Pertanika J. Sci. & Technol. 25 (1): 29 - 42 (2017)

SCIENCE & TECHNOLOGY

Journal homepage: http://www.pertanika.upm.edu.my/

A Combined Analytical Method for Optimal Location and Sizing of Distributed Generation Considering Voltage Stability and Power Loss in a Power Distribution System

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ABSTRACT

In this paper, a multi-objective analytical method to evaluate the impacts of optimal location and sizing of distributed generation is presented. This method is based on an analysis of the exact loss formula and continuous power flow in a radial distribution system. Based on two methods of analysis, power loss and weakest voltage buses and lines are calculated and then the optimal size of distributed generation is determined. After that, by considering the minimum power losses and the maximisation of voltage stability, the proposed index determines and ranks positions to decide the optimal distributed generation location in the system. This method allows us to find the best places and size to connect a number of distributed generation units by optimising the objective functions. The simulation results were obtained using a 33-bus radial distribution system to determine the location and size of the distributed generation units. The results show the effectiveness of voltage profile improvement, loading factor improvement and power loss reduction. Further, the problems of a single objective function and the placement of the distributed generation unit using analytical methods are solved by the proposed approach.

Keywords: Distributed generation, continuous power flow, voltage stability, exact loss formula, optimum size, optimum location

INTRODUCTION

Due to the recent widespread use of distributed generation, the power industry has experienced significant changes in the distribution power system. In general,

Article history:
Received: 30 September 2016
Accepted: 22 April 2016

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ISSN: 0128-7680

distributed generation (DG) can be described as electric power generation that is integrated within distribution networks by utilising a number of smaller generating units, especially at places which are close to the point of consumption (Ugranli & Karatepe, 2012). DG can be an alternative for industrial, residential and commercial applications. DG units are smaller scale based on locally available resources and therefore, they are mostly connected at the distribution level. The penetration of DG is different. When it is high, the generated power of DG units not only changes the power flow in the distribution system, but also in the transmission system. Hernandez, Velasco, and Trujillo (2011) presented some advantages of DG as follows: "(a) reduces power losses; (b) improves the voltage profile and reliability of the system; (c) Reduces greenhouse gas emission; (d) More flexible energy solution due to the small size; and (e) Mitigates environmental concerns."

The connection of DG to the network may influence the stability of the power system, i.e., angle, frequency and voltage stability (Donnelly, Dagle, Trudnowski, & Rogers, 1996; Reza, Slootweg, Schavemaker, Kling, & Van der Sluis, 2003). If DG is connected to the most suitable location in the power system, DG integrated power systems have many advantages in comparison to the classical power systems (Ugranli & Karatepe, 2012). The problem of finding the optimal placing and sizing of DG units is a high priority issue, which if installed in non-optimal places, may lead to increasing power loss, reducing reliability level and growing cost in the system. Therefore, it is important to allocate and determine the optimal size and placing of DG to maximise the system efficiency. Various approaches have been proposed by several researchers to find the optimal and fast methods for placing and sizing of the DG units on the basis of improving the voltage profile, reducing power system losses, maximising system loadability and maximising bus and line stability. Generally, these methods can be classified into three broad categories, which are conventional optimisation methods, meta-heuristic based optimisation methods and a hybrid method. There are different conventional approaches to find the optimal size and locations of DG units in power distribution systems including the analytical approaches (Borges & Falcao, 2003; Acharya, Mahat, & Mithulananthan, 2006; Tuba Gozel & Hocaoglu, 2009; Hung, Mithulananthan, & Bansal, 2010; Hosseini & Kazemzadeh, 2011; Aman, Jasmon, Mokhlis, & Bakar, 2012; Hung, Mithulananthan, & Bansal, 2013), Continuation Power Flow based iterative (Hedayati, Nabaviniaki, & Akbarimajd, 2008; Ettehadi, Vaez-Zadeh, & Ghasemi, 2012; Ettehadi, Ghasemi, & Vaez-Zadeh, 2013), the grid search method (T Gozel, Eminoglu, & Hocaoglu, 2008), reactive power optimisation (Khalesi, Rezaei, & Haghifam, 2011), Optimal Power Flow (Dent, Ochoa, Harrison, & Bialek, 2010), Mixed Integer Nonlinear Programming (Ochoa & Harrison, 2011), Primal-Dual Interior Point Method (Rueda-Medina, Franco, Rider, Padilha-Feltrin, & Romero, 2013), and Deterministic optimisation techniques (AlHajri, AlRashidi, & El-Hawary, 2010). On the other hand, the meta-heuristic methods have been widely used by researchers in recent years as these approaches are intuitive, easy to understand, simple to implement and address the integer variable very well as compared to the conventional method and analytical programming. However, the results produced are not guaranteed to be optimal and the process speed can be slower.

Some examples of the meta-heuristic optimisation class are genetic algorithms (GA) (Celli, Ghiani, Mocci, & Pilo, 2005; Abou El-Ela, Allam, & Shatla, 2010). The Evolutionary Programming (Rahman, Rahim, & Musirin, 2004), tabu search (Katsigiannis & Georgilakis, 2008), simulated annealing (Injeti & Prema Kumar, 2013), particle swarm optimisation (Lalitha, Reddy, & Usha, 2010; El-Zonkoly, 2011; Kayal & Chanda, 2013), ant colony optimisation (Falaghi & Haghifam, 2007), Cuckoo Search (Moravej & Akhlaghi, 2013), bacterial foraging optimisation (S. Devi & Geethanjali, 2014), which have all been applied in most optimisation problems, as well as DG optimal placement and sizing problems. Tabu Search is an efficient combinatorial method which can be used to achieve an optimal or a sub optimal solution within a reasonably short duration. Meanwhile, researchers have not paid much attention on other methods of Evolutionary Programming, Ant Colony Algorithm, Simulated Annealing and Cuckoo Search.

GA is competent at obtaining a solution near the global minima which is computationally intensive. The hybrid method is also a combination of the above approaches, which include the Genetic-Fuzzy (Akorede, Hizam, Aris, & Ab Kadir, 2011), Genetic-Particle Swarm (Moradi & Abedini, 2012), Genetic-Optimal Power Flow (Naderi, Seifi, & Sepasian, 2012), Particle Swarm Optimisation-Optimal Power Flow (Gomez-Gonzalez, Lopez, & Jurado, 2012), and Analytical-Fuzzy (Devi & Subramanyam, 2007) techniques. The performance of the hybrid algorithm is fast and efficient because of the improved versions. The analytical techniques are easily implemented with high efficiency in terms of computational time and best precision factor while OPF, CPF and meta-heuristic approaches are the next advanced level. The problems related to the difficulties of DG placement and sizing issue by use of the Hybrid method remained unsolved problem despite many improvements. This paper presents a combined analytical method to evaluate the impacts of optimal location and sizing of DG. This method is based on the combination of the exact loss formula and continuous power flow (CPF) in a radial distribution system. This method allows finding the best places and size to connect a number of DG units by optimising the objective functions. The simulation results are obtained on a 33-bus radial distribution system in the Matlab environment to determine the location and size of DG units.

DISTRIBUTED GENERATION

DG can have a significant impact on the power-flow, voltage profile, stability, continuity, and quality of power supply (Van Thong, Driesen, & Belmans, 2005). Other aspects of DG are the DG rating, purpose, power delivery area, technology, environmental impact, mode of operation and penetration DG (Ackermann, Andersson, & Soder, 2001). Due to some complex issues of DG, compared to the traditional network, the consideration of the benefits of DG is important. These benefits include power loss reduction, voltage profile improvement, reliability and security improvement, decreasing congestion in feeders, power quality improvement and stability enhancement (Ackermann et al., 2001; Chiradeja & Ramakumar, 2004; Rao, Ravindra, Satish, & Narasimham, 2013).

DG impact on power losses

The design of a distribution system is basically based on the power flows from the source substation (sending end) to the load (the consumer side) and over this direction of flow, the size of the conductors is gradually decreased. Moreover, if a DG is installed with a high capacity to export power beyond the local substation, the losses will be very high. Therefore, determining the size of DG is important when considering the distribution system size in terms of load (MW) (Wang & Nehrir, 2004). According to the above explanation, the relation of the higher DG capacity with the consequent higher losses can be defined. Thus, a higher capacity of the DGs will increase the power losses. Otherwise, the system restrictions must be considered. Figure 1 shows this relationship for a 10 bus radial distribution system (Hosseini & Kazemzadeh, 2011). Based on the figure, the effect of the DG size on system losses is minimal at first, and then the power loss is very sensitive to the size of DG at the lateral buses. Obviously, increasing the DG penetration leads to the increase in the power losses. Therefore, it can be concluded that the correct estimation of the size of DG is an important rule to decrease the power loss in the system. Moreover, to determine the optimal size of the DG from the loss curve, the minimum value of power loss is considered for each bus.

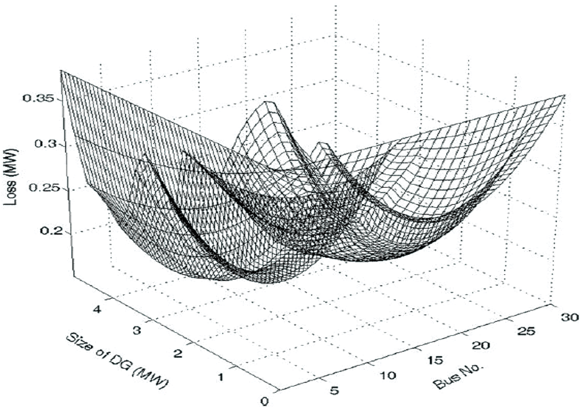

Figure 1. The effects of size and location of DG on system loss.

DG impact on voltage stability

The installation of DG has a positive impact on improving the stability of the voltage in the power system. In order to analyse the static voltage stability, a PV curve is used, which is achieved using the CPF approach (Canizares & Alvarado, 1993). Based on the PV curve in Figure 2, to evaluate the performance of the system from the current loading level or operating point (λ) to the voltage collapse point or the critical point (CP), the voltage stability margin (VSM) is defined. Clearly, the reactive power loss is decreased by increasing the active power injected by a DG unit. Therefore, by raising the voltage to the operating point from (V1) to (V2), then CP1 is increased to CP2. Therefore, the maximum loadability (λmax1) is a growth to (λmax2) for which the relationship is:

$$P_i = (\lambda+1)\, P_{oi}\ , \qquad Q_i = (\lambda+1)\, Q_{oi} \tag{1}$$

where Poi and Qoi are the base case load active and reactive power demands, respectively.

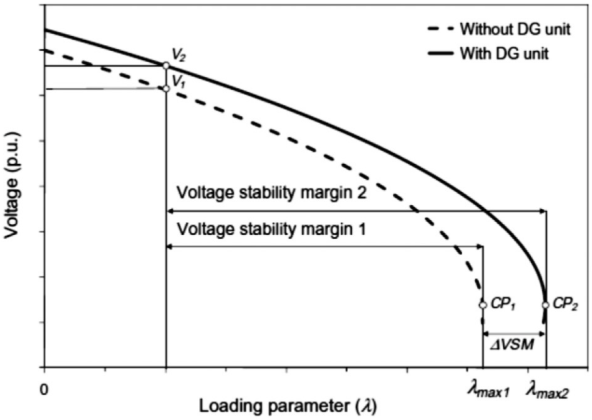

Figure 2. DG impacts on maximum loadability and voltage stability margin.

PROPOSED METHODOLOGY

The total real power loss (P_L) with N buses is calculated by "the exact loss formula" (Elgerd, 1983) in a distribution system.

$$P_L = \sum_{i=1}^{N} \sum_{j=1}^{N} [\, \alpha_{ij} \left(P_i P_j + Q_i Q_j \right) + \beta_{ij} (Q_i P_j - P_i Q_j)] \tag{2}$$

where $\alpha_{ij} = \frac{r_{ij}}{V_i V_j} \cos(\delta_i - \delta_j)$ and $\beta_{ij} = \frac{r_{ij}}{V_i V_j} \sin(\delta_i - \delta_j)$, N is the bus number and P_i, Q_i, P_j and Q_j are the active and reactive power injections at buses i and j, respectively. $R_{ij} + j\, X_{ij} = Z_{ij}$ is the *ij*th element of impedance matrix [Zbus] = $[\text{Ybus}]^{-1}$.

The sensitivity factor of real power loss with respect to real power injection from DG is given as follows:

$$\alpha_i = \frac{\partial P_L}{\partial P_i} = \sum_{i=1}^{N} (\alpha_{ij}\, P_j - \beta_{ij} Q_j) \tag{3}$$

If the partial derivative of Equation (3) becomes zero, the total active power loss will then be minimised.

The active power injection of the bus i, where the DG unit is installed, is given by:

$$P_i = P_{DGi} - P_{Di} \tag{4}$$

where, P_{Di} is the load demand at node i and P_{DGi} is the injection power from DG placed to the node i.

On the other hand, in CPF, by applying the loading parameter of (λ), loads and generations are increased from their base case values, as follows:

$$P_D = P_D^{oi} + \lambda . P_D^{CPF} \tag{5}$$

where $\mathrm{P_D^{CPF}}$ is power increment directions of loads in the CPF and $\mathrm{P_D^{oi}}$ is active powers of loads at the base case (Milano, 2005). Substituting Equation (4) and Equation (5) into Equation (2), the total active power losses with a DG unit can be obtained as follows:

$$P_{DGi} = (P_{Di}^{oi} + \lambda_i . P_{Di}^{CPF}) + \frac{1}{\alpha_{ii}} \left[\beta_{ii} Q_i - \sum_{j=1, j\neq i}^{N} (\alpha_{ij} P_j - \beta_{ij} Q_j)\right] \tag{6}$$

The optimum size of the DG at bus i is calculated by P_{DGi}.

PROBLEM FORMULATION

The objective functions (OF) are achieved by finding the optimal size and location of the DG in a power system. To achieve this goal, minimise point of power losses from the Equation (2) and the most sensitive bus from running the CPF is considered to sit the DG as the first candidate. The optimal size of DG is measured from Equation (6); then, to select a place for DG, the Find minimum of single-variable function is used as:

$$\min_x f(x) \quad that\ x_1 < x < x_2 \tag{7}$$

After sitting, the DG at the initial candidate place and the loop starts from the first step again. The OF to locate the DG in optimal place is firstly calculated by minimising the power losses index based on the ratio of the total active power losses, with and without the DG unit, as:

$$\text{OPL}=\frac{\sum_{i=1}^{N} PL_{base\ case} - \sum_{i=1}^{N} PL_{with\,DG}}{\sum_{i=1}^{N} PL_{base\ case}} \tag{8}$$

After that, the maximum of the loading factor improvement, with and without the DG unit, is defined as a second index by:

$$\text{OVS}=\frac{\sum_{i=1}^{N} \lambda\, max_{withDG} - \sum_{i=1}^{N} \lambda\, max_{base\ case}}{\sum_{i=1}^{N} \lambda\, max_{base\ case}} \tag{9}$$

Consequently, the following OF is defined as a combination of both indices to optimise by:

$$\text{Minimise OF } (P_{DG}) = \text{a} \times \min\{\text{OPL}\} + \text{b} \times \frac{1}{\max\{\text{OVS}\}} \tag{10}$$

Where, a and b are weighting factors that are considered to reduce loss and improve the loading factor. They are determined based on which OF has a higher value. Here, the value for each one is considered as 0.5. The algorithm for locating and sizing the DG, based on the proposed method, is illustrated in Figure 3.

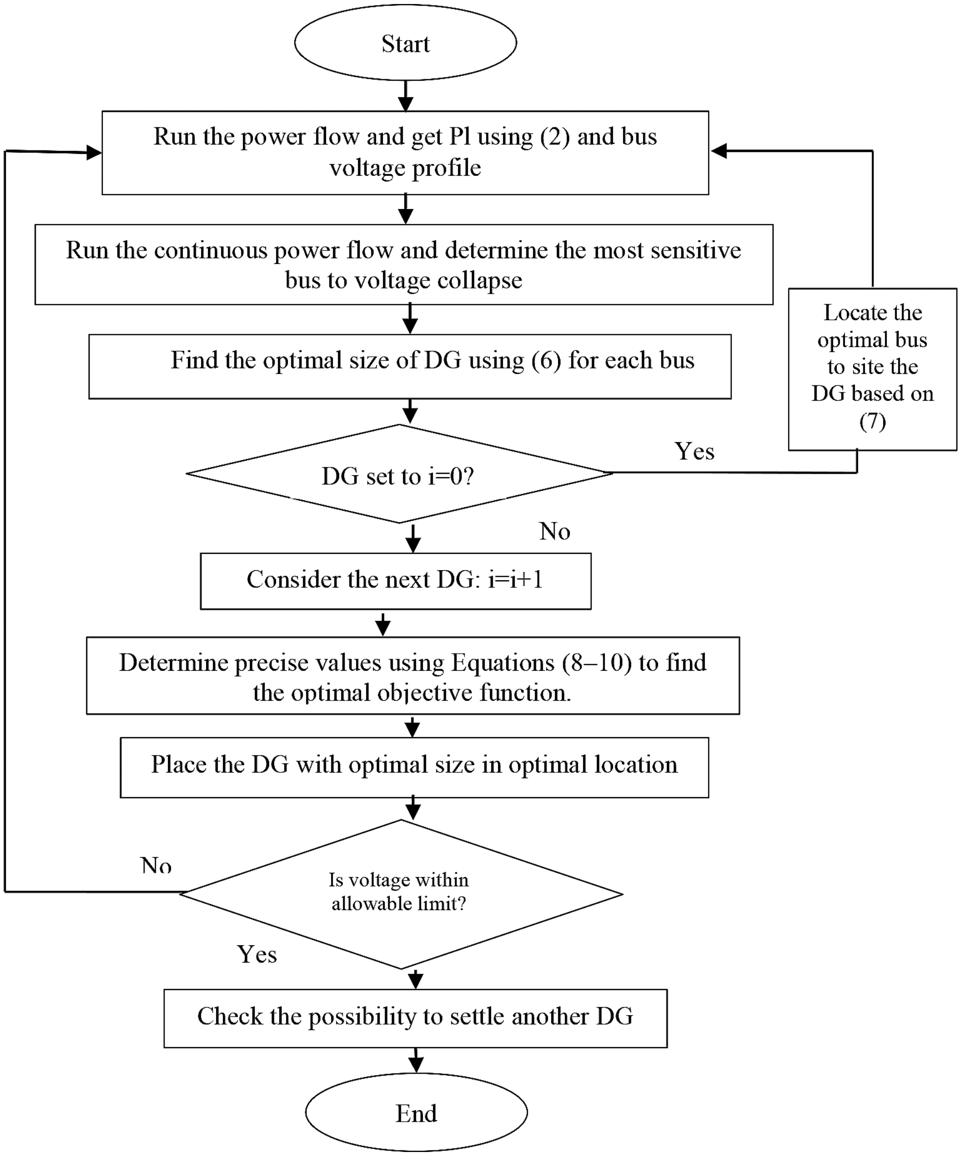

Figure 3. Flowchart of the proposed method.

NUMERICAL RESULTS AND DISCUSSION

The proposed algorithm was tested on a 33-bus radial distribution network, which has 33 buses and 32 branches. The radial system has a total load of 3.72 MW and 2.3 MVAR. The voltage level should be in the allowable voltage level ($0.95 < Vbus < 1.05$). The system is illustrated in Figure 4. After simulating the test system in the Matlab environment, and writing the necessary computer programme, the optimum DG locations and sizes have been calculated. The total power loss and optimal size of DG, based on the proposed formula for each bus, are illustrated in Figure 5 and Figure 6, respectively. Meanwhile, the voltage profile at the base case and the sensitive bus to the voltage collapse is shown in Figure 7.

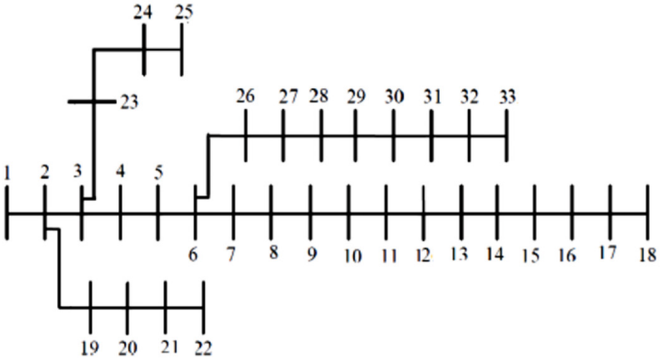

Figure 4. Single line diagram of a 33-bus radial distribution network

As illustrated in Figure 7, the most sensitive bus to voltage collapse is bus number 18, which also has the lowest voltage profile. After calculating the size of DG and sitting in the initial place, the optimal sizing and location of DG are evaluated, as shown in following figure and tables. Figure 8 shows the voltage profile, with and without DG. The voltage level is achieved by installing the DG completely lands in the allowable voltage level, thus presenting the effectiveness of the proposed method on the performance of the system when comparing cases with and without the DG unit condition (base case). The optimum DG sizes and places are shown in Table 1. This table indicates a comparative analysis for the cases with and without DG unit.

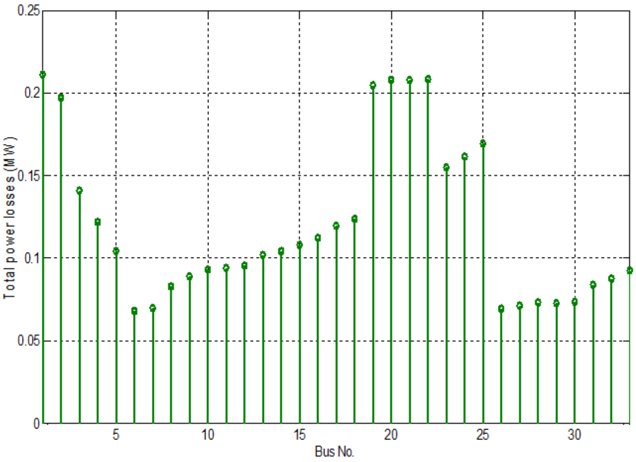

Figure 5. Total power loss of a 33 bus distribution system

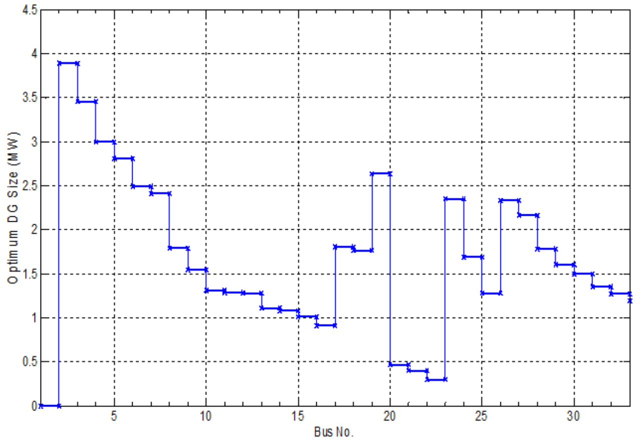

Figure 6. Optimal size of DG of a 33 bus distribution system

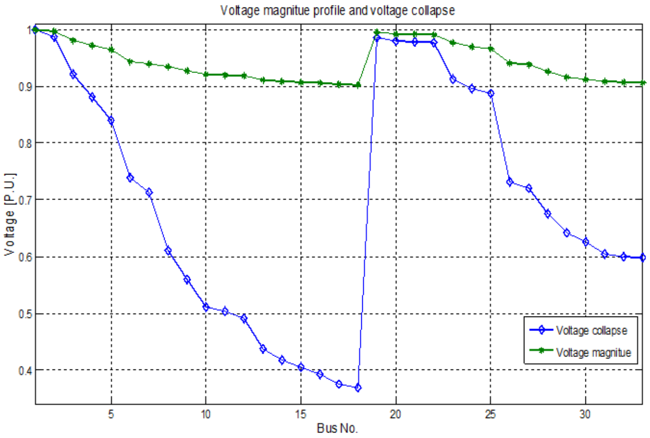

Figure 7. Voltage magnitude profile and voltage collapse

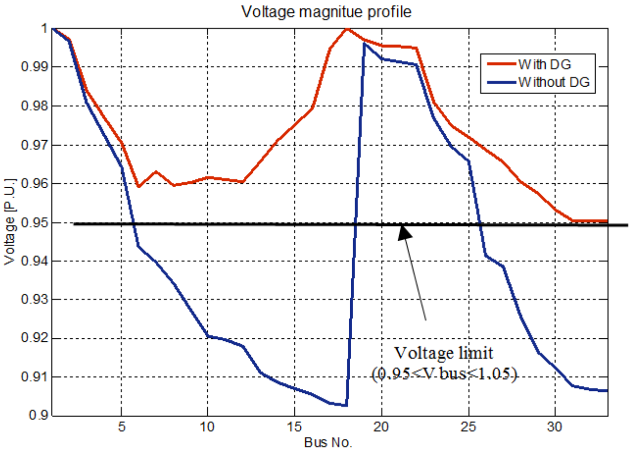

Figure 8. Voltage profile curve with and without DG unit

Based on Figure 3, after sizing DG using (6), the load flow function should be executed two times (one time with the system without DG unit and another with the system with DG unit) to achieve the final solution. Therefore, firstly, DG will be placed in bus 18, which is the most sensitive bus to voltage collapse. The result of the initial step showed voltage profile growth from 0.9089 to 0.9474 and power loss is decreased about 34.6% (see Table 1). Moreover, the loading factor increased after installing the DG unit. In the next step, the second load flow is run to obtain the exact value of results. Obviously, it can be seen that by placing DG, the minimum voltage profile and loading factor parameter were again increased to 4.58% and 11.39% respectively. Moreover, the power loss was dropped to 0.1097. Therefore, it is possible to conclude that by locating the DG in the optimal place with optimal size. The stability of the system was improved and this has a significant effect on improving the loading parameter. To evaluate the performance of the proposed method, it is compared with other three methods (Gozel & Hocaoglu, 2009; Moradi & Abedini, 2012; Ettehadi & Ghasemi, 2013) as shown in Table 2. As shown in Table 2, results of the proposed method show that by siting the one DG unit in the system, the minimum voltage magnitude is increased to the acceptable voltage limit compared to the techniques of Gozel and Ettehadi. In Moradi's method, however, the minimum voltage magnitude reached 9808. Nonetheless, he used three DG units.

Moreover, loading factor difference with and without DG in proposed method is higher compared with the approaches of Gozel and Ettehadi, while Moradi did not consider it at all. Also, the power loss value of the proposed method is lower than the two other methods with one DG unit. Besides, in Moradi's method, by installing three DG units in the system, the power loss just reduced %5.8 more in comparison to the proposed technique. Therefore, the above comparison shows the efficiency of the proposed approach.

Table 1

Effects of optimising DG location and sizing on the loading factors

	DG bus	V max (p.u.)	V min (p.u.) (×10^-4)	System loading (×10^-3)	Power loss (MW) (×10^-4)
Without DG	---	1	9089	3073	2127
With DG at initial step	18	1	9474	3397	1198
With DG based on OF	18	1	9505	3423	1097

Table 2

Comparison of the effects of DG Placement on the system performance

	V max (p.u.)	V min (p.u.) (×10^-4)	Number of DG	Difference of loading (×10^-3)	Power loss (MW) (×10^-4)
Proposed method	1	9505	1	350	1097
Gozel & Hocaoglu (2009)	1	9410	1	300	1112
Ettehadi & Ghasemi (2013)	1	9370	1	240	1420
Moradi & Abedini (2012)	1	9808	3	---	1034

CONCLUSION

This paper proposed a combined analytical method based on the exact loss formula and continuous power flow to find the optimal size and location of the DG unit so as to reduce power loss and increase the stability of voltage. The proposed method presented a new formula to calculate the optimal size of DG unit. Then, the multi-objective index is presented based on the combination of the power losses and loading factor improvement indices by assigning a weight factor for each index. Moreover, the single-variable function is used to find the minimum value of the objective function. The proposed technique is tested on a typical distribution test system and its results are discussed and compared with three previous research. The results show that by finding the optimal size and place of DG unit, the total power losses is reduced %48.43, while voltage profile is enhanced %4.38 and voltage stability is increased %10.23. Consequently, it can be concluded that by installing a DG unit with accurate size and location, the system condition can be improved significantly.

REFERENCES

Abou El-Ela, A., Allam, S., & Shatla, M. (2010). Maximal optimal benefits of distributed generation using genetic algorithms. *Electric Power Systems Research, 80*(7), 869-877.

Acharya, N., Mahat, P., & Mithulananthan, N. (2006). An analytical approach for DG allocation in primary distribution network. *International Journal of Electrical Power & Energy Systems, 28*(10), 669-678.

Ackermann, T., Andersson, G., & Soder, L. (2001). Distributed generation: a definition. *Electric Power Systems Research, 57*(3), 195-204.

Akorede, M., Hizam, H., Aris, I., & Kadir, M. A. (2011). Effective method for optimal allocation of distributed generation units in meshed electric power systems. *Generation, Transmission & Distribution, IET, 5*(2), 276-287.

AlHajri, M. F., AlRashidi, M. R., & El-Hawary, M. E. (2010). *Improved Sequential Quadratic Programming approach for optimal Distribution Generation sizing in distribution networks.* Paper presented at the Electrical and Computer Engineering (CCECE), 23rd Canadian Conference.

Aman, M., Jasmon, G., Mokhlis, H., & Bakar, A. (2012). Optimal placement and sizing of a DG based on a new power stability index and line losses. *International Journal of Electrical Power & Energy Systems, 43*(1), 1296-1304.

Borges, C. L., & Falcao, D. M. (2003). *Impact of distributed generation allocation and sizing on reliability, losses and voltage profile.* Paper presented at the Power Tech Conference Proceedings, 2003 IEEE Bologna.

Canizares, C. A., & Alvarado, F. L. (1993). Point of collapse and continuation methods for large AC/DC systems. *Power Systems, IEEE Transactions on, 8*(1), 1-8.

Celli, G., Ghiani, E., Mocci, S., & Pilo, F. (2005). A multiobjective evolutionary algorithm for the sizing and siting of distributed generation. *Power Systems, IEEE Transactions on, 20*(2), 750-757.

Chiradeja, P., & Ramakumar, R. (2004). An approach to quantify the technical benefits of distributed generation. *Energy Conversion, IEEE Transactions on, 19*(4), 764-773.

Dent, C. J., Ochoa, L. F., Harrison, G. P., & Bialek, J. W. (2010). Efficient secure AC OPF for network generation capacity assessment. *Power Systems, IEEE Transactions on, 25*(1), 575-583.

Devi, A. L., & Subramanyam, B. (2007). Optimal DG unit placement for loss reduction in radial distribution system-a case study. *Journal of Engineering and Applied Sciences, 2*(6), 57-61.

Devi, S., & Geethanjali, M. (2014). Application of Modified Bacterial Foraging Optimization algorithm for optimal placement and sizing of Distributed Generation. *Expert Systems with Applications, 41*(6), 2772–2781.

Donnelly, M., Dagle, J., Trudnowski, D., & Rogers, G. (1996). Impacts of the distributed utility on transmission system stability. *Power Systems, IEEE Transactions on, 11*(2), 741-746.

El-Zonkoly, A. (2011). Optimal placement of multi-distributed generation units including different load models using particle swarm optimization. *Swarm and Evolutionary Computation, 1*(1), 50-59.

Elgerd, O. I. (1983). *Electric energy systems theory: an introduction*: Tata McGraw-Hill Education.

Ettehadi, M., Ghasemi, H., & Vaez-Zadeh, S. (2013). Voltage Stability-Based DG Placement in Distribution Networks. *IEEE* Transactions on Power Delivery*, 28*(1), 171-178.

Ettehadi, M., Vaez-Zadeh, S., & Ghasemi, H. (2012). *DG placement in distribution networks considering voltage stability.* Paper presented at the Environment and Electrical Engineering (EEEIC), 11th International Conference.

Falaghi, H., & Haghifam, M. R. (2007). *ACO based algorithm for distributed generation sources allocation and sizing in distribution systems.* Paper presented at the Power Tech, 2007 IEEE Lausanne.

Gonzalez, M. G., Lopez, A., & Jurado, F. (2012). Optimization of distributed generation systems using a new discrete PSO and OPF. *Electric Power Systems Research, 84*(1), 174-180.

Gozel, T., Eminoglu, U., & Hocaoglu, M. (2008). A tool for voltage stability and optimization (VS&OP) in radial distribution systems using Matlab graphical user interface (GUI). *Simulation Modelling Practice and Theory, 16*(5), 505-518.

Gozel, T., & Hocaoglu, M. H. (2009). An analytical method for the sizing and siting of distributed generators in radial systems. *Electric Power Systems Research, 79*(6), 912-918.

Hedayati, H., Nabaviniaki, S., & Akbarimajd, A. (2008). A method for placement of DG units in distribution networks. *Power Delivery, IEEE Transactions on, 23*(3), 1620-1628.

Hernandez, J., Velasco, D., & Trujillo, C. (2011). Analysis of the effect of the implementation of photovoltaic systems like option of distributed generation in Colombia. *Renewable and Sustainable Energy Reviews, 15*(5), 2290-2298.

Hosseini, R. K., & Kazemzadeh, R. (2011). *Optimal DG allocation by extending an analytical method to minimize losses in radial distribution systems.* Paper presented at the Electrical Engineering (ICEE), 19th Iranian Conference.

Hung, D. Q., Mithulananthan, N., & Bansal, R. (2010). Analytical expressions for DG allocation in primary distribution networks. *Energy Conversion, IEEE Transactions on, 25*(3), 814-820.

Hung, D. Q., Mithulananthan, N., & Bansal, R. (2013). Analytical strategies for renewable distributed generation integration considering energy loss minimization. *Applied Energy, 105*, 75-85.

Injeti, S. K., & Kumar, N. P. (2013). A novel approach to identify optimal access point and capacity of multiple DGs in a small, medium and large scale radial distribution systems. *International Journal of Electrical Power & Energy Systems, 45*(1), 142-151.

Katsigiannis, Y., & Georgilakis, P. (2008). Optimal sizing of small isolated hybrid power systems using tabu search. *Journal of Optoelectronics and Advanced Materials, 10*(5), 1241- 1245.

Kayal, P., & Chanda, C. (2013). Placement of wind and solar based DGs in distribution system for power loss minimization and voltage stability improvement. *International Journal of Electrical Power & Energy Systems, 53*, 795-809.

Khalesi, N., Rezaei, N., & Haghifam, M. R. (2011). DG allocation with application of dynamic programming for loss reduction and reliability improvement. *International Journal of Electrical Power & Energy Systems, 33*(2), 288-295.

Lalitha, M. P., Reddy, V. V., & Usha, V. (2010). Optimal DG placement for minimum real power loss in radial distribution systems using PSO. *Journal of Theoretical and Applied Information Technology, 13*(2), 107-116.

Medina, A. C. R., Franco, J. F., Rider, M. J., Feltrin, A. P., & Romero, R. (2013). A mixed-integer linear programming approach for optimal type, size and allocation of distributed generation in radial distribution systems. *Electric Power Systems Research, 97*(0), 133-143.

Milano, F. (2005). An Open Source Power System Analysis Toolbox. *Power Systems, IEEE Transactions on, 20*(3), 1199-1206.

Moradi, M., & Abedini, M. (2012). A combination of genetic algorithm and particle swarm optimization for optimal DG location and sizing in distribution systems. *International Journal of Electrical Power & Energy Systems, 34*(1), 66-74.

Moravej, Z., & Akhlaghi, A. (2013). A novel approach based on cuckoo search for DG allocation in distribution network. *International Journal of Electrical Power & Energy Systems, 44*(1), 672-679.

Naderi, E., Seifi, H., & Sepasian, M. S. (2012). A dynamic approach for distribution system planning considering distributed generation. *Power Delivery, IEEE Transactions on, 27*(3), 1313-1322.

Ochoa, L. F., & Harrison, G. P. (2011). Minimizing energy losses: Optimal accommodation and smart operation of renewable distributed generation. *Power Systems, IEEE Transactions on, 26*(1), 198-205.

Rahman, T., Rahim, S., & Musirin, I. (2004). *Optimal allocation and sizing of embedded generators.* Paper presented at the Power and Energy Conference, PECon. Proceedings. National.

Rao, R., Ravindra, K., Satish, K., & Narasimham, S. (2013). Power loss minimization in distribution system using network reconfiguration in the presence of distributed generation. *IEEE transactions on power systems, 28*(1), 317-325.

Reza, M., Slootweg, J., Schavemaker, P., Kling, W., & Van der Sluis, L. (2003). *Investigating impacts of distributed generation on transmission system stability.* Paper presented at the Power Tech Conference Proceedings, 2003 IEEE Bologna.

Thong, V. V., Driesen, J., & Belmans, R. (2005). Power quality and voltage stability of distribution system with distributed energy resources. *International Journal of Distributed Energy Resources, 1*(3), 227-240.

Ugranli, F., & Karatepe, E. (2012). Convergence of rule-of-thumb sizing and allocating rules of distributed generation in meshed power networks. *Renewable and Sustainable Energy Reviews, 16*(1), 582-590.

Wang, C., & Nehrir, M. H. (2004). Analytical approaches for optimal placement of distributed generation sources in power systems. *Power Systems, IEEE Transactions on, 19*(4), 2068-2076.