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Determining the Optimal Capacity and Place of DGs in Distribution Systems

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Abstract. Increasing application of distributed generation on distribution networks is the direct impact of development of technology and the energy disasters that the world is encountering. Using these resources in distribution network is one of the most influential solutions to reduce losses, improve voltage profile and improve power quality. To obtain these goals the resources capacity and the installation place are of a crucial importance. In this paper a new method is proposed to find the optimal and simultaneous place and capacity of these resources to reduce losses, improve voltage profile and reduce network harmonics. The proposed method is also capable of identifying the appropriate number of resources. The method is tested on actual power network of Zanjan Province, Iran and the simulation results are presented and discussed. Genetic algorithm is used to obtain the best answers.

Introduction

Distributed Generation (DG) is defines as small generation units which are directly connected to the network [1]. Using these kinds of resources can have a key role in tackling with problems such as too much loss in distribution and transmission network, low power quality and high density of power flow in transmission network [2]. In addition, DG's small capacity makes designing and installing these resources easier in comparison to the immense and concentrated units [3]. Therefore, DG resources are predicted to play a significant role in the network structure and electrical markets of near future [4], [5].

Identifying the optimal capacity and place of DG in distribution network is one of the most important issues of installing and exploiting these resources. The benefits of these resources are available just after comprehensive sitting and sizing studies. Many studies have been conducted about the issue of siting and sizing of DG resources. Authors in [2] have used repetitive research along the network to identify the appropriate size and place of DG to diminish losses and cost.

A determination of the allowable DG penetration level is carried out, based on harmonic limit consideration in [6] which is restricted to radial distribution feeders with uniform, linearly increasing or decreasing load pattern. In [7] the method of identifying the maximum generating capacity of DG to avoid non-coordination of recloser and fuse is used. Authors of [8] proposed a formulation to identify the appropriate capacity and location of DG to diminish losses, improve voltage profile and reduce harmonics using PSO Algorithm. The proposed formulation is tested on a test network and no constraint was considered during siting and sizing. In [9] a value-based method is used to increase the reliability and benefit of installing DG resources. DG benefits which were considered in includes: power cost saving, power loss reduction, and reliability enhancement.

Power quality has turned to be an increasingly important issue due to application of more sensitive loads in the recent years. This issue clears the significant role of considering the power quality factors in sizing and siting the DG resources. Therefore, this paper is aimed to identify the optimal size and capacity of DG to reduce losses, improve voltage profile and diminish network harmonics. GA is used to optimize the objective function and identify the best location and capacity of DG resources. Some constraints are also considered to make the proposed method applicable in actual networks. These constraints includes: the amount of produced power of DG units, the amount of allowable penetration level of resources in network, minimum power factor of resources and the voltage level of buses. The proposed formulation is tested on the actual power network of Zanjan Province, Iran and the simulation results acknowledge the efficiency of the method.

The New Method

Objective function. The proposed method is aimed to find the best place and location of DG according to the improvement of technical parameters of the network which includes: voltage profile, losses and harmonics. THD index presents the impact of the harmonics on network and is considered in the objective function according to the following equation, as in Eq. 1.

$$THD = \frac{\sqrt{\sum_{h=2}^{n} V_h}}{V_L} \tag{1}$$

where V_L is the RMS value of the voltage main character in 50 hertz frequency, h is the harmonic order, and V_h is the RMS value of the voltage in h-th harmonic. Therefore, the objective function ca n be defined as the following equation, as in Eq. 2.

$$OF = \min(f(W_p.F_p + W_V.F_V + W_T.F_T)) \tag{2}$$

where F_p , F_V and F_T represent loss reduction, voltage improvement and THD reduction respectively. W_p, W_V and W_T are also the weighting factors of these objectives, respectively. These weighting factors show the importance of each objective in siting and sizing. The absolute values of the weights assigned to all impacts should add up to one as shown in Eq. 3 [1].

$$W_p + W_V + W_T = 1 \tag{3}$$

Each objective of the objective function is calculated as in Eq.4.

$$F_P = \frac{P_{Loss}^{WithOut\ DG} - P_{Loss}^{With\ DG}}{P_{Loss}^{WithOut\ DG}} \tag{4}$$

where $P_{Loss}^{WithOut\ DG}$ and P_{Loss}^{With} are the total losses of the network before and after installing DG resources, respectively [1].

$$F_V = \sum_{i=1}^{n} \left| 1 - V_{Level,i}^{With\ DG} \right| \tag{5}$$

In Eq. 5 F_V is the sum of all voltage deviations up to 1pu and n is the number of distribution network buses and $V_{Level}^{With\ DG}$ is the voltage value of each bus. To calculate THD value, the following equation is used, as in Eq. 6.

$$F_T = \sum_{i=1}^{n} \frac{THD_i^{withOut\ DG} - THD_i^{With\ DG}}{THD_i^{withOut\ DG}} \tag{6}$$

where $THD_i^{Without\ DG}$ and $THD_i^{With\ DG}$ are the THD value of each bus, before and after installing resources.

Constraints. Optimizing the objective function requires that many constraints be considered. This paper takes into account the following.

The maximum active and reactive power produced by a DG. Although DG exploitation can have many economical benefits, these benefits are significant only when the active and reactive power produced by a DG is less than network load [10], as in Eq.7.

$$\sum_{i=1}^{NDG} P_{DG,i} = \sum_{j=1}^{M} P_{d,j} + P_{Loss} \quad (7)$$

where NDG is the number of DG units, M is the number of network loads, $P_{DG,i}$ is the amount of produced power by each DG unit and $P_{d,j}$ is the require power of each load of the network. There is a similar constraint for the produced reactive power.

DG penetration level. Penetration level of the DG resources on the distribution network is defined as in Eq. 8.

$$DG_{Penetration} = \frac{1}{P_{total}} \sum_{i=1}^{N_{DG}} P_{DG,i} \quad (8)$$

In this paper, this amount is assumed to be 0.3 for DG resources.

Constraint of the power factor of DG resources. Since the electrical companies are interested in exploiting DG resources in a high power factor, the minimum power factor is assumed to be 0.8.

Voltage level constraint. The voltage profile of all the buses should be within the specified range, as in Eq. 9.

$$V_{\min} \le V_{Level}^{WithDG} \le V_{\max} \quad (9)$$

where $V_{\min}$ and $V_{\max}$ are the minimum and the maximum of the allowable voltage and are assumed to be 0.95 and 1.05, respectively [1]. DG resources can be places until the foregoing constraint are observed. Thus the appropriate number of DG resources can be identified using these constraints.

Proposed Method

Case Study. To study the proposed method, actual power network of Zanjan Province, Iran is simulated in DIgSILENT. Fig. 1, illustrates the single-line diagram of this network.

The Proposed Algorithm. The proposed formulation finds the best place and capacity of DG resources according to the following algorithm in Fig. 2.

Genetic Algorithm. Genetic algorithm (GA) is an evolutionary method which involves regarding all control variables as a single chromosome, producing an initial population, and then assessing it. Unlike other methods, this algorithm can optimally determine the place and capacity of more than one DG simultaneously. It is often used to optimize a function with different variables [10]. Further information and details about GA can be obtained from [10].

Simulation Results

Initially, a load flow was run for the case study in both fundamental frequency and harmonics frequencies without installation of DG. Their results are summarized in Table 1, and the network total loss in this state is 10.72MW. Applying the proposed algorithm to the test network, following place and capacity for DG resources is obtained. Table 2 depicts the locations, active and reactive capacity and the power factor of the DG resources. As it is clear, all the obtained values confines with all the considered constraints. The obtained penetration lever is 0.27, which is less than the assumed allowable value. In addition, the power factor of all the units is assumed to be 0.8 and produced active and reactive of DG resources are less than the active and reactive load of the network. The following figure depicts the voltage of distribution buses, before and after installing five DG resources and clarifies the impact of these resources on voltage profile.

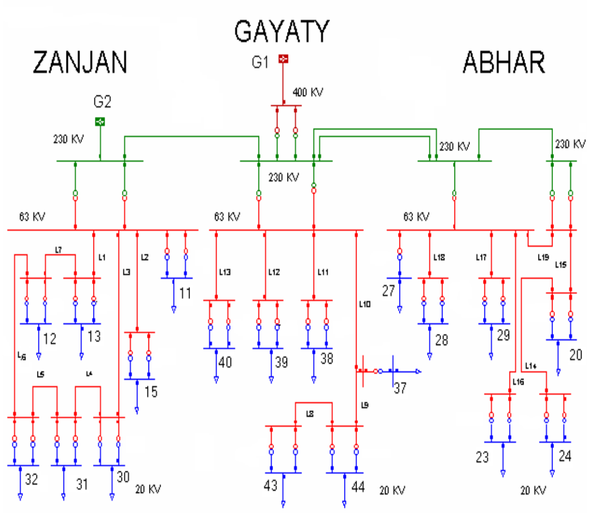

Fig. 1. Single-line diagram of actual power network of Zanjan Province

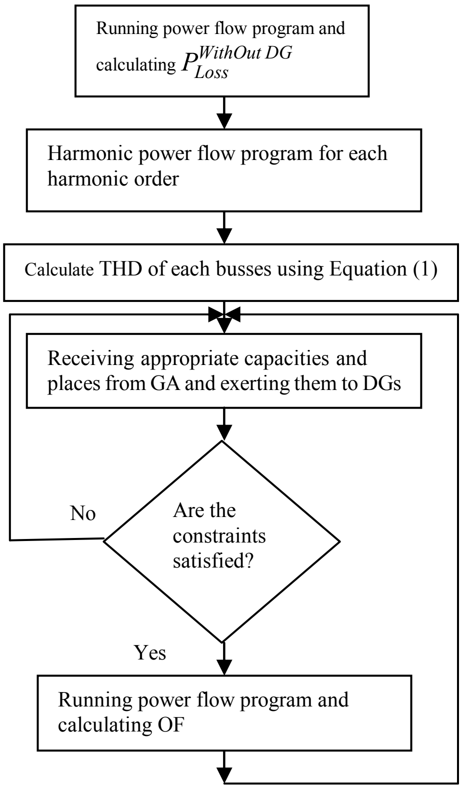

Fig. 2. Flow chart of implemented methodology

Table 1. Results of power flow and harmonic power flow without installation of DG

Bus Number	V(Pu)	%THD
11	0.9726	0. 263
12	0.8993	1. 106
13	0.9561	0. 553
15	0.9659	0. 263
20	0.9456	0. 196
23	0.9423	0. 123
24	0.8905	0. 275
27	0.9519	0. 132
28	0.8955	0. 290
29	0.9411	0. 126
30	0.9268	1. 30
31	0.8876	1. 474
32	0.8818	3. 425
37	0.9393	0. 460
38	0.9541	4. 136
39	0.9481	0. 285
40	0.9418	0. 261
43	0.8495	0. 468
44	0.9055	2. 226

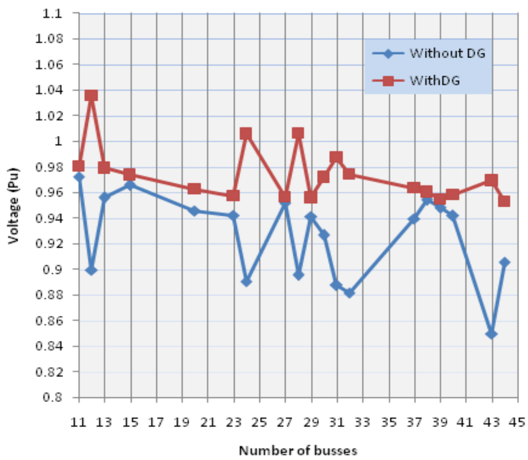

Fig. 3. Voltage profile, before and after installing DG resources

Table 2. Optimal place and capacity of DG resources

DG Locations	DG Capacity (MW)	DG Capacity (MVar)	DG Power factor
12	25	11.75	0.8
31	10	7.5	0.8
28	10	7.5	0.8
43	20	15	0.8
24	15	11.25	0.8

As it is shown in Fig. 3 the voltage profile has experienced a significant improvement. Before installing resources the voltage profile of only 5 buses are in the allowable range, but after installing DG resources, the voltage profile of all the buses have ranged within the allowable range. In addition the total network loss, which was 10.72MW before installing DG resources has diminished to the 4.52MW which shows 57.83% decrease. Table 3 shows the impact of installing five DG resources on THD of buses.

Table 3. Results of power flow and harmonic power flow with installation of five optimal DGs

Bus Number	V(Pu)	%THD
11	0.9802	0. 25
12	0.1.035	0.34
13	0.979	0. 28
15	0.9736	0. 25
20	0.9628	0. 19
23	0.957	0. 09
24	1.005	0. 13
27	0.9565	0. 1
28	1.006	0. 11
29	0.9559	0. 11
30	0.9719	0.42
31	0.9877	0.41
32	0.9742	0.60
37	0.9635	0. 37
38	0.9605	0.62
39	0.9545	0. 25
40	0.9583	0. 23
43	0.9694	0.38
44	0.9528	0.57

As Table 3 shows, all the THD levels are reduced after installing DG resources. The THD of bus 32 which was 3.425% has the highest value in all the buses before installing DG resources, but after installing these resources this amount has faced 82.48% decrease and the THD value of this bus has turned to 060%.

Conclusion

This paper presented a simple and flexible method to optimally determine the capacity and location of DG resources. Using the considered constraints, the proposed method is also capable of identifying the appropriate number of DG resources. The method is aimed to reduce network losses, diminish the THD and improve the voltage profile. The suggested technique has been applied to the actual power network of Zanjan Province, Iran and the optimal capacity and location of 5 DG resources have been identified. Simulation results show that the total network loss is decreased 57.83% and the THD value of all the buses has decreased. In addition the voltage profile of all the buses ranges within the allowable rang, after installing resources.

References

[1] Mohab M. Elnashar, and Magdy M.A. Salama, “Optimum siting and sizing of a large distributed generator in a mesh connected system”, Electric Power Systems Research, 2009.

[2] S. Ghosh, S.P. Ghoshal, “Optimal sizing and placement of distributed generation in a network system”, Electrical Power and Energy Systems, 32, pp. 849–856, 2010.

[3] N. Acharya, P.Mahat, and N.Mithulananthan, “An analytical approach for DG allocation in primary distribution network”, Science Direct, Electrical Power and Energy Systems 28, 2006.

[4] L.F Ochoa, A. Padilha, G.P Harrison, “Evaluating Distributed Generation Impacts With a Multiobjective Index”, IEEE transactions, vol.21, 2006.

[5] Barker P. P., “Determining the impact of distributed generation on power systems: Part 1-Radial distribution systems”, Proc. IEEE Power Eng. Soc. Summer Meeting, pp. 1645–1656, 2000.

[6] A. Bhowmik, A. Maitra, S.M. Halpin, J.E. Schatz, “Determination of allowable penetration levels of distributed generation resources based on harmonic limit considerations”, IEEE Transactions On Power Delivery, 18 (2), pp.619–624, 2003.

[7] S.Chaitusaney, A.Yokoyama, “Prevention of reliability degradation from recloser–fuse miscoordination due to distributed generation”, IEEE Transactions On Power Delivery, Vol. 23, No. 4, pp. 2545-2554, October 2008.

[8] M.Sadighi, S.M.Abedi, “Sitting and Sizing ofDG in Distribution Network to Improve of Several Parameters by PSO algorithm”, International Conference on Mechanical and Electrical Technology, ICMET 2010.

[9] Jen-Hao Teng, Yi-Hwa Liu, Chia-Yen Chen, “Value-based distributed generator placements for service quality improvements”, Electrical Power and Energy Systems, 29, pp. 268–274, 2007.

[10] M. Mashhour, M. A. Golkar, “Optimal sizing and siting of distributed generation in radial distribution network Comparison: of unidirectional and bidirectional power flow scenario”, IEEE Bucharest Power Tech Conference, June 28th - July 2nd, Bucharest, Romania, 2009.