



A normalization method for solving the combined economic and emission dispatch problem with meta-heuristic algorithms



Yun-Chia Liang*, Josue Rodolfo Cuevas Juarez

Department of Industrial Engineering and Management, Yuan Ze University, Taoyuan 32003, Taiwan

ARTICLE INFO

Article history:

Received 24 December 2012

Received in revised form 17 June 2013

Accepted 28 June 2013

Keywords:

Combined economic and emission dispatch problem

Meta-heuristics

Population-based algorithms

Nature-inspired algorithms

ABSTRACT

Solving the economic and emission dispatch (ED/MED) problems separately becomes more complex when the combined version (CEED) of the two aforementioned cases is considered. The basic idea is to achieve the lowest possible cost with the smallest amount of pollutant and this problem is known as the combined economic–emission dispatch (CEED). A new approach for solving the CEED is presented in this paper. The idea consists of normalizing the two conflicting objective functions, ED and MED, using the mean and standard deviation of the members contained in the population-based meta-heuristic algorithms implemented in this study thus preventing units and scale differences when optimizing the CEED problem. The mathematical model for each problem (ED, MED, and CEED) presented in this study is optimized implementing a nonlinear optimization package named TOMLAB available for MATLAB, which helps us to determine the best possible solution for the tested instances. A novel meta-heuristic named Virus Optimization Algorithm (VOA) is implemented along with seven well-known algorithmic tools, which are the Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Harmony Search (HS), Differential Evolution (DE), FireFly algorithm (FF), Gravitational Search Algorithm (GSA), and Seeker Optimization Algorithm (SOA). A comprehensive statistical study is performed to determine the quality of the solutions delivered by the algorithmic tools when compared with TOMLAB. From the test instances, it was observed that the proposed normalization method does not only show to be feasible, but also helps the algorithms to achieve similar results from that coming when solving the ED and MED separately. Furthermore, among the eight meta-heuristic tools (VOA, GA, PSO, HS, DE, FF, GSA, and SOA), VOA showed outstanding performance in both solution quality and computational efficiency.

© 2013 Elsevier Ltd. All rights reserved.

1. Introduction

Finding the best possible allocation of power among the committed generating thermal units in order to satisfy a given demand is the basic idea of the economic dispatch (ED) problem [1–4]. The minimization of the operating cost is the main objective of the ED problem, where each generating unit is subject to physical and technological constraints. However, given that thermal power generation is a major cause of atmospheric pollution, the minimization of the operating cost is no longer the only concern when satisfying power demand. Consequently, the emission of pollutants such as nitrogen and sulfur oxides (NO_x and SO_x) has to be minimized, where this problem is known as the minimum emission dispatch (MED) [5–7].

Due to the nature of the ED and MED problems, finding a high-quality solution that not only provides a reasonable operating cost in (\$/h), but also reduces the emission of pollutants (NO_x and SO_x)

in (ton/h) is a very difficult task. Therefore, implementation of exact optimization methods [8,9] is impractical, since they required enormous computational effort and sometimes are unable to find a solution to the problem under study. The aforementioned problem is known as the combined economic–emission dispatch (CEED) problem, where several approaches have been proposed for solving the CEED problem [10–13] whereas, in recent years meta-heuristic algorithms have gained huge popularity [14–20].

The objectives of this paper are to solve the ED and MED problems independently, to later solve and compare the results with that from the combined economic–emission dispatch problem. Implementing and comparing a nonlinear optimization package for MATLAB along with eight meta-heuristic algorithms will help us to optimize the mathematical model proposed in this study. The algorithmic tools are Virus Optimization Algorithm (VOA) [21], Genetic Algorithm (GA) [22], Particle Swarm Optimization (PSO) [23], Harmony Search (HS) [24], Differential Evolution (DE) [25], FireFly algorithm (FF) [26], Gravitational Search Algorithm (GSA) [27], and Seeker Optimization Algorithm (SOA) [28]. The second goal and main contribution of this paper, is to further investigate a newly proposed approach for the objective function evaluation when solving the CEED problem using

* Corresponding author. Address: Department of Industrial Engineering and Management, Yuan Ze University, No. 135 Yuan-tung Road, Chungli City, Taoyuan 32003, Taiwan. Tel.: +886 3 4638800x2521.

E-mail address: ycliang@saturn.yzu.edu.tw (Y.-C. Liang).

population-based algorithms as in [16], throughout a more comprehensive and detailed testing process. Therefore, not only showing the feasibility of the proposed approach but also its robustness when dealing with a variety of instances implemented on different optimization algorithms to reduce the computational effort.

The approach as in [29] avoids differences in units and scale when combining the ED and MED; therefore, penalty factors and/or multi-objective optimization [30,31,6] are not required. The major difference between this paper and the one presented in [29] is that, the robustness of the proposed method (normalization) is extensively studied with a variety of instances and population based algorithmic tools. The aforementioned, gives more insides in the behavior and power of the proposed normalization method.

Section 2 of this paper introduces the necessary background for the ED, MED, and CEED problems, respectively. Section 3 details the approach proposed as in [29], where the normalized objective function to be optimized by the VOA, GA, PSO, HS, DE, FF, GSA, and SOA is introduced as well. The computational results for the test instances are shown in Section 4; where the ED, MED and CEED are analyzed. Lastly, conclusions and future research directions are addressed in Section 5.

2. Background

The combined economic–emission dispatch is the one that minimizes two conflicting objective functions, the operating or fuel cost (FC) given in dollars per hour (\$/h) and the emission (E) of pollutants such as nitrogen and sulfur oxides (NOx and SOx) given in tons per hour (ton/h).

2.1. The economic dispatch (ED) problem

Minimizing the total cost incurred in power generation among the committed units (thermal generators) is the basic principle behind the economic dispatch problem. The satisfaction of the demand on each generating unit has to guarantee that the power limits $[P_i^{\min}, P_i^{\max}]$ of the i th generator are not violated as well as the power balance constraint. Mathematically the economic dispatch problem is defined as follows [30]:

$$FC(\mathbf{P}) = \sum_{i=1}^m (a_i + b_i P_i + c_i P_i^2) \quad (1)$$

subject to

$$\sum_{i=1}^m P_i = P_D + P_{\text{loss}} \quad (2)$$

$$P_i^{\min} \leq P_i \leq P_i^{\max} \quad (3)$$

where $i = 1, 2, \dots, m$, and m denotes the number of generating units. $FC(\mathbf{P})$ represents the cost of operating the thermal units, \mathbf{P} is the vector containing the power generated by each thermal unit, usually in per unit (p.u.) or megawatts (MW), and coefficients a , b , and c , are the cost coefficients. Additionally (2) and (3) are the power balance and generator constraints, where P_D and P_{loss} represent the power demand and transmission loss respectively, while satisfying the demand P_D . The power loss is calculated using (4), where B_{ij} , B_{0j} , and B_{00} , are the loss coefficients.

$$P_{\text{loss}} = \sum_{i=1}^m \sum_{j=1}^m P_i B_{ij} P_j + \sum_{j=1}^m B_{0j} P_j + B_{00} \quad (4)$$

2.2. The minimum emission dispatch (MED) problem

Given the environmental considerations, the harmful emission of pollutants produced by power generation process need to be

minimized. Many have been the possible solutions proposed to solve this problem [31,6,32], with some of them suggesting the installation of cleaning equipment, change of fuels with fewer pollutants [2]. The emission dispatch problem is defined as in (5) which is subject to (2) and (3), while α , β , γ , ζ , and λ are the emission coefficients. The value coming from (5) is given in ton/h; consequently, its minimization is interpreted as the minimum amount of pollutants emitted in order to satisfy a total demand given by P_D .

$$E(\mathbf{P}) = \sum_{i=1}^m (10^{-2} \times (\alpha_i + \beta_i P_i + \gamma_i P_i^2) + \zeta_i \exp(\lambda_i P_i)) \quad (5)$$

2.3. The combined economic and emission dispatch (CEED) problem

The basic idea of combining the economic and emission dispatch (ED/MED) in a single objective function is that, by optimizing it, the power demand P_D is satisfied with the lowest fuel cost and pollution possible; therefore, solving the ED and MED independently is not necessary. However, it is obvious that the solution obtained by combining (1) and (5) is expected to be more difficult to optimize than solving them separately. The objective function for the CEED problem is detailed as follows:

$$\phi(\mathbf{P}) = w_1 \times FC(\mathbf{P}) + w_2 \times E(\mathbf{P}) \quad (6)$$

where w_1 and w_2 are the weights for the fuel cost function $FC(\mathbf{P})$ and the amount of pollutant emitted by the thermal units $E(\mathbf{P})$. The aforementioned problem has gained popularity in the meta-heuristic optimization field, where in this paper a novel and seven well-known meta-heuristics are implemented, Virus Optimization Algorithm [21], Genetic Algorithm [22], Particle Swarm Optimization [23], Harmony Search [24], Differential Evolution [25], FireFly algorithm [26], Gravitational Search Algorithm [27], and Seeker Optimization Algorithm [28]. The procedure implementing the meta-heuristics mentioned is detailed in Section 3.

3. Methodology

3.1. Meta-heuristic algorithms

Eight meta-heuristic algorithms are implemented in this study in order to solve the mathematical model presented as in (6). Each algorithmic tool encodes continuous variables during the optimization process. The first optimization tool is a novel meta-heuristic named Virus Optimization Algorithm [21], Inspired from the behavior of a virus attacking a host cell, VOA is a population-based method that begins the search with a small number of viruses (solutions). For continuous optimization problems, a host cell represents the entire multidimensional solution space, where the cell's nucleolus denotes the global optimum. Virus replication indicates the generation of new solutions while new viruses represent those created from the strong and common viruses. The strong and common viruses are determined by the objective function value of each member in the population of viruses. To simulate the replication process when new viruses are created, the *population size* will grow after one complete iteration. This phenomenon is controlled by the *antivirus* mechanism that is responsible for protecting the host cell against the virus attack. The whole process is terminated based on the stopping criterion: the maximum number of iterations (i.e., virus replication), or the discovery of the global optimum (i.e., cell death is achieved).

The VOA procedure consists of three main processes: Initialization, Replication, and Updating/Maintenance. The Initialization process uses the values of each parameter (defined by the user) to create the first population of viruses. These viruses are ranked (sorted) based on the objective function evaluation to select strong

متن کامل مقاله

دریافت فوری ←

ISIArticles

مرجع مقالات تخصصی ایران

- ✓ امکان دانلود نسخه تمام متن مقالات انگلیسی
- ✓ امکان دانلود نسخه ترجمه شده مقالات
- ✓ پذیرش سفارش ترجمه تخصصی
- ✓ امکان جستجو در آرشیو جامعی از صدها موضوع و هزاران مقاله
- ✓ امکان دانلود رایگان ۲ صفحه اول هر مقاله
- ✓ امکان پرداخت اینترنتی با کلیه کارت های عضو شتاب
- ✓ دانلود فوری مقاله پس از پرداخت آنلاین
- ✓ پشتیبانی کامل خرید با بهره مندی از سیستم هوشمند رهگیری سفارشات