Available online at http://ijdea.srbiau.ac.ir

Int. J. Data Envelopment Analysis (ISSN 2345-458X)

Vol. 12, No. 1, Year 2024 Article ID IJDEA-00422, Pages 23-29
Research Article

International Journal of Data Envelopment Analysis
Science and Research Branch (IAU)

Optimum placement of Distributed Generation Sources to Minimize Losses and to Improvement Voltage Profile of Distribute Network Using Data Envelopment Analysis Method

Hossein Tohidi*
Departement of Electrical, Malekan branch, Islamic Azad university, Malekan, iran

Received 13 June 2023, Accepted 12 January 2024

Abstract
one of the novel solutions for reduction of power loss and improvement of voltage profile in the distribute network is distributed generation sources. To this purpose, capacity and install location of generation sources in the distribute network are especially important. In this paper, a new algorithm using data envelopment analysis (DEA) method is presented for optimum placement and capacity determination of distributed generation sources for reducing of power loss and modifying of voltage profile. Proposed algorithm is tested on the 33 and 69 buses standard systems. Simulation results show effectiveness of proposed algorithm for optimum placement and capacity determination of distributed generation sources considering boundary conditions such as limitation of voltage and capacity of network feeders.

Keywords: Distributed generation Sources, Minimum losses, Improvement of voltage profile, Data envelopment analysis (DEA)

* Corresponding author: Email: huseyn.tohidi@gmail.com

1. Introduction

After the adoption of the Kyoto Protocol regarding to preservation of the environment, use of novel and renewable energy in the Distributed Generation (DG) sources is important. This remarkably increases contribution of DG technology for consumption power supply.

Usage of DG sources can be also one of the effective solutions for get rid of the problems such as high loss, low power quality, and compression in the transmission line. In addition, low capacity of DGs Facilitates design and installation process of them in comparison with large scale units [1].

As per increase of DG sources penetration in distribution networks, the aim is that with optimum placement and size of DG, loss reduction and voltage profile improvement be better as much as possible. Researches show improper selection of location and capacity of DG sources can increase loss compared to without DG present [2-4]. Also, optimum placement and proper capacity determination of DG can release transmission and distribution line capacity. This causes to decrease and prorogation of new investment costs [5-6].

In some of previous researches Genetic Algorithm (GA) based methods has been used for determination of location and capacity of DG. These methods need to run with heavy computational algorithm that convergence rate is low [7].

In another research, analytical method has been used to minimize loss of radial and ring distribution networks [8] that only location of DG sources is optimized and its capacity is fixed.

In this paper, first an analytical method introduced in [8] is used for calculating of capacity of DG sources for all buses. Secondly, data enveloped method is used for determining of capacity and optimum location of DG sources to reduction of loss and voltage profile improvement. Optimum placement and capacity determination of DG is performed for power flow when the consumption has peak value. Since voltage drop and loss of network are the maximum in such circumstance.

Rest of the paper is organized as follows: a brief introduction of DG is presented in section 2. New algorithm in order to optimum planning for loss reduction and voltage profile improvement in distribution system in presence of DG using data envelopment analysis (DEA) is given in section 3. In Section 4, simulation result of proposed algorithm on the distribution network is provided. Finally, the conclusion is presented in section 5.

2. Distributed generation

DG is power generation in consumption location, but it is sometimes known for technologies that use renewable sources for power generation. What it is often acceptable is relatively small generator, regardless of how they produce the power, and its capacity is usually less than 300 MW that is directly connected to distributed network.

Nowadays, in spite of unknown of renewable energies, they are rapidly developing and neglecting of their penetration is inevitable. Solar, wind, Biomass, geothermal and … are the most popular of novel energy sources. Three factors in 1995 led to a landmark to develop of renewable energy: Firstly, climate change due to the buildup of greenhouse gases in the atmosphere, secondly, increase of electricity demand in the world, and thirdly, Promising growth of renewable energies.

3. Proposed method

In [8], it is shown that for all of the buses in the network, there is an active power which if that be provided, loss of network is minimized. This active power is calculated for all buses as follow:

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

Similar to method in [8], a reactive power can be obtained for all of the buses so that the loss of network is minimized. The reactive power can be calculated using (2):

$$Q_{DGi} = Q_{Di} - \frac{1}{\alpha_{ii}}\left[\beta_{ii}P_i - \sum_{j=1, j\neq i}^{N}(\alpha_{ij}Q_j - \beta_{ij}P_j)\right] \quad (2)$$

where:

$$\alpha_{ij} = \frac{r_{ij}}{V_iV_j}\cos(\delta_i - \delta_j)$$

$$\beta_{ij} = \frac{r_{ij}}{V_iV_j}\sin(\delta_i - \delta_j)$$

$$Z_{ij} = r_{ij} + jX_{ij}$$

$$[Z_{bus}] = [Y_{bus}]^{-1}$$

P_i: injection active power to bus i
Q_i: injection reactive power to bus i
V_i: bus i voltage
δ_i: Voltage angle of bus i
Z_{ij}: ij element of Z_{bus} matrix
N: number of bus

So, it can be obtained for all of the buses using (1) and (2) an active and reactive power that minimize loss if inject to corresponding bus. Up to this point, all the buses are candidate for DG installation.

Suppose there are n candidate unit as follow:

$$DMU_i = \begin{pmatrix} X_i \\ Y_i \end{pmatrix} \quad i = 1, \ldots, N_i$$

Where $X_i = (\overline{C_i})$ and $Y_i = \begin{pmatrix} \Delta\overline{P_i} \\ \Delta\overline{Q_i} \\ \Delta\overline{V_i} \end{pmatrix}$ are input and output of DMU_i, respectively, i.e., each unit has one input and three output and above variables are defined as follow:

$$\Delta P_i = P_0 - P_i \quad (3)$$

$$\Delta Q_i = Q_0 - Q_i \quad (4)$$

$$\Delta V_i = V_0 - V_i \quad (5)$$

Where P0 and Q0 are active power loss and reactive power loss respectively for base case (0), V0 is deviation of network voltage profile for base case (0), Pi and Qi are active power loss and reactive power loss respectively when Ith candidate is added, Vi is deviation of network voltage profile when Ith candidate is added, ΔP_i and ΔP_i are difference of active power loss and reactive power loss for base case except when Ith candidate is added, ΔV_i is difference of network voltage profile deviation for base case except when Ith candidate is added.

The data can be normalized as follow:

$$P_{\max} = Max\{\Delta P_i\}$$

$$Q_{\max} = Max\{\Delta Q_i\}$$

$$V_{\max} = Max\{\Delta V_i\}$$

$$C_{\max} = Max\{C_i\}$$

$$i = 1, \ldots, N_i$$

$\Delta\overline{P_i} = \Delta P_i / P_{\max}$:normalized active power variation of network when i_{th} candidate is added,

$\Delta\overline{Q_i} = \Delta Q_i / Q_{\max}$:normalized reactive power variation of network when i_{th} candidate is added,

$\Delta\overline{V}_i = \Delta V_i / V_{\max}$:normalized network voltage profile deviation variation when i_{th} candidate is added,

$\overline{C_i} = C_i / C_{\max}$: normalized cost

Therefore, according to above definition and using collective model of DEA method, evaluation of efficient candidates' formulation is obtained as follow [9-10]:

$$
\begin{aligned}
Max \quad & W_i = S_1^- + S_1^+ + S_2^+ + S_3^+ \qquad (6)\\
s.t: \quad & \sum_{j=1}^{N_i} \lambda_j \overline{C}_j + S_1^- = \overline{C}_i ,\\
& \sum_{j=1}^{N_i} \lambda_j \Delta\overline{P}_j - S_1^+ = \Delta\overline{P}_i ,\\
& \sum_{j=1}^{N_i} \lambda_j \Delta\overline{Q}_j - S_2^+ = \Delta\overline{Q}_i ,\\
& \sum_{j=1}^{N_i} \lambda_j \Delta\overline{V}_j - S_3^+ = \Delta\overline{V}_i ,\\
& \sum_{j=1}^{N_i} \lambda_j = 1,\\
& \lambda_j \ge 0,\ j = 1,\dots,N_i,\\
& S_1^-, S_1^+, S_2^+, S_3^+ \ge 0.
\end{aligned}
$$

Where:

S_1^- : the possibility of input reduction

S_1^+, S_2^+, S_3^+ : the possibility of outputs rises

W_i : summation of possibility of input reduction and outputs rise from i_{th} candidate up to when i_{th} candidate map on the efficient frontier.

3.1 Ranking of efficient candidates

After evaluating of candidates using collective model of DEA, it is possible to obtain more than one efficient candidate. So, it required to rank the efficient candidates. In [11], norm model L_1 is introduced for ranking of efficient DMU in 2004. In the L_1 model, DMU under evaluation is eliminated from possibility of production set and the shortest distance from the new border is calculated. Movement toward new border in the mentioned model is performed using norm model L_1 to obtain the shortest distance correspond DMU from the new border. According to introduced variable in previous section, norm model L_1 for ranking of efficient candidates is given as fallow:

$$
\begin{aligned}
Min \quad & \Gamma_i(X,Y) = \left|\overline{C} - \overline{C}_i\right| + \left|\Delta\overline{P} - \Delta\overline{P}_i\right| \\
& + \left|\Delta\overline{Q} - \Delta\overline{Q}_i\right| + \left|\Delta\overline{V} - \Delta\overline{V}_i\right| \\
s.t. \quad & \sum_{j=1, j\ne i}^{N_i} \lambda_j \overline{C}_j \le \overline{C}_i, \qquad (7)\\
& \sum_{j=1, j\ne i}^{N_i} \lambda_j \Delta\overline{P}_j \ge \Delta\overline{P}_i,\\
& \sum_{j=1, j\ne i}^{N_i} \lambda_j \Delta\overline{Q}_j \ge \Delta\overline{Q}_i,\\
& \sum_{j=1, j\ne i}^{N_i} \lambda_j \Delta\overline{V}_j \ge \Delta\overline{V}_i,\\
& \sum_{j=1}^{N_i} \lambda_j = 1,\\
& \overline{C}, \Delta\overline{P}, \Delta\overline{Q}, \Delta\overline{V}, \lambda_j \ge 0, \quad j = 1,\dots,N_i.
\end{aligned}
$$

In above model, $DMU,(X,Y)$ is from new border that it has the shortest distance to DMU_i (i.e under study DMU). $\Gamma_i(X,Y)$ is distance between (X_i, Y_i) and (X,Y) using L_1 norm.

$$
X_i = \left(\overline{C}_i\right), i = 1,\dots,N_i, , Y_i = \begin{pmatrix} \Delta\overline{P}_i \\ \Delta\overline{Q}_i \\ \Delta\overline{V}_i \end{pmatrix}
$$

$$
X = \left(\overline{C}\right), Y = \begin{pmatrix} \Delta\overline{P} \\ \Delta\overline{Q} \\ \Delta\overline{V} \end{pmatrix}
$$

Where:

X: input vector of an DMU belongs to the new border

Y: output vector of an DMU belongs to the new border

X_i: input vector DMU_i (under study DMU)

Y_i: output vector DMU_i (under study DMU)

λ_j : input and output coefficients of DMUs

s: number of outputs

m: number of inputs

N_i: number of candidates

According to provided formulation, flowchart of optimum DG sources design to minimize loss and to modify voltage profile of distribution network using DEA method is given in Fig.1.

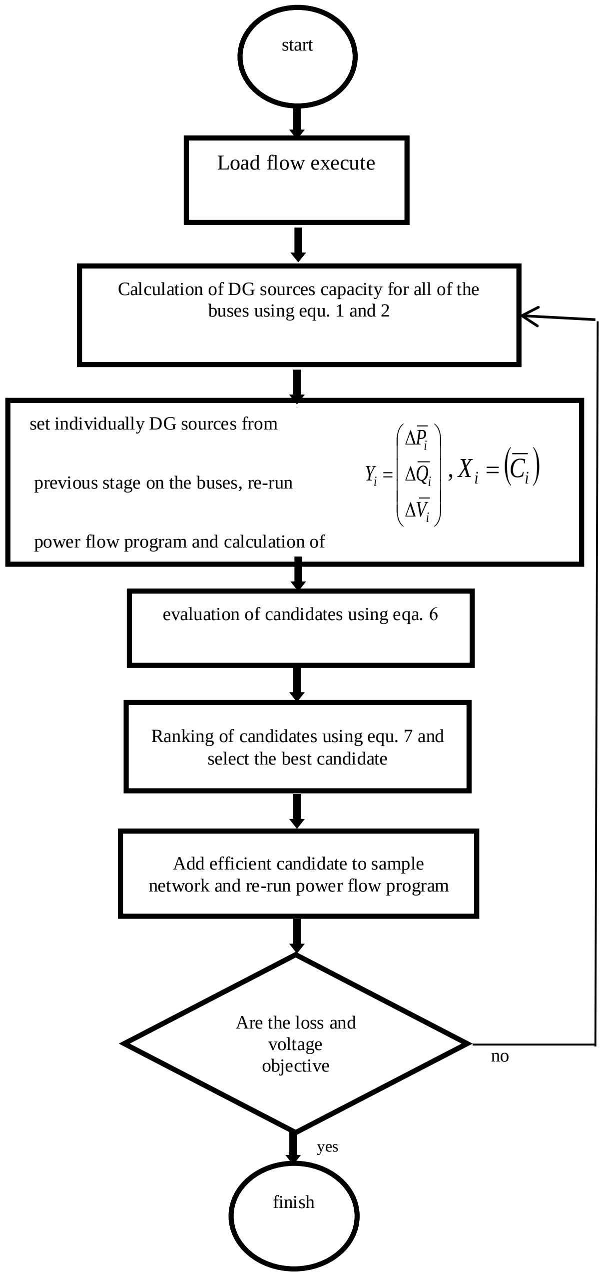

Fig. 1 flowchart of optimum placement and capacity of DG with the aim of loss reduction and voltage profile improvement using DEA method

4. Proposed method simulation

In this section, proposed algorithm is implemented on the 33 and 69 bus sample systems. System information before DG source placement is given in table 1. Active power loss is 0.2100 and 0.2250 for 33 and 69 bus systems, respectively. Here, the aim is loss reduction and voltage profile improvement.

Table1. Sample system information

	33 bus system	69 bus system
Network active power loss (MW)	0.2110	0.2250
Network reactive power loss (MW)	0.1430	0.1021
Vmin (p.u)	0.9038	0.9092
Vmax (p.u)	1.0000	1.0000
Network load (MVA)	3.7150+2.3000i	3.8021+2.6945i

Applying proposed algorithm to system, the results are obtained that are provided in table 3.

Table2. optimum location and capacity of DG install using DEA method

	33 bus system	69 bus system
Optimum location of DG install	6	61
Optimum capacity of DG (MW)	3.0183	2.2399
Network active power loss (MW)	0.0679	0.0238
execution time(s)	6.4510	10.78

It can be observed from table 2 that the best location to install DG for 33 bus system is bus 6 and its optimum size is about 3.0183 MW. After installing the DG, active power loss of 33 bus system is decreased about 71%. Also, the results are obtained for 69 bus system. The best location for DG install is bus 61 and its optimum capacity is 2.2399 MW that in comparison to without DG installation, active power loss is decreased 87%.

In order to validate proposed method, obtained simulation results is compared with results corresponding to GA. The GA-based method results are provided in table 3.

Table 3. optimum location and capacity DG install using GA method

	33 bus system	**69 bus system**
Optimum DG location	6	61
Optimum capacity of DG (MW)	3.1921	2.3456
Network active power loss (MW)	0.0882	0.0739
execution time(s)	20.06	137.99

Considering of table 2 and 3, it is observed that optimum location for DG install is bus 6 and bus 61, for 33 and 69 bus system, respectively, using both proposed and GA method. However, in term of loss, DEA-based method provides better results. On the other hand, as the system is bigger, execution time of GA- base method is very long, so that the execution time of GA method is 13 as much as proposed method. The time is larger bigger systems.

Fig. 2 and 3 show voltage profile of 33 bus system and 69 bus system before and after DG installation, respectively.

Considering fig. 2 and 3, after installing DG, voltage profile for both 33 and 69 bus system is modified. The minimum voltage is 0.96 pu and 0.97 pu for 33 and 69 bus system, respectively.

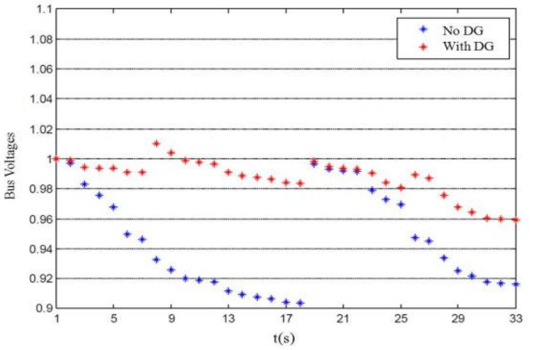

Fig. 2 voltage profile before and after DG install for 33 bus system

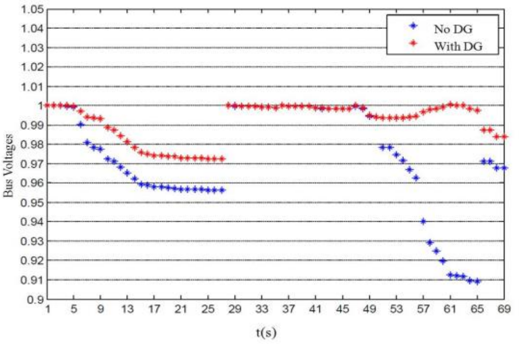

Fig. 3 voltage profile before and after DG install for 69 bus system

5. Conclusion

Location and capacity of DG are two important factors for power loss reduction and distribution voltage profile improvement. A new algorithm for optimum location and capacity determination using DEA method is presented in this paper. As it can be observed from results, location and capacity determination of DG using proposed method, valuable advantage such as loss reduction and voltage profile improvement are obtained.

Also, with comparing the proposed method to GA-based method, it is proved that proposed method introduces a DG with capacity less than GA method which provides better results from different points of view such as loss reduction, voltage profile improvement, and execute time.

References

[1] Golshan M, Arefifar S. Optimal allocation of distributed generation and reactive sources considering tap positions of voltage regulators as control variables. European Transactions on Electrical Power. 2007 Nov; 17(3): 219-239.

[2] Atwa Y, El-Saadany E. Probabilistic approach for optimal allocation of wind-based distributed generation in distribution systems. IET Renewable Power Generation. 2011 Feb; 5(1): 79-88.

[3] Prommee W, Ongsakul W. Optimal multiple distributed generation placement in microgrid system by improved reinitialized social structures particle swarm optimization. European Transactions on Electrical Power. 2011 Jan; 21(1): 489-504.

[4] Rau N, Wan Y. Optimum Location of Resources in Distributed Planning. IEEE Transaction on Power System. 1994 Nov; 9(4): 2014-2020.

[5] Nara K, Hayashi Y, Ikeda K. Ashizawa K. Application of tabu search to optimal placement of distributed generators. Proceedings of IEEE Power Engineering Society Winter Meeting. 2001 Feb; 2(1): 918–923.

[6] El-Khattam W, Bhattacharya K, Hegazy Y, Salama M. Optimal investment planning for distributed generation in a competitive electricity market. IEEE Transaction on Power System. 2004 Jan;19(3): 1674–1684.

[7] Soroudi A, Ehsan M, Caire R, Hadjsaid N. Hybrid immune- genetic algorithm method for benefit maximization of distribution network operators and distributed generation owners in a deregulated environment. IET Renewable Power Generation. 2011 Oct; 5(9): 961-972.

[8] Acharya N, Mahat P, Mithulananthan N. An analytical approach for DG allocation in primary distribution network. International Journal of Electric Power Energy System. 2006 Dec; 28(10): 669–678.

[9] Banker R.D, Charnes A, Cooper W.W. Some models for estimiating technical and scale inefficies in data envelopment analysis. Management Science. 1984 Sep;30(9): 1078-1092.

[10] Charnes A, Cooper W.W, Golany B, Seiford L, Stutz J. Foundations of data envelopment analysis and pareto–koopmans empirical production function. Journal of Econometrics. 1985 Nov; 30(1): 91–107.

[11] Jahanshahloo G.R, Hosseinzadeh Lotfi F, Shoja N, Tohidi G, Razavyan S. Ranking using $l1$ -norm in data envelopment analysis. Elsevier, Applied Mathematics and computation. 2004 May; 153(1): 215-224.