Power Generation Curve Clearing Algorithm based on High-Low Match Auction Mechanism

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Abstract. In the era of power production with coal and gas as the main fuel, the output value of the power system is easy to control and adjust. Therefore, the traditional power trading only focuses on the research of transaction method of electricity quantity. After the addition of clean energy, the output value of power system fluctuates greatly and is difficult to control. At this time, the trading mechanism which only takes electricity as the main factor is no longer applicable. It is necessary to consider adding the fluctuation factors of electricity into the trading process, and use the power of the market to change the purchase decision and electricity consumption habits of users, so that the fluctuation of electricity use curve is consistent with that of power generation curve. Based on the high-low match auction mechanism, this paper designs a clearing rule considering the fluctuation of generation curve, and gives an example to verify it.

1. High-Low Match Auction Mechanism

In the existing electricity market, there are two mature and widely used centralized bidding mechanism. One is marginal price method; the other is high-low match auction mechanism. Scholars at home and abroad have carried out a rich and in-depth study on the characteristics and applicable scenarios of the two bidding mechanisms. In 2007, based on the principle of economics, British scholar Daniel. S.K proposed a power pool model which can stimulate market competition and put forward the pricing mechanism of centralized bidding[1]. Scholar Nicolaisen and other scholars introduced the bilateral market bidding mechanism, which is based on the agency model, and its core idea is to "match the high and low prices" of the buyers and sellers [2-3]. Experts pointed out that although the marginal price method is simple and easy to operate, users have "free riding" behavior, which makes the final transaction price drop significantly, which is not conducive to the long-term development of clean energy [4-5]. Therefore, after careful consideration, this paper uses the high-low match auction mechanism.

The concept of matchmaking was first put forward in the stock market. Reference [6] compared the principles of different matchmaking bidding and the impact of different bidding methods on the market, highlighted the order of transaction priority and discussed its applicability. This lays a theoretical
foundation for the development and application of matching bidding mechanism in power market. The clearing mechanism matches transactions according to the quotations of both parties. Each transaction price is only related to the declared price of the matching parties [7]. If the declared electricity prices of a pair of electricity purchasing and selling entities are $P_d$ and $P_s$ respectively, then the transaction prices $P_{dM}$ and $P_{sM}$ of power purchasing and selling entities are calculated according to the following formula.

\[
P_{dM} = P_d - k_d(P_d - P_s) \quad (1)
\]

\[
P_{sM} = P_s + k_s(P_d - P_s) \quad (2)
\]

Where $k_d$ and $k_s$ are the distribution coefficients of price difference between the buyer and the seller respectively, $k_d + k_s \leq 1$. According to the value of price difference distribution coefficient, there are three clearing methods: average distribution, proportional distribution and incomplete distribution. At present, China’s power trading centers generally adopt the clearing method of average distribution. The corresponding economic principles of this model are shown in the Figure 1 below.

![Figure 1. High-Low Match Auction Mechanism](image)

2. Clearing rules

Based on the classical high-low match auction mechanism, this paper considers the influence of fluctuation factors of renewable energy generation. When making trading rules, participants are required to declare the purchase, sale and price of electricity at 24 time points per day. The power trading center matches the participants’ goals according to the principles described in Section 1. The specific steps are as follows.

1. If the 24-hour declared electricity quantity of user $I$ is $Q_{II} = [Q_{i1}, Q_{i2}, ..., Q_{i24}]$, then the total declared electricity quantity of user $I$ is $Q_I$. Assuming that there are $m$ users, the total power demand on the user side is $Q_D = \sum_{i=1}^{m} Q_I$.

2. If the 24-hour generation capacity of clean energy producer $k$ is $Q_{k} = [Q_{k1}, Q_{k2}, ..., Q_{k24}]$, then its total power generation capacity is $Q_k$. Assuming that there are $n$ generators, the total generation on the generation side is $Q_S = \sum_{k=1}^{n} Q_k$. 

(3) The 24-hour electricity purchase price of user $I$ is $P_{it} = [P_{i1}, P_{i2}, ..., P_{in}, ..., P_{i24}]$, while that of generator $k$ is $P_{kt} = [P_{k1}, P_{k2}, ..., P_{kn}, ..., P_{k24}]$.

(4) After the declaration is closed, the hourly electricity buyer’s quotation will be sorted from high to low, and the hourly electricity seller’s quotation will be sorted from low to high. If the quotations are the same, they shall be sorted in chronological order. If the quoted price and time are the same, the transaction electricity shall be distributed according to the declared electricity ratio.

(5) The price difference is formed by subtracting the electricity buyer’s quotation and the seller’s quotation in order, and the calculation method is as follows.

$$\Delta P_{ik}^t = P_{it} - P_{kt}$$

(6) The rules of quotation matching are as follows.

1. When $\Delta P_{ik}^t > 0$, $P_{ik}^t = P_{it} = P_{kt} - \mu * \Delta P_{ik}^t = P_{kt} - P_{it} + \mu * \Delta P_{ik}^t$, $Q_{ik}^t = \min \{Q_i, Q_k\}$. Among them, $P_{it}$ is the settlement price of the buyer; $P_{kt}$ is the revenue price of the seller; $\mu$ is the price difference coefficient, generally taken as 0.5; $Q_{ik}^t$ is the transaction volume between user $i$ and power supplier $k$ at time $t$.

2. When $\Delta P_{ik}^t = 0$, $P_{ik}^t = P_{it} = P_{kt} = Q_{ik}^t = \min \{Q_i, Q_k\}$.

3. When $\Delta P_{ik}^t < 0$, the transaction cannot be completed.

(7) When matching the declaration of the remaining purchase and sale of electricity, the above principles shall be followed. The transaction is terminated when all the declarations have been met or there is a negative difference pair.

(8) The information of electricity sales without transaction will be disclosed again, so that both parties can participate in the matching transaction again after adjusting the quotation. The second round of transaction is still carried out according to the above steps (1) ~ (7), until all the remaining electricity sales are matched or meet all electricity purchase demands, that is, the following formula is met.

$$\sum Q_{ik}^t \leq \min \{Q_D, Q_S\}$$

3. Example

Suppose that there are five consumers and five clean energy power producers in the market. They forecast their electricity demand and power generation through forecasting technology and obtain data. They use the obtained data and market information to conduct centralized bidding trading in the power trading center. According to the transaction rules described in Section 2, the transaction result as shown in Figure 2 is obtained.

![Trading results](image)

Figure 2. Trading results

From the results of the simulation transaction, we can draw the following conclusions.

(1) In the case of full transparency of market information, users will adjust their own electricity consumption plan according to the generation data and the fluctuation trend of electricity price, so as to achieve the purpose of reducing electricity charges.
(2) Under the condition of full transparency of market information, power producers will adjust their bidding strategies according to the electricity demand data and the fluctuation trend of electricity price, so as to obtain the maximum profit.

(3) Allowing participants to quote at 24 time points can fully reflect the market value of electricity in different periods of time. In the peak period of electricity consumption, the price of electricity rises; in the period of low electricity consumption, the price of electricity drops. The fluctuation of electricity price can guide the electricity consumption behaviours of consumers. After participating in the transaction for many times, the participants can learn the bidding experience and make the optimal decision. This mode realizes the balance of supply and demand in electricity market by means of market means.

4. Conclusion
With the development of market-oriented reform, there are still many aspects to be improved in the design of the relevant mechanism of power centralized bidding. The following aspects need to be further studied in this paper.

(1) The constraints of line congestion, network loss, transmission cost and system energy consumption should be fully considered in the model establishment. In this way, a more accurate matching relationship can be formed, which is of practical significance for the coordinated development of energy conservation and economy in the power market.

(2) This paper does not study the specific transmission cost allocation problem related to cross regional transaction, and does not specifically analyse the bidding strategy of each participant, which needs to be further improved on the existing results.

In addition, through the research, we find that market information is very important for participants to conduct fair trading. Therefore, we suggest that the government should actively build a platform for the exchange of electricity trading information and provide the participants with detailed trading rules in a timely manner. Participants should strengthen the study of trading rules, make full use of market information to optimize the quotation scheme, and strive for the maximum interests.

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