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Energy Procedia 79 (2015) 917 – 923

Energy Procedia

2015 International Conference on Alternative Energy in Developing Countries and Emerging Economies

Power Loss Minimization in Radial Distribution System

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Abstract

Nowadays the number of consumers in the distribution system is increasing, the electricity demand and the number of capacitor bank placement is also increasing. Improper placement of capacitor bank leads to decrease the benefits of the system. The objective function of the proposed work is to minimize the total power loss of the system while satisfying all the constraints. The Loss Sensitivity Factor (LSF) has implemented to pre-identify the optimal location of the capacitor. An effective biologically inspired algorithm (Bat Algorithm) is proposed to search the optimal size of the capacitor banks. The proposed method has been tested on IEEE 34-bus distribution system to demonstrate the performance and effectiveness of the technique.

Peer-review under responsibility of the Organizing Committee of 2015 AEDCEE

Keywords: Power Loss Minimization; Bat Algorithm; Cumulative Voltage Deviation; Distribution system.

1. Introduction

As we move away from the substation the voltage of the radial distribution system will decrease due to lack of reactive power in distribution system. In the distribution system 10-13% of generated power is dissipated as I^2R losses [1]. Improper placement of capacitor will lead to reduce the benefits and even it collapse the entire distribution system [2-3]. The researchers used classical methods to solve optimal location and sizing of the capacitor placement [4]. Genetic algorithm was used to identify the location and sizing of the capacitor units and results were compared [5]. The particle swarm optimization was used to obtain location and sizing for the capacitor bank and their objective is to reduce power losses [6]. Direct search algorithms was implemented to locate and sizing of the capacitor placement in the distribution system [7].

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Peer-review under responsibility of the Organizing Committee of 2015 AEDCEE
doi:10.1016/j.egypro.2015.11.587

A Non-dominated sorting genetic algorithm was used to find the placement of capacitor in electric radial distribution system [8]. Hybrid SA and heuristics method were introduced for solving the optimal capacitor placement in distribution system in order to minimize power loss reduction [9-10]. Antunes Chet al. proposed the non-dominated sorting genetic algorithm to solve the optimal capacitor placement in radial distribution system for reactive power compensation Plant growth algorithm had used to allocate the capacitor units to minimize power losses [11]. Recently Bacterial Foraging Optimization algorithm was used to find the optimal location and sizing of the capacitor for the sake of power loss minimization [12]. All the authors had tried to minimize the power losses, but failed to minimize the number of compensating location. In the present work, the number of compensating location has been decreased to two and simultaneously achieved better results than that of other existing techniques.

In this paper, Bat algorithm has been proposed to find the optimal size of the capacitor. LSF is used to pre-find the optimal location of the capacitor placement. In this paper, the optimal location followed is slightly different from the existing method. The first and foremost aim of this work has to reduce the total power loss of the system. The proposed method is tested on IEEE 34-bus radial distribution system. The obtained results are compared with the other existing methods which founds to be better than that of other existing techniques

2. Problem Formulation.

The direct approach for distribution load flow is used to find the real and reactive power losses and the voltage at each branch [13]. The figure 1 shows the sample distribution system.

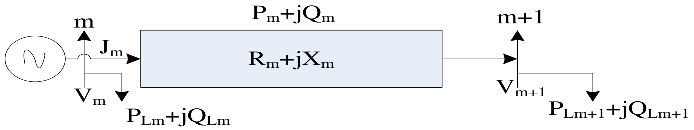

Fig.1. Sample distribution system.

The voltage at node m+1 is given by

$$V_{m+1} = V_m - J_m * (R_m + jX_m) \tag{1}$$

The branch current at each line can be calculated in a matrix form as follows

$$J = [BIBC] * [I] \tag{2}$$

Where BIBC is the Bus current Injection to Branch Current matrix.

$$i_m = \left(\frac{P_{Lm} + jQ_{Lm}}{V_m} \right)^* \tag{3}$$

The real and reactive power loss in the line section between buses m and m+1 is calculated by using the following equation

$$P_{loss}(m, m+1) = \left(\frac{P_m^2 + Q_m^2}{|V_m|^2} \right) * R_m \tag{4}$$

$$Q_{loss}(m,m+1)=\left(\frac{P_m^2+Q_m^2}{|V_m|^2}\right)*X_m \quad (5)$$

The total real and reactive power loss of the system can be easily found by summing of all the branch power loss and it is expressed in Equ. 6.

$$P_{T,Loss}=\sum_{m=1}^{nb}P_{Loss}(m,m+1) \quad (6)$$

2.1 Objective Function

The objective function of the proposed work is to minimize the power loss of the system**.** The mathematical formulation of the objective function is given by

Minimize (F) = min (P_{Loss}) (7)

Subject to the following operating constraints.

Power Balance

$$P_{ss}=\sum_{m=2}^{n}P_{Lm}+\sum_{m=1}^{nb}P_{Loss}(m,m+1)-\sum_{m=1}^{nb}P_{cap,m}$$

Voltage deviation limit

$$V_{m,\min}\le|V_m|\le V_{m,\max}$$

Reactive power compensation

$$Q_{cm}^{\min}\le Q_{cm}\le Q_{cm}^{\max}\ ,m=1,\ldots\ldots,N_B$$

3. Loss Sensitivity factor for capacitor placement.

The loss sensitivity factor is used to identify the location in order to install the capacitor [6]. The node which have highest value of LSF have more chance to install capacitor. Another advantage of using this method leads to reduce the search space for optimization process. The equation (4) is partially differentiate with respect to reactive power and it is given by

$$\frac{\partial P_{loss}(m,n)}{\partial Q_{mn}}=\frac{2Q_{mn}R_{mn}}{|V_m|^2} \quad (8)$$

The LSF values are sorted in descending order for all the lines and the buses which have the higher value has more chance for selecting candidate location to install the capacitor.

3.1 Bat Algorithm

Bat algorithms can be developed by idealizing some of the characteristics of bats. The approximated or idealized three rules are given by

1. Each bat utilizes echolocation characteristic to sense distance, and they also ‘know’ the difference between food/prey and background obstacles in some magical way using echolocation property.

2. Each bat flies randomly with velocity V_i position X_i , with a frequency $f_{\min}$ varying wavelength λ and loudness A0 to seek for prey. It has an ability to regulate the frequency (or wavelength) of their emitted pulse and regulate the rate of pulse emission 'r' in the range of [0, 1] relying on the proximity of its aim.

3. Even though the loudness can vary in different ways we assume that the loudness varies from a large positive A_0 to a minimum constant value Amin.

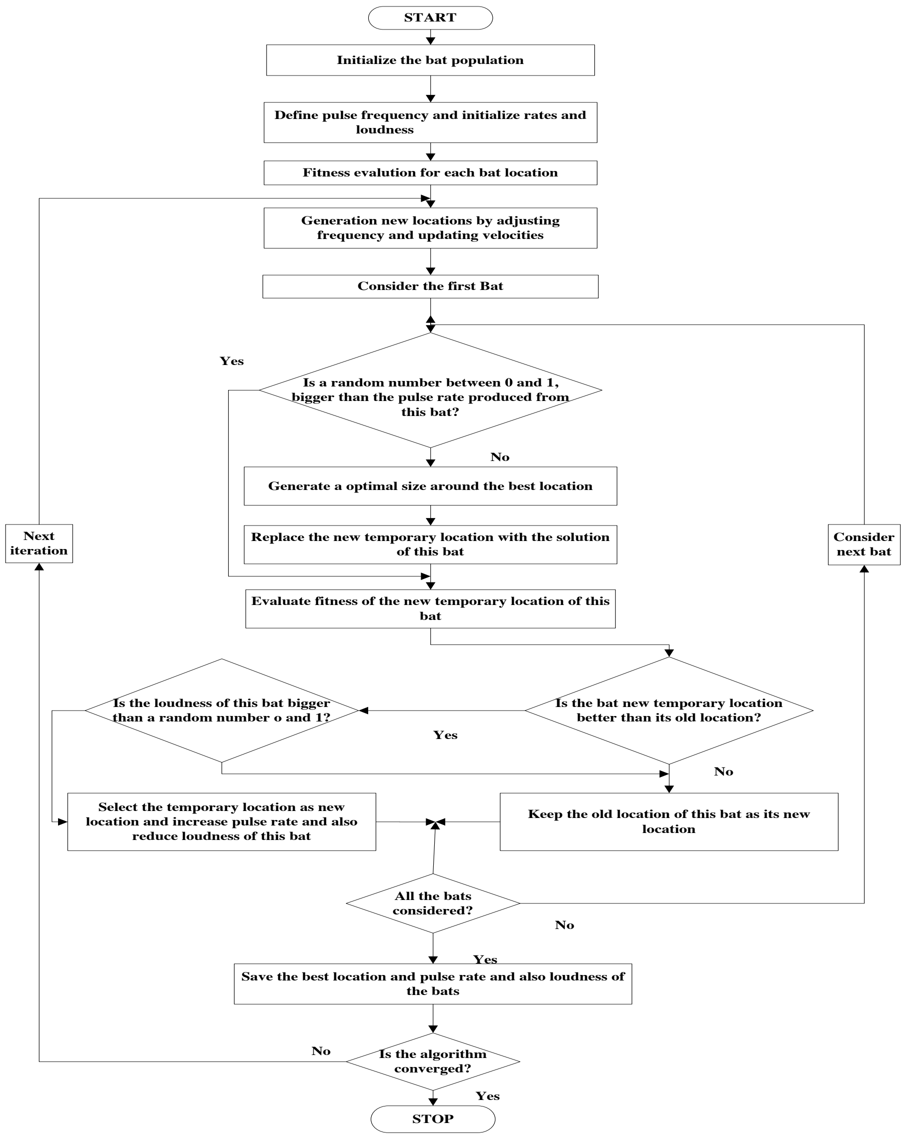

Fig 2. Flow chart of Bat Algorithm.

Hence this steps have to be follow in order to minimize the objective function.

4. Result and Discussion.

IEEE 34-bus radial test system

The proposed method is applied to IEEE 34-bus radial distribution system. The line data and bus data for this system is given in [10]. The total real power of the system is 4636.5 KW and reactive power of the system is 2873.5 KW. The real and reactive power losses of the system without capacitor is 221.29 kW and 65.1 kVAr respectively as shown in table 1. The cumulative voltage deviation of the base case is 0.3353. The parameter used for net savings is energy rate C_e = \$0.06/kWh, installation cost of capacitor C_{cl} = \$1000/each location, purchase cost of capacitor C_c =\$3.0/kVAr, T=8760. The net savings is given by

$$Netsavings = [\left(C_e * P_{Loss}^{Cap} * T\right) - \left(C_{cl} * N_{BC}\right) - \left(C_c * T_c\right)]$$

Where N_{BC} the number of compensated buses in the system.

T_c the total capacitor rating.

P_{Loss}^{Cap} the total power loss of the system with capacitor.

Table 1. Result of 34 bus radial distribution system.

Parameters	Base case	PSO [6]	PGSA Method (11)	DE-PS method (1)	Proposed method
Size (kVAr) and location	----	781 (19), 803(22), 479 (20)	1200(19), 639 (22), 200(20).	750(19), 850(22), 150(20), 150(21).	650(10), 1150(25)
$V_{\min}$ (bus no.)	0.9416(27)	----	----	0.9490 (27)	**0.9500(27)**
$V_{\max}$ (bus no.)	1.00 (1)	----	----	1.00 (1)	**1.00(1)**
P_{loss}	221.2860	168.8	168.7	169.0590	**165.9**
% P_{loss} reduction	----	23.71%	23.76%	23.76%	**25%**
CVD	0.3353	----	----	0.1520	**0**
Total Compensation (kVAr)	----	2063	2039	1900	**1800**
Net savings (\$)	----	18398	18522	17751	**21711**

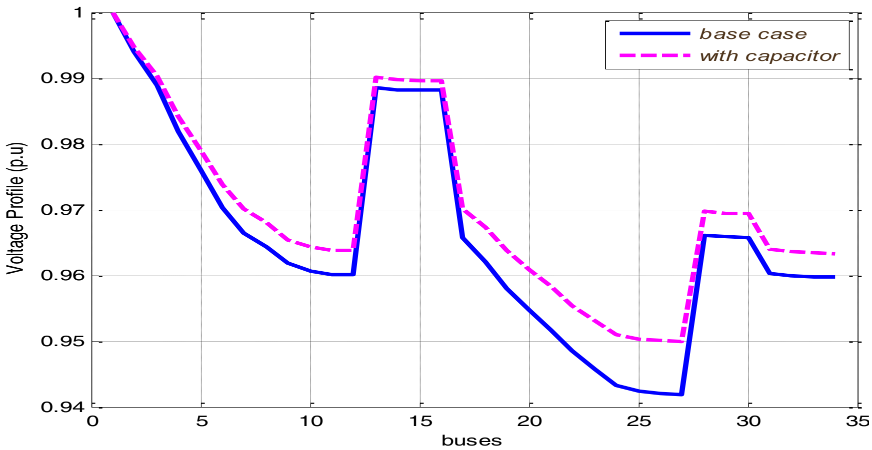

Fig. 3. Voltage profile of the IEEE 34-bus system with and without capacitor

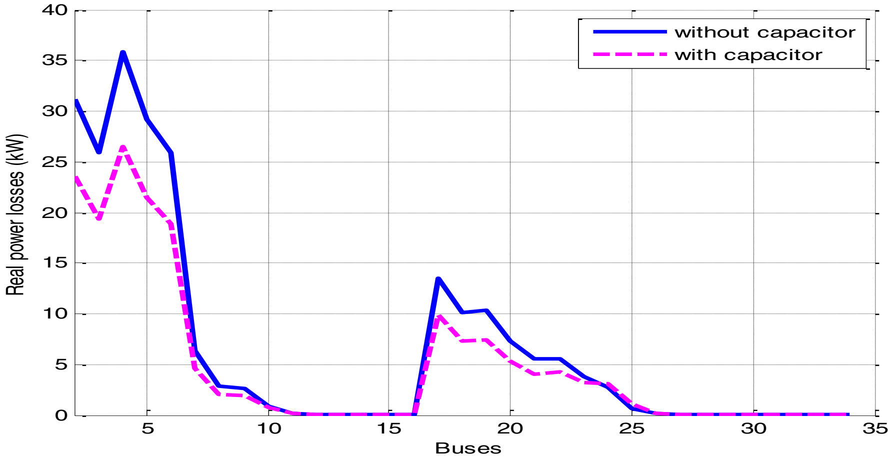

Fig. 4. Real power line losses of IEEE 34-bus radial distribution system.

In order to reduce the compensating location and keep in mind to achieve better power loss reduction, it is planned to install the capacitor at two locations only. The total kVAr used in this system is 1800kVAr (650 kVAr at 10th bus, 1150 kVAr at 25th bus) as presented in table 1. The DE-PS method, the authors are able to reduce the real power loss to 169.059 kW (CVD of 0.1520) with injecting 1900 kVAr. In the proposed method, the real power loss are reduced to 165.9 kW. The proposed method of location will give better voltage profile, achieved the CVD value to 0 and losses are also decreased effectively with less compensating value when compared with existing technique. Hence, voltage profile of the system is within the allowable tolerance. The figure 3 shows the voltage profile of the system with and without compensation and also the Fig. 4 shows the real power line losses of the system with and without compensation.

Acknowledgment

The authors gratefully acknowledge support from VIT University, Vellore and also the authors are thankful to the organizing committee of AEDCEE 2015.

5. Conclusion

In this paper the Bat algorithm has been implemented to test the IEEE 34-bus distribution system. The loss sensitivity factor has been used to pre-identify the optimal location of the capacitor. From the simulation results, it is very clear that the proposed method have achieved better power loss reduction, better net-savings and less compensation location when compared with other existing techniques. Then, this leads to decrease the intake of MVA from grid and it ensures the stability of the system. Hence, the proposed method can able to implement for any kind of distribution system to enhance voltage profile and conclude that the proposed method of capacitor location is suitable to minimize both power loss and CVD.

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