Study on Optimization Operation Simulation of Cross-Province Cross-Regional Power Transaction Based on Multi Agent Technology

Rong Zhang¹,², Jian Geng² and Haihua Cheng²

ABSTRACT

At present, China's electricity market reform has made some achievements. However, it is an urgent issue to be solved that multiple electricity purchasers and power suppliers enter the market and establish a sound electricity market operation mode to promote the healthy and orderly development of the market. This paper simulates the power purchase and sale of electricity by multi agent technology to declare the price, simulates the of the clearance of cross-provincial electricity trading, provides a simulation to verify the trading rules of technical means, which can guide the design and optimization of power trading rules, reduce and control the trading operation risk. The actual example simulates the operation of the collusion behavior of some members in the market under different supply. The result shows that the simulation verification method provided by this paper can identify whether the market members are involved in collusion, and provide a reasonable reference for the healthy and orderly development of the actual electricity market.

Keywords: electricity trading, multi-agent technology, optimization operation

INTRODUCTION

With the reform of the electricity market, establishing a scientific and rational market operation mode becomes the core of improving the electricity market operation mechanism and ensuring the healthy and effective operation of the electricity market [1]. In order to avoid the operation risk of the actual power grid, we establish a corresponding power market

¹School of Electrical and Information Engineering, Shaanxi University of Science & Technology, Xi'an, China 710021
²China Electric Power Research Institute, Nanjing 210003, China
This paper is acknowledged by the State Grid Corporation of Science and Technology Project (DZN17201600244)
simulation system to study the rationality of various market programs and rules before the power market is officially started. This can not only provide effective technical support for the transaction of entities involved in the market, but also carry out market simulation.

In recent years, intelligent agent technology has attracted much attention due to its suitability for dealing with problems that have complex relationships and are difficult to analyze accurately using traditional mathematical theory. Simulation based on intelligent agent simulation has become an effective experimental tool [2]. Literature [3] introduced the Agent technology and proposed the application of Agent technology in the electricity market bidding model network environment. Literature [4] put forward the panoramic experimental platform for electricity market in order to analyze the market members’ decision-making behavior characteristics and their impact on market operation. Literature [5] proposed a power customer evaluation model based on multi-attribute decision-making, selecting high-quality customers for the power sales and reducing operational risk. Literature [6] put forward the calculation method of grid operation efficiency evaluation index, fully considered various operation scenarios and fully and accurately reflected the operation efficiency of power system. Literature [7] designed and implemented a network-based experimental economics and electricity market based on the theory of proxy computing integrated simulation system. Literature [8] simulates the power market operation technical support system, which provides a strong guarantee for the regional power supply company to accurately report the purchase plan.

In this paper, the multi-agent technology is used to construct the agent model of the different market members of the power purchasing and selling parties. This paper simulates the bidding of the market participants in the electricity market, simulates the operation of some members’ collusion in different supply and demand environment, and analyzes the influence of market members’ collusion on the market operation. It provides operational simulation validation techniques to guide and optimize the design of electric power trading rules, reduce and control transaction risk and provide a reference for the healthy and orderly development of the actual electricity market.

AGENT MODEL OF BUYERS AND SELLERS

Sales Side Agent Model

In the market, the seller will adjust the bidding strategy according to the situation of the market and its own interests. In the case of more sellers in the market, the sales side of the electricity market is fiercely competitive and the electricity purchase side leads the market. In the electricity market, there are two kinds of electricity selling targets, one is to ensure their own power generation, the other is to satisfy their own electricity and pursue their own interest maximization. Therefore, when simulating the real market, two different models are set up for these two different purposes by adjusting the reward function \( R \) in the sales decision-making learning module.

(1) Electricity sales agency model

Electricity sales side of the agency model is to ensure that their own power generation. So simulate its behavior, the sales function of agency proxy \( R \). Take the bid after winning the power:
\[ R = Q \]  

Among them, \( Q \) is the winning bidder's electricity sales.

(2) Profit-oriented electricity sales agency's proxy model

Profit-oriented sales side is the pursuit of their own interests, but the premise of the pursuit of profit is to meet the electricity. So simulate its behavior, the sales function of agency proxy \( R \). Take the auction after the profits obtained:

\[ R = \lambda * Q - C \]

Among them, \( \lambda \) is the sale of the successful bidder's electricity price, \( C \) is the sale of electricity generation costs, \( Q \) to win the power.

**Purchase Side Agent Model**

Similar to the selling power, the buyers in the market will also adjust the bidding strategy according to the market situation and their own interests. In the electricity market, there are mainly two kinds of power purchasers purchasing electricity, one is to ensure their own power generation according to their own needs, the other is to lower their prices to achieve the goal of maximizing their own interests according to their own cost. Therefore, in the simulation of the real market, for these two different purposes, we adjust the return function \( R \), in the purchasing decision-making module of the electricity supplier and set up different purchase-side agent models.

(1) Electricity purchase side of the proxy model

The purchasers need to ensure the transaction volume at first, When they participate in the market bidding. So for those who have not yet purchased enough electricity, they pay attention to the volume of electricity. In order to simulate the market behavior of such electricity purchasers, the agency's return function \( R \) is taken as the transaction volume after the auction.

\[ R = Q \]  

Among them, \( Q \) is the electricity purchase side of the successful bidder.

(2) Profit-oriented electricity buyer's agent model

Profit-oriented electricity purchasers participate in electricity purchase transactions with the aim of obtaining cheaper electricity purchase prices. Therefore, the maximum acceptable electricity price for electricity purchasers is generally not higher than the price for purchasing power directly from the electricity grid. The users' basically lower than the catalog price. In order to simulate the profit-oriented power purchase side behavior, the agency's return function \( R \). Take the purchase side to participate in the bidding compared with the directory price to buy the savings:

\[ R = (L - \lambda) * Q \]

In the formula, \( L \) is the market directory price, \( \lambda \) is the market price, \( Q \) is the electricity side of the transaction volume.
Purchaser Agent Learning Decision Model

Because Q-learning algorithm is easy to fall into local optimization, adding \( \epsilon \)-greedy method, that is, each state has the probability of \( \epsilon \) to explore, and the remaining probability of \( 1-\epsilon \) is developed. In general, \( \epsilon \) is small. There are a few more ways to get better results than the \( \epsilon \)-greedy method, but they are much more complicated. Purchaser's learning process is similar, so this article describes the buyer's learning decision-making process:

1. Set the purchaser agent environment status set and quotation strategy set.
2. Initialize the corresponding state of the market state strategy that strategy \( Q(s,a)=0 \), Set the number of iterations \( T \). Set buy-side agency reward discount factor \( \alpha \) and explore the probability \( \epsilon \).
3. Set the purchaser agent reward discount factor \( \alpha \) And explore the probability \( \epsilon \), among them \( \alpha \) with \( \epsilon \) the increase of the number of simulation \( t \) decreases, so \( \epsilon = 1/\sqrt{t} \) (It means that there is no experience available to the purchaser agent at the initial stage of quotation, and often tries some new strategies. With the accumulation of quotation experience in the later period, the number of explorations gradually decreases.)
4. Based on \( \epsilon \)-Greedy Law, we chose a quotation strategy. Purchaser agent used \( \epsilon \)-greedy algorithm in the market state \( s_k \) Corresponding strategy set \( A_k \) in the selection strategy. The specific approach is: first, a random number between \([0, 1]\) \( r \), \( r \) and more \( \epsilon \) the size. If \( r < \epsilon \), then random probability from uniform \( A_k \) choose a strategy; if \( r > \epsilon \), Select \( s_k \) State \( Q \) as the value of the strategy.
5. After all the buyer's agent hands over the quotation to the trading center, the trading center will clear the market according to the unified clearing rules and pass the winning bid information (bid-winning electricity and unified clearing price) to the sales agent.
6. Return based on the seller's agent on day \( t \) \( R_{kj} \) Updated \( Q(s,a) : \)

\[
Q_{t+1}(s,a)=\begin{cases} (1-\alpha)Q_t(s,a)+\alpha R_{kj} & \text{if } s=s_k, a=a_{kj} \\ Q_t(s,a) & \text{others} \end{cases}
\]

7. To determine whether the number of iterations \( t \) has reached the set value \( T \), if \( t = T \), The end of the simulation; \( t < T \), return to step 3.

EXAMPLE VERIFICATION

Changes in different market parameters will have an impact on the trading results of the market operations. Conspiracy among the selling parties will raise the market price far above the normal market price. In economics, the part of the price that is higher than the market price determined under normal competition is called the product premium. The level of premium reflects the ability to collude in manipulating market prices [9]. This article simulates the impact of some members' collusion on the market results in the cross-provincial electricity trading operation involving multiple purchasers, and simulates the influence of market collusion on the market under the conditions of loose supply and demand and tight supply and demand. The ratio between supply and demand was 1.95 (loose supply and
demand) and 0.98 (tight supply and demand), the transaction size is limited to 700 million degrees.

(1) Loose supply and demand

Under the relaxed supply and demand scenario, the other parameters remained unchanged, and several transactions were organized in a row so that some of the sales-side market members declared in conspiracy and conspired with 43.73% of the market members. Adjust the market premium threshold, the other parameters remain unchanged, the quoted price of market members above the threshold after the conspiracy was replaced with the cost value, and then be re-cleared to observe the changing trend of the bid electricity price, the bid price and the profit in the transaction.

![Graph](image1)

(a) The average declared price of the seller and purchaser

![Graph](image2)

(b) The successful bidder of the electricity supplier and purchaser

Figure 1. The Average Selling Price of Electricity Sales and Purchase Side with the Successful Bidder Price.

As shown in Figure 1, with the increase of the conspiracy threshold, the declared price of the seller of electricity increases accordingly, and the declared price of the purchaser and the electric supplier have not fluctuated by a large margin. The change of the conspiracy threshold will also slowly increase the bid winning price.

![Graph](image3)

Figure 2. Power Side and Purchase Side of the Winning Power.

As shown in Figure 2, the market supply and demand are relaxed or not. The winning bid power mainly depends on the demand of the user side. Therefore, with the change of conspiracy threshold, the change of bid winning quantity is not large. When the conspiracy threshold reaches 100% minimum power.
As shown in Figure 3, as the conspiracy threshold decreases, the total profit of the sales side decreases, and the total profit of the power side increases. When the conspiracy threshold is 100%, the total profits of the sales side and the power purchase side reach lowest.

(2) Tight supply and demand situation

Under the scenario of tight supply and demand, the other parameters remained unchanged, and several transactions were organized in a row so that some of the power generation-side market members applied for conspiracy. The proportion of conspiratorial market members was 43.73%. Adjust the premium threshold, the other parameters remain unchanged, the quoted price of market members whose declared electricity price increased above the threshold after the conspiracy in the above transaction is replaced with the cost value and then be re-cleared, observing the trend of the bid electricity price, the bid electricity price and the profit in the transaction.

As shown in Figure 4, the members of the seller's electricity market conspire with the increase of the conspiracy threshold, the higher the declared price of the power generation side and the higher the declared price of the buyer of electric power, the higher the bidding price will be relative to the normal situation. However, with the change of the conspiracy threshold, the price of the winning bidder changed little.

As shown in Figure 5, the members of the seller's electricity market conspire with the increase of the conspiracy threshold, the higher the declared price of the power generation side and the higher the declared price of the buyer of electric power, the higher the bidding price will be relative to the normal situation. However, with the change of the conspiracy threshold, the price of the winning bidder changed little.
As shown in Figure 5, under the condition of tight supply and demand, some power-selling-side market members conspiring with the quotation will raise the transaction price of the market and significantly reduce the volume of electricity traded in the market.

![Figure 6. Sales and Purchasing Party's Total Profit.](image)

As shown in Figure 6, compared with the normal situation, the change of the conspiracy threshold has a greater impact on the profits of the buyers, and the sales-side benefits a lot. The profit of the electricity buyer is far below the normal level.

**SUMMARY**

Collusion between the sellers will raise market prices far above normal market prices. When the sales growth quotient is set smaller, the selling party's price slightly higher is regarded as conspiracy, and the sales price of the selling party drops more. When the threshold is set larger, the selling party whose quotation is greatly changed was considered a conspiracy. The sale side of the transaction price decline is not obvious enough.

In this paper, an intelligent agent quotation is used to declare the market members involved in the transaction. Multiple decisions that mimic market participants include cost-based pricing, learning quotes based on profit maximization, learning quotes based on maximizing power generation, and random quotes. By simulating conspiracies among some members of the market under different supply and demand conditions, the act of conspiracy would raise the market price so much above the normal market price level. The method adopted in this paper can identify whether there exists a joint operation of the market on the seller side, control it through the market and stifle its conspiracy so as to maintain the market electricity price at a normal level and ensure the stable operation of the electricity market. It provides the possibility for the actual operation of the inter-provincial trading market.

**REFERENCES**


