POWER FLOW METHOD: SHARING LOSS IN RADIAL DISTRIBUTION NETWORKS WITH DGS

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ABSTRACT: In the newly reorganized energy industry, determining how to divide up system losses between suppliers and end users is a complex issue. Given the importance of DGs in the new energy market structure, it is crucial that radial distribution networks with DGs properly allocate losses to both customers and generators. New loss allocation mechanism is presented in this study for radial distribution networks with DGs. Losses are divided up based on how the radial distribution network's sink nodes and distributed generators (DGs) are set up. There are three separate stages to the algorithm used in this procedure. In the first stage, power loss is apportioned to the linked loads of the various source nodes. The next step accounts for the findings from this step by assigning the overall power loss to the DGs. At this point, power losses are assigned to individual nodes, beginning with sink nodes, and then normalized to account for them. This paper describes a method for equitably sharing out the costs associated with power flow losses in radial medium-voltage distribution networks powered by decentralized power plants. Using a genetic algorithm, we approximate the voltage at each of the 69 nodes in the distribution network and then compare our results to those obtained using the more traditional method.

Keywords: Distributed generation, Loss allocation, Radial distribution system, Active and Reactive power flows.

1. INTRODUCTION

Multiple regions throughout the world are seeing expansions in distributed generating. Deregulation of the energy market, constraints on the building of new transmission and distribution infrastructure, and rising environmental concerns have all contributed to the growth of distributed generators (DGs). The importance of DG to the power grid is growing. In order to improve power dependability, energy efficiency, and decrease transmission and distribution losses in the electric grid, distributed generation (DG) is being built. It is possible to move the distribution network from a passive to active state by installing Distribution Generators. As a result, various transmission issues associated with the radial distribution network that involve DGs will be investigated. Loss attribution will be the primary research emphasis, but other distribution network issues will be recognized and addressed as well. By "loss allocation," we mean the process of pinpointing the percentage of distribution loss that can be traced back to a given load or DG source. Although there are several methods for apportioning transmission losses, distribution loss allocation is still in its infancy, and most distribution system operators lack a uniform policy.

Various strategies for distributing losses have been described in the academic literature. Each node's share of the loss is proportionate to its active power transmission. Marginal loss coefficients produced from power flow analysis using the marginal technique are used in the loss computation. The results of the Newton-Raphson power flow method constitute the foundation for both of these approaches. The active and reactive power at the branch's terminals are decomposed into nodal injection at the system nodes and downstream branch losses using the power summation algorithm presented in the aforementioned study. The Y-bus matrix for systems with only overhead lines is unique, and the shunt admittance is small, therefore the Z-bus approach cannot be used. This methodology, on the other hand, can. The empirical evidence shows that this approach produces skewed results.

The following considerations are crucial for assigning distribution losses:

The slack node is always the link between transmission and distribution in a given distribution system. However, the slack node in transmission LA provides other options.

Whereas transmission LA approaches allocate some of the loss to the slack node, distribution LA approaches do not attribute any loss to it.

LA methods used in transmission can also be used in distribution networks. However, the loss attributed to the idle node must be distributed among the remaining nodes in proportion to the currents flowing through them.

The distribution corporation is seen as having bilateral agreements with the loads and distribution generators.

In radial medium-voltage distribution systems with scattered generators, this research proposes a method for apportioning power flow losses. The first step is to pinpoint a group of nodes that exhibit zero power losses. Then, the power loss attributable to the other nodes is calculated by factoring in the power loss of the lines connecting the nodes that were given no power.

2. LITERATURE SURVEY

The process is demonstrated. These guidelines originate from research into the actual operation of power grids. The Central Electricity Authority of India enforces numerous laws pertaining to loss allocation, many of which are detailed in the "Power flow method for loss allocation in Radial Systems with DGs" chapter of the Indian Electrical system.

According to P. Both M. Sotkiewicz and J. There is an article titled "Nodal pricing for distribution networks: Efficient pricing for efficiency-enhancing DG" written by M. Vignolo and published in the IEEE Transactions.

Distribution networks become more dynamic and take on characteristics previously seen only in transmission networks as DG implementation rises. Nodal pricing is suggested as it is a widely used method for pricing transmission activities with a limited time horizon. Nodal pricing would ensure that distributed generation (DG) is fairly compensated by providing a financial incentive for lowering line losses. As an added bonus, it would show prospective DG projects where they would be best served by connecting to the distribution system. When nodal pricing is applied to a simulated distribution network, significant price differences are observed among buses, indicating sizable marginal losses. We also show how a distributed generation (DG) resource at the network's endpoint can drastically cut down on losses and ease line congestion. We further show that the DG resource, because of its role in reducing line losses and loading, generates significantly higher profits under nodal pricing.

In 1998, Kluwer in Norwell, MA, published a book titled "Restructuring of Power Systems: Engineering and Economics" by M. To wit: Ilic, F. Galiana, and L. Fink.

In order to facilitate long-term investment planning within reorganized power networks, this thesis describes the development of three decision support models. More competitive markets, greater unpredictability, and decentralized planning are only some of the ways in which the electric power industry has forced revisions to the original model assumptions. As a result, innovative planning models and long-term, all-encompassing evaluations of power systems are becoming increasingly important. The thesis examines the potential benefits of using dynamic and stochastic modeling to the decision-making process in a reorganized power industry.

These models can also serve as decision-support tools for regulatory actions, which is especially useful as the advent of competitive energy markets has made players more susceptible to price volatility and economic risk. Each player in the power system can use our models to determine if it is worthwhile to invest in more power plants. Long-term performance of the power system under various rules and market structures can be evaluated with the help of the models, which can be used as a regulatory decision-support tool.

3. POWER FLOW LOSS ALLOCATION METHOD ASSUMPTIONS

The conventional wisdom holds that there is no loss at any of the nodes in the distribution network.

Loss allocation specifies zero losses to all loads connected to a node if overall generation exceeds demand at that node; this indicates that the loads are being supplied locally by distributed generators (DGs). The method assigns no value to the losses of the connected Distributed Generators (DGs) if the total generation at a node is less than the demand.

In a decentralized network, nodes do not receive a negative loss value.

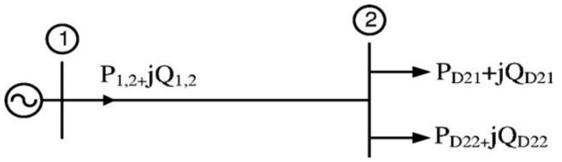


Figure-1

Take a look at the Figure 2 circuit, which features two different system nodes. The symbol stands for the power dissipated along the path connecting nodes 1 and 2.

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

Node 1's voltage is denoted by the variable V1, the active power flowing through the line is denoted by P1, and the reactive power flowing through the line is denoted by Q1. There are two terms in the first term of the above equation. Both phrases refer to the active and reactive currents that flow through the pipe, respectively. Consequently, Eq. 1 might be written as

$$P_{LOSS_{1,2}} = P^{p}_{LOSS_{1,2}} + P^{q}_{LOSS_{1,2}} \qquad (2)$$

As $As P_{1,2} = P_{D21} + P_{D22} + P_{LOSS_{1,2}},$, can be written as

$$P^{p}_{LOSS_{1,2}} = kP^2_{1,2} = k\left(P_{D21} + P_{D22} + P_{LOSS_{1,2}}\right)^2 \quad (3) \qquad (3)$$

When contrasted to the value of and, this expression is negligible: k times the square of the sum of PD21 and PD22. Therefore, we can disregard it.

In order to ascertain how much a player in a multi-player game contributes to the burden PD21 in PpLoss1,2, the Shapley value is used.

4.POWER FLOW LOSS ALLOCATION METHOD

Calculating the loss allocated to the loads:

Loss Allocated to Loads Due to Active PowerFlows:

At this point, the loss at each node owing to active flows is calculated and allocated to the associated loads.

The method relies on the fact that the loss sustained by node k depends on the loss assigned to all neighboring nodes that supply active power to it. How much power is flowing actively through node n if a positive connection exists between nodes n and k? Let's assume that the damage due to traffic at node n is represented by the symbol and is known in advance. Our goal is to distribute the active power flow from node n to the loads connected to node n and the branches that lead from node n. According to the result of the Shapley value technique (4), the contribution is

$P^{s}_{n,k}$ in L^{p}_{n} is proportional to

$$\left\{\left(P^{s}_{n,k}\right)^2 + P^{s}_{n,k}\left(\sum_{\substack{m\epsilon A_{n+1}\\ m\neq k}} P^{s}_{n,m} + \sum_{D_m \epsilon D_n} P_{D_m}\right)\right\} \quad (5) \qquad - (5)$$

Which end of the branch's transmission line has the positive active power flow? Dm; An+1 represents the set of nodes that draw active power from node n and are connected to it via a branch; this is its active electricity demand. Dn, on the other hand, is the collection of charges associated with node n. When referring to node n, the phrase "assigned" means that all of the loads and active power transmitting branches connected to it must add up to exactly one.

$$L^{p}_{n}\frac{\left(P^{s}_{n,k}\right)^2 + P^{s}_{n,k}\left(\sum_{\substack{m\epsilon A_{n+1}\\ m\neq k}} P^{s}_{n,m} + \sum_{D_m \epsilon D_n} P_{Dm}\right)}{\left(\sum_{m\epsilon A_{n+1}} P^{s}_{n,m} + \sum_{D_m \epsilon D_n} P_{Dm}\right)^2} \qquad - (6)$$

The formula for determining L p k's is given by Equation (7). 1) All links in the source, transmission, and distribution systems should have their values reset to zero.

The second step is to iterate over all of the nodes where the first step did not succeed. If you already know the loss assigned to this node's power, you can use equation (7) to get the loss assigned to this node itself. (7)

$$L_k^p = \sum_{n\in A_{k-1}} \left[L_n^p \frac{(P^s_{n,k})^2 + P^s_{n,k}\left(\sum_{\substack{m\in A_{n+1}\\ m\neq k}} P^s_{n,m} + \sum_{D_m\in D_n} P_{D_m}\right)}{\left(\sum_{m\in A_{n+1}} P^s_{n,m} + \sum_{D_m\in D_n} P_{D_m}\right)^2} + P^p_{\mathrm{Loss}_{n,k}} \right] - (7)$$

The process is complete if the L p k of a node has been obtained; otherwise, proceed to Step 2.

The loss assigned to node k is not the real loss; rather, it is used in the calculation of the loss allotted to the loads (rather than the DGs) that are connected to this node. In the next stage, when it is used to calculate the loss assigned to the DGs connected to node k, this will become more clear. Di's share of the loss is calculated as (6). as

$$L^p_{D_i} = L^p_k \frac{(P_{D_i})^2 + P_{D_i}\left(\sum_{\substack{D_n\in D_k\\ n\neq i}} P_{D_n} + \sum_{n\in A_{n+1}} P^s_{k,n}\right)}{\left(\sum_{D_n\in D_k} P_{D_n} + \sum_{n\in A_{k+1}} P^s_{k,n}\right)^2} \qquad (8)$$

Where D k is the set of loads connected to node k

Loss Allocated to Loads Due to ReactivePower Flows:

The procedures are the same as those detailed before. As their reactive generation exceeds their reactive burden, reactive source nodes initially incur no reactive losses. The set of nodes represented by equation (9) that are connected to node k via branches and transmit reactive power to node k.

$Q^s_{n,k}$ Sending end reactive power flow of branch $b_{n,k}$, which is a positive value;

$Q^s_{n,m}$ Sending end reactive power flow of branch $b_{n,m}$, which is a positive value;

$P^q_{lossn,k}$ Power loss of branch $b_{n,k}$ due to reactive power 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 should be applied to calculate the losses to all nodes due to reactive flows. As a result, the loss allocated to load Di is calculated similar to (8) as

$$L_k^q = \sum_{n\in R_{k-1}} \left[L_n^q \frac{(Q^s_{n,k})^2 + Q^s_{n,k}\left(\sum_{\substack{m\in R_{n+1}\\ m\neq k}} Q^s_{n,m} + \sum_{D_m\in D_n} Q_{D_m}\right)}{\left(\sum_{m\in R_{n+1}} Q^s_{n,m} + \sum_{D_m\in D_n} Q_{D_m}\right)^2} + P^q_{\mathrm{LOSS}_{n,k}} \right] - (9)$$

$$L^q_{D_i} = L^q_k \frac{(Q_{D_i})^2 + Q_{D_i}\left(\sum_{\substack{D_n\in D_k\\ n\neq i}} Q_{D_n} + \sum_{n\in R_{k+1}} Q^s_{k,n}\right)}{\left(\sum_{D_n\in D_k} Q_{D_n} + \sum_{n\in R_{k+1}} Q^s_{k,n}\right)^2} - (10)$$

Total Loss Allocated to Loads:

The total loss allocated to load Di is obtained by adding (8) and (10) as

$L_{D_i} = L^p_{D_i} + L^q_{D_i}$- (11)

Calculating the Loss Allocated to the DGs:

Loss Allocated to the DGs Due to ActivePower Flows:

The loss allocated to node k due to active flows is calculated as given in (12),

Where

A_{k+1} Set of nodes receiving active power from node k and are connected to this Node with branch $b_{k,n}$;

$P^r{}_{k,n}$ Receiving end active power flow of branch$b_{k,n}$, which is a positive Value;

$P^r{}_{m,n}$ Receiving end active power flow 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_{Gm} Active power output of DG G_m ;

$L'_n{}^p$ Loss allocated to node n due to active flows.

All active sink nodes have their L 'k p values set to zero because their active load exceeds their active generation. This is due to the fact that the loads connected to these areas consume all of the electricity generated by the connected DGs.

$$L'^{\,p}_k = \sum_{n\in A_{k+1}} \left[L'^{\,p}_n \frac{(P^r_{k,n})^2 + P^r_{k,n}\left(\sum_{\substack{m\in A_{n-1}\\ m\neq k}} P^r_{m,n} + \sum_{G_m\in G_n} P_{G_m}\right)}{\left(\sum_{m\in A_{n-1}} P^r_{m,n} + \sum_{G_m\in G_n} P_{G_m}\right)^2} + P^p_{\mathrm{LOSS}_{k,n}} \right] - (12)$$

The procedure to calculate L' k P s is as follows.

1) Give the node that joins the transmission and distribution networks (and all active sink nodes) a L k p value of 0.

Step 2: Visit each leaf node where L' k p has not been claimed.

L' k p can be calculated for this node using equation (14) if it has already been calculated for all other nodes that draw active power from this node.

If a node's L' k p could not be retrieved, the process would loop back to Step 2.

Let's pretend that node k is connected to a DG G j that can produce P G j of electricity. Distributed generation (DG) losses can be calculated with L' k p due to the presence of active fluxes.

$$L^p_{G_j} = L'^{\,p}_k \frac{(P_{G_j})^2 + P_{G_j}\left(\sum_{\substack{G_n\in G_k\\ n\neq j}} P_{G_n} + \sum_{n\in A_{k-1}} P^r_{n,k}\right)}{\left(\sum_{G_n\in G_k} P_{G_n} + \sum_{n\in A_{k-1}} P^r_{n,k}\right)^2} \quad - (13)$$

Where Gk represents the set of DGs connected to node k.

Loss Allocated to the DGs Due to Reactive Power Flows:

The loss allocated to node k due to reactive flows is calculated as (14), 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

$P^q{}_{loss\,k,n}$ 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_{Gm} Reactive power output of DG G_m ;

Loss allocated to node n, due to reactive flows.

$$L'_k{}^q = \sum_{n\in R_{k+1}} \left[L'_n{}^q \frac{(Q^r_{k,n})^2 + Q^r_{k,n}\left(\sum_{\substack{m\in R_{n-1}\\ m\neq k}} Q^r_{m,n} + \sum_{G_m\in G_n} Q_{G_m}\right)}{\left(\sum_{m\in R_{n-1}} Q^r_{m,n} + \sum_{G_m\in G_n} Q_{G_m}\right)^2} + P^q_{LOSS_{k,n}} \right]^q \quad \text{- (14)}$$

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

$$L^q_{G_j} = L'_k{}^q \frac{\left(Q_{G_j}\right)^2 + Q_{G_j}\left(\sum_{\substack{G_n\in G_k\\ n\neq j}} Q_{G_n} + \sum_{n\in R_{k-1}} Q^r_{n,k}\right)}{\left(\sum_{G_n\in G_k} Q_{G_n} + \sum_{n\in R_{k-1}} Q^r_{n,k}\right)^2} \quad (15)$$

Total Loss Allocated to DGs:

The total loss allocated to DG G j is obtained by adding (14) and (15) as

$$L_{G_j} = L^P_{G_j} + L^q_{G_j} \quad \text{- (16)}$$

Final loss allocated based on normalization:

When estimating the overall loss cost, which is found by adding the amounts paid by loads and DGs, normalization is performed. The following formula can be used to get the normalizing factor:

$$NF = \frac{P_{LOSS}}{\sum L_{D_i} + \sum L_{G_j}} \quad \text{- (17)}$$

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

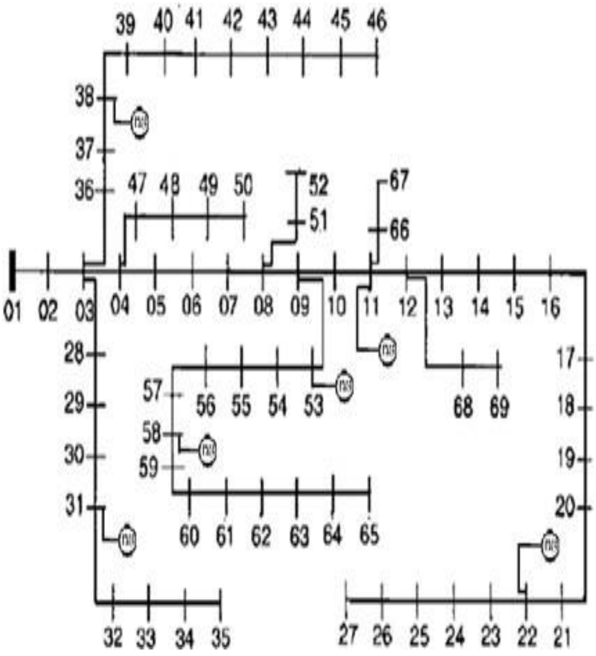
$$L^{normalized}_{D_i} = L_{D_i} NF$$
$$L^{normalized}_{G_j} = L_{G_j} NF \quad \text{- (18)}$$

Equation (18) is the final formulation for calculating the loss allocated to load Di and DG G j.

5. TEST RESULTS

Test system Results for 69 bus sink & source nodes:

Figure 2 depicts a 12.66-KV radial distribution system that uses the power flow technique with 69 nodes, 73 branches, and 6 DGs. Information required for this analysis can be found in [13]. Both the user's location and their electricity consumption or production affect the power flow method's output. The voltages of the nodes, which are determined locally, are affected by the distribution of Distributed Generators (DGs). Tables I and II present the results of the loss allocation study for the 69-node system. You can see the voltage profiles in Figures 3 and 4.



The 12.66KV radial distribution network shown in Figure 2 has 69 nodes. Both the user's location and their demand or generation affect the power flow method's output. The voltages at the nodes, which are determined locally, are also affected by the distribution of Distributed Generators (DGs). Tables I and II present the results of the loss allocation study for the 69-node system. You can see the voltage profiles in Figures 3 and 4. **TABLE Loss Allocation results for the 69-node system: Source node**

Generatio n Node number.	P (KW)	Q (KVAR)	LA in KW (Light loads)	LA in KW (Over loads)
1	93	72	1.21	1.84
2	71	52	1.65	2.36
3	5.5	2	0.19	0.25
4	21	15	1.63	1.98
5	14	10.4	2.06	2.85
6	1	0.6	0.53	1
7	56	31.5	0	0.02
8	64	52.5	0.01	0.06
9	28	20	0.01	0.18
10	33.3	23.4	0.04	0.21
11	44	30	0.1	0
12	44	30	0.14	0
13	26	18.6	0	0
14	26	18000	0.01	0.02
15	20.3	12.7	0.02	0.04
16	35	33	0	0
17	65	52	0.02	0.3
18	75	51	0.08	0.14
19	31	24.5	0.06	0.1
20	26	18.55	0.01	0.02
21	26	18.55	0	0.1
22	35.6	22.4	0	0
23	105	87	0.01	0.04
24	93	72	0.01	0.05
25	139.2	96.3	0.19	0.19
26	71	66	0.18	0.18
27	25	13.3	0.08	0.15
28	54	43.7	0.35	0.38
29	39	26	0.33	0.65
30	1.2	1	0.01	0.09
31	51	43.5	0.03	0.1
32	79	56.4	0.11	0.25
33	284.7	174.5	0.93	1.25
34	284.7	174.5	1.37	1.65
35	40.5	28.3	0.57	1.2
36	26.6	12.7	0.41	0.8
37	87.35	63.5	0	0
38	96.4	79	0.03	0.09
39	24	17.2	0.01	0.01
40	125	85.9	0.16	0.19
41	100	72	0.13	0.25
42	12	7.5	0	0
43	29.5	20	0.01	0.32
44	51.97	43.2	0.06	0.45
45	44	28	0.1	0.18
46	32	23	0.12	3.5
47	13.6	9.7	0.09	0.84
48	27	12	0.3	1.23
49	59	42	1.16	2.044
50	18	13	0	0
51	18	13	0	0
52	28	20	0.07	0.25
53	28	20	0.1	0.56

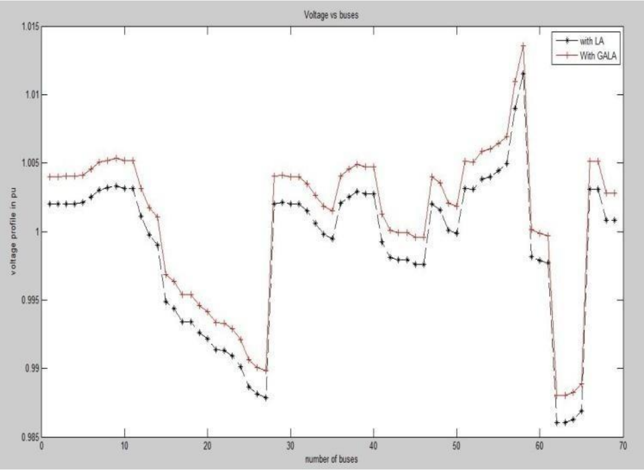


Figure-4 comparison of voltages of Genetic algorithm loss allocation method with loss allocation method for sink nodes.

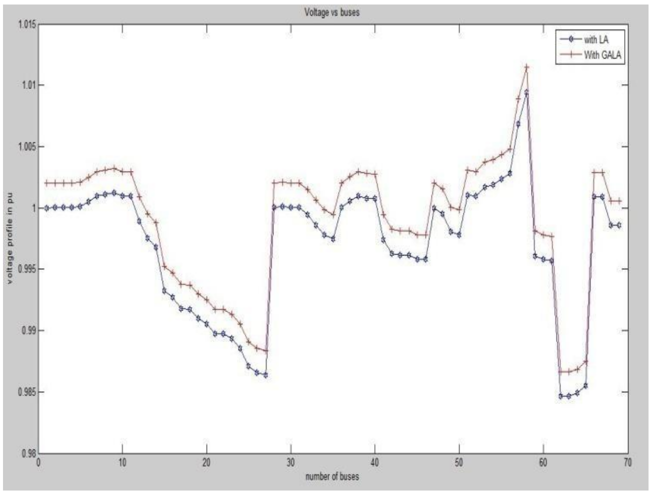


Figure-4 comparison of voltages of Genetic algorithm loss allocation method with loss allocation method for source nodes.

6. CONCLUSION

Each node's loss is determined by adding the losses of its neighboring nodes and accompanying lines, and this process is presented here as part of a power flow approach for radial distribution systems. Specific attributes are evaluated, which are specified as positive aspects of every loss allocation technique, to determine the loss given to each node.

The method is consistent with the findings of the power flow study.

The losses attributed to loads and DGs are calculated based on the total quantity of energy used or generated.

In order to properly apportion losses, it is essential to know where each DG and its associated load is located.

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