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# Optimal Location of a Distributed Generator for Power Losses Improvement

Lucian Ioan Dulău[a,*], Mihail Abrudean[b], Dorin Bică[c]

[a]*PhD School, Technical University of Cluj-Napoca, Cluj-Napoca, Romania*
[b]*Department of Automation, Faculty of Automation and Computer Science, Technical University of Cluj-Napoca, Cluj-Napoca, Romania*
[c]*Department of Electrical and Computer Engineering, Faculty of Engineering, "Petru Maior" University of Tîrgu-Mureş, Tîrgu-Mureş, Romania*

**Abstract**

This paper describes the optimal location of a 2.3 MW distributed generator (DG) in a test system (IEEE 14 bus test system) based on the power losses. The distributed generator (DG) optimal location will determined considering the power losses at each bus where the DG is connected. The power losses at each bus will be determined with the Neplan software, using the Newton-Raphson extended method.

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*Keywords:* distributed generation; distributed generator; power losses; optimal location; IEEE 14.

## 1. Introduction

The term "distributed generation" (DG) refers to the production of electricity near the consumption place. The distributed generation resources are renewable energies and cogeneration (simultaneous production of heat and electricity).

Renewable energy is energy from natural resources such as wind, sunlight, tides, waves, geothermal heat and biomass.

* Corresponding author. Tel.: +40-265-233-112.
*E-mail address:* dulau.lucian@gmail.com


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The connection of distributed generators in the power system can reduce the power losses, improve the reliability of the system, improve the power quality and provide voltage support.

In this paper we present the optimal location of a 2.3 MW distributed generator (DG) in a test system (IEEE 14 bus test system) based on the power losses. The study will be performed using the Neplan software, based on the Newton-Raphson method.

Other papers are focused on the optimal siting and sizing of distributed generations units [9-15, 17] or on the impacts of the integration of a distributed generator in the power system [1, 2, 5, 16].

## 2. Distributed generation overview

Distributed generation (DG) refers to the production of electricity near or the consumer's location using renewable energy sources (RES) and cogeneration (simultaneous production of heat and electricity) units. [3-4, 6-8]

Distributed generation is characterized by some features which have not been present in traditional centralized systems:

- rather free location in the network area;
- relatively small generated power;
- variation of generated power dependent on the availability and variability of primary energy. [3-4, 6-8]

One of the main advantages of DG is its close proximity to the consumer location. DG can play an important role in:

- improving the reliability of the grid;
- reducing the transmission losses;
- providing better voltage support;
- improving the power quality. [3-4, 6-8]

The distributed generation also reduces greenhouse gas emission addressing pollutant concerns by providing clean and efficient energy. [3-4, 6-8]. The DG technologies and their typical module size are the following:
small hydro: 1 - 100 MW;

- micro hydro: 25 kW - 1 MW;
- wind turbine: 200 W - 3 MW;
- photovoltaic arrays: 20 W - 100 kW;
- biomass gasification: 100 kW - 20 MW;
- geothermal: 5 - 100 MW;
- ocean energy: 100 kW - 5 MW. [3-4, 6-8]

Distributed Energy Resources (DER) had changed many aspects of distribution system operation, design and implementation. By increasing more decentralized systems with smaller generating units connecting directly to the distribution networks near demand consumption, the distribution companies reduce loss in their networks. [3-4, 6-8]

The operation of power systems with a large amount of distributed generation raises a number of issues:

- voltage profiles change along the network, depending on how much power is produced and consumed at that system level, leading to a behavior different from that of a typical unidirectional network;
- voltage transients will appear as a result of connection and disconnection of generators or even as a result of their operation;
- short circuit levels are increased;
- load losses change as a function of the production and load levels;
- congestion in system branches is a function of the production and load levels;
- power quality and reliability may be affected;
- utility protection and DG protection measures must be coordinated. [3-4, 6-8]

## 3. Case study

The optimal location of a 2.3 MW distributed generator (DG) will be determined for the test system in Fig. 1 (IEEE 14 bus test system), based on the power losses.The distributed generator (DG) optimal location will determined considering the power losses at each load bus where the DG is connected. The power losses at each load bus will be determined with the Neplan software [18], using the Newton-Raphson extended method [8].

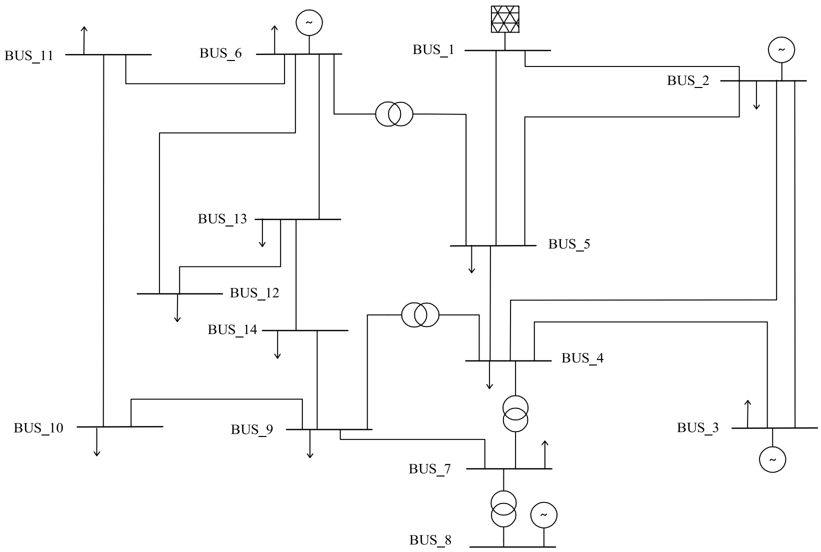


Fig. 1. One-line diagram of IEEE 14 system.

The method starts from initial values of all unknown variables (voltage magnitude and angles at load buses and voltage angles at generator buses). A Taylor series is written, with the higher order terms ignored, for each of the power balance equations included in the system of equations. The result is a linear system of equations that can be expressed as:

$$\begin{bmatrix} \Delta\theta \\ \Delta |V| \end{bmatrix} = -J^{-1} \begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} \tag{1}$$

$$\Delta P_i = -P_i + \sum_{k=1}^{N} |V_i||V_k| (G_{ik} \cos\theta_{ik} + B_{ik} \sin\theta_{ik}) \tag{2}$$

$$\Delta Q_i = -Q_i + \sum_{k=1}^{N} |V_i||V_k| (G_{ik} \sin\theta_{ik} - B_{ik} \cos\theta_{ik}) \tag{3}$$

$$J = \begin{bmatrix} \frac{\delta \Delta P}{\delta \theta} & \frac{\delta \Delta P}{\delta |V|} \\ \frac{\delta \Delta Q}{\delta \theta} & \frac{\delta \Delta Q}{\delta |V|} \end{bmatrix} \tag{4}$$

where:

- $|V|$ - voltage magnitude;
- $\theta$, $\theta_{ik}$ - voltage phase ($\theta$), and voltage angle difference between the i and k buses ($\theta_{ik}$);
- $P_i$ - net power injected at bus i;
- $G_{ik}$, $B_{ik}$ - the real and imaginary part of the element in the bus admittance matrix corresponding to the i row and k column;
- $\Delta P$, $\Delta Q$ - the mismatch equations;
- J - matrix of partial derivatives (Jacobian).

The linearized system of equations is solved in order to determine the next value (m+1) of voltage magnitude and angles based on:

$$\theta^{m+1} = \theta^m + \Delta\theta; |V|^{m+1} = |V|^m + \Delta |V| \tag{5}$$

The process continues until the norm of the mismatch equations are below a specified tolerance.The system power losses without the DG are:

- $\Delta P$ = 13.596557 MW;
- $\Delta Q$ = 27.434015 MVAr.

The power losses results, that were determined with the Neplan software, are presented in Table 1 and represented graphically in Fig. 2.

Table 1. Power losses.

| Bus | ΔP [MW] | ΔQ [MVAr] |
|---|---|---|
| 1 | - | - |
| 2 | - | - |
| 3 | - | - |
| 4 | 13.728263 | 27.177577 |
| 5 | 13.402883 | 26.912447 |
| 6 | - | - |
| 7 | 13.322065 | 26.266123 |
| 8 | - | - |
| 9 | 13.178649 | 25.284754 |
| 10 | 13.203033 | 25.507597 |
| 11 | 13.329444 | 26.117211 |
| 12 | 13.364601 | 26.263243 |
| 13 | 13.298654 | 26.055482 |
| 14 | 13.168036 | 25.497254 |

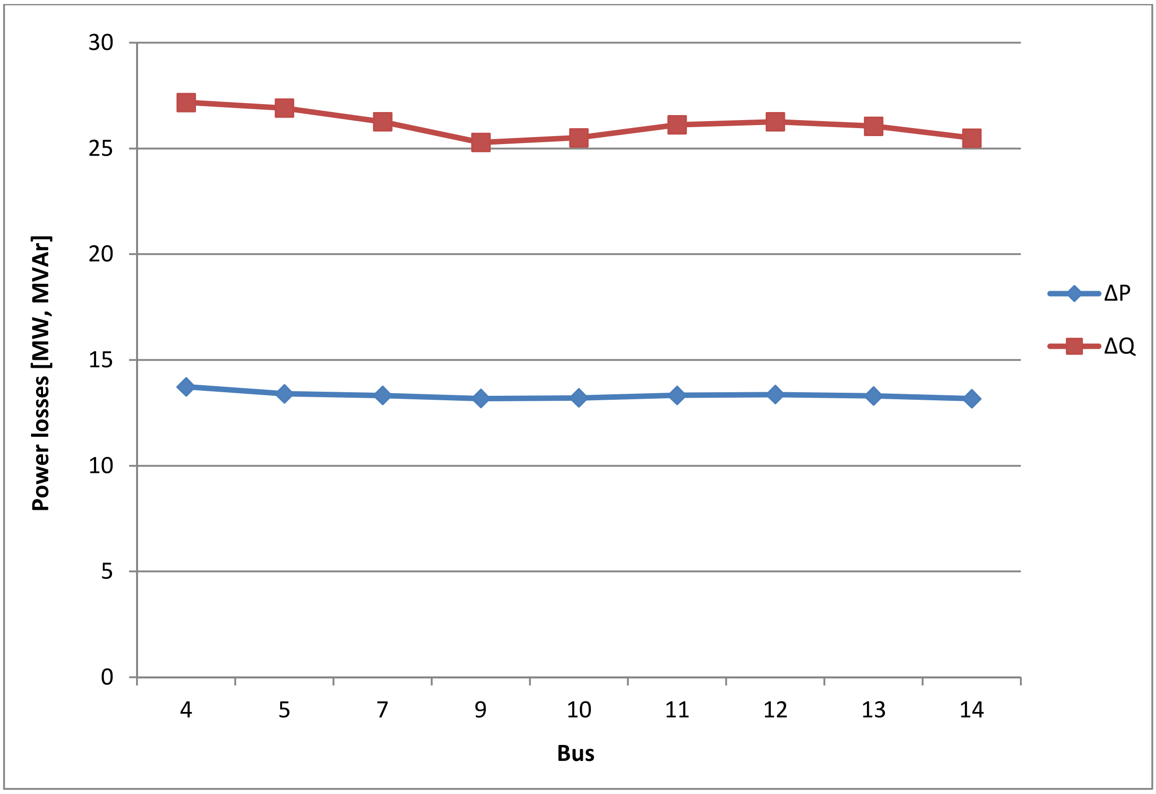


Fig. 2. Power losses results.

## 4. Conclusions

DG has an important role in reducing the power losses, improving the grid reliability, providing better voltage support and improving the power quality. The most important role is the reduction of the power losses.

A case study was performed in order to determine the location of a 2.3 MW distributed generator in the IEEE14 bus test system considering the power losses. These power losses at each load bus were determined with the Neplan software, using the Newton-Raphson extended method.

Based on the power losses results from the case study, it can be concluded that the optimal location for the distributed generator in the IEEE 14 test system is at bus 14.

As a future study, the analysis can consider beside the power losses, the generation costs in order to determine the best location for the distributed generator.

## References

[1] Ayres HM, da Silva LCP, Freitas W, de Almeida MC and da Costa VF. Evaluation of the impact of distributed generation on power losses by using a sensitivity-based method, IEEE Power & Energy Society General Meeting (PES '09), pp. 1-6, 2009.

[2] Bawan EK. Distributed generation impact on power system case study: Losses and voltage profile, 2012 22nd Australasian Universities Power Engineering Conference (AUPEC), pp. 1-6, 2012.

[3] Bollen MH and Hassan F. Integration of Distributed Generation in the Power System, Wiley-IEEE Press, 2011.

[4] Borbely AM and Kreider JF. Distributed Generation: The Power Paradigm for the New Millennium, CRC Press, 2001.

[5] Chiradeja P and Ngaopitakkul A. The impacts of electrical power losses due to distributed generation integration to distribution system, 2013 International Conference on Electrical Machines and Systems (ICEMS), pp. 1330-1333, 2013.

[6] Dulău LI, Abrudean M and Bică D. Automation of a Distributed Generation System, 49th Universities' Power Engineering Conference (UPEC), IEEE Xplore, pp. 1-5, 2014.
[7] Dulău LI, Abrudean M and Bică D. Distributed Generation and Virtual Power Plants, 49th Universities' Power Engineering Conference (UPEC), IEEE Xplore, pp. 1-5, 2014.
[8] Dulău LI, Abrudean M and Bică D. SCADA simulation of a distributed generation system with power losses, Scientific Bulletin of the "Petru Maior" University of Tîrgu-Mureş, Vol. 11, Nr. 2, pp. 25-29, 2014.
[9] Esmaili M, Firozjaee EC and Shayanfar HA. Optimal placement of distributed generations considering voltage stability and power losses with observing voltage-related constraints, Applied Energy, Vol. 113, pp. 1252-1260, 2014.
[10] Imran AM and Kowsalya M. Optimal Distributed Generation and capacitor placement in power distribution networks for power loss minimization, 2014 International Conference on Advances in Electrical Engineering (ICAEE), pp. 1-6, 2014.
[11] Kashem MA, Le ADT, Negnevitsky M and Ledwich G. Distributed generation for minimization of power losses in distribution systems, IEEE Power Engineering Society General Meeting, 2006.
[12] Abu-Mouti FS, El-Hawary ME. Optimal Distributed Generation Allocation and Sizing in Distribution Systems via Artificial Bee Colony Algorithm, IEEE Transactions on Power Delivery, Vol. 26, No. 4, pp. 2090-2101, 2011.
[13] Naik SG, Khatod DK and Sharma MP. Sizing and siting of distributed generation in distribution networks for real power loss minimization using analytical approach, 2013 International Conference on Power, Energy and Control (ICPEC), pp. 740-745, 2013.
[14] Shukla TN, Singh SP, Srinivasarao V and Naik KB. Optimal Sizing of Distributed Generation Placed on Radial Distribution Systems, Electric Power Components and Systems, Vol. 38, No. 3, pp. 260-274, 2010.
[15] Singh RK and Goswamib SK. Optimum Siting and Sizing of Distributed Generations in Radial and Networked Systems, Electric Power Components and Systems, Vol. 37, No. 2, pp. 127-145, 2009.
[16] Bo W and Ka L. Analysis of the Distributed Generation System and the Influence on Power Loss, 2011 Asia-Pacific Power and Energy Engineering Conference (APPEEC), pp. 1-4, 2011.
[17] Zulpo RS, Leborgne RC and Bretas AS. Optimal location and sizing of distributed generation based on power losses and voltage deviation, 2014 IEEE PES Transmission & Distribution Conference and Exposition - Latin America (PES T&D-LA), pp. 1-5, 2014.
[18] www.neplan.ch