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Advanced three-stage pseudo-inspired weight-improved crazy particle swarm optimization for unit commitment problem

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ABSTRACT

This paper proposes an advanced three-stage approach to solve the unit commitment problem. The proposed approach utilizes three different stages to get the optimum solution. In the first stage, a primitive structure of all units is obtained on the basis of predefined priority. In the second stage, a weight-improved crazy particle swarm optimization considering a pseudo-inspired algorithm has been proposed for economic scheduling of operating units. Finally, in the third stage, extra reserve and total operating cost are minimized using solution restructuring process. In addition, problem formulation includes multi-fuel options, prohibited operating zones and nonlinearities like valve point loading effects. The effectiveness of proposed approach is tested on various systems including IEEE 118-bus system and its performance is compared with the existing methods with the help of simulation results.

1. Introduction

Over the past few years, due to rapid industrialization and increased standard in the life style of the domestic consumers, the electric power requirements have been increasing globally. At the same time, power generating unit's emitting harmful pollutants into the atmosphere. Therefore, the effect of different fuel and carbon prices scenarios is to be investigated under the analysis of the primary energy consumption in the thermoelectric sector [1]. It is well known that electrical energy plays an important role in the national economy; therefore, providing reliable and secure power is one of the important aspects of power system operation and control. In past, many research works have been done in the field of power system security. In Refs. [2], authors utilize auction mechanism in power market to describe a scheme for rescheduling pool generation and adjusting contract-transactions for dynamic security enhancement when necessary. Dynamic security constrained economic dispatch using the transient energy margin has been introduced in Ref. [3]. Authors, in Refs. [4], proposed MMP (Multi-objective Mathematical Programming) model which includes generation cost, CTE (Corrected Transient Energy) margin as dynamic security index and VSM (Voltage Stability Margin) as the voltage security index in the objective function. The power system security deals with the security of the system under a particular operating condition, but when the system is under normal operating condition, the economic aspect of the power system is the primary concern.

The sources of energy (coal, river water, marine tide, a wind energy, sun power, oil, etc.) are so diverse, that the choice of one or the other is made on economical, technical and/or geographical basis. Thus it has become a challenging task for the power utilities to perform proper scheduling of the generating units to minimize the total operating cost [5]. This scheduling process is known as UC (Unit Commitment). The main task of unit commitment problem involves scheduling the ON (1)/OFF (0) status of units, as well as the real power output of generating units to satisfy the forecasted demand over a short-term period, meeting all kinds of system and unit constraints to minimize the overall production cost.

The UC performs an important role in the operational planning of modern power system and saves significant amount of total operation cost per year. Various methods have been proposed in the past, to solve the unit commitment problem, such as PL (Priority List) [6], DP (Dynamic Programming) [7], BB (Branch-and-Bound) [8], and LR (Lagrangian Relaxation) approach [9], etc. These methods are known as classical or numerical optimization

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Nomenclature

a_i,b_i,c_i Cost coefficients of the ith generating unit.
e_i,f_i Valve point coefficients of the ith generating unit.
a_{im},b_{im},c_{im} Cost coefficients of the ith generating unit using the fuel type m.
e_{im},f_{im} Valve point coefficients of the ith generating unit using the fuel type m.
CSC_i/HSC_i Cold/Hot start cost of ith thermal unit.
CSH_i Cold start hour.
$D_{h,j}(t)$ Water discharge rate of jth reservoir at hour t.
$D_{h,j}^{min}/D_{h,j}^{max}$ Minimum/Maximum water discharge rate of jth reservoir.
$F_i(P_i(t))$ Fuel cost function of ith thermal unit at hour t.
F_T Total operation cost over the scheduling horizon.
$I_i(t)$ Schedule state of ith thermal unit for hour t.
I_j Schedule state of jth thermal unit of decommitted group.
I_k Schedule state of kth thermal unit of committed group.
K Total number of units in committed group.
NH Number of hydro units.
NT Number of thermal units.
N_i Number of prohibited zones of ith thermal units.
$P_i(t)$ Generation of ith thermal unit at hour t.
$P^l_{i,m}/P^u_{i,m}$ Lower and upper bounds of ith thermal unit using fuel type m.
$P^l_{i,q}/P^u_{i,q}$ Lower and upper bounds of the qth prohibited zone of ith thermal unit.
$P_i^{max}(t)$ Max generation of ith thermal unit at hour t.
$P_i^{min}(t)$ Min generation of ith thermal unit at hour t.
$P_D(t)$ System load demand at hour t.
$P_{Loss}(t)$ Power network losses at hour t.
$SR(t)$ Spinning reserve requirements at hour t.
$S_{h,j}(t)$ Spillage of jth reservoir at hour t.
RU_i/RD_i Ramp-up/down rate of unit i.
$STC_i(t)$ Startup cost of ith thermal unit at hour t.
$t_{off,i}(t)/t_{on,i}(t)$ Time period that ith thermal unit has been continuously down/up till period t.
T Number of time interval (hours).
$T_{up,i}/T_{down,i}$ Minimum up/down time of ith thermal unit.
$V_{h,j}(t)$ Volume of jth reservoir at hour t.
$V_{h,j}^{min}/V_{h,j}^{max}$ Minimum/Maximum volume of jth reservoir.
$X_{h,j}(t)$ Water inflow rate of jth reservoir at hour t.
γ_j Input/output characteristics of jth hydro unit.

techniques. But the numerical convergence and solution quality problems are the major concerns for most of these approaches.

Some stochastic search methods, such as GA (Genetic Algorithm) [10], BF (Bacteria Foraging) [11], PSO (Particle Swarm Optimization) [12], ICA (Imperialistic Competition Algorithm) [13], ICGA (Integer-Coded Genetic Algorithm) [14], IQEA (Improved Quantum-Inspired Evolutionary Algorithm) [15], HAS (Harmony Search Algorithm) [16], ABC (Artificial Bee Colony Algorithm) [17], BRDE (Binary-Real-coded Differential Evolution) [18] and GMTLBO–BH (Gradient Based Modified Teaching–Learning Optimizer with Black Hole Algorithm) [19] can successfully handle complex nonlinear constraints and provide high-quality solutions, but curse of dimensionality is a major concern. The efforts have also been made to develop hybrid techniques, such as LR with GA (LRGA) [20], LR with PSO (LR-PSO) [21], FAPSO (Fuzzy Adaptive PSO) [22], BCPSO (Binary Clustered PSO) [23], SF (Straight Forward) [24] and THS (Three-Stage) approach [25], for better and faster optimum results.

Several priority list approaches have been proposed with their attention on increasing optimality level and convergence rate. Authors in Ref. [26] proposed a new unit commitment method which uses fast EPL (Extended Priority List) method. The EPL method consists of two steps; in the first step plurality of initial solutions is obtained by PL method and in the second step, several heuristics to plurality of initial solutions are applied for better solution. SPL (Stochastic Priority List) method for solving large-scale unit commitment problem is introduced in Ref. [27]. However, these models usually suffer from the highly heuristic property and relatively poor quality solutions. THS (Three-Stage method) [25], utilized priority list along with AI (Artificial Intelligence) (PSO and Nelder-Mead algorithm) and used for small system without considering unit ramp-rate limit. The simulation results obtained from THS are not very effective.

In past decades, many methods have been proposed to solve short-term hydrothermal unit commitment in power systems such as GA (Genetic Algorithm) [28], SA (Simulated Annealing) [29], DE (Differential Evolution) [30] and DRQEA (differential real coded quantum inspired evolutionary algorithm) [31] etc. Although, above evolutionary methods have shown great strength in solving the non-smooth optimization problems. But, because of their limited local or global search capabilities, they may get trapped in the local optima due to population diversity when handling large-scale problems with highly complex constraints [32]. Compared to other evolutionary techniques, PSO is simple and easy to implement. Furthermore, PSO also has a flexible and well-balanced mechanism for improving and adjusting the global and local search capabilities.

In this paper, an ATHS (Advanced Three-Stage) algorithm is developed for UC (unit commitment) of large systems. A WICPSO (Weight-Improved Crazy Particle Swarm Optimization) along with pseudo-inspired algorithm is proposed for solving the proposed UC problem. The significant contributions of the paper are highlighted as follows:

- ATHS (Advanced Three-Stage) approach is developed. In the first stage, primitive status of all units is obtained on the basis of predefined priority. Second stage utilizes WICPSO along with pseudo-inspired algorithm for accelerating optimization process. In the final stage, SRP (Solution Restructuring Process) is developed to reach an optimum solution.
- The problem formulation incorporates multi-fuel options, prohibited operating zones and nonlinearities due to valve point loading effects. The effectiveness of the proposed approach is demonstrated on several systems including IEEE-118 bus system and results are compared to other techniques available in literature.

2. Problem formulation

The objective of a short-term generation scheduling problem is to minimize thermal unit fuel cost subjected to various system and unit constraints. System configuration and line impedances are not considered in the problem formulation. To perform the proposed approach scheduling period is divided into T time interval and model is formulated as follows: