to active flows. L'^p_k is set to zero for all of the active sink nodes, that is, the nodes whose active load is more than their active generation. This is because the active generated power of all DGs connected to these nodes is consumed locally by the loads connected to

$$L'^p_k = \sum_{n \in A_{k+1}} \left[L'^p_n \frac{(P^r_{k,n})^2 + P^r_{k,n} \left(\sum_{\substack{m \in A_{n-1} \\ m \neq k}} P^r_{m,n} + \sum_{G_m \in G_n} P_{G_m} \right)}{\left(\sum_{m \in A_{n-1}} P^r_{m,n} + \sum_{G_m \in G_n} P_{G_m} \right)^2} + P^p_{LOSS_{k,n}} \right] - (14)$$

These nodes. Consequently, the DGs connected to these nodes should not be allocated any active loss. The procedure to calculate L'^p_k is as follows.

Step 1) Assign zero L'^p_k to each of the active sink nodes, as well as the node Connecting the transmission and distribution systems.

Step 2) Loop over all the nodes whose L'^p_k is not obtained yet: If L'^p_k of all nodes that receive active power from this node is previously Calculated, then obtain L'^p_k for this node using (14).

Step 3) If there is a node whose L'^p_k is not obtained yet, go back to Step 2); otherwise, stop the procedure.

A similar proof to the one previously explained could demonstrate that this method can calculate L'^p_k for all nodes

Assume DG G_j with power output of P_{G_j} is connected to node k . The loss allocated to this DG, due to active flows, can be calculated using L'^p_k as

$$L^p_{G_j} = L'^p_k \frac{(P_{G_j})^2 + P_{G_j} \left(\sum_{\substack{n \in G_k \\ n \neq j}} P_{G_n} + \sum_{n \in A_{k-1}} P^r_{n,k} \right)}{\left(\sum_{n \in G_k} P_{G_n} + \sum_{n \in A_{k-1}} P^r_{n,k} \right)^2} - (15)$$

Where G_k represents the set of DGs connected to node k

2) Loss Allocated to the DGs Due to Reactive Flows:

The loss allocated to node k due to reactive flows is calculated as (16), shown at the bottom of the page, where R_{k+1} Set of nodes receiving reactive power from node k and are connected to This node with branch $b_{k,n}$; $Q^r_{k,n}$ Reactive power flow at the receiving point of branch $b_{k,n}$ which is a Positive value; $Q^r_{m,n}$ Reactive power flow at the receiving point of branch $b_{m,n}$ which is a Positive value $P^q_{lossk,n}$ Power loss of branch $b_{k,n}$ due to reactive flows; R_{n-1} Set of nodes sending reactive power to node n and connected to this node With branch $b_{m,n}$;

Q_{G_m} Reactive power output of DG G_m ; L'^q_n Loss allocated to node n , due to reactive flows.

$$L'^q_k = \sum_{n \in R_{k+1}} \left[L'^q_n \frac{(Q^r_{k,n})^2 + Q^r_{k,n} \left(\sum_{\substack{m \in R_{n-1} \\ m \neq k}} Q^r_{m,n} + \sum_{G_m \in G_n} Q_{G_m} \right)}{\left(\sum_{m \in R_{n-1}} Q^r_{m,n} + \sum_{G_m \in G_n} Q_{G_m} \right)^2} + P^q_{LOSS_{k,n}} \right] - (16)$$

The loss allocated to DG G_j due to reactive flows might be obtained as

$$L_{G_j}^q = L_k^q \frac{(Q_{G_j})^2 + Q_{G_j} \left(\frac{\sum_{n \neq j} G_n \square G_k Q_{G_n} + \sum_{n \square R_{k-1}} Q_{n,k}^r}{n \neq j} \right)}{\left(\sum_{n \square G_k} Q_{G_n} + \sum_{n \square R_{k-1}} Q_{n,k}^r \right)^2} - (17)$$

1) Total Loss Allocated to DGs:

The total loss allocated to DG G_j is obtained by adding (15) and (17) as

$$L_{G_j} = L_{G_j}^p + L_{G_j}^q - (18)$$

Normalization for Calculating the Final LA Formula

In this step, normalization is executed, so that the total amount of money paid by loads and DGs is equal to the total loss cost. The normalization factor is obtained as

$$NF = \frac{P_{LOSS}}{\sum L_{D_i} + \sum L_{G_j}} - (19)$$

Hence, the loss allocated to load D_i and the loss allocated to DG G_j is normalized as

$$\begin{aligned} L_{D_i}^{normalized} &= L_{D_i} NF \\ L_{G_j}^{normalized} &= L_{G_j} NF - (20) \end{aligned}$$

Equation (20) is the final formulation for calculating the loss allocated to load D_i and DG G_j . To summarize, the steps of the proposed LA method are depicted in Fig. 5. As the figure shows, calculating the loss allocated to loads is executed parallel to calculating the loss allocated to DGs, which considerably decreases the computation time for large systems.

MATLAB Results

In this section, the proposed LA method is implemented on a sample rural distribution system (line & bus data can be taken from IEEE 16-bus and 69-bus radial distribution system), whose single-line diagram is shown in Fig. 6. This system comprises 17 nodes, 12 loads, 3 DGs, and 16 distribution lines. Table I presents the power-flow results as well as the distribution lines' resistance (r), reactance (x), and total charging capacitance (b), taking 1 MVA and 20 kV as the base power and voltage. Node 1 is fed by a 63/20-kV transformer. Nonzero shunt parameter of lines makes it possible to use the Z-bus LA method, since the Y-bus matrix is not singular in this case. The loads' and DGs' data and the results of the proposed LA method as well as pro rata, marginal, Z-bus, BCDM and succinct method are provided in Table 2. As Table 2 shows, three DGs are located at nodes 15–17. The DGs are considered as negative loads for power-flow calculations.

The proposed method has been applied to a larger system comprising 69 nodes, whose data can be found in except the loads and DGs output power, which are given in Table 3. The results of applying the proposed method to this system are shown in Table 3 as well.

IV. FIGURES AND TABLES

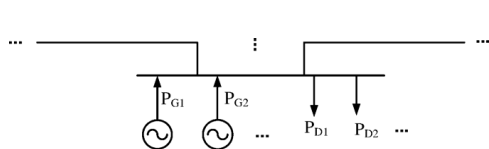


Fig.1 Sample node of a distribution system.



Fig.2 Sample feeder

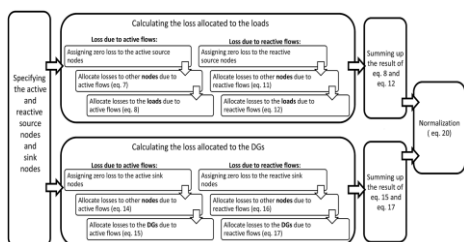


Fig3 Steps of the proposed LA method

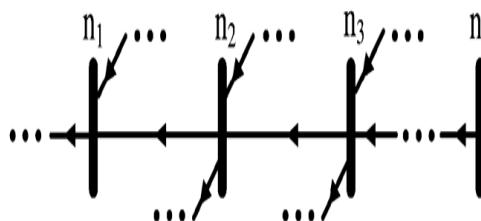


Fig.4 Part of a sample distribution feeder.

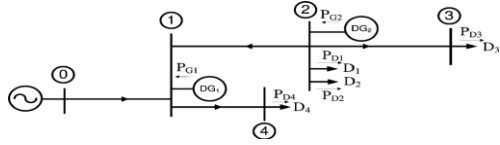


Fig. 5 Sample distribution feeder

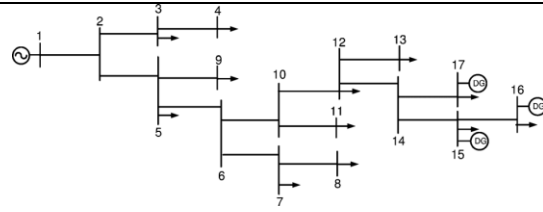


Fig . 6. Test distribution feeder.

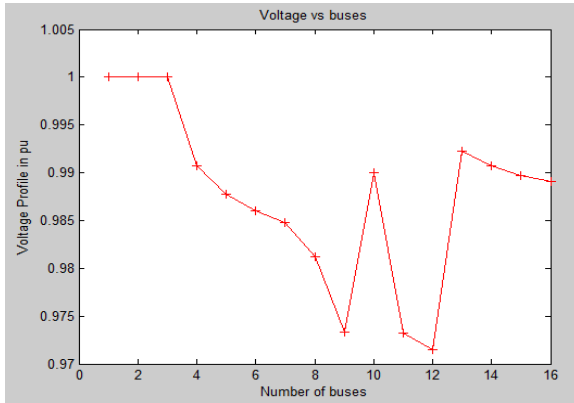


Fig7. Voltage Profile for 16-bus system

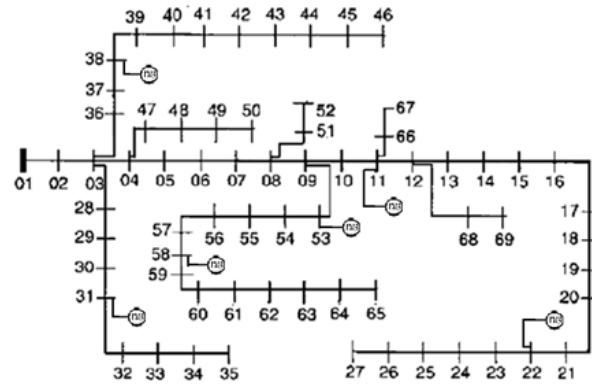


Fig.8 69-bus diagram with DGs

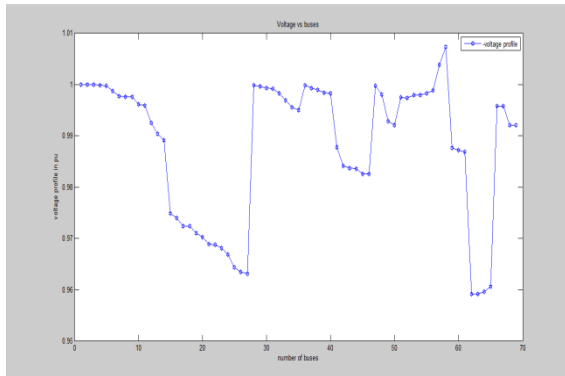


Fig.9 Source node Voltage profile of 69-bus distributed system

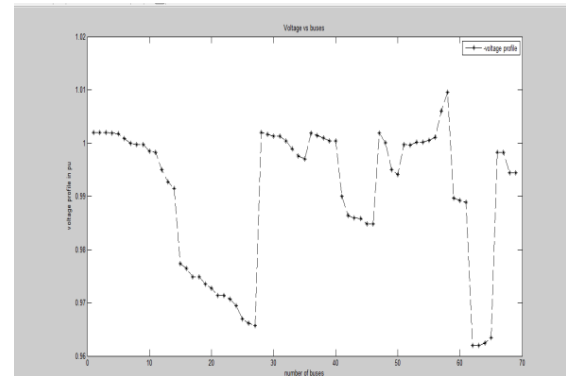


Fig.10 Sink node Voltage profile of 69-bus distributed system

TABLE-I
Distribution Lines Data

| Branch No. | From Node | To Node | R (p.u) | X (p.u) | Pl (KW) | Q1 (KVAR) |
|------------|-----------|---------|---------|---------|----------|-----------|
| 1 | 1 | 2 | 0.0025 | 0.0026 | 0 | 0 |
| 2 | 2 | 5 | 0.0007 | 0.0007 | 140.0000 | 80.0000 |
| 3 | 2 | 3 | 0.0008 | 0.0008 | 89.0000 | 50.0000 |
| 4 | 3 | 4 | 0.0007 | 0.0007 | 111.0000 | 63.0000 |
| 5 | 5 | 9 | 0.0021 | 0.0022 | 89.0000 | 50.0000 |

| | | | | | | |
|----|----|----|--------|--------|----------|----------|
| 6 | 5 | 6 | 0.002 | 0.0021 | 0 | 0 |
| 7 | 6 | 10 | 0.0001 | 0.0001 | 0 | 0 |
| 8 | 6 | 7 | 0.0009 | 0.0009 | 141.0000 | 80.0000 |
| 9 | 7 | 8 | 0.0017 | 0.0017 | 338.0000 | 192.0000 |
| 10 | 10 | 11 | 0.0006 | 0.0006 | 152.0000 | 86.0000 |
| 11 | 10 | 12 | 0.0018 | 0.0018 | 266.0000 | 151.0000 |
| 12 | 12 | 13 | 0.0003 | 0.0003 | 10.0000 | 5.0000 |
| 13 | 12 | 14 | 0.0011 | 0.0011 | 0 | 0 |
| 14 | 14 | 15 | 0.0011 | 0.0011 | 205.0000 | 116.0000 |
| 15 | 14 | 17 | 0.0007 | 0.0007 | 72.0000 | 41.0000 |
| 16 | 15 | 16 | 0.0001 | 0.0001 | 241.0000 | 137.0000 |

TABLE- 2
Load and DG data and LA results: Sink node

| Load Node no. | P (KW) | Q (KVAR) | LA Results in KW | | |
|---------------|----------|----------|------------------|----------|-----------------|
| | | | Z-bus Method | BCDM | PROPOSED Method |
| 3 | 89.0000 | 50.0000 | 0.220000 | 0.330000 | 0.090000 |
| 4 | 111.0000 | 63.0000 | 0.290000 | 0.430000 | 0.180000 |
| 5 | 140.0000 | 80.0000 | 0.430000 | 0.620000 | 0.260000 |
| 7 | 141.0000 | 80.0000 | 0.780000 | 0.960000 | 0.860000 |
| 8 | 338.0000 | 192.0000 | 2.120000 | 2.560000 | 3.390000 |
| 9 | 89.00000 | 50.0000 | 0.300000 | 0.410000 | 0.160000 |
| 11 | 152.0000 | 86.0000 | 0.770000 | 0.970000 | 1.230000 |
| 12 | 266.0000 | 151.0000 | 1.360000 | 1.700000 | 0.390000 |
| 13 | 10.0000 | 5.0000 | 0.050000 | 0.060000 | 0.010000 |
| 15 | 205.0000 | 116.0000 | - 0.250000 | 1.050000 | 0.000000 |
| 16 | 72.0000 | 41.0000 | - 0.090000 | 0.390000 | 0.000000 |
| 17 | 241.0000 | 137.0000 | - 0.510000 | 0.720000 | 0.000000 |

TABLE II
Load and DG data and LA Results: Source node

| Generation Node no. | P (KW) | Q (KVAR) | Z-bus Method | BCDM | PROPOSED Method |
|---------------------|----------|------------|--------------|--------|-----------------|
| 15 | 300.0000 | 145.290000 | 0.360000 | -1.530 | 0.030000 |
| 16 | 200.0000 | 96.860000 | 0.240000 | -1.080 | 0.020000 |

| | | | | | |
|----|----------|------------|----------|-------|----------|
| 17 | 260.0000 | 125.920000 | 0.550000 | 3.400 | 0.000000 |
|----|----------|------------|----------|-------|----------|

TABLE- III
LA results for the 69- node system-Sink node

| Load Node no. | P (KW) | Q (KVAR) | LA in KW (Light loads) | LA in KW (Over loads) |
|---------------|----------|-----------|------------------------|-----------------------|
| 6 | 20.60000 | 12.20000 | 0.050000 | 0.09 |
| 7 | 40.40000 | 30.00000 | 0.270000 | 0.35 |
| 8 | 75.0000 | 54.0000 | 0.970000 | 1.60 |
| 9 | 30.0000 | 22.0000 | 0.690000 | 1.35 |
| 10 | 28.0000 | 19.0000 | 1.200000 | 1.78 |
| 11 | 145.0000 | 104.0000 | 0.000000 | 0.23 |
| 12 | 145.0000 | 104.0000 | 0.330000 | 0.698 |
| 13 | 81.0000 | 52.0000 | 0.470000 | 0.98 |
| 14 | 93.0000 | 72.0000 | 1.210000 | 1.84 |
| 15 | 71.0000 | 52.0000 | 1.650000 | 2.36 |
| 16 | 5.50000 | 2.0000 | 0.190000 | 0.25 |
| 17 | 21.0000 | 15.0000 | 1.630000 | 1.98 |
| 18 | 14.0000 | 10.40000 | 2.060000 | 2.85 |
| 20 | 1.0000 | 0.60000 | 0.530000 | 1.0 |
| 22 | 56.0000 | 31.50000 | 0.000000 | 0.02 |
| 23 | 64.0000 | 52.50000 | 0.010000 | 0.06 |
| 24 | 28.0000 | 20.0000 | 0.010000 | 0.18 |
| 25 | 33.30000 | 23.40000 | 0.040000 | 0.21 |
| 26 | 44.0000 | 30.0000 | 0.100000 | 0 |
| 27 | 44.0000 | 30.0000 | 0.140000 | 0 |
| 28 | 26.0000 | 18.60000 | 0.000000 | 0 |
| 29 | 26.0000 | 180000 | 0.010000 | 0.02 |
| 30 | 20.30000 | 12.70000 | 0.020000 | 0.04 |
| 31 | 35.0000 | 33.0000 | 0.000000 | 0.0 |
| 32 | 65.0000 | 52.0000 | 0.020000 | 0.30 |
| 33 | 75.0000 | 51.0000 | 0.080000 | 0.14 |
| 34 | 31.0000 | 24.50000 | 0.060000 | 0.10 |
| 35 | 31.0000 | 24.0000 | 0.090000 | 0.14 |
| 36 | 26.0000 | 18.550000 | 0.010000 | 0.02 |
| 37 | 26.0000 | 18.5500 | 0.000000 | 0.1 |
| 38 | 35.6000 | 22.4000 | 0.000000 | 0 |
| 39 | 105.000 | 87.0000 | 0.010000 | 0.04 |
| 40 | 93.0000 | 72.0000 | 0.010000 | 0.05 |
| 41 | 139.220 | 96.3000 | 0.190000 | 0.19 |
| 42 | 71.0000 | 66.0000 | 0.180000 | 0.18 |
| 43 | 25.0000 | 13.3000 | 0.080000 | 0.15 |
| 44 | 54.0000 | 43.7000 | 0.350000 | 0.38 |
| 45 | 39.0000 | 26.0000 | 0.330000 | 0.65 |
| 46 | 1.20000 | 1.00000 | 0.010000 | 0.09 |
| 47 | 51.0000 | 43.5000 | 0.030000 | 0.1 |
| 48 | 79.0000 | 56.4000 | 0.110000 | 0.25 |
| 49 | 284.700 | 174.500 | 0.930000 | 1.25 |
| 50 | 284.700 | 174.500 | 1.370000 | 1.65 |
| 51 | 40.5000 | 28.3000 | 0.570000 | 1.2 |

| | | | | |
|----|---------|---------|----------|-------|
| 52 | 26.6000 | 12.7000 | 0.410000 | 0.8 |
| 53 | 87.3500 | 63.5000 | 0.000000 | 0 |
| 54 | 96.4000 | 79.0000 | 0.030000 | 0.09 |
| 55 | 24.0000 | 17.2000 | 0.010000 | 0.01 |
| 56 | 125.000 | 85.9000 | 0.160000 | 0.19 |
| 57 | 100.000 | 72.0000 | 0.130000 | 0.25 |
| 58 | 12.0000 | 7.50000 | 0.000000 | 0 |
| 59 | 29.5000 | 20.0000 | 0.010000 | 0.32 |
| 60 | 51.9700 | 43.2000 | 0.060000 | 0.45 |
| 61 | 44.0000 | 28.0000 | 0.100000 | 0.18 |
| 62 | 32.0000 | 23.0000 | 0.120000 | 3.5 |
| 63 | 13.6000 | 9.70000 | 0.090000 | 0.84 |
| 64 | 27.0000 | 12.0000 | 0.300000 | 1.23 |
| 65 | 59.0000 | 42.0000 | 1.160000 | 2.044 |
| 66 | 18.0000 | 13.0000 | 0.000000 | 0 |
| 67 | 18.0000 | 13.0000 | 0.000000 | 0 |
| 68 | 28.0000 | 20.0000 | 0.070000 | 0.25 |
| 69 | 28.0000 | 20.0000 | 0.100000 | 0.56 |

TABLE-IV

LA results for the 69-node system: Source node

| Generation Node no. | P (KW) | Q (KVAR) | LA in KW (Light loads) | LA in KW (Over loads) |
|---------------------|-----------|----------|------------------------|-----------------------|
| 11 | 500.0000 | 220.0000 | 0.770000 | 1.520000 |
| 22 | 100.0000 | 44.0000 | 0.010000 | 0.950000 |
| 31 | 200.0000 | 88.0000 | 0.050000 | 0.360000 |
| 38 | 1000.0000 | 440.0000 | 0.100000 | 0.530000 |
| 53 | 300.0000 | 132.0000 | 0.050000 | 0.230000 |
| 58 | 400.0000 | 176.0000 | 0.130000 | 0.492000 |

CONCLUSION

This paper presents a novel LA method for radial distribution systems, in which the loss allocated to each node is dependent on the loss allocated to its adjacent nodes and the loss of the lines connected to the node. The proposed method has the following properties, which are explained in to be the desirable properties of every LA method: This paper has discussed the optimal placement of DG's in 16 & 69-bus RDS system considering the dynamic loaded conditions or load levels and provided the considerable improvement of voltage profile and the reduction of real and reactive power losses in the system by using Loss Allocation method the comparison between the obtained results were done. The placement of DG's in the weak buses has produced the considerable improvement in the annual cost savings of the 69-bus RDSSystem. Future works will focus on studying the effect of harmonics in the 69-bus RDS In order to allocate energy losses throughout a day, the method must be executed separately for each hour, which is time-consuming. Hence, the authors are working on

a stochastic method, which could find equivalent loads based on their variation during a particular time span with an equal energy loss effect to replace the value of loads.

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