Loss Allocation reduction to customers by optimal location and sizing of DG in electrical distribution systems

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Abstract: This paper deals radial distribution system power losses allocation to connected consumers before and after distribution generator (DG) in a deregulated environment. Allocation of power loss is made in a proposed exact method way, which is calculated based on allocating power losses to consumers by taking each branch current suppling to customer load from substation to customer load. Proposes a new methodology to reduce the burden of loss allocation to customers by allocating the optimal DG size at best location. The best location derive based on highest value line of power stability index (PSI) and increase in small steps of DG values in best location obtain the optimal DG size at the best location. The impact of DG on voltage profile, system losses and customer losses allocation are visualized by an analytical approach. The robustness and scalability of proposed method is tested on 12 bus and 69-bus radial distribution networks and compared with the existing Golden Section Search (GSS) algorithm

Keywords: Electrical distribution system; power loss allocation; distributed generator; PSI, voltage profile

1. Introduction

Deregulation of the power industry was intended to acquaint rivalry and with cut down costs, enhance productivity and make a hard and fast change in the business. It was principally gone for annihilating the monopolistic, defensive and vertically incorporated structure of the industry and giving an opportunity to the new contestants to make their commitments to the business. Dissimilar to era and offer of electrical vitality, exercises of transmission and distribution are for the most part considered as a characteristic syndication. The cost of transmission and distribution exercises should be designated to the clients of these systems. Allocation should be possible through system utilize tariffs, with an attention on the genuine effect they have on these expenses. Among others, distribution power losses are one of the expenses to be allocated. The primary trouble confronted in allocating power losses is the nonlinearity between the losses and delivered power which complicates the impact of each client on system losses, which is discussed in Gomez et al. [1].

Various techniques have been published in the publications for allocation of losses, most of them dedicated to transmission networks and can be classified into three groups – pro rata procedures, marginal procedures, proportional sharing procedures, and circuit-based procedures. Pro rata procedure in Gonzalez et al. [2] and Bialek et al. [3] are the simplest one in which the total losses are first assigned to generators and loads, generally 50% of losses are assigned to each category. Then the losses are allocated to individual generators proportional to their active power generated or consumed irrespective of their location within the network. Thus remotely located generators or loads will be benefited at the expense of the others. In marginal procedures in [4-7], losses are assigned to generators and demands through the so-called incremental transmission loss (ITL) coefficients. This method depends on the location of the slack bus. Hence, different slack buses will give different ITL coefficients. The method has the disadvantage that it results in over recovery and needs normalization. The ITL coefficients can be positive or negative. The negative ones can be interpreted as cross subsidies in [5]. In

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proportional sharing procedures in [8-13], losses are allocated to the generators and consumers by using the results of a converged power flow. The losses are then allocated to different generators or consumers based on a linear proportional sharing principle.

Conejo et al.[14] have proposed a circuit-based procedure for allocating transmission losses to generation and loads based on the networks Z-bus matrix. Z-bus loss allocation technique can also yield negative allocation to those participants who contribute to reduce network losses due to their strategically well positioned location in the system, which again can be interpreted as cross subsidies. Conejo et al. [15] have also presented a comparison of different practical algorithms available for loss allocation in transmission systems. Costa and Matos [16] have addresses the allocation of losses in distribution networks with embedded generation by considering quadratic loss allocation technique.

In recent years, with the Distributed Generation (DG), many power companies are investing in small scale renewable energy resources such as wind, photo-voltaic cells, micro-turbines, small hydro turbines, CHP or hybrid. DG was only 1.2 GW during 1993–1994, however today this figure has increased substantially and reached up to over 12GW in [17-18].

It is also expected with the KYOTO protocol commitment by various countries to reduce CO2 emission, the market for DGs as a ‘‘Clean Energy’’ resource is promising. According to Energy Network Association (ENA) report (2010) [19] is implying rapid growth in DG and investment in the power infrastructure. However there are several issues concerning the integration of DGs with existing power system networks; that needs to be addressed in [19-20]. The integration of DG changes the system from passive to active networks, which affects the reliability and operation of a power system network as given in [21-22]. Furthermore, the non-optimal placement of DG can result in an increase of the system losses and thus making the voltage profile lower than the allowable limit by referring to Griffin et al [23]. Since utilities are already facing technical and non-technical issues, they cannot tolerate such additional issues. Hence an optimum placement of DG is needed in order to minimize overall system losses and therefore improve voltage profiles.

A few specialists have focused on the static voltage stability studies in the conveyance frameworks [24]. The effect of coordinating wind-driven squirrel case induction generator-based Distribution generator (DG) on the static voltage stability of radial distribution system (RDN) has been examined in [25]. Ref. [26] has tackled the issue of static voltage soundness advancement in a distribution framework with DG utilizing continuation power flow (CPF). In addition, in [27], a continuation technique is utilized to think about the voltage stability of conveyance framework. The CPF permits the assurance of the most extreme stacking purpose of distribution system. Be that as it may, the computational weight of CPF is high a result of the refresh of Jacobian network for indicator and corrector steps [28]. Proposed an approach for the voltage stability evaluation in radial systems in [29]. In any case, the proposed model is valid just at the operating point [30]. The analysts have proposed different static VSIs to distinguish the critical buses and lines of distribution frameworks. Steady state VSIs can be grouped into two sorts [31]: local indices and system indices. The system indices estimate the voltage stability margin of system. The system load margin indices are generally proposed based on the optimization methods or CPF. Then again, the local indices measure the stability margin of each node or branch, furthermore, along these lines the system critical bus or branch can be distinguished. Paper [32] has proposed diverse local branch based indices. Be that as it may, they have a few mistakes in the hypothetical inductions [33]. In [30] have proposed a VSI for all buses of RDNs. In this strategy, the bus with least value of VSI is the most sensitive bus to the voltage collapse. In [34], a VSI is proposed for finding the most critical bus to the voltage instability in RDN. The investigation depends on the catastrophe theory.

In the past, the methodologies for DG are either based on analytical tools or on optimization programming methods. Analytical approaches have been proposed by several authors. In [35], the authors presented analytical approach to determine the optimal location for the DG with an objective of loss minimization for distribution and transmission networks. In Acharya et al. [36], the author used the loss sensitivity equation to determine the optimum size of DG and the exact

loss equation to determine the optimum location of DG based on minimum losses.

A method proposes for DG placement and sizing based on the line voltage stability index. Previously the author in [37-38] has used the continuation power flow method to determine the most voltage-sensitive bus in the distribution system which could results in voltage instability in the system. DG is placed on the identified sensitive bus and the size of DG on that bus is increased gradually till the objective function (voltage constraints) is achieved. Also, in the deregulated environment, the losses are allocated to different consumers in the network.

In this work, impact of placement and size of DG on loss allocation in radial distribution networks is presented. This work formulates loss allocation based on exact loss allocation scheme to consumers in a radial distribution network. It is assumed that consumers have to pay for losses. The problem formulation proposed herein considers the following aspects:

A new algorithm to identify sensitive bus and DG size on that bus by gradually increasing till the objective function is satisfied.

Loss allocation to consumers before and after distributed generator placement and size calculation.

This paper is organized as follows: Section 2 introduces the mathematical equations and also derived the equation for the PSI. Algorithm for the placement and sizing of the DG and loss allocation to customer before and after the DG placement in section 3. Numerical example is given in Section 4 to verify the results proposed in this paper.

A. Mathematical Formulation for Electrical Distribution System

A.1. Load flow equations and customer loss calculation

Consider an equivalent circuit model of typical branch between buses p and q of the radial distribution system as shown in figure 1.

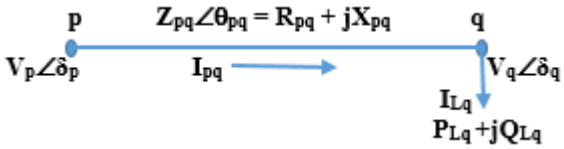

Figure 1. Simple two bus distribution system

In figure 1, $V_p\angle\delta_p$ and $V_q\angle\delta_q$ are the voltage magnitudes and phase angles of two buses p and q respectively and current flowing through the line *pq* is I_{pq}. The substation voltage is assumed to be (1+j0) p.u.

From figure 1 we can write

$$\boldsymbol{S_{Lq} = P_{Lq} + jQ_{Lq} = V_q I_{Lq}^*} \quad \textbf{(1)}$$

Receiving end voltage can be calculated by

$$\boldsymbol{V_q = V_p - I_{pq} Z_{pq}} \quad \textbf{(2)}$$

where,

$$I_{pq} = \frac{P_{Lq} - jQ_{Gq}}{V_q^*} \quad (3)$$

The power loss is calculating as

$$Ploss_{\mathrm{pq}} = Real\left\{\left(\mathrm{V_p} - \mathrm{V}_q\right)\mathrm{I}_{\mathrm{pq}}^*\right\} \quad (4)$$

The contribution of the q bus customer in the line *pq* is shown below

$$ploss(pq,q) = Real\left\{\left(\mathrm{V_p} - \mathrm{V}_q\right)\mathrm{I}^*_{Lq}\right\}$$

The global value of losses to be supported by consumers results from the sum of the losses allocated to it in each line pq of the system, i.e.,

$$Tploss(q) = \sum_{pq=1}^{br} ploss(pq,q) \quad (5)$$

Note that bus 1 is substation. Each consumer has allocated losses only at branches to which power flow contributes in equation (5).

A.2 Development of an index for DG placement

The important factor in maintaining the voltage between two buses is the drop in the line connecting the two buses, commonly known as voltage regulation. Ideally voltage regulation should be zero, but there are drops due to resistance and reactance of a line. In transmission lines, resistance is much less than the reactance of the transmission lines (R/X); while in overhead distribution system, reactance is much less than the resistance of the line (X/R). There is no anti-resistance element which could improve the voltage regulation. The series capacitor is commonly connected in long transmission lines having high reactance than a distribution network, in order to improve the voltage profile and increasing the system efficiency. However by supporting the active and reactive power demands locally could significantly reduce the voltage drop in the line by reduction in line current and losses and thus improves the system efficiency.

An index is derived for finding the most optimum site of DG based on the most critical bus in the system that can lead to system voltage instability when the load increases above certain limit. When DG consider in the figure 1, load is changes as shown below in figure 2.

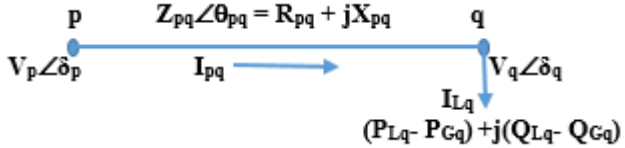

Figure 2. Simple two bus distribution system with DG

From figure 2, we can write equation (3) as below

$$\boldsymbol{I_{pq}} = \frac{(\boldsymbol{P_{Lq}} - \boldsymbol{P_{Gq}}) - \mathrm{j}(\boldsymbol{Q_{Lq}} - \boldsymbol{Q_{Gq}})}{\boldsymbol{V_q^*}} \quad (6)$$

Substitute I_{pq} from equation (6) into equation (2) and separate into real and imaginary parts will give

$$P_{Lq} - P_{Gq} = \frac{|V_p||V_q|}{V_q^*} cos\left(\theta_{pq} - \delta_p + \delta_q\right) - \frac{|V_q|^2}{Z_{pq}} cos\left(\theta_{pq}\right) \quad (7)$$

$$Q_{Lq} - Q_{Gq} = \frac{|V_p||V_q|}{V_q^*} sin\left(\theta_{pq} - \delta_p + \delta_q\right) - \frac{|V_q|^2}{Z_{pq}} sin\left(\theta_{pq}\right) \quad (8)$$

Rearranging equation (7) will give

$$\left|V_q\right|^2 - \frac{|V_p||V_q|\cos(\theta_{pq} - \delta)}{\cos(\theta_{pq})} + \frac{Z_{pq}(P_{Lq} - P_{Gq})}{\cos(\theta_{pq})} = 0 \quad (9)$$

where

$$\delta = \delta_p - \delta_q$$

The equation (9) is a quadratic equation. For stable node voltages, equation (9) should have real roots, i.e. discriminant $B^2 - 4AC > 0$, which results in the proposed index referred as Power Stability Index (PSI) given by equation (10)

$$PSI = \frac{4R_{pq}(P_{Lq}-P_{Gq})}{[|V_p|\cos(\theta_{pq}-\delta)]^2} \leq 1 \quad (10)$$

Under stable operation, this value should be less than unity; closer the value of PSI to zero, more stable will be the system. The above index is used to find the optimum placement of DG. The PSI value is calculated for each line in the given network and sorted from the highest to the lowest value. For the p-q line having the highest value of PSI, the DG should be placed at q-bus. For multi DG placement, the location of the second DG will be based on the effect of first DG on PSI using equation (10). PSI value for each line will be re-calculated and sorted in the same fashion from highest to lowest. The DG will be placed at the end of the line having the highest value of PSI.

A.3 Objective function for DG size and constraint

In [27], the author used the following mathematical formulation which needs to be considered in DG placement.

Minimize total active power losses

$$Min\{\sum_{pq=1}^{br} Ploss_{pq}\} \quad (11)$$

Subject to the following generation and voltage constraints

$$0 \leq P_{Gq} \leq \sum P_{load} \quad (12)$$

$$|V_q^{min}| \leq |V_q| \leq |V_q^{max}| \quad (13)$$

$$|V_q| \leq 1 \pm 0.05\ pu \text{ q = 1, 2, ….., n} \quad (14)$$

where *br* is the no. of lines; n the no. of buses; P_{Gq} the distributed generation power at q bus; and P_{load} is the total connected load.

The main constraints as defined in equations (12-14) are to restrain the voltages at each bus along the radial system within the acceptable range and the total active power support should not exceed the system load.

Once the optimum location of DG is identified, the amount of active power from DG changes from 0% to 100% of the total active load, with generation and voltage constraint given in equations (12–14). The main objective in selecting DG size is to minimize total system power losses (P_{loss}) by injecting active power (P_{Gq}), given in equation (11). The relation between DG size and losses follow the parabolic curve, first decreases and then start increases, thus the accuracy of the DG size estimated will depend on the step size selected. In the present case, the step size is maintained 1% of total load. However much smaller size could also be used, but the computation will take much longer time.

Algorithm for loss allocation for customers before and after the DG placement and size for Electrical Distribution System

For a radial distribution network, load flow analysis is carried out, calculate the loss allocation to each customer using equation (5) and PSI value is computed for each line using equation (10). For pq line having the highest value of PSI, the DG will be placed at qth bus. The search algorithm is used for finding the optimum size of DG at optimum location based on a

minimum total power loss, with constraints given in equations (12–14). After DG placement and size, calculate the loss allocation to each customer using equation (5). The complete algorithm steps summarized below for DG allocation and sizing is explained along with the loss allocation to each customer.

Step 1. Read the bus data and line data for the electric distribution test system.
Step 2. Identify the loads for each branch and calculate the voltage of receiving buses, system losses using the load flow solution using equations (2-4).
Step 3. Calculate the total active power loss and also calculate each customer loss allocation from each branch using equation (5).
Step 4. Calculate PSI values for the each line of the distribution system using equation (10). Find the maximum value of PSI line whose receiving bus is DG optimal placement.
Step 5. By setting small increment of PGq at bus q, run the load flow solution and check the constraints of using equations (12-14).
Step 6. Store the system losses and voltages for present and previous DG size.
Step 7. Check losses and constrains, if decreased the step 5 should continue, otherwise consider the previous solution and consider the previous DG size as optimal size of system
Step 8. Once optimal size of DG obtained, calculate the each customer loss allocation from each branch using equation (5) after DG placement.
Step 9. Stop the process.

4. Numerical examples for electrical distribution systems

The proposed algorithm for DG placement and sizing is presented. For verification, the proposed algorithm is applied on 12-bus and 69-bus radial distribution networks. A computer program has been written in MATLAB 8.0 and run on AMD A10 PRO 2.10 GHz processor. The load flow analysis is carried out with [17] in this method. As conventional load flows are not suitable for radial distribution systems because they got diverges, due to high X/R ratio which results in singularity of Jacobian matrix.

A. Basic information of the system

The 11 kV 12-bus [39] and 12.66kV 69-bus [40] radial distribution test systems are shown in figures. 3 and 4 respectively. The total active and reactive loads are 435 kW and 405 kVAr for 12-bus distribution system and 3791.80 kW and 2683.40 kVAr for 69-bus distribution system.

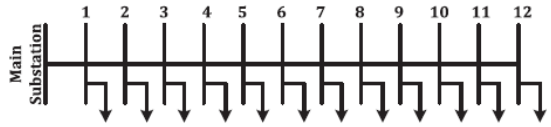

Figure 3. Single line diagram of 12-bus radial distribution system

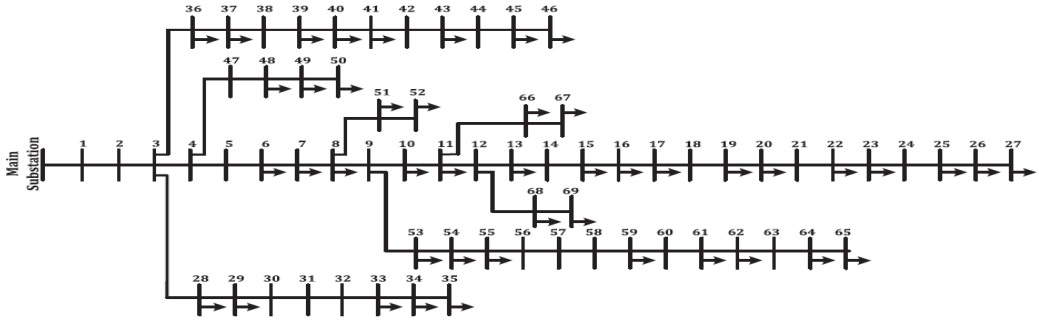

Figure 4. Single line diagram of 69-bus radial distribution system

B. Identifying the DG placement bus for test systems using PSI

The load flow analysis is carried out on 12-bus system and the PSI value is computed for each line using equation (10) considering initially no DG. From Fig. 5, the PSI value for each line, it could be observed that the 8th line connected bus 8 to bus 9 has the highest value than the others. So the installation of DG at bus 9 will be the optimum place in 12-bus system. The same approach is carried out for 69-bus test system with PSI values in figure 6, it could be observed that the 60th line in 69-bus test system has the highest value. Hence, the optimum location of DG is at bus 9 and bus 61 for 12-bus and 69-bus test systems respectively. All lines PSI values are shown the figure 5 and figure 6 for 12-bus and 69-bus radial distribution system respectively.

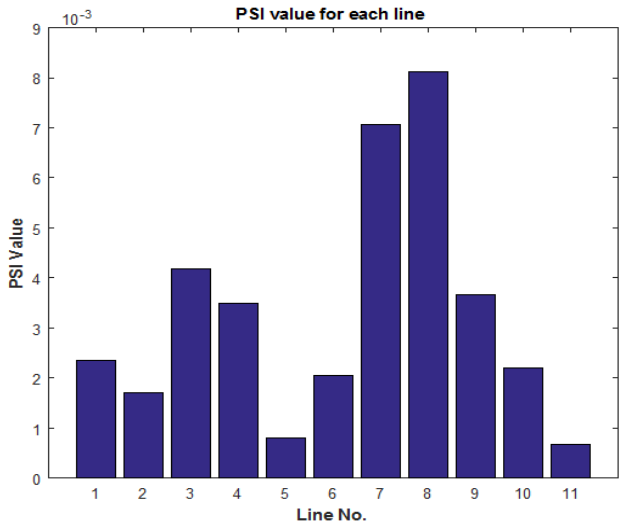

Figure 5. PSI value for each line in 12-bus system

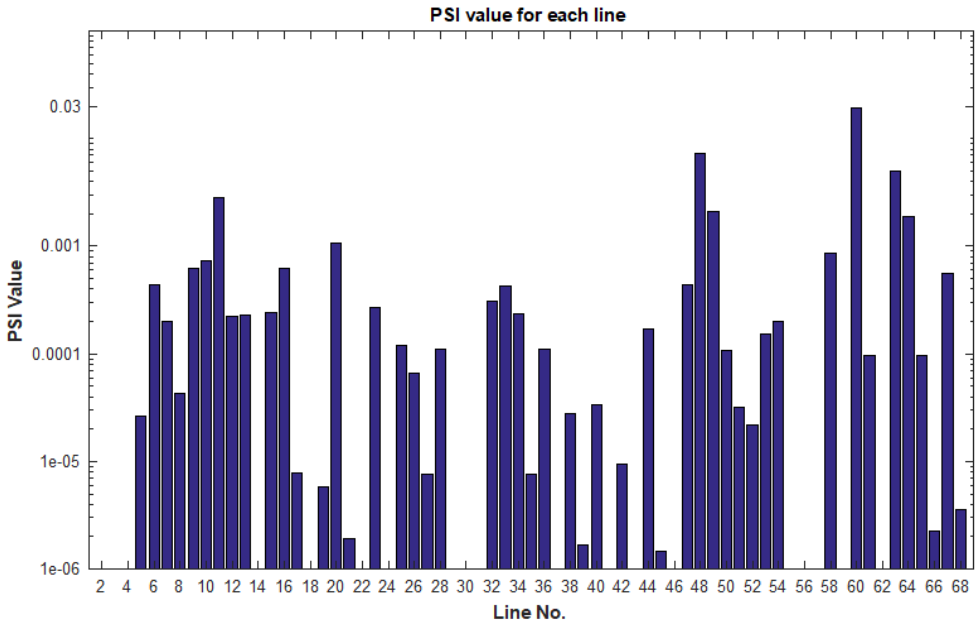

Figure 6. PSI value for each line in 69-bus system

C. Optimal DG Size Calculation and Analysis of effectiveness

To determine the optimum size of DG, the proposed algorithm is applied on all test systems and the results are tabulated in Table 1. The proposed algorithm is also compared with the GSS Algorithm, implemented using VS&OP power tool [41]. The results are shown in Table 1, from where it could be seen the close agreement of the propose method with the existing one. From the Table 2, it is also observed that the base case minimum voltage and losses with respect to proposed algorithm.

Table 1. Application of proposed algorithm on radial distribution networks

Bus System	Proposed Algorithm				Golden Section Search Algorithm [41]		
	Max PSI Value	Bus No	Optimum Size, MW	CPU Time (s)	Bus No	Optimum Size, MW	CPU Time (s)
12-Bus	0.0081	9	0.2349	0.302	9	0.23545	0.892
69-Bus	0.0192	61	1.8580	9.047	61	1.87270	26.681

Table 2. Comparison of base case to proposed algorithm on radial distribution networks

Bus System	Base Case			Proposed Algorithm		
	Minimum Voltage	Active Power Loss, kW	Reactive Power Loss, kVAr	Minimum Voltage	Active Power Loss, kW	Reactive Power Loss, kVAr
12-Bus	0.9434	20.71	8.04	0.9835	10.77	4.13
69-Bus	0.9098	224.61	101.98	0.9683	82.88	40.40

From Tables 1 and 2, it could be observed that:

- The proposed method results are in close agreement with GSS algorithm
- The computation time has been decreased considerably for two test systems (53.6%, and 58.45% respectively with the 12-bus and 69-bus).
- The minimum voltage is improved in 12-bus and 69-bus distribution systems and also observed the system losses also reduced.
- There is 4.5% improvement in the voltage, active and reactive power losses are reduced 48.00% and 48.63% respectively in 12-bus radial distribution system after placement of DG as compared with before DG placement.
- Similarly, there is 6.42% improvement in the voltage, active and reactive power losses are reduced 63.10% and 60.38% respectively in 69-bus radial distribution system after placement of DG as compared with before DG placement.

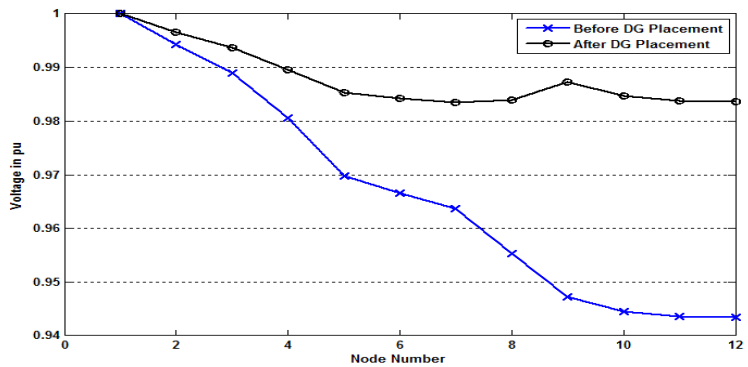

Figure 7. Effect of DG on system voltage profile of 12-bus system (DG size = 0.2349 MW @ bus 9th)

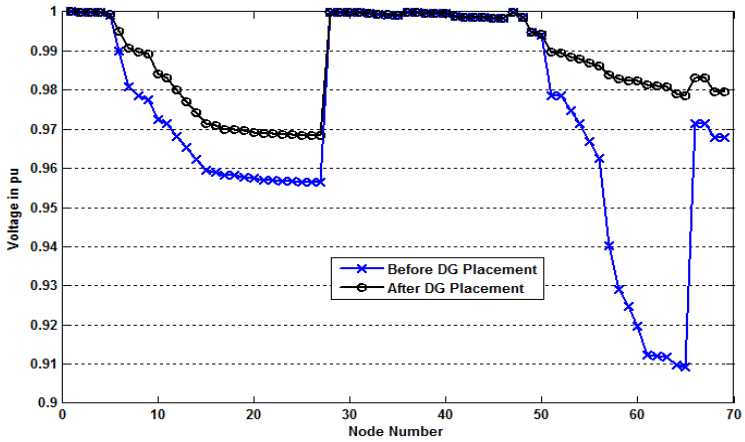

Figure 8. Effect of DG on system voltage profile of 69-bus system
(DG size = 1.8580 MW @ bus 61st)

From Figures 7 and 8, this could be visualized where by the optimum placement of DG at 9th bus and 61st have improved the overall voltage profile for 12-bus and 69-bus radial distribution system.

D. Loss allocation to the customer before and after DG placement

Comparison of loss allocation to consumers before and after DG placement for 12-bus and 69-bus respectively, it can be concluded that the active power minimization objective considered for distribution generation have greater influence on the loss allocated to each consumer. It can be seen from figures 9 and 10, the losses allocated to most of the heavily loaded consumers after DG placement considering only power loss reduction for consumers at all buses for 12-bus and at bus nos. 51, 52, 53, 54, 55, 59, 61, 62, 64, 65, etc. for 69-bus system. Although, most of the consumers are benefited due to loss allocation after DG placement but it appears that some of the consumers may have to pay same after DG placement. For example, consumers at bus nos. 28, 29, 33, 36, 37, 40, 48 etc. have to pay same after DG placement and their tariff structure need to be modified such that they need not pay same for this constant in loss allocation. It has been observed that there is a negative losses are showing in the figure 9 which will be injected power to the system and will help the customer to boost the voltage and reduce the losses and help the system to work more efficient during the high loads.

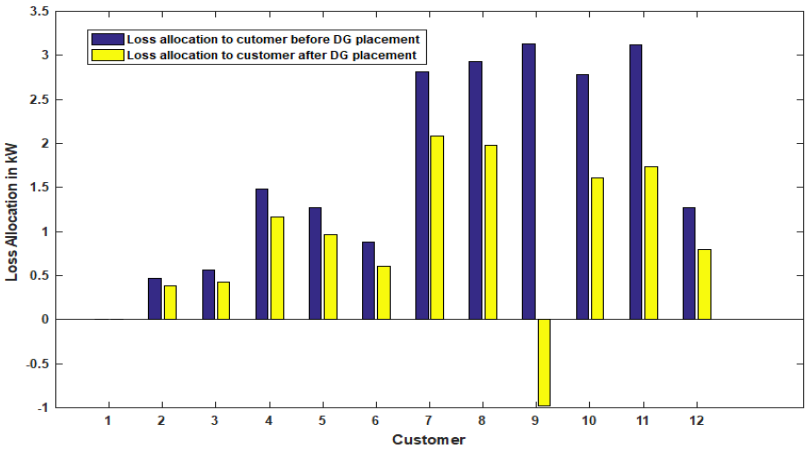

Figure 9. Effect of DG on system on loss allocation to customer of 12-bus system

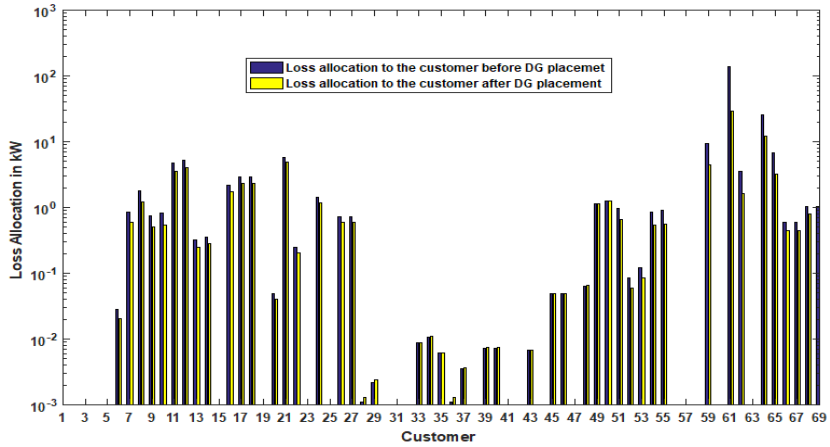

Figure 10. Effect of DG on system on loss allocation to customer of 69-bus system

5. Conclusions

The proposed solution has presented for impact of distributed generator on real power loss allocated to consumers connected to radial distribution system based on exact loss allocation. A new algorithm has been proposed for DG location and sizing. The DG location and sizing is based on a novel Power Stability Index (PSI) index to determine the most voltage sensitive bus and minimum total power losses. Using the proposed algorithm optimum DG allocation and correct sizing results is an improved voltage profile and minimizes the burden of system losses. The proposed algorithm has also been tested using two different radial distribution test systems and the results are verified using GSS Algorithm. It has been found that overall the proposed algorithm takes less computation time by 50–60% as compared to Golden Section Search (GSS) algorithm for DG placement and sizing. Exact loss allocation scheme is based on branch current flow and ensures that each consumer only has allocated losses at branches for which current it contributes. Analysis reveals that even though distribution generator placement results reduction in system real power loss and the loss allocation to most of the consumers will decrease and they have to pay less, but it also appears that loss allocation to a small group of consumers may not change and they may have to pay remains same after distribution generator placement. Further, it was also observed that the objectives considered for distribution placement has significant influence on the real power loss allocated to each consumer.

6. References

[1]. Gómez A, Riquelme JM, González T, Ruiz E. "Fair allocation of transmission power losses", *IEEE Transactions on Power Systems, Vol. 15, No. 1, pp. 184–188, 2000*.

[2]. Gonzalez JJ, Basagoiti P. "Spanish power exchange market and information system. Design concepts, and operating experience", *Proceedings of the IEEE power industry computer applications conference, Santa Clara, USA; May 1999. pp. 245–252*.

[3]. Bialek JW, Ziemianek S, Abi-Samra N. "Tracking-based loss allocation and economic dispatch", *Proceedings of the 13th power systems computation conference. Trondheim, Norway; July 1999. pp. 375–381*.

[4]. Elgerd OI. "Electric energy systems theory: an introduction". McGraw-Hill: New York; 1982.

[5]. Schweppe F, Caramanis M, Tabors R, Bohn R. "Spot pricing of electricity", *Boston: Kluwer Academic Publishers, 1988*.

[6]. Meisingset M, Breidablik Ö. "A method to determine charging principles for losses in the Norwegian main grid", *Proceedings of the 13th PSCC. Trondheim, Norway; June/July 1999. pp. 382–387*.

[7]. Galiana FD, Conejo AJ, Kockar I. "Incremental transmission loss allocation under pool

dispatch", *IEEE Transactions on Power Systems, Vol. 17, No.1, pp. 26–33, 2002*.
[8]. Bialek JW. "Identification of source-ink connections in transmission networks", *Proceedings of the 4th international IEE conference on power system control and management. London, UK; April 16–18 1996. pp. 200–204*.
[9]. Bialek JW. "Tracing the flow of electricity", *Proceeding of IEE Generation Transmission Distribution, Vol. 143, No.4, pp. 313-320, 1996*.
[10]. Kirschen D, Allan R, Strbac G. "Contributions of individual generators to loads and flows", *IEEE Transactions on Power Systems, Vol. 12, No.1, pp. 52–60, 1997*.
[11]. Bialek JW. "Topological generation and load distribution factors for supplement charge allocation in transmission open access", *IEEE Transaction on Power Systems, Vol. 12, No. 3, pp. 1185–1193, 1997*.
[12]. Strbac G, Kirschen D, Ahmed S. "Allocating transmission system usage on the basis of traceable contributions of generators and loads to flows", *IEEE Transactions on Power Systems, Vol. 13, No. 2, pp. 527–534, 1998*.
[13]. Kirschen D, Strbac G. "Tracing active and reactive power between generators and loads using real and imaginary currents", *IEEE Transactions on Power Systems, Vol. 14, No. 4, pp.1312–1319, 1999.*
[14]. Conejo AJ, Galiana FD, Ivana Kockar I. "Z-bus loss allocation", *IEEE Transactions on Power Systems, Vol. 16, No. 1, pp. 105–110, 2001*.
[15]. Conejo AJ, Arroyo JM, Alguacil N, Guijarro AL. "Transmission loss allocation: a comparison of different practical algorithms", *IEEE Transactions on Power Systems, Vol. 17, No. 3, pp. 571–576, 2001*.
[16]. Costa PM, Matos MA. "Loss allocation in distribution networks with embedded generation", *IEEE Transactions on Power Systems, Vol. 19, No. 1, pp. 384–389, 2004*.
[17]. Ramana1 T, Ganesh V, Sivanagaraju S. "Simple and fast load flow solution for electrical power distribution systems", *International Journal Electrical Engineering and Informatica, Vol. 5, No. 3, pp. 245–255, 2013.*
[18]. Jenkins N, Ekanayake J, Strbac G. (2010) 'Distributed generation' – IET Factfiles, http://www.theiet.org/factfiles/energy/distributed-generation.cfm [accessed 10.08.11].
[19]. Energy Networks Association (UK). (2010) <http://2010.energynetworks.org/distributed-generation> [accessed 10.08.11].
[20]. Koeppel. G. "Distributed generation-literature review and outline of the Swiss station", *Internal Report, ETH Zurich, 2003*.
[21]. Hadjsaid N, Canard JF, Dumas F. "Dispersed generation impact on distribution networks', *IEEE Transactions on Computer Applications in Power, Vol. 12, No. 2, pp. 22–28, 1999.*
[22]. Tuitemwong K, Premrudeepreechacharn S. "Expert system for protection coordination of distribution system with distributed generators", *International Journal of Electrical Power & Energy Systems, Vol. 33, No. 3, pp. 466–471,2011*.
[23]. Griffin T, Tomosovic K, Secrest D, Law A. "Placement of dispersed generations systems for reduced losses", *Proceedings of the 33rd International conference on sciences. Hawaii, pp. 1-9, 2000*.
[24]. Aman MM, Jasmon GB, Bakar AHA, Mokhlis H. "A new approach for optimum DG placement and sizing based on voltage stability maximization and minimization of power losses", *Energy Conversion and Management, Vol. 70, pp. 202–210, 2013*.
[25]. Raja P, Selvan MP, Kumaresan N. "Enhancement of voltage stability margin in radial distribution system with squirrel cage induction generator based distributed generators", *IET Generation Transmission and Distribution, Vol. 7, No. 8, pp. 898–906, 2013*.
[26]. Liu K, Sheng W, Hu L, Liu Y, Meng X, Jia D. "Simplified probabilistic voltage stability evaluation considering variable renewable distributed generation in distribution systems", *IET Generation Transmission and Distribution, Vol. 9, No. 12, pp. 1464-1473, 2015*.
[27]. Almeida AB, Lorenci EVD, Leme RC, Souza1 AC Zambronid D, Lopes BIL, Lo K. "Probabilistic voltage stability assessment considering renewable sources with the help of the PV and QV Curves", *IET Renewable Power Generation, Vol. 7, No. 5, pp. 521-530,*

2013.
[28]. Akher MA. "Voltage stability analysis of unbalanced distribution systems using backward/forward sweep load-flow analysis method with secant predictor", *IET Generation Transmission and Distribution, Vol. 7, No. 3, pp. 209-317, 2013*.
[29]. Gubina F, Strmcnik B. A "simple approach to voltage stability assessment in radial networks", *IEEE Transactions on Power System, Vol. 12, No. 3, pp. 1121-1128, 1997*.
[30]. Chakravorty M, Das D. "Voltage stability analysis of radial distribution networks", *International Journal on Electrical Power and Energy System, Vol. 23, pp. 129-135, 2001*.
[31]. Yu J, Li W, Ajjarapu V, Yan W, Zhao X. "Identification and location of long-term voltage instability based on branch equivalent", *IET Generation Transmission and Distribution, Vol. 8, No. 1, pp. 46-54, 2014*.
[32]. Moghavvemi M, Faruque MO. "Technique for assessment of voltage stability in ill-conditioned radial distribution network", *IEEE Power Engineering Review, Vol. 21, No. 1 pp. 58-60, 2001*.
[33]. Yu J, Li W, Yan W. "A new line loadability index for radial distribution systems", *Electrical Power Components and Systems, Vol. 36. No. 11, pp. 1245-1252, 2008*.
[34]. Mahmoud GA. "Voltage stability analysis of radial distribution networks using catastrophe theory", *IET Generation Transmission and Distribution, Vol. 6, No. 7, pp. 612-618, 2012*.
[35]. Caisheng W, Nehrir MH. "Analytical approaches for optimal placement of distributed generation sources in power systems", *IEEE Transactions on Power Systems, Vol. 19, No. 4, pp. 2068–2076, 2004*.
[36]. Acharya N, Mahat P, Mithulananthan N. "An analytical approach for DG allocation in primary distribution network", *International Journal of Electrical Power & Energy Systems, Vol. 28, No. 10, pp. 669–678, 2006*.
[37]. Hedayati H, Nabaviniaki SA, Akbarimajd A. "A method for placement of DG units in distribution networks", *IEEE Transactions on Power Delivery, Vol. 23, No. 3, pp. 1620–1628, 2008*.
[38]. Lalitha MP, Reddy VCV, Usha V. "Optimal DG placement for minimum real power loss in radial distribution systems using PSO", *Journal of Theoretical and Applied Information Technology, Vol. 13, No. 2, pp. 107–116, 2010*.
[39]. Das D, Nagi HS, Kothari DP. "Novel method for solving radial distribution networks", *IEE Proceeding on Generation, Transmission and Distribution, Vol. 141, No. 4, pp. 291–298, 1994*.
[40]. Baran ME, Wu FF. "Optimum sizing of capacitor placed on radial distribution systems", *IEEE Transactions on Power Delivery, Vol.4, No. 1, pp. 735–743, 1989*.
[41]. Gözel T, Eminoglu U, Hocaoglu MH. "A tool for voltage stability and optimization (VS&OP) in radial distribution systems using matlab graphical user interface (GUI)", *Simulation Modelling Practice and Theory, Vol. 16, No. 5, pp. 505–518, 2008*.

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