Energy Conversion and Management 139 (2017) 45–70

Contents lists available at ScienceDirect

Energy Conversion and Management

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

A new global particle swarm optimization for the economic emission dispatch with or without transmission losses

Dexuan Zou [a,*], Steven Li [b], Zongyan Li [c], Xiangyong Kong [a]

[a] School of Electrical Engineering and Automation, Jiangsu Normal University, Xuzhou, Jiangsu 221116, China
[b] Graduate School of Business and Law, RMIT University, 379-405 Russell St, Melbourne, VIC 3000, Australia
[c] School of Information and Electrical Engineering, China University of Mining and Technology, Xuzhou 221116, China

ARTICLE INFO

Article history:
Received 1 November 2016
Received in revised form 22 January 2017
Accepted 13 February 2017

Keywords:
New global particle swarm optimization
Economic emission dispatch
Position updating
Randomization
Single objective optimization
Multi-objective optimization

ABSTRACT

A new global particle swarm optimization (NGPSO) algorithm is proposed to solve the economic emission dispatch (EED) problems in this paper. NGPSO is different from the traditional particle swarm optimization (PSO) algorithm in two aspects. First, NGPSO uses a new position updating equation which relies on the global best particle to guide the searching activities of all particles. Second, it uses the randomization based on the uniform distribution to slightly disturb the flight trajectories of particles during the late evolutionary process. The two steps enable NGPSO to effectively execute a number of global searches, and thus they increase the chance of exploring promising solution space, and reduce the probabilities of getting trapped into local optima for all particles. On the other hand, the two objective functions of EED are normalized separately according to all candidate solutions, and then they are incorporated into one single objective function. The transformation steps are very helpful in eliminating the difference caused by the different dimensions of the two functions, and thus they strike a balance between the fuel cost and emission. In addition, a simple and common penalty function method is employed to facilitate the satisfactions of EED's constraints. Based on these improvements in PSO, objective functions and constraints handling, high-quality solutions can be obtained for EED problems. Five examples are chosen to testify the performance of three improved PSOs on solving EED problems with or without transmission losses. Experimental results show that NGPSO is the most efficient approach on solving the single objective optimization (fuel cost or emission minimization) and multi-objective optimization (fuel cost and emission minimizations) problems.

1. Introduction

The economic dispatch (ED) problem [1–3] is an interesting and meaningful realworld issue which considers the minimization of total fuel costs as its objective function. Moreover, the scientific and reasonable schedule of the generation units can bring considerable economic and social benefits. The importance of ED has gained researchers' attention and promoted them to make efforts to minimize the objective function associated with the fuel cost. Some researchers applied the gradient based techniques to the ED problems, for example fast lambda iteration [4], quadratic programming [5], lagrange relaxation [6], dynamic programming [7], interior point technique [8], and linear programming [9]. The others utilized many classical evolutionary methodologies to solve the ED problems, such as particle swarm optimization algorithm [10,11], modified symbiotic organisms search algorithm [12], intelligent θ-Modified bat algorithm [13], harmony search algorithm [14,15], gray wolf optimization [16], crisscross optimization algorithm [17,18] and diffusion particle optimization [19]. On the other hand, with the development and progress of our society, the enviromental issue is becoming increasingly important, thus researchers have to add this key factor to the ED problems to satisfy people's practical needs.

In the normal operation of power systems, it is inevitable that a vast number of pollution emissions will be produced by the generating units. It goes against the environmental conservation policies and regulations from the governments, which forces the electric utilities and power producers to pay close attention to the environmental effect of power generating plants [20]. For this purpose, the generation units are allocated according to the requirements of minimizing the total fuel costs and controlling the pollution emissions. The combined issue of fuel cost and emission is usually called the economic emission dispatch (EED) [21] or the combined

* Corresponding author.
E-mail address: zoudexuan@163.com (D. Zou).

http://dx.doi.org/10.1016/j.enconman.2017.02.035
0196-8904/

economic environmental dispatch [22]. It is essentially a type of multi-objective optimization problem, and aims to simultaneously minimize the fuel cost and pollution emission on the premise of that the requirements of the power balance constraint and generation limits are satisfied. All of these complicated factors make the EED very intractable to solve because of its highly nonlinear characteristic. Since the stochastic algorithm has become a viable alternative as a kind of optimization technique, interest has been centered around employing this technique to handle the EED problems. For the last two decades a large number of investigations have been carried out in order to assess the stochastic algorithm's potential for the EED problems.

Scatter search (SS) is a newly proposed optimization technique which explores the solution space by performing on a small data collection related to intensification and diversification, and takes advantage of different systematic sub-methods and several groups of randomizations. Silva et al. [23] proposed an improved scatter search (ISS) to tackle the EED problems. They combined good characteristics of the subset of solutions in an attempt to produce high quality solutions. Experimental results show that the ISS method is a potential alternative for coping with the EED problems. Roy and Bhui [24] presented a quasi-oppositional teaching learning based optimization (QOTLBO) to handle the EED problems. The opposition-based learning technique simultaneously utilizes current population and its opposite population to generate better candidate solutions. Furthermore, an opposite solution is more likely to be closer to the global optimum compared with a randomly generated solution [25]. Therefore, QOTLBO incorporates this technique [26] into the teaching learning based optimization (TLBO) approach [27]. The enhanced version of TLBO was successfully tested and implemented in four EED problems. The backtracking search algorithm (BSA) is a new evolutionary approach proposed by Civicioglu [28], and it searches the optimum by combining crossover and mutation operators. Based on the potential of BSA in tackling numerical optimization problems, Modiri-Delshad and Rahim [29] developed a multi-objective version to solve the EED problems. Moreover, an elitist external archive was utilized to record non-dominated solutions called pareto front. In addition, a single objective function was constructed by combining both objective functions of the problem according to weighted sum method. Several groups of case studies confirmed the effectiveness of the multi-objective BSA on solving the EED problems. The reproduction of a flower can be achieved by means of pollination, and flower pollination mainly depends on both the pollinators and the transfer of pollen. Moreover, only the fittest and the optimal reproduction of plants will survive to pass their good characteristics on to the next generation. This is analogous to the optimization process of an evolutionary approach. Enlightened by the interesting natural phenomenon, Yang [30,31] proposed the flower pollination algorithm (FPA) in 2012. FPA can optimize both single objective and multi-objective optimization problems, and hence it has high flexibility on solving various optimization problems. For these advantages Abdelaziz et al. [32] implemented FPA to ED and EED problems. Experimental results illustrate that FPA outperforms other approaches for various power systems, and large scale power system in particular. The gravitational search algorithm (GSA) is a new heuristic method[33], and it is inspired by the Newtonian physical law of gravity and law of motion. In the GSA system, each agent is treated as an object, and its performance is evaluated in terms of mass. Every object is analogous to the solution or a part of the solution for a optimization problem. Accordingly, some objects are attracted by the other objects according to the gravity force, and lighter objects are pulled towards heavier objects according to the law of motion. Heavier mass implies higher fitness value, hence it is analogous to the optimum of a optimization problem. Owing to its great potential in practical optimization problems, Güenç et al. [34] employed GSA to search the optima of the EED problems, and hence obtained good results. As an important characteristic, similarity exists between two or more things, but it is very difficult to evaluate. To make a distinction between one's object and another, the generalized context model (GCM) [35] was introduced by Nosofsky in 1986. This model assumes that humans represent categories by means of storing every exemplar in memory, and category decisions are made by using the similarity computation between a probe stimulus and stored exemplars [36]. Owning to the simpleness and convenience of the similarity measure, Güenç [37] developed a novel genetic algorithm (GA) based on similarity crossover for tackling the EED problems. In the improved GA approach, children are produced by using similarity measurement between mother and father chromosomes relationship. Simulation results suggest that the improved GA approach is able to yield solutions of higher quality for the EED problems. Qu and Suganthan proposed a multi-objective differential evolution (DE) algorithm based on summation of normalized objective values and diversified selection [38], which is abbreviated as MODE (SNOV-DS). The summation of normalized objective value is utilized to sort the population, and then diversified selection is carried out in the population. By combining the two steps, the MODE method is capable of alleviating the complexity of non-domination sorting and maintaining population diversity. Therefore, it performs well on nineteen benchmark problems [39]. In addition, Qu et al. introduced a enhanced version of the original summation based multi-objective differential evolution algorithm [40], and rely on this method to solve the EED problems with stochastic wind power. In short, the enhanced version is different from the original version in two aspects. First, a parameter-free summation is adopted to avoid the inconvenience caused by trying to determine a proper value for real-world problems. Second, a stopping point is located and utilized to identify the scanning area. These new ideas enables the enhanced MODE method to produce good solutions for the EED problems. Singh and Dhillon proposed an opposition-based greedy heuristic search (OGHS) [41] to solve multi-objective thermal power dispatch problems. Any candidate solution of the initial population is randomly produced according to the uniform distribution, and its opposite solution is produced by using opposition-based learning [42]. The better of the two solutions is selected for subsequent optimization process, which is helpful in accelerating convergence. In addition, the opposition-based learning technique is also applied to the migration step of OGHS, which is helpful in maintaining the population diversity. Moreover, the mutation is considered as a success if the mutated member is better than the previous one, otherwise it is considered as a failure, and the mutated member is excluded. Wilcoxon signed-rank test validates the performance of OGHS. The behavior of animals in foraging and decision making provides reference and inspiration for tackling engineering optimization problems. The idea of bacteria foraging is enlightened by the natural selection principle. That is, the animals which have successful foraging strategies will survive to propagate their genes to the next generations, and the animals with poor foraging strategies in locating, handling, and ingesting food will die out. To promote and develop this impressive idea, Hota et al. presented a modified bacterial foraging algorithm (MBFA) for dealing with the EED problems [43]. MBFA is involved with four processes, and they are, respectively, chemotaxis, swarming, reproduction, and elimination and dispersal [44]. The step size of fittest bacteria is adjusted dynamically in a new chemotactic stage [45], which is beneficial for improving convergence. Moreover, a fuzzy based mechanism is utilized to find the best compromise solution over the trade-off curve. Experimental results show that MBFA is a reliable approach for solving the EED problems. Enlightened by the assessing and decision making behavior of elite stockholders in selling