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Minimisation of Distribution Loss for Radial Systems Including DG's

Koduru Sarada,
M.Tech Student,
Department of EEE ,
Sreenivasa Institute of Technology and Management, Chittoor, A.P, India.

L. Sagar,
Associate Professor,
Department of EEE
Sreenivasa Institute of Technology and Management Chittoor, A.P, India.

Dr.Shaik Rafi Kiran,
Associate Professor and HoD,
Department of EEE,
Sreenivasa Institute of Technology and Management, Chittoor, A.P, India.

ABSTRACT

Due to the liberalization of the electricity market and the introduction of distributed generation (DG), the importance of distribution loss allocation (LA) has increased. This paper presents a new method for distribution power LA in radial systems. The proposed method, which is based on the results of power flow and considers active and reactive power flows of lines for LA, is composed of three steps. In the first step, starting from the source nodes (i.e., the nodes whose generation is more than their load), the power loss allocated to all nodes is calculated and then the power loss allocated to the loads connected to each node is obtained. In the next step, the total power loss is allocated to the nodes in order to calculate the power loss allocated to the DGs based on the results of this step. In contrast to the previous step, in this step, allocating power losses to the nodes starts from sink nodes, which are the nodes whose load is more than their generation. In the final step, normalization is executed. The application of the proposed method is illustrated on two distribution feeders, and the results are compared with other methods.

Index Terms ***Distributed generation, loss allocation, radial distribution systems.***

I. INTRODUCTION

The increase in deployment of distributed generation (DG) and the shift of distribution loads from customer mode to prosumers 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 [1]. 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 for transmission LA, which are listed below:• pro rata [2], which allocates the distribution loss to DGs and loads based on their active power levels, neglecting their location, which is not fair marginal method, which calculates the marginal loss coefficients (i.e., the changes in total loss due to a change in active/ reactive node injection), based on the results of power flow; these coefficients are then used to obtain the share of DGs and loads in total loss; the results of this method needs reconciliation in order to compensate for over-recovery of loss [3]–[5]; • direct loss coefficients method, presented in [3], which finds a direct relation between the losses and nodal injections; both this method and marginal method are based on the results of Newton–Raphson power flow and, hence, have the flaws of application of this type of power flow in specific distribution systems where the number of nodes is large, the lines' resistance is negligible to their reactance, or consists of very long or very short lines

• Substitution method, where the responsibility of a participant is calculated by subtracting the total loss when the participant is not attached to the system from the loss when it is attached; this method is proved to give unfair results.

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• Circuit-based methods, which contain a group of methods as follows.

1) Z-bus method , which is not applicable to distribution systems containing only overhead lines, since the Y-bus matrix is singular for such systems, due to the fact that the shunt admittance of such lines is negligible.
2) The method based on a modified bus admittance matrix. 3) Succinct method, which considers active and reactive flows for LA and is proved by to be incapable of providing reliable results under particular circumstances.
4)Branch current decomposition method (BCDM) [8], in which the loss allocated to each node is calculated based on the current of its upward branches (i.e., the branches that connect the node to the root node).

• tracing methods, which are based on attributing the branch power flows to the nodes injection powers; although a considerable amount of transmission LA literature is dedicated to these methods, the terminology seems to disappear in distribution LA; this is due to the fact that in radial distribution systems, each branch current can be easily written in terms of the current of its downward nodes; meanwhile, the BCDM, categorized as circuit- based methods, is a version of tracing methods used for distribution LA; the method presented by Costa and Matos is another version of tracing methods, which implemented the quadratic LA technique; the power summation algorithm proposed is a tracing method, in which the active and reactive power of the receiving end of each branch are decomposed to the nodal injection of the system nodes and the losses of downstream branches that are connected to the branch;
• the method presented in [12], which applies graph theory for LA; however, the method is not applicable when DGs exist in the distribution systems;
• the exact method for real power LA, in which the consumers have to pay for losses;
• the method presented in, which allocates the losses to the consumers of a radial distribution system in a quadratic way, based on identifying the real and imaginary parts of the current of each branch. Reference present a comparative study of distribution LA methods.

The following points should be considered in distribution LA:
1) The slack node for distribution systems is always the node connecting transmission and distribution systems; however, in transmission LA, there are many alternatives for the slack node.
2) Unlike the transmission LA methods, in which a fraction of loss may be allocated to the slack node, in distribution LA methods, no loss is assigned to the slack node.
3) The methods used for transmission LA could be used in distribution systems; however, the loss allocated to the slack node in these methods should be redistributed among other nodes in proportion to the nodes' currents. This point is really important, as the slack node current in distribution systems is usually large and it allocates a high proportion of total losses to itself, using the transmission LA methods.
4) It is implicitly assumed that the loads and DGs have bilateral contracts with the distribution company.

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. This paper is organized as follows: the next section explains the bases of the method, which is proceeded by the formulation of the method presented in Section III. In Section IV, 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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II. PROPOSED METHOD ASSUMPTIONS AND BASES

1) The distribution loss allocated to the node connecting the distribution and transmission network is set to zero. 2) Consider the node depicted in Fig. 1.$(P_{G_1} + P_{G_2+\dots}) > (P_{D_1} + P_{D_2} + \cdots)$, In case , 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.

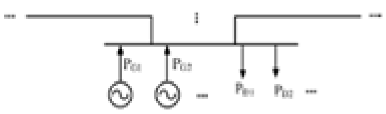

Fig. 1. Sample node of a distribution system.

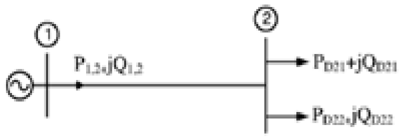

Fig. 2. Sample feeder.

In case . 1.$(P_{G_1} + P_{G_2+\dots}) > (P_{D_1} + P_{D_2} + \cdots)$,

The method allocates zero losses to the DGs connected to the node. 3) The proposed method does not allocate negative losses to the loads and DGs. 4) The distribution system is assumed to be a radial system, in which the loads and DGs have private owners. 5) Consider the circuit depicted in Fig. 2, which shows two nodes of a system. The power loss of the line connecting nodes 1 and 2 can be written as

$$P_{\mathrm{Loss}_{1,2}} = r_{1,2}\frac{P_{1,2}^2 + Q_{1,2}^2}{|V_1|^2} = k\left(P_{1,2}^2 + Q_{1,2}^2\right), \qquad (1)$$

where is the resistance of the line; and are the active and reactive power through the line; and is the voltage of node 1. As it is seen, is composed of two terms. The first term, which is , is due to the active flows through the line and the second term, which is$KP_{1,2}^2$, is due to the reactive lows. Let us denote these two terms, respectively, as$P_{LOSS1,2}^P$ and$P_{LOSS1,2}^Q$. Consequently, (1) can be written as

$$P_{\mathrm{Loss}_{1,2}} = P_{\mathrm{Loss}_{1,2}}^p + P_{\mathrm{Loss}_{1,2}}^q. \qquad (2)$$

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

$$P_{\mathrm{Loss}_{1,2}}^p = kP_{1,2}^2 = k(P_{D21} + P_{D22} + P_{\mathrm{Loss}_{1,2}})^2 \qquad (3)$$

which is equal to$K(P_{D21} + P_{D22})^2)$, since is $P_{LOSS1,2}$usually small compared to P_{D21}andP_{D22} and, 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 loadP_{D21} in$P_{LOSS1,2}^P$ is equal to

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

and that of loadP_{D22} is$K(P_{D21}^2 + P_{D21}P_{D220})$. A similar formulation can be derived, in case the number of loads or lines connected to node 2 increases. Moreover, the same approach is applicable if we want to allocate$P_{LOSS1,2}^Q$to$Q_{D21} And Q_{D22}$ These formulae are the basis for the proposed LA method, which is presented in the following section.

III. PROPOSED LA METHOD

The method is composed of three steps as follows.

Calculating the loss allocated to the loads:

a) Loss due to active flows:

i) specifying the active source nodes, which are the nodes whose active generation exceeds their active demand;

ii) assigning zero active loss to the active source nodes;

iii) calculating the loss assigned to nodes other than the source nodes, due to active flows;

iv) calculating the loss allocated to the loads due to active flows.

b) Loss due to reactive flows:

i) specifying the reactive source nodes, which are the nodes whose reactive generation exceeds their reactive demand;

ii) assigning zero loss to the reactive source nodes;

iii) calculating the loss allocated to other nodes due to reactive flows;

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iv) calculating the loss allocated to the loads due to reactive flows.

c) Total loss: by summing up the loss allocated to loads due to active and reactive flows

Calculating the loss allocated to the DGs:

a) Loss due to active flows:

i) determining the active sink nodes, which are the nodes whose active demand exceeds their active generation

ii) assigning zero loss to the active sink nodes

iii) calculating the loss assigned to other nodes due to active flows

iv) calculating the loss allocated to the DGs due to active flows.

b) Loss due to reactive flows:

i) Determining the reactive sink nodes, which are the nodes whose reactive demand exceeds their reactive generation

ii) assigning zero loss to the reactive sink nodes

iii) calculating the loss assigned to other nodes due to reactive flows

iv) calculating the loss allocated to the DGs due to reactive flows.

c) Total loss: by summing up the loss allocated to DGs due to active and reactive flows.

Normalization so that the losses allocated to the loads and DGs add up to the total active loss.

The loss allocated to each node when calculating the loss allocated to the loads is different from the values obtained when calculating the loss allocated to DGs. In any of the first and second steps, the loss allocated to each node is calculated based on the loss allocated to its adjacent nodes. The detailed description of the steps of the proposed method is provided in the three following subsections.

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 is dependent on the loss assigned to all nodes that are adjacent to this node and send active power to it. Let branch connect node to node and , which is the active power flow at sending node of this branch, be positive. Presume that the loss allocated to node due to active flows is denoted as and is known. We want to distribute among: 1) all the loads that are Connected to node 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 in is proportional to

$$\left\{ \left(P_{n,k}^{s}\right)^{2} + P_{n,k}^{s}\left(\sum_{\substack{m\in \mathbf{A}_{n+1} \\ m\neq k}} P_{n,m}^{s} + \sum_{D_m \in \mathbf{D}_n} P_{Dm} \right) \right\} \quad (5)$$

where is the active power flow at the sending point of branch , which is a positive value; is the active power demand of load is the set of nodes receiving active power from node and connected to this node with branch ; and is the set of loads connected to node . Since the contribution of all loads and active power sending branches connected to node should add up to , the following term is assigned to :

$$L_{n}^{p} \frac{\left(P_{n,k}^{s}\right)^{2} + P_{n,k}^{s}\left(\sum_{\substack{m\in \mathbf{A}_{n+1} \\ m\neq k}} P_{n,m}^{s} + \sum_{D_m \in \mathbf{D}_n} P_{Dm} \right)}{\left(\sum_{m\in \mathbf{A}_{n+1}} P_{n,m}^{s} + \sum_{D_m \in \mathbf{D}_n} P_{Dm} \right)^{2}}. \quad (6)$$

Node is not only responsible for a fraction of the loss assigned to node, but also the power loss of branch due to active power flows. As a result, can be calculated as shown in (7), at the bottom of the next page, where is the set of nodes that send active power to node and are connected to this node with branch ; and is the power loss of branch due to active power flows. As (7) shows, a fraction of the loss assigned to node is assigned to node . 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

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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 's is as follows.

Step 1) Assign zero 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 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).

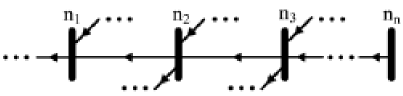

Fig. 3. Part of a sample distribution feeder.

Step 3) If there is a node whose is not obtained yet, go back to Step 2); otherwise, stop the procedure. For the proof of why can be determined for all nodes using the proposed method, imagine node is a node, whose 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 , say node Likewise, the impossibility of determining the loss due to active flows allocated to node should be because the loss due to active flows allocated to node , which is adjacent to , 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 , 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 due to active flows should be zero, which contradicts the fact that it is impossible to determine the loss allocated to node , and . As a result, the proposed method can always calculate for all nodes. The same explanation can be used to demonstrate that it is always possible to calculate, and for all nodes, which are later introduced. Furthermore, note that is not the actual loss allocated to node , 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 in the following step, which is used to calculate the loss allocated to the DGs connected to node . Similar to (6), the loss allocated to load connected to node , which has the active power demand of , is alculated as

$$L^p_{D_i} = L^p_k \frac{(P_{Di})^2 + P_{Di}\left(\sum\limits_{\substack{D_n \in \mathbf{D}_k \\ n \neq i}} P_{Dn} + \sum\limits_{n \in \mathbf{A}_{k+1}} P^s_{k,n}\right)}{\left(\sum\limits_{D_n \in \mathbf{D}_k} P_{Dn} + \sum\limits_{n \in \mathbf{A}_{k+1}} P^s_{k,n}\right)^2} \tag{8}$$

where $\mathbf{D}_k$ is the set of loads connected to node k.

$$L^p_k = \sum_{n \in \mathbf{A}_{k-1}} \left[L^p_n \frac{\left(P^s_{n,k}\right)^2 + P^s_{n,k}\left(\sum\limits_{\substack{m \in \mathbf{A}_{n+1} \\ m \neq k}} P^s_{n,m} + \sum\limits_{D_m \in \mathbf{D}_n} P_{Dm}\right)}{\left(\sum\limits_{m \in \mathbf{A}_{n+1}} P^s_{n,m} + \sum\limits_{D_m \in \mathbf{D}_n} P_{Dm}\right)^2} + P^p_{\mathrm{Loss}_{n,k}} \right] \tag{7}$$

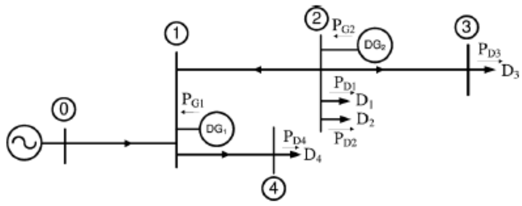

Fig. 4. Sample distribution feeder.

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, is dependent on , which has term 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 . Since node 2 is a source node, the loss assigned to this node is zero as well . Now using (7), the loss assigned to nodes 1, 3, and 4 is calculated As

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$$\begin{aligned} L_1^p &= P^p_{\text{Loss}_{0,1}} + P^p_{\text{Loss}_{2,1}}, \\ L_3^p &= P^p_{\text{Loss}_{2,3}}, \\ L_4^p &= L_1^p + P^p_{\text{Loss}_{1,4}}. \end{aligned} \tag{9}$$

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

$$\begin{aligned} L^p_{D_1} &= 0, \\ L^p_{D_2} &= 0, \\ L^p_{D_3} &= L_3^p, \\ L^p_{D_4} &= L_4^p. \end{aligned} \tag{10}$$

2) 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

$\mathbf{R}_{k-1}$	set of nodes that send reactive power to node k and are connected to this node with branch $b_{n,k}$;
$Q^r_{n,k}$	reactive power flow at the sending point of branch $b_{n,k}$, which is a positive value;
$Q^r_{n,m}$	reactive power flow at the sending point of branch $b_{n,m}$, which is a positive value;
$P^q_{\text{Loss}_{n,k}}$	power loss of branch $b_{n,k}$ due to reactive flows;
$\mathbf{R}_{n+1}$	set of nodes receiving reactive power from node n and connected to this node with branch $b_{n,m}$;
$\mathbf{D}_n$	set of loads connected to node n;
Q_{D_m}	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 is calculated similar to (8) as

$$L'^q_k = \sum_{n\in\mathbf{R}_{k+1}} \left[L'^q_n \frac{\left(Q^r_{k,n}\right)^2 + Q^r_{k,n}\left(\sum\limits_{\substack{m\in\mathbf{R}_{n-1}\\ m\neq k}} Q^r_{m,n} + \sum\limits_{G_m\in\mathbf{G}_n} Q_{G_m}\right)}{\left(\sum\limits_{m\in\mathbf{R}_{n-1}} Q^r_{m,n} + \sum\limits_{G_m\in\mathbf{G}_n} Q_{G_m}\right)^2} + P^q_{\text{Loss}_{k,n}} \right] \tag{16}$$

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

$$L^q_{G_j} = L'^q_k \frac{\left(Q_{G_j}\right)^2 + Q_{G_j}\left(\sum\limits_{\substack{G_n\in\mathbf{G}_k\\ n\neq j}} Q_{G_n} + \sum\limits_{n\in\mathbf{R}_{k-1}} Q^r_{n,k}\right)}{\left(\sum\limits_{G_n\in\mathbf{G}_k} Q_{G_n} + \sum\limits_{n\in\mathbf{R}_{k-1}} Q^r_{n,k}\right)^2}. \tag{17}$$

3) Total Loss Allocated to DGs: The total loss allocated to DG is obtained by adding (15) and (17) as

$$L_{G_j} = L^p_{G_j} + L^q_{G_j}. \tag{18}$$

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

$$\text{NF} = \frac{P_{\text{Loss}}}{\sum L_{D_i} + \sum L_{G_j}}. \tag{19}$$

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

$$\begin{aligned} L^{\text{normalized}}_{D_i} &= L_{D_i}\text{NF} \\ L^{\text{normalized}}_{G_j} &= L_{G_j}\text{NF}. \end{aligned} \tag{20}$$

Equation (20) is the final formulation for calculating the loss allocated to load and DG . 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.

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VI.RESULTS

Result for 37 bus system:

Load Node no	Voltage (p.u)	Angle (radius)	P (kw)	Q (kvar)	Ploss (kw)	Qloss (kvar)
1	1.0000	0	0.1000	0.0600	0.6815	0.3479
2	0.9978	-0.0003	0.0900	0.0400	1.1333	1.0810
3	0.9935	-0.0023	0.0900	0.0400	9.7902	8.8222
4	0.9562	-0.0190	0.0900	0.0400	2.5051	2.9266
5	0.9457	-0.0258	0.0900	0.0400	4.0567	5.3636
6	0.9278	-0.0398	0.0900	0.0400	2.6314	1.3405
7	0.9278	-0.0418	1.0500	0.0900	2.2365	1.5287
8	0.9179	-0.0451	0.4200	0.2000	1.7061	1.3470
9	0.9088	-0.0480	0.4900	0.4200	0.8562	0.6700
10	0.8966	-0.0496	0	0	0.0874	0.0874
11	0.8880	-0.0507	0.1200	0.0800	0.0640	0.0326
12	0.8858	-0.0509	0.0600	0.0300	0.0324	0.0165
13	0.8845	-0.0511	0.0600	0.0200	0.4405	0.0380
14	0.8835	-0.0482	0.0600	0.0250	0.0063	0.0032
15	0.8687	-0.0482	0.0600	0.0250	0.0039	0.0020
16	0.8684	-0.0483	0.0600	0.0200	0.0035	0.0031
17	0.8681	-0.0487	0.1200	0.0700	0.0128	0.0112
18	0.8676	-0.0490	0.2000	0.6000	0.6508	0.3316
19	0.8665	-0.0479	0.4900	0.1500	0.4538	0.4485
20	0.8615	-0.0523	0.2100	0.1000	0.0143	0.0167
21	0.8552	-0.0528	0.0600	0.0400	0.0015	0.0024
22	0.8545	-0.0530	0.2000	0.1000	0.0320	0.1058
23	0.8542	-0.0549	0.2000	0.1000	0.0304	0.0101
24	0.8529	-0.0549	0	0	0	0
25	0.8517	-0.0549	0.0600	0.0200	0.7946	0.5709
26	0.8433	-0.0580	0	0	1.3450	1.3450
27	0.8270	-0.0680	0.2000	0.1000	0.7022	0.4977
28	0.8191	-0.0710	0.0450	0.0300	0.0724	0.0239
29	0.8181	-0.0711	0.0600	0.0350	0.1154	0.0382
30	0.8164	-0.0711	0	0	0.4776	0.4776
31	0.8069	-0.0778	0.0600	0.0350	0.3506	0.2758
32	0.8003	-0.0813	0.1200	0.0800	0.0961	0.1265
33	0.7980	-0.0836	0.0600	0.0100	0.0471	0.0420
34	0.7965	-0.0848	0.0600	0.0200	0.0372	0.0286
35	0.7950	-0.0857	0.0600	0.0200	0.0333	0.0444
36	0.7930	-0.0880	0.0900	0.0400	0.0070	0.0055
37	0.7923	-0.0884	0	0	0	0

Generation Node no	Voltage (p.u)	Angle (radius)	P (kw)	Q (kvar)	Ploss (kw)	Qloss (kvar)
28	0.8191	-0.0710	0.0450	0.0300	0.0724	0.0239
29	0.8181	-0.0711	0.0600	0.0350	0.1154	0.0382
30	0.8164	-0.0711	0	0	0.4776	0.4776
33	0.7980	-0.0836	0.0600	0.0100	0.0471	0.0420
34	0.7965	-0.0848	0.0600	0.0200	0.0372	0.0286
35	0.7950	-0.0857	0.0600	0.0200	0.0333	0.0444
36	0.7930	-0.0880	0.0900	0.0400	0.0070	0.0055
37	0.7923	-0.0884	0	0	0	0

Table:5.1 solution for37bus system

V. 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 [19] to be the desirable properties of every LA method: • The method is consistent with the results of power flow. • The losses allocated to the loads/DGs depend on the amount of energy they consume/produce. • The location of each load and DG is a key factor in the amount of loss allocated to them. • The method is easy to understand. • The implementation of the method is straightforward and does not need complicated programming or extensive Computational effort. 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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Author Details

Name: Koduru Sarada

Branch (specialization):- electrical power engineering (EPE)

College:-Sreenivasa Institute of Technology and Management Studies(SITAMS)

MailId:- saradakoduru13@gmail.com

Name: L.Sagar

Received his B.E Degree in 2000 and M.Tech(PE) from VIT,Vellore in 2005. He is working as Associate Professor in EEE Dept.,Sreenivasa Institute of Technology and Management Studies (SITAMS), Chittoor. He is pursuing Ph.D in Electrical Engineering from JNTUA,Anatapur.His research interests are in the areas of Power Electronics &Drives, AI Techniques to Solid state drives.

Mail id :karnamsagar@gmail.com

Name: Dr.Shaik Rafi Kiran
Obtained his Masters degree(Control Systems) from JNTU, Anantapur. And Ph.D from JNTU, Anantapur. His Area of interest includes System Identification and Control Systems. He has over 15 years of teaching experience and published more than 10 papers in International and National Journals .Currently, he is a Professor and head of EEE Department, Sreenivasa institute of Technology and Management studies.