SFLA approach to solve PBUC problem with emission limitation

T. Venkatesan [a,*], M.Y. Sanavullah [b]

[a] Department of EEE, K.S.Rangasamy College of Technology, Tiruchengode 637 215, Tamil Nadu, India
[b] VMKV Engineering College, Salem 636 308, Tamil Nadu, India

ARTICLE INFO

ABSTRACT

In this paper, the Shuffled Frog Leaping Algorithm is proposed to solve the Profit Based Unit Commitment problem under deregulated environment with emission limitation. The bi-objective function optimization problem is formulated as a maximization of the Generation Companies profit and a minimization of the emission output of the thermal units, while all of the constrains should be satisfied. This work, considers the new softer demand constraint to allocate fixed and transitional cost to the scheduled hours. The IEEE 10 unit 39 bus test system with 24 h data is taken as the input for simulation using MATLAB 7.10 version. From the results obtained, it is observed the proposed algorithm achieves maximum profit and minimum emission level with less computational time compared to traditional unit commitment.

© 2012 Elsevier Ltd. All rights reserved.

1. Introduction

Unit Commitment (UC) is a nonlinear mixed integer optimization problem to schedule the operation of the generating units at minimum operating cost while satisfying the demand and reserve requirements. In earlier days the UC problem has to determine based on the on/off state of the generating units at each hour of the planning period and optimally dispatch the load and reserve among the committed units. UC is the most significant optimization task in the operation of the power systems. The global optimal solution to the UC problem can be obtained by complete enumeration, which is restricted to large power systems due to its excessive computational time requirements [1]. Numerous solutions have been proposed to solve the unit commitment problem [2], such as Priority List (PL), Dynamic Programming (DP), Lagrangian Relaxation (LR), Genetic Algorithm (GA), and Particle Swarm Optimization (PSO). The PL method is fast but highly heuristic and gives schedule with relatively higher operating costs [2]. The DP method has the advantage of being able to solve problems of variety of sizes [3]. But it may lead to more mathematical complexity with increased in computation time, if the constraints are taken in to consideration [4]. Even though the LR is considered the best to deal with large-scale unit commitment, it cannot guarantee the optimal solution [5].

The process of deregulation and creating the market conditions in electricity sector was pioneered by Chile in 1978. It was later succeeded by England and Wales that started trading through the pool from 31st of March 1990. In power sector, the foremost process is deregulation that was taken over by the state reformation act of 1989. Most of the companies started the deregulation laws, that includes Argentinean and Chile, who were initiatives followed by South America, Peru in 1993, Bolivia and Columbia in 1994. According to Electricity Act of June 1990, deregulation and market competition was introduced in Norway. The current deregulation process in Brazil is the gradual outcome of these laws on February 1995. Many more countries like India also adopt the similar process of developing deregulation in power sector [6].

In the past decade, the power industry has moved from vertically integrated electric utilities to one that has been horizontally integrated electric utilities, in which the generation, transmission and distribution are unbundled. Consequently, the traditional method needs some changes in power generation, operation and control methods [7,8]. In deregulated power industry, unit commitment refers to optimizing generation property in order to maximize the GENeration COmpanies (GENCOs) profit called as Profit Based Unit Commitment (PBUC). Deregulation in power sector increases the efficiency and reliability of electricity production and distribution, at lower prices, higher quality, a secure and a more reliable product to consumers.

The deregulation of electric power systems has resulted in market-based competition by creating an open market environment [9]. Also, it has the advantage that customers are allowed to choose their suppliers and provide choice of different generation options at cheaper price to consumers [10].

The determination of thermal units which is to be committed and available for generation at each period and the associated generation or dispatch, during the time horizon of 1 day to 1 week can be done by the short term thermal scheduling. The economic

Nomenclature

N	number of units
T	scheduling horizon
PD_t	system power demand at hour t
R_{it}	system spinning reserve of unit i at hour t
C	number of operating cycles for each unit i
P_{it}	output power of ith unit at hour t
$P_{i\,max}$	maximum output power of ith unit
$P_{i\,min}$	minimum output power of ith unit
$P_{it\,max}$	maximum output power of ith unit at hour t
$P_{it\,min}$	minimum output power of ith unit at hour t
$T_i(c)$	duration of operating cycle c for unit i
MU_i	maximum up-time limits of unit i
MD_i	minimum down-time limits of unit i
$H_{cost(i)}$	hot start cost of unit i
$C_{cost(i)}$	cold start cost of unit i
$C_{hour(i)}$	cold start hour of unit i
SU	start-up cost for unit i

SU_T	start-up cost
FC	fuel cost
RV	revenue
TC	total cost
PF	profit
X_{it}	operation status of unit i at hour t (1 = ON and 0 = OFF)
RU_i	ramp-up rate of unit i
RD_i	ramp-down rate of unit i
SP_i	spot price of ith unit
T_i^{ON}	minimum time that the ith unit has been continuously on line
T_i^{OFF}	minimum time that the ith unit has been continuously off line
r	random number generator with uniform distribution between 0 and 1
Round (x)	rounds of x to the nearest integer
EC_i	emission cost function of unit i

consequences of short term thermal scheduling plays a very important role, the saving of small percent helps in the reduction of fuel consumption. The reason for scheduling is now changed from cost-minimization to profit maximization of GENCO. The term of obligation to serve, is removed in this competitive environment. Now days, the generating companies consider the scheduling as the process that produces demand less than the forecasted level, if this scheduling is more profitable.

The implementation of GA (Genetic Algorithm) on Profit Based Unit Commitment problem is based on binary coding. So, the implementation and formulation of PBUC problem is difficult to get a optimal solution [11]. Particle Swarm Optimization (PSO) is a stochastic, population based evolutionary algorithm for problem solving. But PSO has some disadvantages like premature convergence and more computational time consumption to solve PBUC [12]. In [13], Muller Method was introduced to solve Economic Dispatch (ED) problem and Information Pre-Prepared Power Demand (IPPD) table was introduced to solve combinatorial sub problem for deregulated environment. In nodal ant colony optimization [14], to maintain the good exploitation and exploration search capabilities, the movements of the ants are represented with a search space consisting of optimal combination of binary nodes for unit on/off status. A hybrid computational model which is the combination of Genetic Algorithm and local search algorithm called memetic algorithm helps to cultural evolution [15]. In [16], Delarue et al. achieves the difference between the profit obtained when using perfect price forecast and without using perfect price forecast. In [17], Catalao et al. proposed a practical approach for PBUC with emission limitation, trade off curve can be found by parametrically varying the weighting factor between 0 and 1. From the literature survey, it is observed that most of the existing algorithms have some limitations to provide the qualitative solution. In this paper, Shuffled Frog Leaping Algorithm has been introduced to solve the PBUC.

The Kyoto Protocol is an international agreement linked to the United Nations Framework Convention on Climate Change [18]. The advantage of this agreement is that the sets binding targets for 37 industrialized countries and the European Community for reducing GHG emission. These amounts to an average of five percent against 1990 levels over the five years period 2008–2012. There are six main green house gases; they are carbon dioxide, methane, nitrous oxide, hydro fluorocarbons, per fluorocarbons, and sulfur hexafluoride. The monitor's emission from plants in the oil refining, smelting, steel, cement, ceramics, glass, and paper

sectors and trading of emission allowances are done by emission trading scheme which is entered into force on Jan 2005. The Kyoto
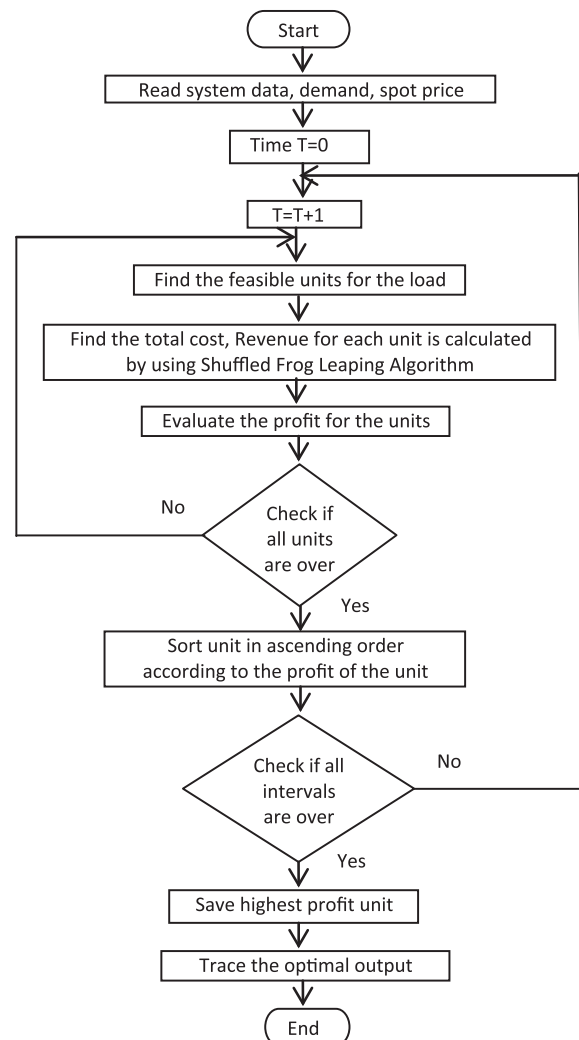

Fig. 1. Flowchart of proposed method.