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Adaptive simulated annealing schedule to the unit commitment problem

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ABSTRACT

This paper presents an approach for solving the unit commitment problem based on a simulated annealing algorithm with an adaptive schedule. The control parameter, temperature, is adapted to the cost levels on which the algorithm operates during the annealing process. This shortens the time taken to find a good solution meeting all constraints and improves the convergence of the algorithm. The operators specific to this problem, mutation and transposition, are used as the transition operators. The method incorporates time-dependent start-up costs, demand and reserve constraints, minimum up and down time constraints and unit power generation limits. There are different definitions of the objective function for the feasible and infeasible solutions. Test results showed an improvement in effectiveness compared to results obtained from simulated annealing with a static schedule, genetic algorithm and other techniques.

1. Introduction

Unit commitment (UC) is the process of determining the optimal set of generating units and their generation levels within a power system to satisfy the required demand and system operating constraints at any time. The scheduling period is from a day to a week. This problem is defined as a non-linear, mixed-integer combinatorial optimization problem. The optimization of this important problem in the daily operation and planning of the power system may save the electric utilities millions of dollars per year in production costs.

The optimal solution to the problem can be obtained only by the complete enumeration method, which is, however, useless for realistic power systems because of the immense size of the solution space. Various optimization methods have been employed to approach the UC problem, such as the priority ordering methods [1,2], dynamic programming [3–6], Lagrangian relaxation [7,8], the branch-and-bound method [9], and the integer and mixed-integer programming [10] (a detailed literature synopsis is summarized in [11–13]). Among these methods, the priority list is easy to implement and the simplest, but the quality of the solution is usually far from optimal due to the incomplete search of the solution space. Many classical methods such as branch-and-bound, dynamic and integer programming suffer from the “curse of dimensionality” because the problem size and the solution time increase rapidly with the number of generating units to be committed. To reduce the search space several approaches have been adopted. Most of them are based on the priority list technique [3,4], thus the solution obtained is suboptimal. The Lagrangian relaxation approach, compared with other methods, has higher computational efficiency and is more flexible for handling different types of constraint. However, because of the dual nature of the algorithm, its primary difficulty is associated with obtaining solution feasibility. Furthermore, the optimal value of the dual problem is not generally equal to that of the primal (original) problem.

Another class of methods applied to the UC problem are the artificial intelligence methods such as the expert systems [14–16], neural networks [6,15,17], fuzzy logic [15,16,18], genetic algorithms [19–22] and simulated annealing [18,23,24]. In the expert system approach, the knowledge of experienced power system operators and UC experts is combined to create an expert system rule base. However, a great deal of operator interaction is required in this approach, making it inconvenient and time-consuming. Neural networks based on a database holding typical load curves and corresponding UC schedules are trained to recognise the most economical UC schedule associated with the pattern of the current load curve. The fuzzy approach allows taking into account many uncertainties involved in the planning and operation of power systems. The key factors such as load demand and reserve margin are treated as fuzzy variables. A fuzzy decision system has been developed to select the units to be on or off based on these fuzzy variables. Genetic algorithms represent a class of stochastic, adaptive and parallel search techniques based on the mechanism of natural selection and genetics. They search from a population of individuals and use probabilistic transition rules. By adding problem-specific genetic operators and by the proper choice of variables and their representation, good near-optimal solutions to the UC problem can be obtained. Simulated annealing (SA) is a general-purpose stochastic

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