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Solution to non-convex economic dispatch problem with valve point effects by incremental artificial bee colony with local search

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ABSTRACT

In literature, economic power dispatch problems are generally categorized as convex and non-convex optimization problems. In this study, incremental artificial bee colony (IABC) and incremental artificial bee colony with local search (IABC-LS) have been used for the solution of the economic dispatch problem with valve point effect. In these kind of problems, fuel cost curve increases as sinusoidal oscillations. In the solution of the problem B loss matrix has been used for the calculation of the line losses. Total fuel cost has been minimized under electrical constraints. IABC and IABC-LS methods have been applied to four different test systems one with 6 buses 3 generators, the other with 14 buses 5 generators (IEEE), the third one with 30 buses 6 generators (IEEE) and the last one is 40-generator system. The obtained best values have been compared with different methods in literature and the results of them have been discussed.

1. Introduction

Economic power dispatch problem is one of the important issues in the operations of the power systems. The fact that the cost of the fuel used in power generation reaches a considerable amount on generation costs leads companies that generate power to use the fuel more efficient. Thence, economical operations of the power generation systems have come into question. In literature, the economic power dispatch problem is defined as the adjustment of the active power output of the generation units in order to meet the present load in the system (under system constraints and with minimum fuel cost). In these kinds of problems, fuel cost function curves belonging to generation units are used for the calculation of the total fuel cost [1,2].

Traditionally, for each generation unit fuel cost function is shown approximately with a second degree function when valve point effects are ignored. This kind of presentation causes the found optimum solution to be faulty. When different physical and operating constraints are added to the problem in order to make the optimum solutions correct, the problem turns to too limited non-linear optimization problem. Economic power dispatch problem with valve point effects, which is one of these problems, has non-convex characteristic and the solution of it is rather difficult to find [1–12].

In thermal generation units composed of multi-valve steam turbines cost function is a non-convex function. The cost function used for these generation units are as sinusoidal surges [1–11].

In literature non-convex valve point effect economic power dispatch problems have been solved with many new hybrid search optimization algorithms [1–5], differential evolution and modified differential evolution algorithms [6–12], particle swarm optimization and improved particle swarm optimization algorithms [13–21], firefly optimization algorithm [22], artificial bee colony optimization method [23], evolutionary programming and improved evolutionary programming algorithms [24–26], genetic algorithm and improved genetic algorithm approaches [25–31], cultural self-organizing migrating strategy optimization method [32], Taguchi method [33], biogeography-based optimization method [34], bacterial foraging algorithm [35], tabu search and multiple tabu search algorithms [36,37] and pattern search method [38].

Incremental artificial bee colony optimization (IABC) and incremental artificial bee colony optimization with local search (IABC-LS) algorithms proposed by Aydın et al. [39] are contemporary, interesting, very high performing ABC variants. IABC and IABC-LS algorithms are based on the principle of increase in population number during the process. Their efficiency and search behaviour were discussed and compared with classical ABC and the state-of-the-art algorithms (which are the best contributed algorithms

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in Soft Computing Journal special issue about large-scale continuous optimization [40]) in our previous work [39]. IABC and IABC-LS have shown an equal or better performance than other state-of-the-art algorithms, and they are significantly better than classical ABC algorithm. However, outstanding performances on a set of benchmarks may not guarantee a similar performance on every practical optimization problem too as it is well-nigh impossible to model all the complexities of the real world problems by a limited set of benchmarks.

Therefore, importance of this study we worked here arises from the following reasons:

We have presented a new variant of ABC. It is based on incremental social learning behaviour.

- We have tried to understand real strength of IABC and IABC-LS algorithms by testing them on hard real-world problems. As a case study, we have taken non-convex economic power dispatch problem with valve-point effect for this study.
- For the tackling test problems here, we worked on discovering new better solutions.
- We have shown the importance of hybridizing local search procedure with swarm intelligence technique. To do this, Mtsls1 local search procedure is called at the each iteration of the IABC algorithm with an intelligent way.
- In algorithm parameter configuration, we have used automatic parameter tuning algorithm, Iterative F-race [41,42]. We believe that parameter tuning task is necessary to obtain better results for a stochastic algorithm. However many researchers have selected parameter values with an ad-hoc way. We have indicated the importance of parameter tuning by obtaining better results than other approaches.

2. Formulation of the problem

The solution of the economic power dispatch problem is found by the minimization of the total fuel cost under system constraints. And, this is the purpose function of the optimization problem given in Eq. (1) [1,2,7,15,23].

$$\min F_{total} = \min \sum_{n=1}^{N} F_n(P_{G,n}) \tag{1}$$

The fuel cost function belonging to generation units has been shown in Fig. 1. In the figure, the graphic shown with broken line is convex fuel cost function and as represented in Eq. (2) it is taken as two degree function of active power generation for each unit [1,2,7,15,23].

$$F_n(P_{G,n}) = a_n + b_n P_{G,n} + c_n P_{G,n}^2, \quad (\$/\text{h}) \tag{2}$$

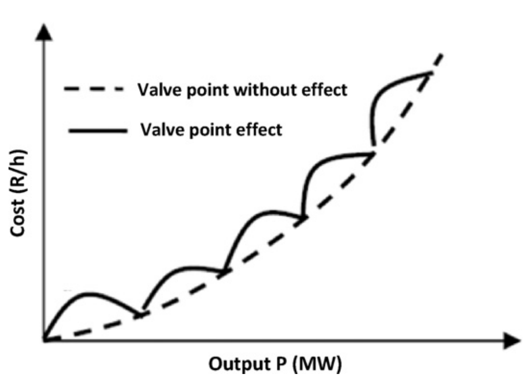

Fig. 1. Input–output characteristics of the generation units.

In the equation, $F_n(P_{G,n})$ shows the fuel cost function of n generation unit, a_n, b_n and c_n respectively show the cost function coefficients of the generation unit, and $P_{G,n}$ shows the output power of n generation unit.

In fact, when the input–output curve of the generation units with multi-valve steam turbine is compared with the equality in Eq. (2), it is very different. The inclusion of the valve point effect as well to the fuel cost of the generation unit makes the presentation of the fuel cost more appropriate. As shown in Fig. 1, since valve point results in sinusoidal surges, the fuel cost function contains non-linear higher sequences (series). Therefore, in the studies done to be able to consider the valve point effects instead of Eq. (2), the non-convex cost function in the following equation has been used [1–4,7–23].

$$F_n(P_{G,n}) = a_n + b_n P_{G,n} + c_n P_{G,n}^2 + |e_n . \sin(f_n(P_{G,n}^{\min} - P_{G,n}))|, \quad (\$/\text{h}) \tag{3}$$

In the equation, e_n and f_n are the cost function coefficients of n generation unit showing valve point effect. In Eqs. (2) and (3) the unit of $P_{G,n}$ is taken as MW. Active power equality constraint in the loss system has been taken as Eq. (4):

$$P_{load} + P_{loss} - \sum_{n=1}^{N} P_{G,n} = 0 \tag{4}$$

Operation limit values of the generation units have been given in the following equation:

$$P_{G,n}^{\min} \le P_{G,n} \le P_{G,n}^{\max}, \quad (n \in N) \tag{5}$$

The power losses occurring in the transmission lines of the system are calculated with B loss matrix by using Eq. (6) [1–4,7,15,23].

$$P_{loss} = \sum_{n=1}^{N}\sum_{j=1}^{N} P_{G,n} \cdot B_{nj} \cdot P_{G,j} + \sum_{n=1}^{N} B_{0n} \cdot P_{G,n} + B_{00} \tag{6}$$

3. Artificial bee colony algorithm

Artificial bee colony (ABC) algorithm, that mimics the foraging behaviour of real honey bee colonies, is a recent swarm intelligence technique. Real bee colonies consist of three different kinds of bee:employed bees, onlooker bees and scout bees. Each type of bees has different responsibility in colony. Employed bees search for a food source and when they find one, they give information to onlooker bees about the food source by dancing. Onlooker bees watch all dances of employed bees and assess the food sources. Then they decide one of them for foraging. When a food source is abandoned some employed bees turn to scout bees. The scout bees search for a new food sources in the environment [43,44].

In classical ABC algorithm, while the location of a food source indicates a solution, nectar amount in food source refers to the fitness value. Employed and onlooker bees look around a food source for finding better food sources. The scouts are assigned to find new food sources if few food sources reach their limits similar as real bee swarms do [43,44]. The general steps of the algorithm are shown in Fig. 2.

At first step of the algorithm, the colony and randomly located food sources are created. Number of the employed bees and onlooker bees are set usually equal to the number of food sources. Total number of food source is denoted by *SN*. The rest of the algorithm is consists of three steps in a loop.

At *Employed bees step*, employed bees search for a new better food source in vicinity of a selected reference food source by modifying its location according to

$$v_{i,j} = x_{i,j} + \phi_{i,j}(x_{i,j} - x_{k,j}), \quad i \ne k \tag{7}$$