Energy Conversion and Management 54 (2012) 7–16

Contents lists available at SciVerse ScienceDirect

Energy Conversion and Management

journal homepage: www.elsevier.com/locate/enconman

A new hybrid evolutionary algorithm based on new fuzzy adaptive PSO and NM algorithms for Distribution Feeder Reconfiguration

Taher Niknam [a], Ehsan Azadfarsani [b], Masoud Jabbari [c,*]

[a] Department of Electrical and Electronics Engineering, Shiraz University of Technology, Shiraz, Iran
[b] Young Researchers club, Science and Research Branch, Islamic Azad University, Tehran, Iran
[c] Department of Electrical Engineering, Marvdasht Branch, Islamic Azad University, Marvdasht, Iran

ARTICLE INFO

Article history:
Received 6 October 2009
Received in revised form 18 September 2011
Accepted 19 September 2011
Available online 4 November 2011

Keywords:
New Fuzzy Adaptive Particle Swarm Optimization (NFAPSO)
Fuzzy Adaptive Discrete Particle Swarm Optimization (FADPSO)
Fuzzy Adaptive Binary Particle Swarm Optimization (FABPSO)
Nelder–Mead (NM)
Distribution Feeder Reconfiguration (DFR)

ABSTRACT

Network reconfiguration for loss reduction in distribution system is a very important way to save the electrical energy. This paper proposes a new hybrid evolutionary algorithm to solve the Distribution Feeder Reconfiguration problem (DFR). The algorithm is based on combination of a New Fuzzy Adaptive Particle Swarm Optimization (NFAPSO) and Nelder–Mead simplex search method (NM) called NFAPSO–NM. In the proposed algorithm, a new fuzzy adaptive particle swarm optimization includes two parts. The first part is Fuzzy Adaptive Binary Particle Swarm Optimization (FABPSO) that determines the status of tie switches (open or close) and second part is Fuzzy Adaptive Discrete Particle Swarm Optimization (FADPSO) that determines the sectionalizing switch number. In other side, due to the results of binary PSO(BPSO) and discrete PSO(DPSO) algorithms highly depends on the values of their parameters such as the inertia weight and learning factors, a fuzzy system is employed to adaptively adjust the parameters during the search process. Moreover, the Nelder–Mead simplex search method is combined with the NFAPSO algorithm to improve its performance. Finally, the proposed algorithm is tested on two distribution test feeders. The results of simulation show that the proposed method is very powerful and guarantees to obtain the global optimization.

1. Introduction

In the radially distribution system, the configuration may be varied to obtain a new network structure to reduce power loss, increase system security and enhance power quality. This change (reconfiguration) is performed by opening sectionalizing (normally close) and closing tie (normally open) switches of network so that the radiallity of network is maintained and all of the loads are energized. The discrete nature of the switch values and radiallity constraint prevent the use of classical optimization techniques to solve the DFR problem. Therefore, most of the algorithms in the literature are based on heuristic search techniques by using either analytical or knowledge-based engines.

In recent years, considerable researches have been conducted for loss minimization in the DFR. Kim et al. [1] proposed a neural network-based method to identify network configurations corresponding to different load levels. Taylor and Lubkeman [2] presented an expert system using heuristic rules to shrink the search space. Hsiao and Chen [3] proposed the problem as a multiobjective programming that the objectives are considering power loss, system security and power quality. These performances of the system were expressed in fuzzy sets to represent their inaccurate nature. An evolutionary programming was then introduced to determine the optimal solution. Kashem et al. [4] proposed "distance measurement technique algorithm" that found a loop first and then to improve load balancing a switching option was determined in that loop. Jeon incorporated the simulated annealing algorithm with Tabu search for loss reduction in [5]. The Tabu search attempted to determine a better solution in the manner of a greatest-descent algorithm but it could not give any guarantee for the convergence property. Lin et al. [6] presented a refined genetic algorithm (RGA) to reduce losses. Morton and Mareels presented a brute-force solution for determining a minimal-loss radial configuration [7]. The graph theory involving semi sparse transformations of a current sensitivity matrix was used, which guaranteed a globally optimal solution but needed an exhaustive search. Goswami and Basu proposed a power-flow-minimum heuristic algorithm for the DER problem [8]. Lopez et al. proposed a method for online reconfiguration [9]. Debaprya presented a fuzzy multi-objective approach to solve DFR [10]. Niknam presented two approaches based on norm2 for multi-objective Distribution Feeder Reconfiguration [11,12]. In [13], a new reconfiguration based on differential evolution algorithm was proposed for DSTATCOM allocation in distribution networks. Niknam et al. proposed a hy-

* Corresponding author.
E-mail addresses: Jabbari@miau.ac.ir, tatnma2002@yahoo.com (M. Jabbari).

0196-8904/$ - see front matter © 2011 Elsevier Ltd. All rights reserved.
doi:10.1016/j.enconman.2011.09.014

brid algorithm based on Honey Bee Mating Optimization (HBMO) and a fuzzy set for the multi-objective Distribution Feeder Reconfiguration [14]. Gomes proposed an algorithm based on simple heuristic rules for optimal network reconfiguration in distribution systems [15]. McDermott et al. presented a heuristic nonlinear constructive method for the DFR problem [16]. Shirmohammadi and Hong proposed a heuristic method for the reconfiguration of distribution networks in order to reduce their resistive line losses under normal operating conditions [17]. Su and Lee proposed a method to reduce power loss and enhance the voltage profile by the improved mixed-integer hybrid differential evolution (MIHDE) method for distribution systems [18]. Chiou et al. presented a method based on the variable scaling hybrid differential evolution (VSHDE) for solving the network reconfiguration for power loss reduction and voltage profit enhancement of distribution systems [19]. Viswanadha Raju and Bijwe presented an algorithm based on sensitivity and heuristics for minimum loss reconfiguration of distribution system [20]. In [21], a new reconfiguration scheme was considered for voltage stability enhancement of radial distribution systems. Ahuja et al. presented a hybrid artificial immune systems and ant colony optimization (AIS–ACO) approach for the multi-objective DFR problem [22]. Assadian et al. proposed a guaranteed convergence particle swarm optimization in cooperation with graph theory to distribution network reconfiguration for minimization of power losses [23]. Arun and Aravindhababu proposed a fuzzy genetic based approach for reconfiguration of radial distribution systems to maximize the voltage stability for a specific set of loads [24]. Cheng and Kou used simulated annealing to solve the DFR problem in distribution system [25].

As shown in mentioned references, saving electrical energy is one of the most important problems in electrical networks. Feeder reconfiguration is a very important and usable operation to reduce distribution feeder losses and improve system security. Therefore, this paper presents a new algorithm for the DFR problem, which its aim is to minimize the electrical power losses.

In the distribution system, since there are many candidate switching combinations, the DFR problem is modeled as a mixed integer nonlinear optimization problem. Therefore, it is difficult to solve the problem by conventional approaches. Also most optimal algorithms cannot effectively solve this kind of problem and they usually achieve local optimal solutions rather than global optimal solutions. Most of the mentioned methods in above have low accuracy and slow convergence rate. In this paper, a new hybrid algorithm is presented which its accuracy and convergence rate is very high. The proposed algorithm is based on the combination of the New Fuzzy Adaptive Particle Swarm Optimization (NFAPSO), with Nelder–Mead (NM). In the proposed algorithm, we use of discrete Particle Swarm Optimization (DPSO) and Binary Particle Swarm Optimization (BPSO). The BPSO determines the status of tie switch (open or close) while DPSO determines the sectionalizing switch number. In other side, PSO algorithm is a powerful and effective optimization method [26]. Although PSO eventually determines the desired solution [28] but its convergence rate is slow. To solve this drawback of PSO, it should be noted that its parameters should be carefully selected for efficient performance. In order to find a good set of parameters, the algorithm has to be run several times with different parameter sets [29]. However, any set of static parameters seems to be inappropriate. The use of rigid parameters that do not change their values may not be optimal since different values of parameters may work better/worse at different stages of the evolutionary process [30]. Some attempts have been made to define an adaptive PSO. Shi and Eberhart presented a promising technique. They used a fuzzy controller for adapting one of the parameters dynamically [26].

In this paper, a fuzzy system based on some heuristics is designed to adaptively adjust the parameters of DPSO and BPSO during the optimization process to improve the overall performance. In other side, the Nelder–Mead is a simplex search method that has been widely used in unconstrained optimization problem [27]. The NM is not always available since it is very sensitive to the choice of initial points and not guaranteed to obtain the global optimization solution. The proposed algorithm (NFAPSO–NM) guarantees that the final solution converges to the global solution. Two distribution test feeders are used to demonstrate the accuracy of the algorithm.

Main contributions of the proposed algorithm are as follows:

(i) Discrete nature of the switch values prevents the use of classical optimization techniques to solve the reconfiguration problem, therefore in this paper we use Discrete Particle Swarm Optimization (DPSO) and Binary Particle Swarm Optimization (BPSO) to determine the status of the tie switches (open or closed) and determine the sectionalizing switch number, respectively.
(ii) In the original PSO algorithm, there are two tuning parameters (C_1, C_2) and an inertia weight (W) that greatly influence the algorithm performance. Proper selection of these parameters increases the performance efficiency of algorithm. However, as in other evolutionary algorithms, appropriate adjustment of PSO's parameters is cumbersome and usually requires a lot of time. Thus, in this paper, a fuzzy-adaptive framework is proposed for adjusting the PSO algorithm's parameters.
(iii) The PSO algorithm is a relatively weak local search procedure and its convergence rate is slow. In the proposed algorithm, in order to increase the ability of PSO in local search and its convergence rate, we combine PSO with NM.

The paper is organized as follows: In Section 2, the proposed DFR is formulated. In Sections 3 and 4, the basic principles of the NM and NFAPSO algorithms are introduced, respectively. In Section 5, the application of the NFAPSO–NM to solve the proposed DFR is shown. In Section 6, the feasibility of the NFAPSO–NM method and the proposed DFR is demonstrated and compared with the solution results by other works and other evolutionary methods such as the DPSO algorithm and NM over different distribution test systems. Finally, a summary and the conclusion is presented in Section 7.

2. Distribution Feeder Reconfiguration problem

The DFR problem is a mixed integer nonlinear optimization problem and is a multi-objective problem. In the multi-objective DFR, there are many different objectives including loss minimization, balancing load on transformers, balancing load on feeders, maximum load on feeders, and deviation of voltages from nominal. In this paper, loss minimization is considered as the objective while the other objectives are considered as constraints. The DFR problem is described as below:

2.1. Objective function

In this paper the objective function for the DFR problem is to minimize the power losses, which can be calculated as follows:

$$f(X) = \sum_{i=1}^{N_{br}} R_i \times |I_i|^2 \tag{1}$$

$$X = [Tie_1,\ Tie_2,\ \ldots,\ Tie_{N_{tie}},\ Sw_1,\ Sw_2,\ \ldots,\ Sw_{N_{tie}}]$$

where R_i and I_i are resistance and actual current of the ith branch, respectively. N_{br} is the number of the branches. X is the control variables vector. Tie_i is the state of the ith tie switch (0 = open and