Energy 115 (2016) 468–477

Contents lists available at ScienceDirect

Energy

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

The combined economic environmental dispatch using new hybrid metaheuristic

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ARTICLE INFO

Article history:
Received 21 September 2015
Received in revised form
7 April 2016
Accepted 22 August 2016

Keywords:
Multi-objective optimization
Economic-environmental dispatch
Metaheuristic algorithm
Firefly algorithm
Bat algorithm and hybrid algorithm

ABSTRACT

The combined economic/environmental dispatch treats the economic and environmental impact as competing objectives. This requires effective optimization algorithms to achieve a solution. The firefly algorithm and bat algorithm are the latest methods; they have already proven their effectiveness in several research areas.

In this paper, we will use these two methods to optimize the production cost and the emission of NO_x for three tests networks: three units systems, six units system and the last fourteen units systems, with variable transmission losses and different loads. Then the hybridization of these two Metaheuristics is developed and tested.

1. Introduction

Engineers are faced daily with technological problems of increasing complexity. These problems can be expressed in the general form of an optimization problem, in which one or more objective functions are defined, which seeks to minimize (or maximize). An optimization problem is often supplemented by data constraints where all the proposed solution parameters must meet these constraints, failing which the solution is not feasible.

In a traditional economic dispatch (ECD), production costs are reduced by the appropriate allocation of the amount of power to be produced by different units. However, the optimal production cost may not be the best in terms of environmental criteria. Recently many countries around the world have focused on reducing the amount of pollutants from fossil fuel to produce electrical energy for each unit. The gaseous pollutants from power plants cause adverse effects to humans and the environment as sulfur dioxide (SO_2), nitrogen oxide (NO_x) and carbon dioxide (CO_2) [1]. So the production cost optimization should not be the only objective, the emission reduction must also be considered.

Several methods are available in the literature on reducing the atmospheric emission caused by power plants. These include installation of pollutant cleaning, the transition to low-emission fuels, and replacement of old burners with cleaner and emission dispatch. The first three options require design and installation of new equipment and/or modify existing equipment and involve a big capital and therefore they are considered long-term solutions [2]. On the other hand, the fourth option requires only small changes in the distribution strategy, which include emission constraints. Therefore, the environmental dispatch has become an attractive solution because it is easy to apply and does not require any additional investment.

Find optimal solutions to these problems require efficient optimization algorithms. Metaheuristics, appeared in 1980, are a family of stochastic algorithms for solving difficult optimization problems. Their uniqueness lies in the fact that they are adaptable to many problems without major changes in their algorithms. Their ability to optimize a problem from a minimum of information is offset by the fact that they offer no guarantee as to the optimality of the best solution found. Only the global optimum approximation is given. However, this is not a disadvantage because we always prefer an approximation of the global optimum

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http://dx.doi.org/10.1016/j.energy.2016.08.079
0360-5442/

quickly found that a precise value found in an unacceptable time [3].

The metaheuristic inspired by nature are the current methods and have already proven their effectiveness in several areas of research. the best known methods are the genetic algorithm (GA) (John Holland 1960–1970) [4,5], optimization ant colony (ACO) (Marco Dorigo, 1992) [6], particle swarm optimization (PSO) (Kennedy and Eberhart, 1995) [7,8], artificial bee colony (ABC) (Karaboga Dervis, 2005) [9] and the latest firefly algorithm (FA) (Xin She Yang, 2007) [10–12] and bat algorithm (BA) (Xin She Yang, 2010) [12–15].

This paper presents a new method to solve the combined economic/environmental dispatch (CEED) resulting from the hybridization of two metaheuristics inspired by nature. Firefly algorithm (FA) is a meta-heuristics, behavior-based fireflies, including light emission, light absorption and mutual attraction. It was developed to solve continuous optimization problems [16]. Bat Algorithm (BA) is a metaheuristic that is part of the optimization algorithm based on a population. It was initially inspired by the research of bats to find their food. Bats send some signals to the environment and listen to the echo this process is called echolocation [17].

2. Mathematical formulation of the problem

2.1. Economic dispatch (ECD)

Electric power producers experimentally determined the curves depicting the cost of production for each unit on the basis of the power it delivers. A polynomial function of degree "n" is associated with these curves. In practice, most often, it is presented as a second-degree polynomial:

$$F_i = a_i P_i^2 + b_i P_i + c_i \tag{1}$$

The function F_i is known only in a discrete form, that is, from a number of points. Therefore, interpolation methods are used to determine the coefficients a_i, b_i and c_i, which are specific to each production unit.

The cost production function of electrical energy is minimized as follows:

$$Min\left\{ A = \sum_{i=1}^{nG} F_i(P_i) \right\} \tag{2}$$

Under the following constraints:

$$P_{i,min} < P_i < P_{i,max} \tag{3}$$

$$\sum_{i=1}^{nG} P_i = P_D + P_L \tag{4}$$

where P_D is the total demand and P_L represents the active transmission losses. $P_{i,min}$ and $P_{i,max}$ are the minimum and maximum limits, respectively for the production of the ith unit.

The expression of transmission loss as a function of the generated power is given by:

$$P_L = \sum_{i=1}^{nG} \sum_{j=1}^{nG} P_i B_{ij} P_j \tag{5}$$

where B_{ij} is the constant called the losses coefficient.

2.2. Environmental dispatch (END)

The END problem function is to minimize the emissions of gases from power plants. We can describe it as follows:

$$E_i = \alpha_i P_i^2 + \beta_i P_i + \gamma_i \tag{6}$$

Under the constraints given by equations (3) and (4).

Ei is the function of emissions and α_i, β_i and γ_i are the coefficients of emission characteristics specific to each production unit.

2.3. The combined economic/environmental dispatch (CEED)

The CEED studies are designed to seek the simultaneous minimization of two functions described by the same variable objects yielding a dual objective optimization problem or bi-criteria. The primary difficulty with such an optimization problem is associated with the presence of conflicts between two features. For which, we have converted this problem into a single-objective optimization problem by introducing a price penalty factor "h_e", therefore, the objective function to be optimized is defined as follows:

$$Min\left\{ C = \sum_{i=1}^{nG} F_i(P_i) + he \sum_{i=1}^{nG} E_i(P_i) \right\} \tag{7}$$

under the constraints given by equations (3) and (4).

2.4. Calculating the coefficient h_e

The coefficient "h_e", called price penalty factor is expressed by the following function:

$$h_{ei} = \frac{F_i(P_{i,max})}{E_i(P_{i,max})} \tag{8}$$

To determine the price penalty factor "h_e" associated with a given load, the following steps must be followed:

- Calculate the ratio $F_i(P_{i,max})/E_i(P_{i,max})$ for each generator;
- Sort the factor values obtained in ascending order;
- Add the maximum generated power of each generator ($P_{i,max}$) one by one, starting with the plant capacity with the lowest price factor corresponding to the given load. Once $\sum P_{i,\,max} \geq P_D$, stop calculation;
- At this stage, "h_e" connected to the last unit in the summing process is the price penalty factor corresponding to the given load [18].

3. Firefly algorithm

Fireflies are small winged beetles capable of producing a cold flashing light for mutual attraction. Females can imitate the light signals of other species to attract males, which they catch and consume. Fireflies possess a capacitor-like mechanism, which slowly discharges until a certain threshold is reached, they release energy as light. The phenomenon is repeated cyclically. The fireflies algorithm (FA) was developed by (Xin Yang She, 2007) which was inspired by the dependence of light attenuation on the distance and the mutual attraction.

In the Fireflies algorithm, we have three idealized special rules that have their basis certain principles characteristic of real fireflies:

1 All fireflies are unisex; therefore, a firefly is attracted to another regardless of its sex;