academicJournals

Vol. 8(31), pp. 1471-1477, 18 August, 2013
DOI 10.5897/SRE2013.5527
ISSN 1992-2248 © 2013 Academic Journals
http://www.academicjournals.org/SRE

Scientific Research and Essays

Full Length Research Paper

Placement of distributed generation units using multi objective function based on SA algorithm

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Accepted 6 August, 2013

This article presents an optimal placement method in order to size and sit distributed generation in IEEE 33 bus test system. The algorithm for optimization in this paper is Simulated Annealing. The proposed objective function considers active power losses of the system and the voltage profile in nominal load of system. In order to use Simulated Annealing algorithm, at first, placement problem is written as an optimization problem which includes the objective function and constraints, and then to achieve the most desirable results, Simulated Annealing (SA) method is applied to solve the problem. High performance of the proposed algorithm in mention system is verified by simulations in MATLAB software and in order to illustrate of feasibility of proposed method this optimization in three cases – one DG unit, Two DG units, and Three DG units- will accomplish.

Key words: Distributed generation, DG placement, simulated annealing, multi-objective function, optimization.

INTRODUCTION

Nowadays distributed or decentralized generation units connected to local distribution systems, almost are not dispatchable by a central operator, but they can have intricately effect on the power-flow, voltage profile, stability and quality of power supply for customers and electricity supplier’s (Hedayati et al., 2008). The output power of Major of Distributed Generations (DGs) such as wind turbine and fuel cells depends on the condition of weather and cannot forecast originally (Noradin Ghadimi, 2013).

The concern about the limitation of fossil fuels and also rising consciousness of environmental protection, cause the installation of DGs increase annually (Noradin and Alireza, 2013). Growing of Distributed Generation can have influence in voltage profile, stability, power loses at power system both in distribution and transmission side. In order to improve power system situation such as correction of voltage profile, addition of stability, decrease of loses power and etc, it is necessary that the installation of DGs in power system become systematical (Thong et al., 2007).

In Gandomkar et al. (2005), the authors determined the optimum location of the DG in the distribution network. The work was directed towards studying several factors related to the network and the DG itself such as the overall system efficiency, the system reliability, the voltage profile, the load variation, network losses, and the DG loss adjustment factors. The main idea behind the study of Gozel and Hocaoglu (2009) is the selection of the optimum type of the DG. Depending on the DG type, the best location and size in distribution feeders is selected (Noradin and Rasoul, 2012).

In keane and O’Malley, (2006), a mixed integer linear program was proposed to determine optimum location. A TS search method to find the opFtimal solution of their problem was explained in Katsigiannis and Georgilakis,

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(2008), but the TS is known to be time consuming algorithm also it may be trapped in a local minimum.

In order to minimize real power losses of power system (Lalitha et al., 2010), a PSO algorithm was developed to specify the optimum size and location of a single DG unit. The problem was converted to an optimization program and the real power loss of the system was the only aspect considered in this study in order to determine optimal location and size of only one DG unit.

In El-Khattam et al. (2005), a deferent scenario was investigated for determination of optimum location of distributed generation in order to modify voltage profile and minimize the investment risk. A Genetic Algorithm (GA) based method with optimal power flow (OPF) calculations were formulated in order to minimize the cost of active and reactive power generation for determination of best size and location of DGs in power system. GA is a time consuming technique but it could reach global or near global solutions. In order to minimize line losses of power system - an analytical technique to determine the optimum location-size, a pair of DG unit was suggested (Gozel and Hocaoglu, 2009).

The placement of one DG unit with specific size in Ochoa et al. (2006) was explained. In this paper multi objective function such as power line losses, modifying of voltage profile, line loading capacity and short circuit level were considered. P-V curves in Singh and Goswami, (2010) have been used for analyzing voltage stability in electric power system to determine the optimum size and location of multiple DG units to minimize the system losses under limits of the voltage at each node of the system.

In this paper, Simulated Annealing (SA) which is capable of finding global or near global optimum solution is used for optimal size and site of Distributed Generation in 33-bus of IEEE test system with tie line that is present (Kashem et al., 2000). Objective functions are gathered to form a multi objective optimization problem. The objective function is formed by combining on real power losses and voltage profile of the mention system.

PROBLEM FORMULATION

Objective functions formulation

The objective function combined from two components. One part is Real Power Loss (RPL) that is 70% of mention objective function and Voltage Profile Improvement (VPI) that combined 30% of objective function.

Real power loss formulation (RPL)

Buses voltage, line currents and real power loss in system lines calculates from the output results of power-flow which is used of Newton-Raphson in this paper.

If v_i is *ith* bus voltage and v_j is *jth* bus voltage that specify power flow results, the line current between ith and jth buses is given by:

$$I_{ij} = \frac{V_i - V_j}{Z_{ij}} \tag{1}$$

Where Zij is the impedance between ith and jth buses, the transmission power between the ith and jth buses and vice versa is calculated by:

$$S_{ij} = V_i I_{ij}^* \tag{2}$$

$$S_{ji} = V_j I_{ji}^* \tag{3}$$

The real active loss between ith and jth buses is defined as:

$$P_{loss}^{i,j} = real(S_{ij} + S_{ji}) \tag{4}$$

Total loss power in power system is defined by:

$$P_{Loss}^{Total} = \sum_{i=1}^{N} \sum_{j=i}^{N} P_{loss}^{i,j} \tag{5}$$

Where, N is the number buses of power system and RPL is given by:

$$RPL = \frac{P_{Loss}^{Total}}{P_{Loss}^{nomin\,al}} \tag{6}$$

Where, $P_{Loss}^{nomin\,al}$ is the real power loss in nominal condition of study system.

Voltage profile improvement (VPI)

One of the avails of optimizes location and size of the DG is the improvement in voltage profile. This index penalizes the size-location pair which gives higher voltage deviations from the nominal value (Vnom). In this way, the closer the index to zero the better is the network performance. The VPI can be defined as

$$VPI = \max_{i=2}^{n} \left(\frac{|V_{nom}| - |V_i|}{|V_{nom}|} \right) \tag{7}$$

The Multi Objective Function (MOF) in this paper is in order to achieve the performance calculation of distribution systems for DG size and location is given by:

$$MOF = \sigma_1 IVD + \sigma_2 ILP \qquad (8)$$

Where σ_1 and σ_2 are consider in this paper as 0.7 and 0.3 respectively.

Constrains formulation

The multi objective function (11) is minimized and subjected to various operational constraints to satisfy the electrical requirements for distribution network. These constraints are as follows:

Power-conservation limits

The algebraic sum of all incoming and outgoing power including line losses over the whole distribution network and power generated from DG unit should be equal to zero.

$$P_{Gen} + P_{DG} - \sum_{i=1}^{n} P_D - P_{total}^{Loss} = 0 \qquad (9)$$

Distribution line capacity limits

Power flow through any distribution line must not exceed the thermal capacity of the line

$$S_{ij} < S_{ij}^{\max} \qquad (10)$$

Voltage limits

The voltage limits depend on the voltage regulation limits and should be satisfied.

$$V_i^{\min} \le V_i \le V_i^{\max} \qquad (11)$$

This paper employs Simulated Annealing technique to solve the above optimization problem and search for optimal or near optimal set of problem. Typical ranges of the optimized parameters are [0.01 100] MW for PDG and [0.95-1.05] for voltage of buses.

Simulated annealing algorithm

The SA algorithm performance like the other algorithms is based on search technique in the desired zone. First, several initial conditions are assumed to start the algorithm. In this process, determination is based on the particles energy, that is, an action in this method is acceptable whenever a particle in the position X_0 having energy E_0 goes to the position X having energy E such that if the current position is better than the before one, it is selected, unless the current position is selected with the following probability:

$$p(x) = e^{\frac{E-E_0}{k_B T}} \qquad (12)$$

Which, K_B and T are the Boltzmann coefficient and temperature, respectively. The possibility to accept the inferior position will be higher whenever the current position energy will be less than the previous one and the temperature is high. In T=0, the inferior condition will be never accepted. During this process, the temperature is decreased based on annealing law from the initial temperature T0 to the zero temperature, so that it means a search algorithm. Since this algorithm is strong, it could be better than the other ones to find the optimum point (Goffe et al., 1994). One of the annealing laws in the algorithm is defined as follows:

$$T(i) = \frac{T_0}{\ln(i)} \qquad (13)$$

i is the number of iterations.

In this optimization problem, the number of particles and the number of iterations are selected as 30 and 50, respectively. Dimension of the particles will vary for each condition.

CASE STUDY AND PLACEMENT RESULTS

In the case study presented in this part of this work, we investigated how DG placement affects system power loss reduction and voltage profile enhancement. The placement of only a single DG, two DGs and Three DGs are considered. To demonstrate the utility of the proposed placement algorithm, a 33-bus test system with tie lines that are present in Kashem et al. (2000) and shown in Figure 1 is considered and the system details are given in Table 1.

At first, this paper assumes that one DG unit size vary between 25 KW to 10 MW and will be placement in mentioned network. The results of this study are shown in Table 2 and Figure 2. Table 2 shows that the power loss of the network with DG and without DG. With comparing of power loss in two cases it is obvious that the DG placement can have effect in power loss in the whole mentioned network. Figure 2 illustrate buses voltage in two cases. With attention to this Figure, the voltage profile with DG unit is better than without DG and almost DG unit can have effect on all of the buses voltage.

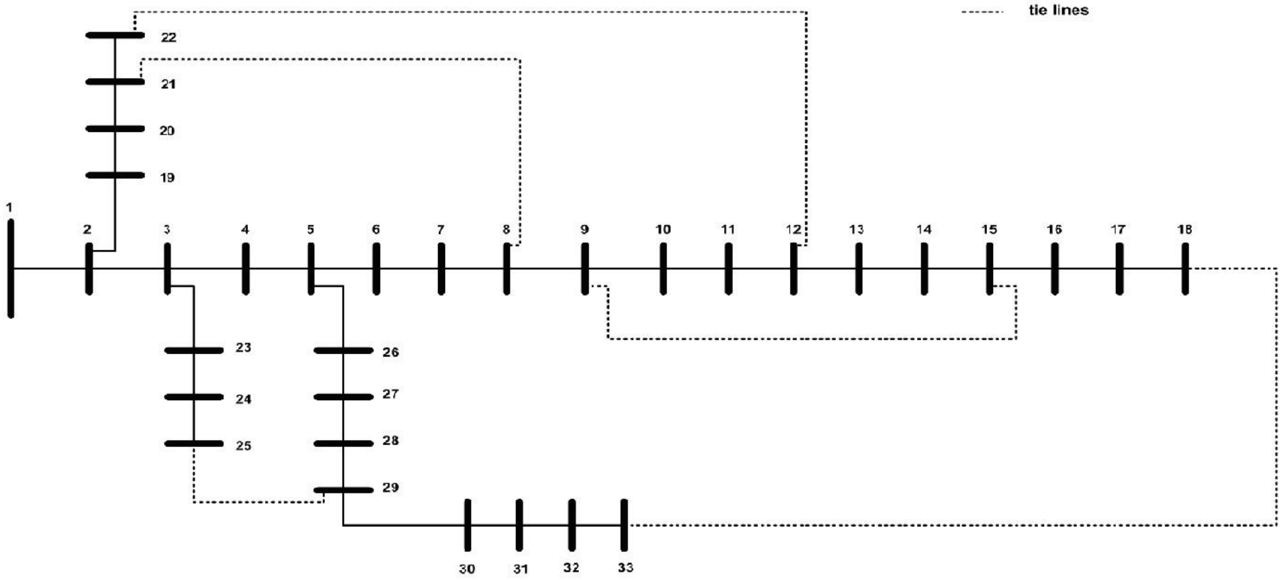

Figure 1. IEEE 33 bus study system with tie lines in ref (Kashem et al., 2000).

Table 1. Lines, active and reactive power details in study system.

Branch nom	Sen. node	Rec. node	Active Power of Rec. node KW	Reactive Power of Rec. node KVAr	Resistance ohms	Reactance ohms
1	1	2	100	60	0.0922	0.0470
2	2	3	90	40	0.4930	0.251 1
3	3	4	120	80	0.3660	0.1 864
4	4	5	60	30	0.3811	0.1941
5	5	6	60	20	0.8190	0.7070
6	6	7	200	100	0.1872	0.6188
7	7	8	200	100	1.7114	1.2351
8	8	9	60	20	1.0300	0.7400
9	9	10	60	20	1.0440	0.7400
10	10	11	45	30	0.1966	0.0650
11	11	12	60	35	0.3744	0.1238
12	12	13	60	35	1.4680	1.1550
13	13	14	120	80	0.5416	0.7129
14	14	15	60	10	0.5910	0.5260
15	15	16	60	20	0.7463	0.5450
16	16	17	60	20	1.2890	1.7210
17	17	18	90	40	0.7320	0.5740
18	2	19	90	40	0.1640	0.1565
19	19	20	90	40	1.5042	1.3554
20	20	21	90	40	0.4095	0.4784
21	21	22	90	40	0.7089	0.9373
22	3	23	90	50	0.4512	0.3083
23	23	24	420	200	0.8980	0.7091
24	24	25	420	200	0.8960	0.7011
25	5	26	60	25	0.2030	0.1034
26	26	27	60	25	0.2842	0.1447
27	27	28	60	20	1.0590	0.9337
28	28	29	120	70	0.8042	0.7006

Table 1. Contd.

29	29	30	200	600	0.5075	0.2585
30	30	31	150	70	0.9744	0.9630
31	31	32	210	100	0.3105	0.3619
32	32	33	60	40	0.3410	0.5302
33*	21	8			2.0000	2.0000
34*	22	12			2.0000	2.0000
35*	9	15			2.0000	2.0000
36*	25	29			0.5000	0.5000
37*	33	18			0.5000	0.5000

Table 2. Results of sizing and sitting with a single DG unit.

Number of DG	DG size	DG site	Network loss (KW)
Without DG	------	------	70.2
DG 1	2074.6	8	46.1

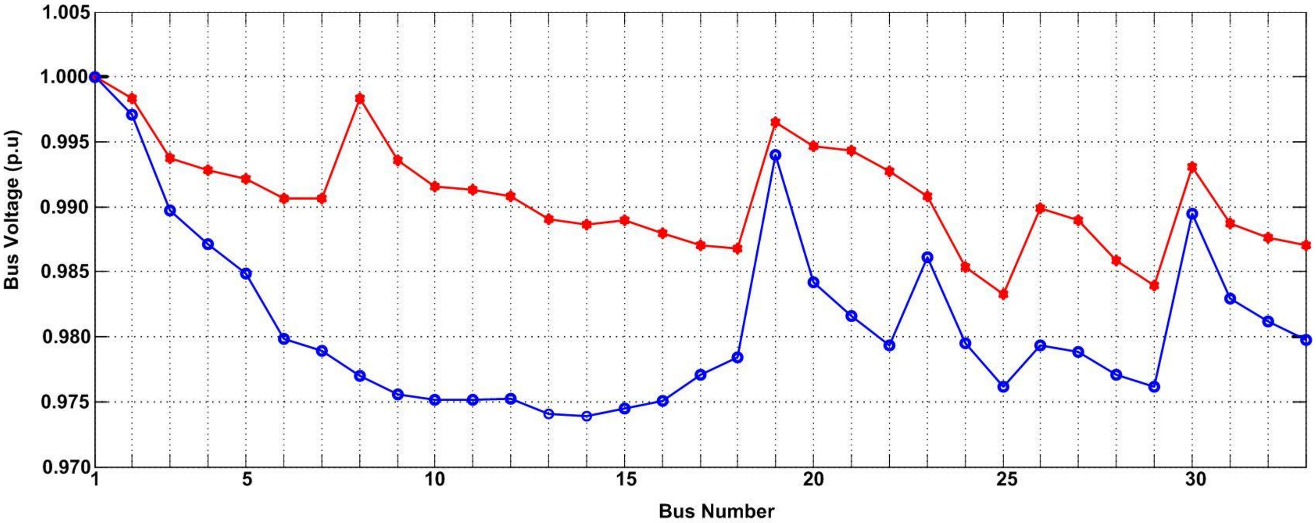

Figure 2. Voltage profile of study system with a single DG unit and without DG.

In other case, two DG units that size of them between 25 KW to 10 MW too, considered in order to location in mentioned system. Results of this case present in Table 3 and Figure 3. In this figure the voltage profile of three cases (without DG, one DG and Two DG units sizing and sitting) are presented. As can be seen, that is obvious the two DG placement results in line power losses and voltage profile is better than one DG unit and without DG in study system.

In the next study, we assume that three DG units in order of optimal placement are considered. The result of this study is in represented power system. The results of line power loss that are present in Table 4 depict in this case this power loss become less than other cases and in Figure 4 the voltage profile is shown. The voltage profile in this case is better than previous cases.

Conclusion

In this paper, a different approach based on Simulated Annealing in order of Multiobjective optimization analysis, including one, two and three DG units, for size-site planning of distributed generation in distribution system was presented. In solving this problem, at first, the problem was written in the form of the optimization problem which its objective function was defined and written in time domain and then the problem has been solved using SA. The proposed optimization algorithm was applied to the 33-bus test system with tie lines.

Table 3. results of sizing and sitting with two DG units-single DG and without DG.

Number of DG	DG Size	DG Site	Network Loss (KW)
Without DG	------	------	70.2
One DG	2074.6	8	46.1KW
Two DGs	1474.1 1605.8	14 25	34.8KW

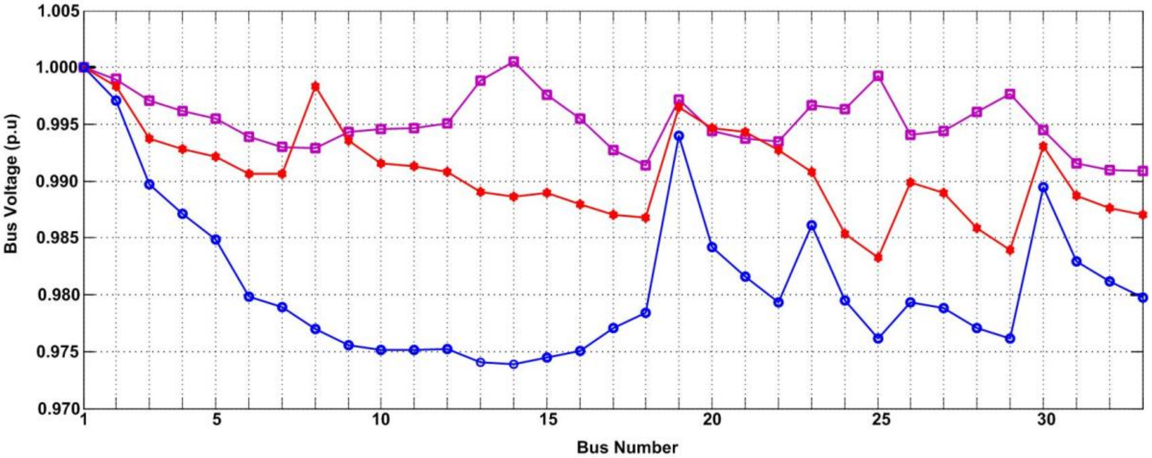

Figure 3. Voltage profile of study system with two DG units - single DG unit and without DG.

Table 4. Results of sizing and sitting with three DG units-two DG units-single DG and without DG.

Number of DG	DG Size	DG Site	Network Loss (KW)
Without DG	------	------	70.2
One DG	2074.6	8	46.1
Two DGs	1474.1 1605.8	14 25	34.8
Three DGs	1036.4 1416.4 939.47	18 9 25	31.7

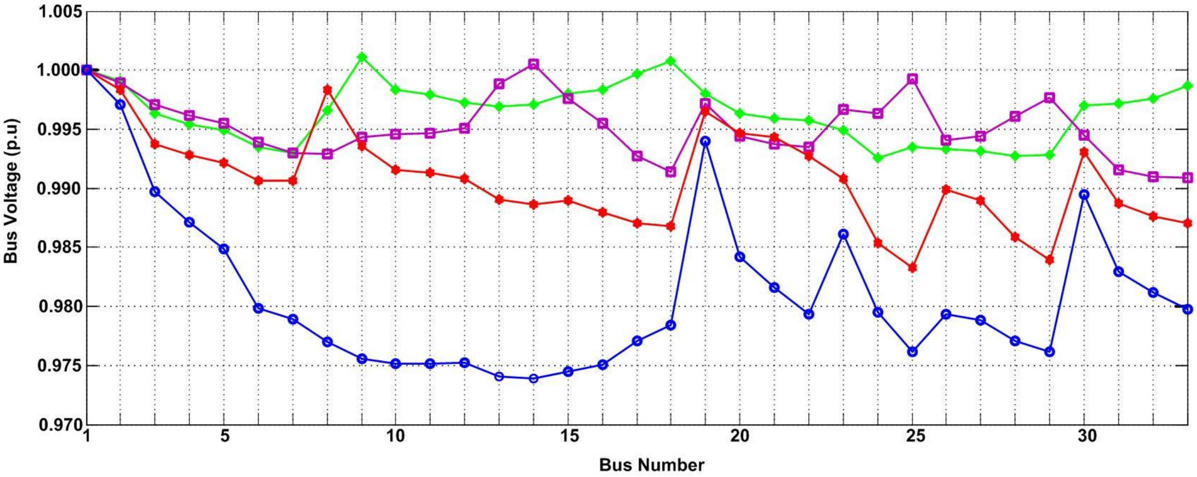

Figure 4. Voltage profile of study system with three DG units- two DG units - single DG unit and without DG.

The results clarified the efficiency of this algorithm for improvement of voltage profile and reduction of power losses in study system.

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