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Binary real coded firefly algorithm for solving unit commitment problem

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ABSTRACT

This paper presents a new biologically-inspired binary real coded firefly (BRCFF) algorithm to solve the unit commitment problem (UCP) by considering system and generating unit constraints. The firefly (FF) algorithm is inspired by the flashing behavior of fireflies and the phenomenon of bioluminescent communication. Upon solving UCP, the proposed binary coded FF algorithm determines the ON/OFF status of the generating units, while the economic dispatch problem (EDP) is solved using the real coded FF algorithm. The manner of firefly communication through luminescent flashes and their synchronization is imitated and suitably implemented in UCP. An effective constraint handling mechanism is introduced to solve complicated system and unit constraints. Finally, the proposed algorithm is applied to 3, 12, 17, 26, and 38 generating unit systems for a 24 h scheduling horizon and a comparative study is conducted using other recently reported results. Numerical results clarify and verify the significance of the proposed algorithm. The results obtained indicate that the proposed biologically-inspired algorithm could be an important player in swarm-based optimization.

1. Introduction

The optimum economic operation and planning of electric power generation systems occupies a crucial position in the electric power industry. Unit commitment is an important function in the generation of resource management in a power system. A unit commitment problem (UCP) in a power system is a combinatorial optimization problem that determines the ON/OFF status of the generating unit in order to satisfy the load demand, spinning reserve, and physical and operational constraints of the individual unit. The economic dispatch problem (EDP) [57,58] (is the sub problem of UCP) determines the optimal dispatch among the committed generating units during each period of operation in order to satisfy the system load. Therefore, UCP is a nonlinear mixed integer programming problem and is a computationally expensive proposition for large power systems.

1.1. Literature survey for UCP

In UCP, power system operators have to maintain a certain amount of generation capacity as spinning reserve [8–10]. This approach ensures that the power system is able to withstand the sudden outage of some generating units, transmission lines, or an unforeseen increase in load, without having to resort to load shedding. In the deterministic method of setting spinning

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Nomenclature

$Fc\ (Pi,k)$	fuel cost ($)
a_i, b_i, c_i	cost coefficient of ith generator unit
H	total number of hours considered
$I_{i,k}$	status of unit i at kth hour. (i.e.) 1 for ON and 0 for OFF
$Load_k$	total system demand at kth hour
$LOLP_{k,}^{spec}$	specified LOLP at kth hour
$LOLP_k$	calculated LOLP at kth hour
$P_{i,k}$	generation power output of unit i at kth hour
$P_{i,max}$	maximum power output of unit i
$P_{i,min}$	minimum power output of unit i
hc_i	hot start cost
cc_i	cold start cost
$RU(i)$, $RD(i)$	ramp up/ramp down rate limit of unit i
$SC_{i,k}$	startup cost of unit i at kth hour
SR_k	system spinning reserve in MW at kth hour
$T^{on}(i)$, $T^{off}(i)$	minimum ON/OFF time for unit i
$X^{on}(i,k)$	time duration for which unit i is ON at kth hour
$X^{off}(i,k)$	time duration for which unit i is OFF at kth hour
TOC	total operating cost
γ	absorption coefficient
r	distance between two fireflies
n	constant

Indices

i, k	generating unit and time index, respectively
j	jth state of capacity outage probability table
p, q	firefly position

reserve, the minimum amount of spinning reserve is set to a value that is at least equal to the capacity of the largest unit, or to a specific percentage of the hourly system load [12–14,35,37–39].

1.2. Literature survey for solution techniques

Many optimization techniques are available for solving the nonlinear mixed integer programming problem [59]. A literature review of the UCP and the solution techniques are given in [32,42]. The classical optimization methods such as the priority list method [2], dynamic programming [46], branch and bound [4,6], mixed integer programming [23,28], and Lagrangian Relaxation (LR) [29,60] are widely used conventional techniques. The priority list method is simple and fast. However, it produces a sub-optimal solution with a higher operation cost. The dynamic programming method has dimensionality problems, whereby the execution time increases rapidly with the number of generating units to be committed as the size of the problem increases. The LR method provides a quick solution. However, the dual nature of the algorithm suffers from numerical convergence and solution quality. In the branch-and-bound and mixed integer programming methods, the computational time increases substantially for a large-scale power system. Therefore, artificial intelligence techniques such as neural networks [31], expert systems [51], genetic algorithms (GA) [7,19], simulated annealing (SA) [24], evolutionary programming (EP) [18], tabu search [25], fuzzy logic [40], particle swarm optimization (PSO) [16,36,41,48], ant colony optimization (ACO)[5,43], frog leaping algorithm (FLA) [17], tuned harmony search algorithm (HAS) [33], teaching–learning algorithm [26], T-cell algorithm [49] and migrating birds optimization (MBO) [11] are often used. These solution techniques are good for searching the near global optimal solution and can be considered successful to a certain extent. Since new swarm-based optimization techniques are also emerging, the best commitment solution with less computational time is a challenging task within the research community. In recent years, a new biologically-inspired meta-heuristic algorithm, known as the firefly algorithm and developed by Xin-She Yang, has been successfully used to solve the nonlinear and non-convex optimization problems [15,53–56]. Based on these previous findings, we attempted to demonstrate a new methodology for solving the UCP problem with the FF algorithm, with the goal of providing a practical alternative for conventional solution methods.