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Generation Scheduling problem by Intelligent Genetic Algorithm ☆

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ABSTRACT

This paper presents a Genetic Algorithm (GA) solution to solve the Generation Scheduling (GS) problem with intelligent coding scheme. The intelligent coding scheme effectively handles minimum up/down time constraints of GS problem. GA with intelligent coding is called as Intelligent Genetic Algorithm (IGA). Penalty parameter-less constraint handling technique is used for satisfying power balance constraint. Performance of the IGA is tested on a 10-unit 24-h and 26-unit 24-h unit commitment test systems. The result obtained using IGA is compared with the results reported using Lagrangian Relaxation (LR), Enhanced Lagrangian Relaxation (ELR), LRGA, GA and Evolutionary Programming methods. Simulation results show the effects of intelligent coding scheme in obtaining feasible and minimum cost solution.

1. Introduction

Generation Scheduling (GS) in a power system is to prepare the schedule of the generators with their output power in such a way that the total system production cost over the time period is minimized while meeting various plant and system constraints. In general, GS involves with the decisions with regards to unit status subjected to the loading levels, the amount of spinning reserve for each unit and satisfying Minimum Up-Time (MUT) and Minimum Down-Time (MDT) constraints over a given scheduling period. GS problem is a nonlinear, mixed-integer combinatorial optimization problem. The global optimal solution can be obtained by complete enumeration, which is not practicable to large power systems due to its excessive computation time [1].

A number of methods have been used previously for solving the above problem and each method has its own difficulties. The various traditional methods used for this problem are Priority List based method, Branch and Bound, Dynamic Programming and Lagrangian Relaxation [2,3]. In the Priority List method, an exhaustive enumeration of all unit combinations is performed at each load level. Hence, it is hard to handle if the dimension of the problem is large, whereas in the case of Branch-and-Bound method, finding the optimal solution is time consuming, because it can only be obtained by successive elimination of a set of inappropriate solutions [4]. Based on the "Principle of Optimality", Dynamic Programming was suggested for GS problem. However, the main drawback of this is that it could not take into account the coupling time constraints and time dependent start-up costs [5]. Lagrangian Relaxation for GS problem is superior to Dynamic Programming due to its higher solution quality and faster computational time [6]. However, by using this, there is no guarantee to get an optimal solution. Many times the solution tend to be sub-optimal.

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List of symbols

OF	objective function in dollars ($)
i	$1,2,\ldots,N$, no. of generators
t	$1,2,\ldots,T$, no. of hours
a_i	fixed cost of ith unit ($)
b_i	coefficient of the linear term of the variable cost function of the ith unit ($/MW)
c_i	coefficient of the quadratic term of the variable cost function of the ith unit ($/MW^2)
$U_{i,t}$	unit's status at hour t
$ST_{i,t}$	Start-up cost of ith unit at hour t
$SD_{i,t}$	shutdown cost of ith unit at hour t
R_t	spinning reserve at hour t
$P_{i,t}$	real power generated at ith unit during hour t
$P_{i,min}$	lower generation limits for ith unit
$P_{i,max}$	upper generation limits of ith unit
P^t_{demand}	load demand at hour t
MUT_i	minimum up time of ith unit
MDT_i	minimum down time of ith unit
t_s	the hour at which unit is start-up
t_d	the hour at which unit is shutdown

In addition, it is difficult to handle the minimum up and down time constraints unless some heuristic methods are used. Hence, heuristic approaches like Genetic Algorithm (GA) [7–10], Evolutionary Programming (EP) [11], Simulated Annealing (SA) [12], Tabu Search (TS) [13], Fuzzy Logic/expert systems [14–16], Artificial Neural Networks (ANN) [17], have been proposed to solve this problem. However, the results obtained by these methods required a considerable amount of computational time especially for a large system. Hence, recently, the traditional methods are integrated with these heuristic methods to solve this problem effectively. These hybrid methods are claimed to accommodate the constraints that are more complicated and claimed to have better quality solutions even though the system under consideration is very large [18–20]. Later hybridization between two heuristic algorithms has been used to solve the GS problem [21–23]. Recently, Particle Swarm Optimization approach inspired by quantum computing has also been introduced in [24].

GAs are having widespread application because of their aspects like simplicity, function independent and not being limited by the properties of the function such as continuity, existence of derivatives, unimodality, etc. In order to deal effectively MUT and MDT constraints of GS problem with GA, intelligent coding is used in this paper [25,26]. GA with intelligent coding is termed as Intelligent GA (IGA) in this paper. The other constraints are handled by integrating constraint violations into the fitness function, using penalty parameter-less constraint handling technique. Performance of the IGA approach is tested on 10-unit and 26-unit GS test systems.

The remainder of the paper is organized as follows: Section 2 addresses the GS problem formulation. The GA for GS problem is described in Section 3, whereas, Section 4 explains the concepts of IGA and penalty parameter-less constraint handling scheme. Section 5 deals with the Economic dispatch and Section 6 discusses the numerical results followed by conclusion.

2. Generation Scheduling problem formulation

The objective of GS problem is to minimize the operating cost over the scheduled period, under the generator operational and spinning reserve constraints. The objective function to be minimized is

$$OF = \sum_{i=1}^{N}\sum_{t=1}^{T}[F_i(P_i^t) + ST_{i,t}(1 - U_{i,t-1})]U_{i,t} + (1 - U_{i,t})SD_{i,t}U_{i,t-1} \tag{1}$$

subject to,

(i) Power balance constraint

$$\sum_{i=1}^{N} P_{i,t}U_{i,t} = P^t_{demand} \tag{2}$$

(ii) Generation limit constraint

$$P_{i,min}U_{i,t} \leqslant P_{i,t} \leqslant P_{i,max}U_{i,t} \tag{3}$$

(iii) Spinning reserve constraint