Consider medium and long-term electricity market different supply and demand than the sale of electricity price simulation method and system design

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Abstract. After a new round open of electricity sales market, a large number of new sell electricity company involved in the sale of electricity market. Which leads to market instability. Because hair, sale members on both sides of the market in the electric power business behaviour real-time change. So only through the analysis of theory and can't get the real power market operation state. Based on the analysis of electric power market supply and demand ratio, power suppliers and electric power company in different than the market price of supply and demand, set up to simulate long-term market members under supply and demand than bidding decision-making model, the application of RE-Learning, reinforcement Learning algorithm in 10 power suppliers and 30 sell electricity companies bidding behaviour simulation market under the participation of members. The experimental results show that the use of bidding decision model is a good way to express market members under different supply and demand than market clearing. Which verifies the effectiveness of the proposed method.

1. Introduction
In March 2015, the party central committee and the state council issued the several opinions on further deepening the reform of electric power system, this paper expounds the implementation of power system reform since 2002's achievements and the problems which needs to be through reform, introducing competition and sell electricity link to increase the market vigour[1].

Electricity market simulation is an important research method in the field of electric power market. Foreign in electricity market simulation technology research has made some achievements. Britain in power market, power unit profits and utilization for comprehensive target transform the basis of market information for simple reasoning agent module[2].The Iowa State university developed application RE learning algorithm as the core of electricity market simulation system based on agent Ames, market clearing value of node power method considering network constraints[3].The national laboratory developed the application of electricity price forecasting and greedy algorithm as agent decision-making function of EMCAS complex adaptive system, electricity market agent with decision making and learning ability are adopted to simulate the power users, power generation, transmission
and other market participants[4]. Literature [5] electricity generators is developed using the Q-learning intelligent algorithm to participate in the program module of market bidding, and simulated on 5 node test system, sell electricity traders can only handle daily round of bidding and decisions to take into account the load change. But in the real market clearing electricity generators in the decision will consider the market demand. Literature [6] on the basis of the electric power market simulation system platform, carried out under different levels of supply and demand, electricity market members intelligent agent algorithm research, which does not take into account changes in demand characteristics of the dynamic behaviour of power suppliers. Literature [7] JADE framework of multi-agent based simulation system, the simulation for multiple scenario monthly electricity centralized price bidding in domestic market rules, quantitative analysis of the two kinds of different market clearing model. Literature [8] using multi-agent technology designed to maximize their income target market game model for decision-making and reinforcement learning methods optimize the bidding behaviour of market main body to solve. In the literature [9] the only goal is to earnings, decision-making power suppliers have not considered other operational objectives. Literature [10] to generate company's revenue and market share results in the same function, which enables the power suppliers maximize returns and achieve the goal of improve the market occupancy rate. Literature [11] to electricity generators returns and continuous usage of unit as the goal, to optimize the generators bidding decisions.

Electricity market simulation technology is different to the above mentioned model in this paper. First of all, on the basis of intelligent agent model of power suppliers joined the model of intelligent agent sell electricity companies, completing the simulation of electric power market clearing model. Second, This paper consider market power generation side and sell electricity side of supply and demand ratio in a market clearing at the same time, under different market environment of supply and demand get market clearing result, which simulate market supply and demand market clearing results under different conditions of dynamic evolution process.

2. Background

2.1 Electricity sales status
Current our country electric power market reform has entered a critical period. With the development of electricity market reform, on the basis of the power generation side competition, sell electricity is gradually opening, a lot of sell electricity companies have involved in the market. Sell electricity company become a new market main body and appear some market behaviour in the process of participating in market transactions. The risk management contains the electric power market, the market model design, trading rules, etc. which puts forward some new challenges and will be more significant in the future.

2.2 Meaning and purpose
With diverse sell electricity company development mode and sell electricity body created enormous, this phenomenon led to the sell electricity market scale and form diversification, the participation of some market main body behaviour had bad effects on the electric power market. Facing the present situation, the need to analyse the behaviour of electric power company. At the same time considering market huge cost of trial and error, we do not through market operations to verify the actual effect. The operation of the electric power market is a long-term process of dynamic evolution, sell electricity company behaviour has been adjusted, only through the theory analysis is very difficult to estimate the running effect of the market. So we need to analysis of the sell electricity company behaviour, especially the simulated analysis of bidding strategies.

3. The design of the simulation system

3.1 Analog input and output of the system
To true according to the simulation of electric business and sell electricity market clearing model and security market safe and stable operation, the system of power suppliers and sell electricity companies declare on the power and electricity price lower limit settings. Power suppliers to quote the unit as the basic unit to participate in, each unit has its declaration on floor. Sell electricity companies will according to the agent based on the contract quantity of the user to set the upper and lower to declare. Electricity generators to participate in the competitive market in order to clinch a deal the quantity maximization as the goal model of intelligent agent algorithm, sell electricity companies participate in the market clearing at two declare means: artificial quotation and the intelligent agent model of profit maximization as the goal.

3.2 Market clearing model
Bidding strategies learning process is as follows: (1) sell electricity companies submit declaration power and electricity prices to ISO. (2) the ISO calculate according to the rules of market clearing market clearing price and sell electricity companies clinch a deal the quantity, and feedback the information to sell electricity companies after receiving all the quote information. (3) electric power company calculate about bidding strategies to achieve the transaction according to the feedback of market clearing price and clinch a deal the quantity. (4) sell electricity companies get the next round of price, according to the bidding strategy to reach a situation and experience optimal bidding strategy.

4. Intelligent agent algorithm
Pursuing profit maximization electric power company and seeking to maximize clinch a deal the quantity of electricity generators will continue to learn from market bidding decision-making experience in order to improve the income level of the next bid. Intelligent agents can use the past historical experience to constantly optimize the follow-up strategy [11], which represents the sell electricity companies and the dynamic learning process of power suppliers.

This paper adopts the intelligent agent model of RE-learning algorithm which is adopted to simulate the sell electricity companies and electricity generators bidding decision-making behaviour. Roth put forward the algorithm in 1995. Algorithm and corresponding decision module as be shown in literature [5]. Figure 1 shows the overall process of quotation.

![Figure 1. RE-learning algorithm flow chart](image-url)
4.1 Construction bidding strategies
Sell electricity companies $i$ construct the quotation strategy space $A_i = \{a_i^1, a_i^2, \ldots, a_i^{M_i}\}$. Which contains all the quotation of electric power company $i$. Space $A = \{A_1, A_2, \ldots, A_{n}\}$ will contain all sell electricity companies strategy, $n$ including total to electric power company. Power suppliers $j$ construct its bid strategy space $B_j = \{a_j^1, a_j^2, \ldots, a_j^{M_j}\}$, $B_j$ contains all $j$ power suppliers the quotation. All the generators bidding strategies make up the strategy space $B = \{B_1, B_2, \ldots, B_k\}$, $k$ is the total number of power suppliers.

4.2 The roulette wheel selection bidding strategies
Roulette strategy refers to all the selected probability. Which form the corresponding probability interval, and then generate a random number before every quotation. When the random number fall in the random probability interval. The choice of the interval strategy participate in bidding. Experiment policy set at the beginning of the initial probability of each policy within the same, assuming that $i$ electric power company have $M$ bidding strategies, each offer initial probability are $1/M$, according to the roulette way according to the probability of randomly selected a bidding strategies involved in trading. According to the result of trading update the probability of each policy after the deal. The new probability random quotation again to participate in a new round of trade, until electric power company choose the reasonable bidding strategies.

Because of computer not like people to make decisions, the policy space $S$ all marked the corresponding coefficient of behaviour $Q$ and the behaviour choice probability $P$ as the basis of agent learning decision. The corresponding strategy of behaviour tendency coefficient $Q$ update every round of profits. At $t$ wheel for electric power company chose a certain strategy $a_i^m$, and profits $u_i^t$ for the first $t$ round. At $t+1$ wheel, the strategy $a_i^m$ corresponding coefficient of behaviour do the following update:

$$Q_{ct}(m) = \begin{cases} (1-r)Q_{ct}(m) + (1-e)u_i^t & m = i \\ (1-r)Q_{ct}(m) + e \cdot Q_{ct}(m) / M & m \neq i \end{cases}$$

(1)

Type: $Q_{ct}(m)$ is the $t+1$ round of the updated value tendency coefficient, $t$ is bidding rounds, $m$ is a strategy for the choice in a round number, $M$ is the number of strategies for the policy space, $r$ is the forgetting factor, which weaken the influence of previous experience and make a new strategy for the influence of the behaviour of reinforcement, $e$ is an experience parameter value scope for $(0, 1)$, electric power company $i$ will use the update strategy $m$ behaviour tendency coefficient at $m = i$, in addition to electric power company $i$ and other companies sell electricity coefficient of updates at $m \neq i$.

The choices of the strategies $a_i^m$ calculate probability:

$$P_i(m) = \frac{\exp[Q_i(m) / c]}{\sum_{j=1}^{M} \exp[Q_j(j) / c]}$$

(2)

Type: $P_i(m)$ is the strategy $m$ for $t$ round of update probability, $Q_i(m)$ is the strategy $c$ for the cooling coefficient, which decide to tendency coefficient of choice the influence degree of probability.
According to each wheel tendency coefficient, Parameter $c_t$ selection for dynamic adjustment strategy as follows:

$$c_t = \frac{\varepsilon}{M} \sum_m Q_m(m)$$

(3)

Type: $\varepsilon$ is a real number greater than zero and generally be set in the range of $(0, 3)$. It value in different system will change, $\varepsilon$ change the $c$ value, $\varepsilon$ effect convergence and influence of intelligent agent, $\varepsilon$ value greater led to the intelligent agent the slower convergence.

5. Example analysis

5.1 Day-ahead market bidding model setting up

Assume that markets are 10 electricity generators, 30 sell electricity, symbols respectively $G1 \sim G10$, $S1 \sim S30$. All power suppliers are involved in RE learning, its operation objectives set to clinch a deal the quantity maximization. Electric power company $S1 \sim S17$ setting, not participate in the study, with the method of artificial quotation, $S18 \sim S30$ participate in RE learning, them operating target is set to maximize profits.

5.2 Clearing the results

State of the market is the current supply and demand in centralized price bidding electricity market. Different supply and demand makes different bidding behavior of power suppliers. When the market supply is greater than demand. The market will be in a state of saturated. Sell electricity will be submitted to the low price. When the market demand is greater than supply. Electric power in electricity market will increase demand. Sell electricity will raise the quotation to adapt to the market at this time.

Example 1: Electric power market supply and demand is greater than 1. We set up the intelligent agent decision factor $e = 0.02$, $r = 0.1$. Power generators operation objectives uses the clinch a deal the maximum.

When electric power market supply and demand is greater than 1. Power suppliers have a stronger internal competition. Which lead to the price of power suppliers falling. Due to electric power company can clinch a deal. So that supplier declare on the electricity purchasing party spreads to temptation, fish ever deeper in the market price which has obvious "fishing" curve (most of the electricity price is on the high side, a small number of electricity is on a low price to gain lower uniform clearing price. Electricity generators in this way will get more benefits). It is important to note that all the demand quantity and clinch a deal would happen sometimes, but because of higher than or supplier strategy adjustment of supply and demand, this situation cannot continue. When the market supply and demand is bigger, the last several rounds of price change is beginning to slow. Main reason has two: one is at this point the market members declare spreads have basically the same, this also led to a small power plant competition is weak, the possible of market members declare a smaller price difference to get higher profits will reduce; two is when market supply and demand is bigger, the small power plant adopted a relatively modest means. According to their cost to declare the price to ensure that won't be at a loss. But actually small power plant as withdrawn from the market competition. Figure 2 and Figure 3 respectively, when market supply and demand is bigger, the total quantity and price variation.
Figure 2. The total power variation when the supply and demand is bigger

Figure 3. The price variation when the supply and demand is bigger

What can be seen from the diagram is that clinch a deal the quantity to maintain in the aggregate demand of the market power, electric power company general declaration power get off. With the increase of market clearing rounds spreads close to zero in the market price.

Figure 4. The supply and demand ratio is greater than 1 power suppliers and electric power company clearing curve

Above figure 4 represents that the market clearing curve when the power suppliers in the market supply is greater than 1, clearing capacity is 4.8 billion KW.h and clearing price is 0.39 yuan/ KW.h.

Example 2: Electric power market supply and demand is less than 1. We set up the intelligent agent decision factor $e = 0.02$ $r = 0.1$. Power generation company operation objective is clinch a deal the maximum.

When electric power market supply and demand is less than 1, the two sides of supply and demand competition is very fierce. Small power plant yield significantly lower because of low clearing price in the first several rounds of uniform clearing price. Small power plant have been trying to ascend price difference in order to obtain higher yields. The causes of this phenomenon is primarily a small power plant power limit and cost disadvantage. After in the first several rounds of experiment, due to the loss of more, the small power plant is no longer with large power plant at a low price competition power. Small plants efforts to raise price. Largest power plants can even meet half market demand and have a
larger market share. However, due to the large power plant on the premise of guarantee power generation use hours cost to participate in quotation. Large power plant has obvious competitive advantage than small power plant in market competition. Figure 5 and 6, respectively, when market supply and demand is smaller, the total quantity and price variation.

![Figure 5](image1.png)

**Figure 5.** The total power variation when the supply and demand is smaller

![Figure 6](image2.png)

**Figure 6.** The price variation when the supply and demand is bigger

Can be seen from the diagram in the market turnover capacity as market clearing rounds volatile. In the market price with the increase of market clearing rounds spreads growth trends.

![Figure 7](image3.png)

**Figure 7.** The supply and demand ratio is less than 1 power suppliers and sell electricity price curve

Above figure 7 represents that the power suppliers in the market supply is less than 1 when the market clearing curve, clearing capacity is 4.2 billion KW.h and clearing price is 0.4 yuan/ KW.h.

6. **Conclusion**

In this paper put forward a method. Which based on the intelligent agent power suppliers and sell electricity companies bidding simulation method, this method can effectively simulate the generators and sell electricity company long-term market bidding behaviour. The simulation results is advantageous to the electric power market mechanism and rules. Numerical examples show that: (1) When the electric power market supply and demand is bigger, sell electricity company power can
declare the total sale.(2) When the electric power market supply and demand is bigger, the clearing price is relatively low; The supply and demand is small, the clearing price is higher.(3) In this paper, the model can well simulate the dynamic evolution behavior of power suppliers and sell electricity companies, through the study of historical bidding experience, power suppliers and sell electricity companies bidding behavior will evolve to a steady state market finally.

In the rational market clearing model, power suppliers and sell electricity companies have a lot of factors influenced. This article from the perspective supply and demand of market. When the market will under different ratio of supply and demand, power suppliers and sell electricity companies change bidding behavior. However, there are many factors influencing the power suppliers and sell electricity companies bidding. For example: other bidding behavior of power suppliers and sell electricity companies, power suppliers and sell electricity company's daily operation cost and sell electricity company proxy user type and scale, the deviation of power and demand side response, etc.

We put more relevant factors into consideration. Only in this way can we get a better simulation of the market clearing model in reality. Therefore, under the condition of considering the simulation convergence, add more factors influencing the power off the market is the focus of the next need further research.

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