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COOPERATIVE EVOLUTION GENETIC ALGORITHM ON BIDDING OF POWER MARKET

Li Maojun
College of Electrical & Information Engineering
ChangSha University of Science & Technology
ChangSha, China
Phone: +86-731-2618239, Fax: +86-731-2618236, E-mail:famgge@yahoo.com.cn

Abstract- This paper presents a modified genetic algorithm that is a cooperative mutation genetic algorithm on bidding of power market. This algorithm follows the basic pattern of genetic algorithms, but imposes gene cooperative mutation during genetic operation to raise efficiency of genetic operators. This algorithm can simultaneously solve on/off status of unit commitment and economic load distribution, and can expediently dispose constrains of bidding of power market. So the cooperative mutation genetic algorithm is an effective method of the bidding of power market.

Key Words: Genetic Algorithm; Cooperative Evolution; Bidding of Power Market

I. INTRODUCTION

It is a necessary trend to deregulate electrical power market. Deregulated power market makes power industry vigorous and meanwhile it also introduces many new problems, one of which is bidding algorithm [1]. As traditional unit commitment [2--5], the bidding of power market is a nonlinear optimal problem with constraints, which belongs to the class of NP (non-deterministic polynomial) complete problems, thus it is very difficult to solve bidding problem of power market effectively. Reference [6] introduces a lot of optimal algorithms of unit commitment of power system, but the bidding algorithm of power system is hardly discovered in science and technology references [7]. Based on the basic principle of partheno-genetic algorithm[8], this paper presents a modified genetic algorithm, that is Cooperative Evolution Genetic Algorithm (CEGA) for the bidding problem of power market. The algorithm resembles traditional genetic algorithms, but its new individual is produced by single individual and imposes gene cooperative mutation during genetic operation to raise efficiency of genetic operators.

II. MATHEMATICAL MODEL OF BIDDING PROBLEM

In this paper the mathematical model of bidding in power markets not only considers on/off status of unit commitment but also considers economic load distribution.

A. Objective Function

If power market is fully deregulated, the objective of bidding should be an optimal social benefit, but if only generation market is deregulated, the objective should be the lowest cost of electrical power, that is

$$F_a = \min \sum_{i=1}^{U} C_i(P_i)P_i \ , \tag{1}$$

where F_a is the cost of all of the power; P_i is the power of unit(or power plant) i by bidding; $C_i(P_i)$ is the quoted price as the power of unit i is P_i; U is the number of the units.

B. Constraints

The constrains of generation bidding problem can be divided into three classes, that is system constraints, unit constraints and security constraints.

1) System Constraints: System constraints aim at all of the bidding units, including the following aspects.

(1) System Load Balance

$$\sum_{i=1}^{U} P_i - P_D = 0 \ , \tag{2}$$

where P_i is the power of unit i; P_D is all of the loads.

(2) System Static Reserve

$$\sum_{i=1}^{U} P_{i,\max} - P_D \geq P_{ssu} \quad ; \tag{3}$$

$$P_D - \sum_{i=1}^{U} P_{i,\min} \geq P_{ssd} \quad , \tag{4}$$

where $P_{i,\max}$ or $P_{i,\min}$ is respectively the maximum or minimum power of unit i ; P_{ssu} or P_{ssd} is respectively the static reserve maximum or minimum power of system.

(3) System Spinning Reserve

$$\sum_{i=1}^{U} \min\{P_{i,\max} - P_i, \Delta P_{i,u}\} \geq P_{dsu} \quad ; \tag{5}$$

$$\sum_{i=1}^{U} \min\{P_i - P_{i,\min}, \Delta P_{i,d}\} \geq P_{dsd} \, , \tag{6}$$

where $\Delta P_{i,u}$ or $\Delta P_{i,d}$ is respectively the ascending or descending maximum rate of unit i ; P_{dsu} or P_{dsd} is respectively the spinning reserve maximum or minimum power of system.

2) Unit Constraints: Unit constraints aim at single unit, including the following ones.

(1) Limitation on Unit Output

$$P_{i,\min} \leq P_i \leq P_{i,\max} \quad , \quad i = 1,2,\cdots,U \quad . \tag{7}$$

(2) Limitation on Ramping Rate

$$P_i(t) - P_i(t-1) \leq \Delta P_{i,u} \quad , \qquad i = 1,2,\cdots,U; t = 1,2,\cdots,T \quad . \tag{8}$$

$$P_i(t-1) - P_i(t) \leq \Delta P_{i,d} \quad , \qquad i = 1,2,\cdots,U; t = 1,2,\cdots,T \quad . \tag{9}$$

where $P_i(t)$ is the power of unit i at period t.

(3) Maximum Number of Unit Start-up and Shut-down

$$\sum_{t=1}^{T} \left| C_{it} - C_{i,t-1} \right| \leq N_i, i = 1,2,\cdots,U \quad , \tag{10}$$

where N_i is the maximum number of unit i start-up and shut-down every period of time; C_{it} is state variable of unit i at period t, if C_{it} =1, unit i is running at period t; if C_{it} =0 , unit i pauses at period t.

(4) Minimum Running Periods of Time

$$\left(C_{it} - C_{i,t-1}\right) \sum_{j=t-T_1}^{t-1} (1 - C_{ij}) \geq T_1 \quad , i = 1,2,\cdots,U, \tag{11}$$

where T_1 is the minimum running periods of time.

(5) Minimum Pausing Periods of Time

$$(C_{i,t-1} - C_{it}) \sum_{j=t-T_2}^{t-1} C_{ij} \geq T_2, i = 1,2,\cdots,U \quad , \tag{12}$$

where T_2 is the minimum pausing periods of time.

3) Security Constraints: Security Constraints protect electrical network from barrage and ensure electrical network to run on the safe side.

(1) Limitation on Power Flow

$$P_l \leq P_{l,M} \, , \qquad l = 1,2,\cdots,L \quad , \tag{13}$$

where P_l is power transported by line l; $P_{l,M}$ is the maximum power transported by line l.

(2) Limitation on Voltage

$$V_{j,\min} \leq V_j \leq V_{j,\max}, j = 1,2,\cdots,J \quad , \tag{14}$$

where $V_{j,\min}$ or $V_{j,\max}$ is respectively the minimum or maximum voltage of bus j; V_j is the voltage of bus j.

III COOPERATIVE EVOLUTION GENETIC ALGORITHM ON BIDDING OF POWER MARKET

A. Steps of the Algorithm

Step1: determining fitness function;

Step2: determining encoding method of individual, producing initial population;

Step3: evaluating individuals;

Step4: if stop condition satisfied then ending, else doing step5;

Step5: genetic operating, producing new individuals;

Step6: evaluating new individuals;

Step7: selecting, producing new population, and then doing step4.

The steps of cooperative evolution genetic algorithm resemble the one of traditional genetic algorithm, which mainly imposes gene cooperative mutation technology during genetic operation to raise efficiency of genetic operators.

B. Genetic Operation

In order to solve bidding of power market efficiently, three kinds of genetic operators are constructed, which are gene regulation operator, gene row mutation operator and gene row exchange operator. The gene regulation operation acts on single gene; gene row mutation operation and gene row exchange operation act on the line of genes.

The gene regulation operator randomly changes non-zero gene in chromosome by probability p_m, that is to say, it randomly regulates the power generated by the committed unit, and enables the power system tend to satisfying constrain of system load balance. The gene row mutation operator randomly changes class of the line of gene in chromosome by probability p_l, and enables the power system tend to satisfying constrains of maximum number of unit start-up and shut-down, minimum running periods of time, minimum pausing periods of time as well as system load balance. The gene row exchange operator randomly exchanges two lines of gene in chromosome by probability p_c, and enables the power system tend to satisfying constrain of system load balance.

The gene row mutation operators are made up of gene revival operators and gene death operators. The gene revival operators enable the units turned off to turn on while the gene death operators enable the units turned on to turn off. The gene revival/death operators consist of whole gene revival/death operator, full gene revival/death operator, part gene revival/death operator and single gene revival/death operator.

C. Cooperative Mutation

To enhance convergence rate of the algorithm, a gene cooperative mutation technology is proposed. That is both gene revival operator and gene death operator are used in pairs so that the number of the revived genes equals or approximately equals the number of the died genes so that power system basically enables to satisfy constrain of system load balance.

IV. CONCLUSION

This paper presented a cooperative mutation genetic algorithm for the bidding problem of power market. This algorithm can simultaneously solve economic load distribution and on/off status of unit commitment, and can expediently dispose constrains of bidding of power market. So the cooperative mutation genetic algorithm is an effective method of the bidding of power market.

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