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Application of multiple tabu search algorithm to solve dynamic economic dispatch considering generator constraints

Saravuth Pothiya [a,*], Issarachai Ngamroo [b], Waree Kongprawechnon [a]

[a] School of Communication, Instrumentation and Control, Sirindhorn International Institute of Technology, Thammasat University, P.O. Box 22, Pathumthani, Thailand
[b] Electrical Engineering Department, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang, Bangkok, Thailand

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Abstract

This paper presents a new optimization technique based on a multiple tabu search algorithm (MTS) to solve the dynamic economic dispatch (ED) problem with generator constraints. In the constrained dynamic ED problem, the load demand and spinning reserve capacity as well as some practical operation constraints of generators, such as ramp rate limits and prohibited operating zone are taken into consideration. The MTS algorithm introduces additional mechanisms such as initialization, adaptive searches, multiple searches, crossover and restarting process. To show its efficiency, the MTS algorithm is applied to solve constrained dynamic ED problems of power systems with 6 and 15 units. The results obtained from the MTS algorithm are compared to those achieved from the conventional approaches, such as simulated annealing (SA), genetic algorithm (GA), tabu search (TS) algorithm and particle swarm optimization (PSO). The experimental results show that the proposed MTS algorithm approaches is able to obtain higher quality solutions efficiently and with less computational time than the conventional approaches.

Keywords: Dynamic economic dispatch; Genetic algorithm; Particle swarm optimization; Power system operation; Tabu search algorithm

1. Introduction

In power system operation, the economic dispatch (ED) problem is an important optimization problem. Moreover, it has complex and nonlinear characteristics with heavy equality and inequality constraints. Generally, there are two types of ED problem, i.e. static and dynamic. Solving the static ED problem is subject to the power balance constraints and generator operating limits. For the dynamic ED, it is an extension of the static ED problem. The dynamic ED takes the ramp rate limits and prohibited operating zone of the generating units into consideration.

To solve the static ED problem, various conventional methods such as the lambda iteration methods, the gradient method, dynamic programming (DP), etc. have been employed [1,2]. Unfortunately, for generating units with nonlinear characteristics, such as ramp rate limits, prohibited operating zones and non-convex cost functions, the conventional methods can hardly achieve the optimal or near optimal solution. Furthermore, for a large-scale system, the conventional methods have oscillatory problems, resulting in a local minimum solution or a longer computational time.

In the past decade, random search optimization methods, such as simulated annealing (SA) [3], evolutionary programming (EP) [4], genetic algorithms (GA) [5–8], tabu search (TS) algorithm [9,10] and particle swarm optimization (PSO) [11], which are probabilistic heuristic algorithms, have been successfully used to solve the dynamic ED problem.

A conventional TS algorithm, an iterative search algorithm, has been developed by Glover [12,13]. It has been applied to solve combinatorial optimization problems

* Corresponding author. Tel.: +66 2 222959; fax: +66 2 226826.
E-mail address: saravuthpothiya@yahoo.com (S. Pothiya).

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[14–17]. The main advantages of the TS algorithm are its ability to escape from local optima and fast convergence to the global optimum. However, a conventional TS algorithm might have problems with reaching the global optimum solution in a reasonable computational time when the initial solution is far away from the region where the optimum solution exists.

In order to improve the performance of a conventional TS algorithm, this paper proposes the multiple tabu search (MTS) algorithm. The MTS algorithm introduces additional salient mechanisms for improvement of the search process, i.e. initialization, adaptive searches, multiple searches, crossover and restarting process.

The feasibility study of the MTS algorithm is demonstrated for solving the dynamic ED problem. The results optimized by the MTS algorithm are compared to those obtained by conventional approaches such as SA, GA, TS and PSO in terms of solution quality and computational efficiency.

The paper is organized as follows. Section 2 gives the mathematical model of the constrained dynamic ED problem. Section 3 mentions the MTS algorithm. Section 4 presents the detailed procedures of using the MTS algorithm to solve the ED problem. Section 5 shows two application cases and gives the corresponding comparison results with the traditional methods (SA, GA, TS and PSO). Conclusions are finally given in Section 6.

2. Mathematical model of the ED problem

The ED problem is a nonlinear optimization problem, which is a sub-problem of the unit commitment (UC) problem. The objective of the ED problem is to find the optimal combination of power generation that minimizes the total generation cost while satisfying the system load demand, spinning reserve capacity and practical operation constraints of generators that include ramp rate limits and prohibited operating zones [11].

2.1. Objective function

The main objective of the ED problem is simultaneously to minimize the generation cost rate and meet the load demand of a power system over some appropriate period while satisfying various equality and inequality constraints. The objective function of the ED problem can be expressed as

$$\min F_t = \sum_{i=1}^{n} F_i(P_i) = \sum_{i=1}^{n} (a_i + b_i P_i + c_i P_i^2) \tag{1}$$

where F_t is the total generation cost; F_i is the generation cost function of the ith generator, which is usually expressed as a quadratic polynomial; a_i, b_i and c_i are the cost coefficients of the ith generator; P_i is the power output of the ith generator and n is the number of generators committed to the operating system.

2.2. Constraints

2.2.1. Power balance constraints

$$\sum_{i=1}^{n} P_i = P_D + P_L \tag{2}$$

where P_D is the load demand and P_L is the total transmission network losses, which is a function of the unit power outputs that can be represented using B coefficients:

$$P_L = \sum_{i=1}^{n} \sum_{j=1}^{n} P_i B_{ij} P_j + \sum_{i=1}^{n} B_{0i} P_i + B_{00} \tag{3}$$

2.2.2. Practical operation constraints of generators

To achieve the actual economic operation, two constraints of generator operation are taken into account.

(1) *Ramp rate limits*: The ramp rate limits of generating units are caused by the fact that the thermal generating outputs cannot be adjusted instantaneously. To reflect the actual operating process, the ramp rate limits are included in the ED problem to ensure the feasibility of the solutions. The operating range of all on line units is restricted by their ramp rate limits. Fig. 1 shows two possible situations when a unit is on line from hour $t-1$ to hour t. Fig. 1a shows that the unit is in an increasing power generation status. Fig. 1b shows that the unit is in a decreasing power generation status.

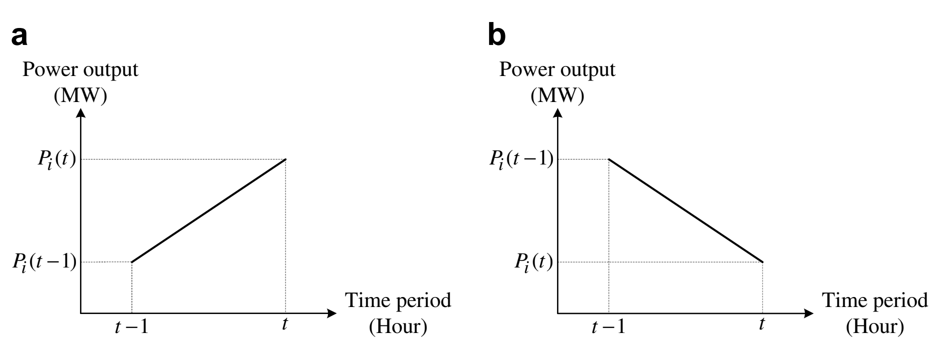

Fig. 1. Two possible situations of the on line ith generating unit.