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Optimal Allocation of Solar based Distributed Generators in Distribution system using Bat Algorithm

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Abstract:

With increased demand of electrical energy, limited availability of fossil fuels and environmental concerns, it is necessary to consider renewable energy based generation in a power system network. Optimal allocation of renewable based distributed generators in the distribution system is a challenging task in the recent years. In this paper an effective technique is proposed for optimal allocation of solar based distributed generators in the distribution network using a Bat algorithm (BA) is presented. The objective is to minimize power loss of radial distribution system. Different operating constraints related to the distribution network are considered. The stochastic nature of solar irradiance is modeled by using suitable probability distribution function (PDF). The proposed method is tested and validated on IEEE 33 bus test system

Key words: Distributed Generators; BAT Algorithm; Power Loss Minimization; Solar DG

1. Introduction:

In recent years the entire world towards green technology, because of its concern regarding the environment, limited availability of fossil fuels and, rising demand of electrical energy. So there is a need to consider the renewable based generation in the distribution network. Among different types of renewable based generators, solar and wind-based generators are most commonly using technologies for generating electrical power. In the power system network, the losses in the distribution system are high, which needs to be minimized to improve the distribution network performance [1]. The losses in the distribution network are reduced with the optimal allocation of solar based distributed generators in the distribution network. From the last decade, many optimization techniques are used to solve DG allocation problem in the distribution system [2, 3, 4].In this paper, an efficient technique based on the bat algorithm is proposed to determine the optimal allocation of solar based distributed generators in the distribution system for minimizing distribution network power losses.

The remaining sections are as follows: Problem formulation is explained in section2, solar farm modeling is explained in section 3, Application of the bat algorithm for optimal allocation of solar based DGs is explained in section 4, Results and discussion followed by conclusion are explained in section 5 and 6.

2. Problem formulation:

The main goal of solar based DG allocation is to reduce the real power losses of the distribution system with satisfying different constraints.

$$Objfun = \min(P_{loss}) \tag{1}$$

Constraints:

Power balance constraints:

$$\sum_{m=1}^{nDG} P_{solarDG} + P_{subs} = P_{loss} + P_D \tag{2}$$

Voltage constraint:

$$V_{m,\min} \leq |V_m| \leq V_{m,\max} \tag{3}$$

3. Solar irradiance modeling and output calculation of PV module:

PV module output power mainly depends upon meteorological conditions like solar irradiance and temperature of a specific location. So it is necessary to model the stochastic nature of solar irradiance using the beta distribution function. The solar irradiance using beta distribution function is given by [5].

$$f_b(s) = \frac{\Gamma(\alpha+\beta)}{\Gamma(\alpha)\Gamma(\beta)} s^{\alpha-1}(1-s)^{(\beta-1)} \ \alpha, \beta > 0 \ \ 0 \leq s \leq 1 \tag{4}$$

where $\beta = (1-\mu)\left(\frac{\mu(1+\mu)}{\sigma^2} - 1\right)$, $\alpha = \frac{\mu\beta}{1-\mu}$, *Γ(°)*is the gamma function,*s* is the random variable of solar irradiance (KW/m^2) ,$f_b(s)$ is Beta distribution function. α and *β* are the parameters of the Beta distribution function. Mean and standard deviation of *s* is represented by *μ* and *σ* .

The output of a PV module at corresponding solar irradiance s is given by

$$P_o(s) = N*FF*V*I \tag{5}$$

The output power expected at solar irradiance s can be written as

$$P(s) = P_o(s) * f_b(s) \tag{6}$$

Where N is total number PV modules used. The specifications of PV module for determining output is taken from [5].

4. Bat algorithm for optimal allocation of solar based DGs

Bat algorithm is nature inspired algorithm developed by Xin-she-yang[6]. The basic concept depends upon echolocations of micro bats. Based on these bats are searching for maximum potential prey. The steps involved for solving the objective function are

1) Read the system data, i.e. line and bus data and run the distribution load flow and determine the base case power loss

2) Initialize the parameters, i.e. Population size(20), No of generations(40), loudness(A=0.5) and pulse rate(r=0.5) no of iterations, f_{min}, f_{max} dimension of search variables(No of solar DGs=3)[6].

3) Start the iterations and Update the solutions using

$$Q(i) = Q_{\min} + (Q_{\min} - Q_{\max}) * rand \tag{7}$$

$$V(i) = V(i) + (sol(i) - best)Q(i) \tag{8}$$

4) Determine the new solutions and if the new solutions are better, i.e. best fitness value update them.

5) Check the maximum iterations

6) If it reaches maximum iterations stopped otherwise repeat from step3

7) Display the best fitness values in terms of reduced power losses.

5. Results and discussion:

The data related to 33 bus test system are taken from [7]. The real power loss without placement of solar based DGs is 210.99KW. Next, calculate the output power of solar based DGs and placed optimally in distribution system using bat algorithm. For that specification of PV module, solar irradiance, mean and standard deviation are taken from [5]. Next, determine the probability distribution function and expected output power from PV module. The output power of PV module 97.179 watts. The number PV modules used in this is 1400 to form a PV array. The output power of the PV array is 136.05KW. At any bus maximum 7 PV arrays are connected because of space and land availability. The best locations are identified by using bat algorithm, i.e. 15, 25, 30. At these identified locations PV arrays are placed from minimum penetration level to maximum penetration level that is shown in Table1.

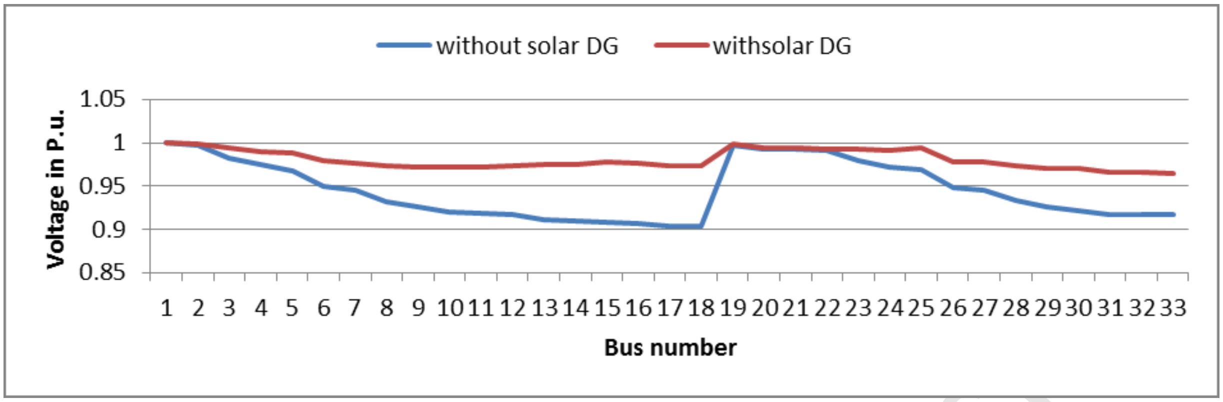

Fig.1. Voltage profile comparison without and with solar based DGs

Table1. Optimal allocation of PV arrays with different penetration levels for 33 bus system

Test system	No of buses	Location of Bus(Number of PV arrays)	P_{loss}(KW)	% Reduction of P_{loss}
33-Bus system	1	15(6)	137.20	34.97
	2	15(7), 25(7)	112.88	46.49
	3	15(6), 25(7), 30(7)	75.05	64.42

Table2: Comparisonof the proposed method with PSO and GA/PSO methods

Method	No of buses	Location of bus	Size of DG (KW)	P_{loss}(KW)	%Reduction of P_{loss}
PSO[3]	3	13 32 8	981.6 829.7 1176.8	105.35	50.06
GA/PSO[3]	3	32 16 11	1200 863 925	103.409	50.98
BA	3	15 25 30	816.3 952.35 952.35	75.05	64.42

From Table 1 it is clear that power loss is reduced effectively at highest penetration level. Next proposed method is compared with PSO and GA/PSO methods and the results are shown in Table 2. From Table 2 it is clear the bat algorithm performs well with reduced power loss minimization. Next comparison of the voltage profile before and after placement of solar based DGs is shown in Fig.1.It is observed that voltage profile is improved effectively with placement of solar based DGs. From the above results it is noticed that the proposed method minimizes the power loss effectively with satisfying all constraints.

6. Conclusion

Optimal allocation of solar based DGs in the distribution system using bat algorithm is presented. The developed method is tested on an IEEE 33 bus test system. From the simulated results it is observed that at highest penetration level of PV arrays optimally in the distribution system reduce the power loss effectively. Also a comparison of the proposed method with PSO and GA/PSO methods. The results clearly indicate that proposed method minimizes the power losses effectively.

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