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Application of a hybrid evolutionary algorithm on reactive power compensation problem of distribution network☆

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ABSTRACT

Development of evolutionary optimization algorithms has provided more capability for enhancement of power system performance. To improve the performance of these algorithms, the combination of them can be a suitable option. This paper has proposed a hybrid algorithm based on combination of particle swarm optimization (PSO) and electromagnetic-like (EM) algorithms. The proposed algorithm covers the problems of trapping in local optimum problem of PSO and low convergence rate of EM. The optimal capacitor siting and sizing in distribution networks as the one of important problems of power system operators have been studied for validation of proposed algorithm performance. A comprehensive comparison has been carried out between proposed and other popular evolutionary algorithms. The results show that proposed algorithm has better performance for increasing the net saving value as the optimization objective function. Two well-known test systems of IEEE 34-bus and IEEE 85-bus power distribution networks have selected for these investigations.

1. Introduction

Power loss reduction strategies of distribution network are typical manners to decrease the cost of power distribution system. Distributed generation (DG) placement [1] or installation of capacitor banks have provided worthwhile potential for reducing the operational cost of distribution system by lowering the current level of network. Also, these allocations have positive impacts on the operational indices of distribution network. Solving the optimal capacitor placement (CP) problem have been considered widely in order to find the best location and size of capacitor banks. A high number of researches presented new methods for solving this classic problem of power distribution systems. The result of the CP optimization problem has a significant impact on the daily cost of distribution system. Consequently, these progressive studies of the CP problem is justifiable.

Hitherto different approaches have been used to solve the CP problem. These approaches can be classified to mathematical and heuristic methods. Mathematical methods are one of the main groups of mentioned approaches [2,3]. Mixed integer linear programming has presented in both [2,3], which guarantees the global optimum result of problem with accepting approximation errors' disadvantages. Solving the set of mixed integer non-linear equations to find optimal size and site of capacitor banks in radial/mesh distribution network has been done by Nojavan et al. [4].

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Large size of the CP problem, non-linearity and non-convexity of it, makes finding the global optimum result too difficult. Evolutionary algorithms which are so appropriate for application on large optimization problems have been used in the CP, too. These algorithms that can be categorized as heuristic methods have good capability to handle high number of variables without any simplification. Determination of global optimum point may can not be guaranteed by these methods, but, utilization of them can be so beneficial in finding better optimum points. Considerable numbers of studies have concentrated on proposing well-known and new evolutionary algorithms to solve the CP problem. Different types of genetic algorithms (GAs) [5,6], ant colony (AC) algorithms [7,8], tabu search algorithm [9], and particle swarm optimization (PSO) based algorithms [10,11] have been used for carrying out the CP problem. In [7], at first the candidate buses are determined by sensitivity analysis and then the optimal location and size of capacitors are obtained by using the AC algorithm. Accelerated PSO (APSO) algorithm [10] and PSO with Gaussian and Cauchy probability distribution functions based operators [11] are examples of PSO based methods in the CP problem. In addition to recognized evolutionary algorithms, a most number of recently proposed evolutionary algorithms have been applied to the CP problem, of which we can mention crow search algorithm (CSA) [12], teaching-learning based optimization (TLBO) [13], direct search algorithm (DSA) [14], gravitational search algorithm (GSA) [15], flower pollination algorithm (FPA) [16]. Some of the papers have taken additional objectives or constraints beside the CP problems main issue into consideration. Voltage improvement, energy loss reduction and peak power cost decreasing have been considered by Tabatabaei and Vahidi [17] as the objective functions, which that has used bacteria foraging (BF) algorithm as optimization tool. The authors in [18] have proposed an extremal optimization approach to solve the CP problem that incorporates resonance constraints.

Each optimization method has some highlighted features, in despite of including some weak points. Some researches attempt to enhance optimization methods by seeking synergistic impact from combination of methods. Application of combined methods or hybrid algorithms on the CP problem can also be found in the literatures. Hybrid algorithm based on heuristic and greedy search approaches has been indicated in [19] to find capacitors' locations and sizes in radial distribution networks. Ref. [20] has utilized combination of differential evolution and multi-agent PSO algorithms for handling the CP problem.

The advantages of the hybrid optimization algorithms have been efficaciously demonstrated in many of real-world applications such as the CP problem. Combination of evolutionary algorithms can exploit the remarkable features of the two initial algorithms and also cover their imperfections in a proper manner. The PSO and electromagnetic-like (EM) algorithms are two well-known swarm intelligence based algorithms which have been examined by using a large number of optimization problems. In this paper, a new hybrid optimization algorithm is extended, which is formed of combination of the PSO and EM algorithms. The proposed algorithm uses the advantages of the PSO and EM algorithms to cover disadvantages of each other. In the PSO algorithm, all particles have memory, while, particles in the EM do not have this feature. So, the search space in the PSO is rummaged deliberately compared with the EM. On the other hand, each particle in the EM moves towards particles position which result better objective functions value in proportion to that particle, whereas moving direction of particles in the PSO is so simple. Thus, particles in the EM, search more area of solution space in contrast with the PSO method. In addition, the PSO has higher convergence rate and the EM can escape better from sticking in the local optimum points. Accordingly, the proposed hybrid algorithm would overcome the PSO and EM algorithms drawbacks. On the other hand, the CP problem which is one of the main issues of power distribution companies is chosen as the case study to test the proposed algorithm. The impact of power losses in the operational cost of distribution system has necessitated continuance in improving the CP problems solutions. The CP problem in this paper is organized as an optimization problem with the objective function of energy loss minimization and capacitor installation's cost. Utilizing the proposed combined algorithm causes to determine the better size and location for the fixed and switchable capacitors in comparison the other literatures. Also, most of literatures in this topic apply a previously proposed algorithm to the CP problem, whereas this paper proposes a new algorithm. The algorithm in addition to application to the CP problem has been tested on a number of benchmark functions to can compare with a broad range of optimization algorithms. The contributions of the paper can be summarized as follows:

- A new hybrid evolutionary optimization algorithm is proposed that is formed of the combination of the PSO and EM algorithms.
- The proposed algorithm utilizes the PSO and EM properties to rectify their deficiencies.
- The CP problem which is one of the main problems of distribution companies is used as a case study to evaluate the performance of the proposed algorithm.
- The results of the algorithm shows its capability in the real-world and combinatorial optimization problems.

The remainder of this paper has been organized as follows: mathematical formulation of the CP problem has been discussed in Section 2. Section 3 explains the proposed hybrid algorithm, completely. In Section 4, the methodology of the paper has been expounded. Section 5 describes simulation's case studies and their relative information where Section 6 presents simulation's result and discussion and finally conclusion is provided in Section 7.

2. Problem formulation

Mathematical formulation of optimal capacitor allocation in radial distribution network can be indicated as follows: