Identification of Typical Behaviors of Market Subjects in Competitive Power Market Environment

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Abstract. In the power market, some illegal behaviors of market subjects violate the market rules. There are also some potential harmful behaviors, such as profiteering pricing, speculation, alliance, which do not violate market rules directly. These harmful market behaviors impair the competitiveness and effectiveness of the market, cause adverse effect for the optimal allocation of limited resources. Consequently, it will impair the efficiency of the electricity market. Market illegal behaviors can be judged, punished and controlled according to market rules; However, harmful market behaviors are difficult to be identified and controlled according to market rules, so an effective method must be established to identify, monitor and control them. According to the different characteristics of potentially hazardous behaviors, four methods are proposed in this paper, namely, index supervision method, quotation behavior supervision method, trading behavior analysis method based on expert system and market simulation test method to identify the illegal behaviors in the power market. Then, this paper takes the compliance analysis of market player behavior and the compliance analysis of electricity purchase price as an example to carry out simulation test.

1. Introduction
At present, with the continuous improvement of the degree of marketization of China's electricity market, more and more studies have been conducted on the regulation of electricity market transaction behavior and the risks of electricity market. Xia Qing et al. analyzed and learnt the methods, indicators and means of foreign power market supervision. Foreign mature power market regulation means include information disclosure, fines, price adjustment, market rules and parameters modification, etc., which can be used for reference for the normative development of China's power market. Liu Dunnan et al. studied the basic principle of the index system of power market and put forward the method and steps of constructing the index system. It also introduces the qualitative analysis process of index system construction by taking power generator, power buyer, market operation center and supervision department as examples. With the continuous improvement of power industry informatization, power big data plays a vital role in market operation monitoring and analysis. Li Xiaolan et al. explored the
potential correlation of electric power related indicators by using data mining methods, constructed the operation monitoring indicator system, and introduced data mining technology to carry out refined operation analysis. Based on the massive power data of the power marketing system, Wang Zhijian et al. fully mined the power trading data information, realized the power trading business trend prediction, marketing strategy formulation, etc. On this basis, they optimized the trading mode. The existing studies mainly focus on some market behaviors. Such as modeling and analysis based on the trading irregularities in the power market \cite{1} \cite{2}. They identify the illegal behaviors in the whole process of power trading under the open market and constructs the identification framework. Ada Boost-DT classification algorithm is used to train the intelligent recognition model of collusive behavior, and research on the recognition of collusive behavior in power market \cite{3}. A new method based on cloud model and fuzzy Petri net is proposed to identify potential hazard behaviors in power market \cite{4}. Based on the existing studies results, in order to comprehensively analyze the market trading irregularities, this paper identifies the irregularities in the whole process of the electricity market trading, and establishes an indicator system that considers the whole process of the electricity market trading irregularities.

2. Principle of analysis

2.1. Index supervision method

In order to analyze the bidding behavior of electricity market participants comprehensively, the following steps should be followed:

2.1.1. Determine analysis basis.

The analysis of participants' bidding behaviors is based on the relevant data that can be obtained from the power market transaction support system, which can be divided into three categories: basic information of market participants, declaration information and transaction information. From the analysis time, method and purpose listed in the above table, which can assist us know have a more comprehensive and in-depth understanding of the bidding behavior of each market participant.

2.1.2. Determine analysis content:

Table 1. Failure status of Transmission line

| Time        | Method                                      | Theme                       | Purpose                |
|-------------|---------------------------------------------|-----------------------------|------------------------|
| Before trade| Compare the basic information horizontally  | Bid position evaluation     | Find out who can make  |
|             | Compare the declared information with the basic information | Evaluation of Bidding strategy | Find out who is making |
| During the trade | Compare transaction information with declared information | Bid risk assessment       | Find out who made      |
| After the trade | Compare transaction information with basic information | Bid revenue evaluation |                        |

From the analysis time, method and purpose listed in the above table, which can assist us know have a more comprehensive and in-depth understanding of the bidding behavior of each market participant.

2.2. Quotation behavior supervision method

For the supervision of power market participants, in addition to the index method, analyzing the bidding behavior of market participants is also a very effective supervision method.

In the power generation market, the bidding behavior of the market participants is mainly supervised. The key part is to analyze the bidding strategies of the power generation companies and compare and analyze the relationship between the bidding strategies of the power generation companies and their market share.
The following is an example of the market regulation of power generation enterprises. The supervision projects include:

- Supervision of the annual contract trading market.
- Supervision of the monthly contract trading market.
- Supervision of the day-ahead market.
- Supervision of real-time market.
- Supervision of ancillary service market.

2.3. Trading behavior analysis method based on expert system

The main structure of the trading behavior analysis method based on expert system is shown in the figure below:

![Figure 1. Trading behavior analysis method based on expert system](image)

As for the analysis of typical application scenarios of electricity market transaction behavior, firstly, the electricity market transaction results should be analyzed through the comprehensive evaluation index of the electricity market after the transaction. After the abnormality is detected, the subjective and objective reasons for the abnormality will be analyzed according to the indicators in the transaction and the indicators before the transaction. Then for the subjective reason, through the analysis of the power market subject behavior evaluation index system, find the root cause and take corresponding measures.

Through the monitoring of the electricity market transaction results, the abnormality of the comprehensive indicators of the market after the transaction can be monitored. There are two main situations about abnormality of the indicators after the transaction:

- **Situation one**: Large social benefit index, in this case, \( LI < Ro \).
- **Situation two**: Small social benefit index, in this case, \( LI > R_{cap} \).

Typical market behavior one: social benefit index is too large, \( LI < Ro \)
- When market supply is more than demand, power generation companies with market power or some power generation companies conspire to malignantly lower prices (below their marginal cost) to seize market share.
- When market supply is less than demand, electricity sales companies or departmental electricity sales companies with market power conspire to raise prices viciously to seize market share.

Typical market behavior two: social benefit index is too small, \( LI > R_{cap} \)
- When the market supply is more than demand, some power generation enterprises with market power or some power generation enterprises conspired to raise the market price.
When the market supply is less than the demand, the power selling companies and important users or some of the power selling companies and large users conspire to depress the market price.

2.4. Market simulation test method

By adopting the method of indicator supervision and trading behavior supervision, it can reflect from different aspects whether there be manipulation or unfair competition in the electricity market. Therefore, after comparing and summarizing, relatively reliable judgments can be made. For further analysis, it is necessary to transfer to the simulation simulation analysis module to simulate the production process and quotation strategy of a specific market participant to confirm whether the market participant’s behavior violates the regulations.

There are two ways to simulate: one is the simulation under the non-speculative mode of specific market participants, and the results are mainly used for comparison with actual data; the other is the simulation under the speculative mode of specific market participants, and the results are mainly used to verify whether specific market participants have conducted speculation. There are two types of simulation test methods:

Design a computer system based on intelligent learning algorithms, and conduct unattended simulation experiments. As long as the computer system is designed to simulate the power market and the decision-making behavior of market participants in the market according to the problem to be studied, then a large number of unattended simulation tests are carried out, and finally the results are analyzed to obtain the problem to be studied. in conclusion. The advantage of method is that it can use the powerful functions of the computer to perform thousands of simulation tests and simulate the actual power market in as much detail as possible. But how to describe or simulate market participants to decide their own bidding strategies based on market conditions and past information, this is more difficult to solve.

3. Case analysis

3.1. Typical scenario one: Market compliance analysis

The subjective bidding behavior of market participants is affected by objective factors. This example will analyze the relationship between subjective and objective factors in the market based on actual data from the electricity market and using relevant indicators.

3.1.1. Analysis of the influencing factors of the behavior of reporting high prices.

Table 2 reflects the correlation coefficients of various indicators calculated based on the electricity market data of a region.

| Coefficient                     | Market share | Capacity supply/demand ratio | High bid winning rate | Rate of quotation |
|--------------------------------|--------------|------------------------------|-----------------------|-------------------|
| The market share               | 1            | .001                         | .799                  | .694              |
| Capacity supply/demand ratio   | .001         | 1                            | .389                  | -.624             |
| High bid winning rate          | .799         | .389                         | 1                     | .323              |
| Rate of quotation              | .694         | -.624                        | .323                  | 1                 |

As it is shown in table 2, the proportion of high market prices is closely related to the supply-demand ratio of market capacity and the market share of power plants themselves. The tighter the market supply and demand, the greater the market share of power plants themselves, and the more inclined to declare high prices; the ratio of high market prices to market capacity supply-demand ratios, and the high bid-winning rate of power plants from power plants are most closely related to their market share. It is foreseeable that power plants with a large market share tend to quote high prices, and the correlation coefficient of the high-price bid winning rate is also large, and the price increase rate is large. The market share of the body has a large correlation. The tighter the market supply and
demand, the greater the market share of power plants themselves, and the more inclined to declare high prices.

3.1.2. Analysis of the influencing index score.
Using the dynamic clustering method, as shown in table 3, the samples can be divided into three categories in the order of the high price winning rate of power plants, and the following enlightenment can be obtained:

The supply-demand ratio of the market capacity is above 1.25, and the market is highly competitive. If it is lower than 1.08, it is likely to make prices climb rapidly.

When the supplier's market share is less than 3%, it will basically not report high prices. Even if the high price is reported, it is difficult to win the bid. Large manufacturers with a market share of more than 17% will be more inclined to declare high prices.

Table 3. Index dynamic classification results

| Index                | Good | Average | Bad  |
|----------------------|------|---------|------|
| High bid winning rate| .00  | .52     | .96  |
| Rate of quotatio     | .29  | .75     | 1.00 |
| Capacity supply/demand ratio | 1.25 | 1.16 | 1.08 |
| Market share         | 3%   | 7%      | 17%  |

The above analysis results reveal potential market operation laws, which can provide the following enlightenment for market operations and compliance departments: Before each bidding, the market capacity supply-demand ratio and the market share index of each bidding power plant should be calculated. If the capacity supply-demand ratio index is less than 1.08, market participants may declare high prices; if the market share of certain power plants is greater than 17%, special attention should be paid to the fact that these power plants will have the ability to control market prices.

3.2. Typical scenario two: Compliance analysis of electricity purchase quotation
This example will introduce the main influencing factors and avoidance strategies of the risk of electricity purchasers in a regional monthly bidding market.

For provincial-level power companies as power purchasers, they are most concerned about being able to purchase enough power to reduce the risk of power purchase, which can be quantitatively reflected by the power purchase bid rate indicator. In the case of marginal price settlement, the more the average electricity purchase price deviates from the marginal price, the smaller the risk is. Figure 2 reflects the relationship between the power purchase bid rate of a certain provincial power company and the security index of the power purchase price in a certain region.

Figure 2. The relationship between the winning rate of power purchase and the security of quotation in a power company
Using the dynamic clustering method, based on the monthly electricity purchase quotations and transaction data in the region, the two indicators are dynamically clustered to obtain the following table:

| Index                  | Level-1 | Level-2 | Level-3 | Level-4 | Level-5 |
|------------------------|---------|---------|---------|---------|---------|
| rate of tender         | 0.44%   | 21.43%  | 44.28%  | 72.50%  | 99.99%  |
| Quotation safety       | -14.14% | -2.10%  | -1.46%  | 0.92%   | 11.46%  |

In table 2, according to the order of the bid winning rate of electricity purchase, the samples are divided into 5 levels, and the corresponding quotation security index values is also list in the table. The power purchaser can check the risk of the new quotation strategy based on the reference value of these five levels of quotation security. For example, if the security of electricity purchase price is 0.92%, that is, when it exceeds the market marginal price expectation of 0.92%, the expected bid winning rate for electricity purchase is 72.50%.

4. Conclusion

Based on the power market transaction operation evaluation and transaction behavior analysis index system constructed previously, this paper proposes four types of market entity behavior analysis methods, index supervision method, quotation behavior supervision method, analysis method based on expert system, and market simulation experiment method. Two types of typical scenarios are simulated and analyzed.

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