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Refined Genetic Algorithm for Short Term Generation Scheduling Problem in Regulated and Deregulated Power System

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ABSTRACT

In the new restructured electricity power industry, a Generation Company (GENCO) with thermo-electric amenities faces the optimal problem of how to attain a maximum profit by considering the price uncertainties. In deregulated power markets, the maximization of profit is different from the minimization of cost because generation companies no longer have the obligation to serve the whole demand. They may choose to generate less than the demand, which allows more flexibility in unit commitment schedules. In the proposed method, the Lagrange multipliers are updated using GA technique to overcome the convergence problems with LR. Here the system constraints have been relaxed in the objective function by using Lagrange multipliers. The relaxed problem is then solving through the dual optimization procedure. A case study based on the standard IEEE 39-bus system is presented to illustrate the proficiency of the proposed refined Genetic Algorithm technique and the simulation results are compared with those obtained from traditional unit commitment.

Keywords — Price Based Unit Commitment, Restructured electricity markets, Lagrange Relaxation, Genetic Algorithm.

Introduction

With the fast changing technologies in the power industry, economic dispatch and unit commitment schedules become more complex and competitive problems. In deregulated environment, the optimal operations and planning of power systems are ranked high among the major tasks in the electric power generation. But in the regulated system, utilities had an obligation [1] to serve their customers, where all demand and spinning reserve must be completely met and this is not essential in the restructured power system. Generation companies can now consider a schedule that produces less than the predicted load demand but creates a maximum profit. This problem is referred as Profit Based Unit Commitment (PBUC) problem. It is much more difficult to solve than Traditional Unit Commitment (TUC) problem.

The Lagrange Relaxation (LR) method is a mathematical tool for mixed-integer programming problem. With the application [2,3] of this method in unit commitment, system constraints are relaxed by Lagrange multipliers and added to the objective function. A new unit commitment scheduling algorithm using GA [4-6] with specific mutation operators has been investigated in regulated power system. A parallel GA based on the constraint handling technique has been used to solve the unit commitment problem. The hybrid methods are claimed to accommodate more complicated constraints and to have better quality solutions. The robustness of Genetic algorithm was demonstrated by comparison with LR method in different utilities [7, 8] to solve the traditional unit commitment problem.

In this paper, short term generation scheduling problem in regulated and deregulated power system using refined GA has been proposed. This approach use the advantages of GA which can provide a near global optimum solution combined with the advantages of LR method, which can find a solution within a short duration of time.

Mathematical Modelling of Short Term Generation Scheduling Problem

The short term generation scheduling problem under restructured environment[9-13] can be defined as to schedule the generators economically in order to maximize the profit of Generation Companies (GENCO's) based on forecasted information such as power demand and prices. Generation Companies solves economic dispatch and unit commitment problem not for minimizing the total production cost as traditional but for maximizing their own profit. Hence, the objective function is modified from cost minimization to profit maximization. Profit is defined as the revenue obtained from sale of energy with market price minus total operating cost of the generating company. The PBUC problem based on forecasted demand and power price with a profit maximizing objective can be represented as,

Objective Function:

$$\max \; PF_{it} = \sum_{i=1}^{N}\sum_{t=1}^{T}\left\{ (P_{it} \cdot SP_t)U_{it} - (C_{it}(P_{it}) + S_{it})U_{it} \right\} \quad (1)$$

where,

$$C_{it}(P_{it}) = a_i + b_i P_{it} + c_i P_{it}^2$$

$$S_{it} = \begin{cases} HSC, & \text{if } DT \le CSH \\ CSC, & \text{Otherwise} \end{cases}$$

Constraints:

1) Power Demand Constraints

$$\sum_{i=1}^{N} P_{it} U_{it} \le PD_t ; \quad 1 \le t \le T \quad (2)$$

2) Spinning reserve constraints

$$\sum_{i=1}^{N} R_{it} U_{it} \leq SR_t; \quad 1 \leq t \leq T \tag{3}$$

3) Power generation Limits

$$P_i^{\min} \leq P_i \leq P_i^{\max}, \qquad i = 1 \ldots\ldots, \ \mathrm{N} \tag{4}$$

4) Minimum Up/Down Time Constraints

$$Ton_i \geq Tup_i, \qquad i = 1, \ldots\ldots, \ N \tag{5}$$

$$Toff_i \geq Tdown_i, \qquad i = 1, \ldots\ldots, N \tag{6}$$

5) Ramp rate limits

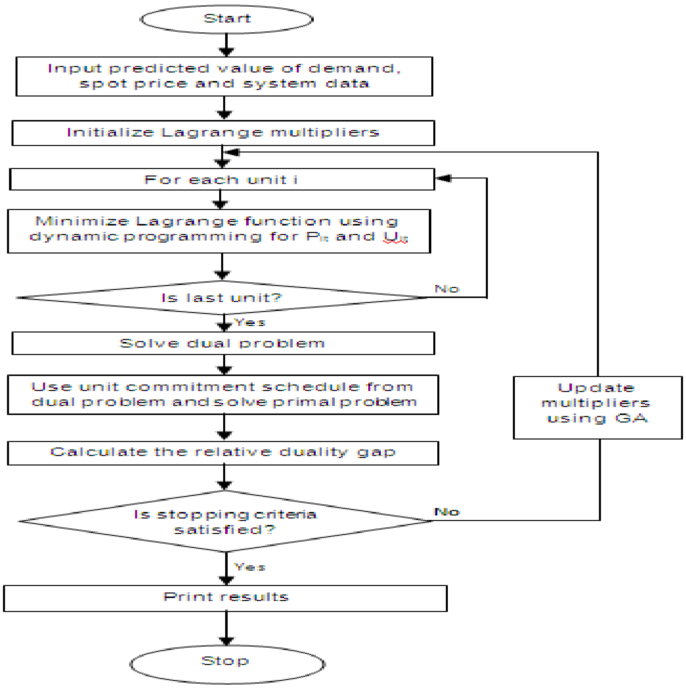
$$P_{i(t)} - P_{i(t-1)} \leq R_{uri} \text{ as generation increases} \tag{7}$$

$$P_{i(t-1)} - P_{i(t)} \leq R_{dri} \text{ as generation decreases} \tag{8}$$

where variables are defined as follows:
$C_{it}(P_{it})$ - production cost of unit i at time t; P_{it} – output power from unit i at time t
S_{it} - startup cost of unit i at hour t; U_{it} – on/off status of unit i at hour t
a_i, b_i, c_i – the cost function coefficients of unit I; SR_t - forecasted spinning reserve at hour t
CSC – cold start cost of unit I; *CSH* – cold start hours of unit I; *HSC* – hot start cost of unit i
N – number of generating units; *T* – scheduled time horizon (24 hrs)
PD_t – power demand at time t; R_{it} –reserve generation of unit i at hour t
P_i^{min} – lower bound on the output power of unit I; $T_{up\,i}$ - unit i minimum up time
P_i^{max} – upper bound on the output power of unit I; $T_{down\,i}$ - unit i minimum down time
$T_{off\,i}$ - duration for which unit i is continuously OFF
PF_{it} – profit of unit i at hour t; SP_t – forecasted power price at hour t

Implementation of Refined Genetic Algorithm to Solve PBUC

A new refined GA is used to solve the Profit Based unit commitment problem. In this proposed approach, the Lagrange multipliers are updated using GA technique to overcome the convergence problems with LR such as slow and unsteady convergence of LR has always been a problem in finding the global optimum solution as reported in most of the unit commitment solutions. The basic idea is to relax or ignore the coupling constraints (demand constraints and generating unit status in this case) into the objective function by proper selection of Lagrange multipliers using refined Genetic Algorithm. The flow steps involved in the proposed technique are shown in Fig.1 and also the control parameters settings of the proposed new refined GA method are given below.



Population size=60

Crossover probability=0.8

Mutation probability=0.002

Maximum generation=500

RDG threshold=0.00015

Fig.1 Flow steps of Refined GA approach

Simulation Results

The applicability and validity of the proposed method has been tested on IEEE-39 bus system [5]. Software programs were developed using MATLAB and 20 independent test trials were made for each population set because of stochastic nature of GA, with each run starting with different initial population. The required system data for solving the profit based unit commitment problem are shown in Table I and Table II.

Table I – Forecasted Demand and Power Price

Hour	**Forecasted Demand (MW)**	**Forecasted Power Price ($)**	**Hour**	**Forecasted Demand (MW)**	**Forecasted Power Price ($)**
1	**700**	**22.15**	**13**	**1400**	**24.60**
2	**750**	**22.00**	**14**	**1300**	**24.50**
3	**850**	**23.10**	**15**	**1200**	**22.50**
4	**950**	**22.65**	**16**	**1050**	**22.30**
5	**1000**	**23.25**	**17**	**1000**	**22.25**
6	**1100**	**22.95**	**18**	**1100**	**22.05**
7	**1150**	**22.50**	**19**	**1200**	**22.20**
8	**1200**	**22.15**	**20**	**1400**	**22.65**
9	**1300**	**22.80**	**21**	**1300**	**23.10**
10	**1400**	**29.35**	**22**	**1100**	**22.95**
11	**1450**	**30.15**	**23**	**900**	**22.75**
12	**1500**	**31.65**	**24**	**800**	**22.55**

Table II -Ramp rate limits for IEEE -39 bus system

Unit i	1	2	3	4	5	6	7	8	9	10
R_{uri}(MW/hr)	35	66	80	55	143	128	271	55	161	143
R_{dri}(MW/hr)	55	70	93	118	139	261	276	83	150	87

The proposed technique is primarily used to solve the PBUC problem and the results obtained are compared with the results of traditional cost minimization problem. Fig.2 and Fig.3 shows the Performance of Refined GA and profit comparisons for Traditional Unit Commitment and Profit Based Unit Commitment problems.

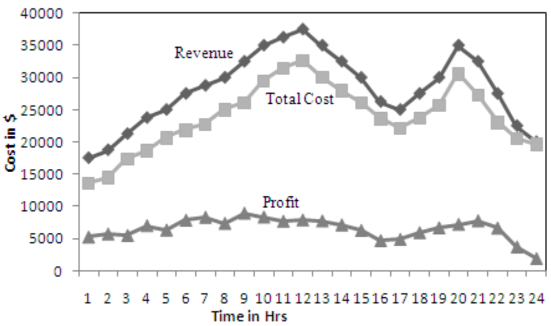


Fig. 2 Performance of Refined GA for IEEE-39 ***Bus system***

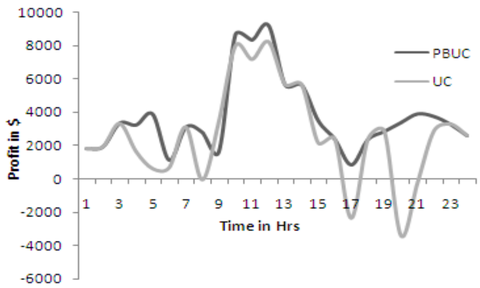


Fig. 3 Profit Comparisons for ***PBUC*** Traditional UC

The implementation of new refined GA to the short term generation scheduling problem provides higher profit for PBUC than that of traditional unit commitment.

Conclusion

This paper presents a solution to short tern generation scheduling in restructured electricity markets. While the objective of traditional unit commitment problem has changed to profit maximization, the results shown that the PBUC provides better representation of deregulated electricity markets. Based on the forecasted information, profit based unit commitment problem is solved by using new refined Genetic Algorithm. Here, GA is used to update Lagrange multipliers in the traditional LR method. In this paper, an IEEE-39 bus system is used to demonstrate the proposed approach and the simulation results were compared with the results obtained from traditional unit commitment. Moreover, the profit using the profit based unit commitment problem is about 1.32 times the profit when traditional unit commitment is used.

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