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Analysis and Comparison for the Unit Commitment Problem in a Large-Scale Power System by Using Three Meta-Heuristic Algorithms

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Abstract

This work applied three algorithms including charged search system (CSS), particle swarm optimization (PSO), and ants colony search (ACS) to solve the unit commitment problem in a large-scale power system. The three algorithms were applied to 10-, 20-, 40-, 60-, 80-, 100-bus testing systems to solve the UC problem. Then, this work compares the total generation cost and calculation time obtained from the three algorithms. This work also discussed the tunable parameters in the three algorithms, and compared the solutions on UC cost and computation time by setting different parameters.

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Keywords: Unit commitment, particle swarm optimization (PSO), charged search system(CSS), ants colony search (ACS)

1. Introduction

The unit commitment (UC) plays a central role in power system operation. The objective of the UC is to schedule operation of the generating units to serve the load demand at the minimum operating cost while observing all plant and system constraints over a given scheduling period, ranging from several hours to days ahead. The UC is a large-scale, non-convex, nonlinear, mixed-integer optimization problem [1]. It is usually complex to solve because of its enormous dimensions, nonlinear objective function and coupling constraints. The need for practical cost-effective UC solutions leads to the development of various UC algorithms [2-10].

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The UC algorithms so far developed are classified into two main categories: One is the numerical optimization techniques such as priority list methods [2], dynamic programming [3], Lagrangian relaxation methods [4, 5], branch-and-bound methods [6], integer and mixed-integer programming method, and mixed-integer programming [7]. The other is the stochastic search methods such as genetic algorithms [8, 9], evolutionary programming [10], simulated annealing [11, 12], ant colony search [13, 14], and particle swarm optimization [15, 16]. The priority list approach is simple and fast, but it usually yields high production cost. The dynamic programming is flexible but suffers from the problem of high dimensionality. The branch-and-bound method uses a linear function to represent the fuel consumption and time-dependent start-up cost and obtains the required lower and upper bounds. However, its computational time increases exponentially with the increment of the dimension of the UC problem. The mixed-integer programming method employs linear programming technique to solve and check for an integer solution, but it also suffers from an excessive computational time requirement. The Lagrangian relaxation method offers a faster solution; however, it may encounter numerical convergence problems. One of artificial intelligence methods, which was based on heuristic depth-first search method, was also developed but it could be limited in its application to large-scale UC problem.

This work uses the Particle Swarm Optimization (PSO), Ant Colony Search (ACS) and Charged System Search (CSS) respectively to solve the UC problem, and compares the advantages and disadvantages between them. PSO is a social behavior based optimization method in which each particle dynamically adjusts its velocity and position according to its own experience and flying experience from its neighbor [15]. The ant colony search (ACS) algorithm [17] [18] is inspired by the behavior of real ants. Charged System Search (CSS) is a new optimization algorithm based on principles from physics and mechanics. CSS is a new optimization algorithm based on physics and mechanics.

2. Introduction to three UC algorithms and their applications on UC

In this work, PSO, ACS and CSS were used, individually, to solve the optimization problem of the unit commitment. In terms of the CSS algorithm, the modified priority list (MPL) method is used first to obtain a group of 24-hour initial unit status for each charged particle. The initial location and velocity of each charged particle are set. The fitness value (total power generation cost) of each charged particle is calculated using the objective function and constraints. Next, the effect of Coulomb attraction between the charged particles is determined. The position and velocity of each charged particle is updated. The new fitness value (total power generation cost) is thus calculated, and the temporary storage is provided to store, retrieve, and update the optimal solution after each iteration. Finally, whether the convergence conditions are met is checked, and the output is the optimal unit dispatching solution. This work also applied the search rules and characteristics of PSO to search for the optimal solution (G_{best}), and presents the corresponding UC results. First, 10 groups of initial particle locations and velocities in the 24-dimensional search space (i.e., 1-24 hours) are generated by using the MPL method, where the location of each particle indicates the unit commitment of 1 to 24 hours. The fitness value (i.e., generation cost) represented by each particle is calculated through the objective function and constraints. The initial P_{best} of each particle and the initial G_{best} of the overall particles are generated. When entering into iterations, the PSO velocity updating rules are applied. After updating, the particle location would move according to the updated velocity and further generate new particle locations. Next, the new fitness value represented by each particle is calculated from the updated particles using the objective function and constraints. Finally, the P_{best} of each particle and G_{best} of the overall particles are compared to update the them. In terms of the ACS algorithm, the ants are placed on the initial unit commitment solution generated by MPL as the starting points. The fitness value (generation cost) represented by each ant is calculated using the objective function and all constraints. All ants follow the state transition rules to select the next dispatchable unit state. After the completion of each patch by each ant, the expenditure cost of each path (unit commitment) is calculated. Next, pheromone concentration updating is performed, including "Regional Updating Rules" and "Overall Updating Rules". After the path selection of each ant is completed, regional pheromone recession parameter is used to evaporate the pheromone concentration of each path section. After completion of all paths of all ants, only the ants covering the shortest path (the minimum power generation cost) are updated.