Energy Conversion and Management 51 (2010) 2062–2067

Contents lists available at ScienceDirect

Energy Conversion and Management

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

An improved Pattern Search based algorithm to solve the Dynamic Economic Dispatch problem with valve-point effect

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A R T I C L E I N F O

Article history:
Received 7 July 2009
Accepted 18 February 2010
Available online 25 March 2010

Keywords:
Dynamic Economic Dispatch
Dynamic Economic and Emission Dispatch
Pattern Search
Valve-point effect

A B S T R A C T

In this paper, an improved algorithm based on Pattern Search method (PS) to solve the Dynamic Economic Dispatch is proposed. The algorithm maintains the essential unit ramp rate constraint, along with all other necessary constraints, not only for the time horizon of operation (24 h), but it preserves these constraints through the transaction period to the next time horizon (next day) in order to avoid the discontinuity of the power system operation. The Dynamic Economic and Emission Dispatch problem (DEED) is also considered. The load balance constraints, operating limits, valve-point loading and network losses are included in the models of both DED and DEED. The numerical results clarify the significance of the improved algorithm and verify its performance.

1. Introduction

The Dynamic Economic Dispatch (DED) formulation allows for a more advanced treatment of the Economic Dispatch problem (ED). The addition of certain periods of time in which the traditional ED is scheduled and operated, and the variation of the load demands over this period of time, have made the DED a more realistic representation of real conditions. The introduction of the ramp-up and ramp-down constraints in DED – in addition to the load balance constraints, operating limits, valve-point loading and network losses – has added an important aspect to the formulation. Furthermore, the concern about air pollution has also been taken into consideration. The combined Dynamic Economic and Emission Dispatch (DEED) have been addressed as a result of increased awareness of the need to reduce the release of harmful gases into atmosphere.

The DED was introduced in 1971 by Bechert and Kwanty [1]. The authors overcame the drawbacks of applying static optimization methods by combining economic load allocation and an additional control action. This combination was called the dynamic optimal control and is considered to be the foundation of the DED. Many modifications and additions have been proposed since to the original formulation. Ross and Kim [2] introduced a set of procedures and algorithms that protect the generation units from over-responding to the change of the predicted load. The authors split the large problem into smaller subproblems, and then solve each subproblem using forward dynamic programming. In [3] a particle swarm optimization (PSO) method is proposed to solve DED, in which the ramp rate limits, prohibited zones constraints and the non-smooth cost functions were all taken into consideration. A comparison between the proposed method and the genetic algorithm (GA) was undertaken to verify the quality of the algorithm. In the most recent publication [4], a new multiple tabu search algorithm (MTS) was presented and discussed. The authors considered most of the DED problem constraints, such as load demand, spinning reserve capacity, ramp rate limits and prohibited zones. The results of this novel algorithm were compared with PSO, ordinary tabu search, GA and simulated annealing (SA) methods to demonstrate the applicability and the superiority of MTS in DED applications.

The work reported in this paper regarding the DED problem has been conducted in the context of the following two journal papers. First, the authors of [5] used the simulated annealing (SA) method to solve the DED problem on a model that consists of five unit generators with non-smooth fuel cost functions. The unit ramp constraints for the five units were observed and maintained throughout the period of 24 h and the results were assumed to be global or near global. However, the authors admitted that the computing times were long and they suggested parallel processing as a solution. In the second paper, Basu [6] solved the Dynamic Economic Emission Dispatch (DEED) problem using evolutionary programming based fuzzy satisfying method. Moreover, the author treated the optimization problem as a minimax where the cost and the emission are competing to be the priority function by a decision maker (DM). Although the author listed the achieved optimal or near optimal total cost

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doi:10.1016/j.enconman.2010.02.039

solutions, but unfortunately the outputs of each unit for the period of 24 h were not presented, as it was done in [5]. In addition, the solution of the EDE problem presented in [5] has not taken in consideration the consistency of the unit ramp constraints for all of the units in operation during the transaction time between one 24 h period to another. In other words, to avoid violating the unit ramp constrains after a period of 24 h, the controller must shut down the whole power system and restart it again. This paper offers a solution how to rectify this drawback by improving the algorithm and making the necessary adjustments to ensure the continuity of the unit ramp constraint during the transaction time.

In this paper, a new approach to solve the Dynamic Economic Dispatch problem is developed and its results are compared with similar approaches in the literature. The proposed algorithm implements the Pattern Search (PS) method to solve the DED and DEED problems. After a brief introduction to PS is presented, the problem formulation is described in Section 3, followed in Section 4 by numerical results and comparison with other approaches [5,6].

2. Pattern Search method

The Pattern Search (PS) optimization routine is an evolutionary technique that is suitable to solve a variety of optimization problems that lie outside the scope of the standard optimization methods. Generally, PS has the advantage of being very simple in concept, easy to implement and computationally efficient. Unlike other heuristic algorithms, such as genetic algorithms [7,8], PS possesses a flexible and well-balanced operator to enhance and adapt the global and fine tune local search. A useful review of direct search methods for unconstrained optimization is presented in [9], whereas details of the implementation adopted in this paper may be found in [10] and [11].

The Pattern Search (PS) algorithm proceeds by computing a sequence of points that may or may not approach the optimal value. The algorithm starts by establishing a set of points called a mesh, around the given point. This current point could be the initial starting point supplied by the user or it could be computed from the previous step of the algorithm. The mesh is formed by adding the current point to a scalar multiple of a set of vectors called a pattern. If a point in the mesh is found to improve the objective function at the current point, the new point becomes the current point at the next iteration. The flow chart of the process is shown in Fig. 1 (based on [10]).

3. Problem formulation

The formulation of the Dynamic Economic Dispatch consists of the traditional formulation of the ED scheduled over a period of time and supplemented by certain system bounds and operational constraints. In this section, the formulation of the DED is presented and the addition of an emission index is also considered. The objective function of the ordinary DED is as follows:

$$f_1 = F = \sum_{m=1}^{M} \sum_{i=1}^{N} F_{im}(P_{im}) \tag{1}$$

with the incremental fuel cost functions of the generation units with valve-point loading represented as:

$$F_{im}(P_{im}) = a_i P_{im}^2 + b_i P_{im} + c_i + |e_i \sin(f_i(P_{imin} - P_{im}))| \tag{2}$$

where $a_i,\ b_i,\ c_i,\ e_i,\ f_i$ are the cost coefficients of ith unit, P_{im} is the output power of ith unit at time m, $P_{i\min}$ is the lower generation bound for ith unit, N is the number of generation units, M is the number of hours in the time horizon.

If the emission index is considered, then the following additional term should be added to the formulation

$$f_2 = E = \sum_{m=1}^{M} \sum_{i=1}^{N} E_{im}(P_{im}) \tag{3}$$

and the amount of emission of each generator can be expressed [6,12] by

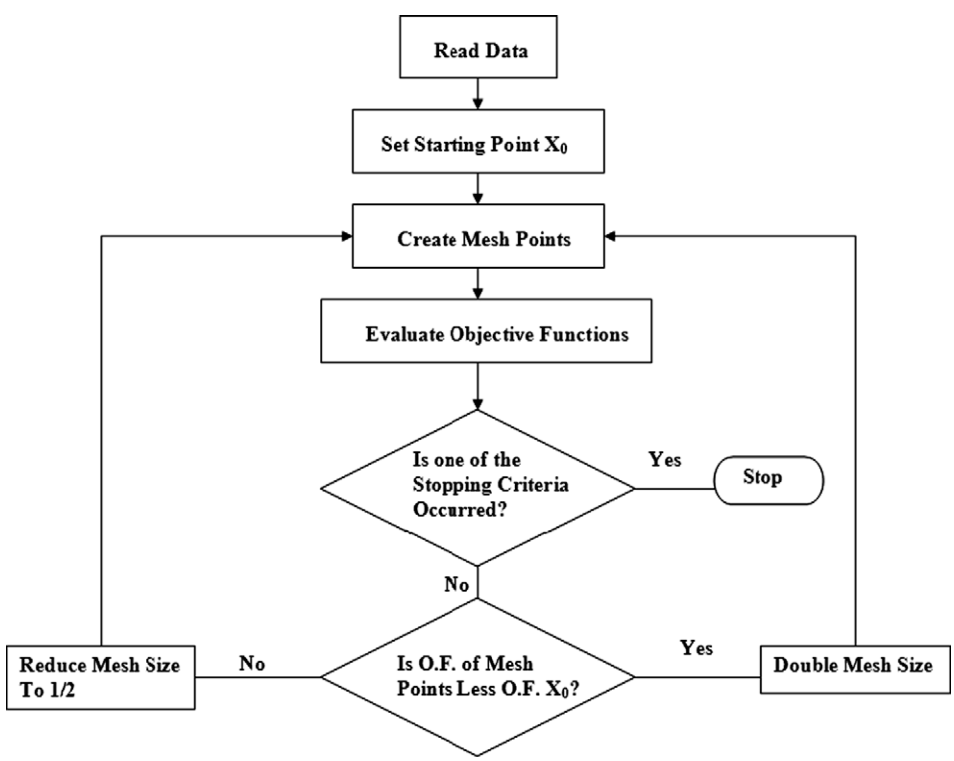

Fig. 1. PS flow chart [10].