Design of China's Electricity Market Evaluation Indicators Based on SCP Model

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Abstract. The establishment of China’s electricity market has been conducted since 2015. In order to inform the condition of electricity market operation through evaluation index, this paper proposes an evaluation index system based on structure-conduct-performance (SCP) model, containing three principal aspects: market structure, participant behavior and market benefit. Meanwhile, considering the specific situations in China such as the differences among provinces and the immature rules in the initial stage of market construction, some of the market evaluation indexes should be specially designed in order to adapt to China's national conditions.

1. Introduction
The electricity market evaluation index system is a scientific method using which can quantitatively analyze the electricity market from a series of indicators. Under the rapid development of China’s electricity market, an affective and comprehensive market evaluation index system becomes crucial for market operators and designers to figure out the market situation. Therefore, the electricity market evaluation index system plays an important role in the market design and management.

The market evaluation indexes have been investigated in some pervious work as an important tool for market supervision and analysis. The authors in [1] investigate the sets of assessment criteria for auction performances in 13 countries. Each criterion includes a set of indexes to score and measure quantitatively, finding that auction indexes have to be adjusted based on each country’s market condition. In [2], a unified index has been given to assess the electric power quality of the distribution network based on the proposed ideal analytic hierarchy process (AHP) model. The principles and methods of China’s electricity market evaluation index system establishment are given in [3], which lays the foundation for the future index system. Literature [4] constructed a power market evaluation index system from the aspects of fairness, safety, economy and environmental protection, and adopted a multi-level fuzzy method for evaluation. Authors in [5] proposed a risk-control index for measuring the degree of electricity deviation before and after the transaction, but this indicator is mainly used in day-ahead market scenarios. Literature [6] proposed a market manipulation evaluation strategy for multiple entities in a market from both the generation side and the demand side. However, this method mainly focuses on the technical operation risks of each generating unit. Furthermore, Herfindahl Hirschman Index (HHI) is usually used to evaluate the market manipulation and to strengthen risk control [7]-[10]. For example, literature [7] selected key evaluation indexes such as HHI, concentration cumulative distribution function, to analyze the operation of the electricity market in Guangxi province in 2018 to show the market competition. For some cases the assessment of the...
competition degree using HHI is not accurate enough. Literature [11] and [12] found that the increased production from small producers will not increase competition significantly if there is a dominant firm in the market. Therefore, literature [12] improved HHI by difference in market shares of the two largest companies as an indicator of dominance.

Although there have been previous studies on the market evaluation index area, the evaluation index was designed focusing only on individual market issues. A more comprehensive market evaluation index system is necessary in China’s current and future electricity market.

2. Brief introduction of electricity market evaluation in typical countries

2.1. Electricity market evaluation in the U.S.

2.1.1. PJM electricity market evaluation. The PJM market in the United States is mainly evaluated from the aspects of market structure, behavior and performance by the independent market supervision (IMU) department, which is responsible for publishing the annual evaluation report of the electricity market. through the research on the specific market conditions. Federal Energy Regulatory Commission (FERC) is supported by IMU to improve the schemes of the electricity market rules using the market evaluation model. The main features of the evaluation model includes: 1) builds an evaluation system based on the SCP paradigm of industrial economics to evaluate the market operation state; 2) focuses on market behavior and market manipulation to prevent market monopoly. The main aspects and its relevant indexes of PJM market evaluation model are as follows:

- Market structure: market supply and demand, market concentration, demand side response, marginal unit concentration, demand side response capability, etc;
- Market behavior: Quotation increase, price cap, regional market power, frequent load shedding units, etc;
- Market performance: system load demand and power generation, clearing price and marginal cost ratio, etc.

2.1.2. FERC’s evaluation methods for ISO/RTO. In 2011, the FERC established a set of evaluation methods for the market operation and performance of ISO (Independent System Operator) and RTO (Regional Transmission Organization), including three dimensions: reliability, market efficiency and organizational efficiency. The evaluation system includes 21 first level indicators and 57 second level indicators. The main features of the system include: 1) focus on the evaluation of market organization efficiency, including organization cost and customer satisfaction; 2) pay attention to the safe and reliable operation of power grid, and construct 10 indexes including dispatching reliability and transmission network operation coordination. The main features of the evaluation model include:

- Operation reliability: compliance degree of federal and regional reliability standards, dispatching reliability, load forecasting accuracy, wind power forecasting accuracy, transmission network outage coordination, long-term reliability planning, etc;
- Market efficiency: market competition, market price, marginal cost, congestion management, resource utilization, fuel diversity, renewable energy consumption, etc;
- Organizational efficiency: cost management, consumer satisfaction, etc.

2.2. Electricity market evaluation in Nordic countries

The Nordic energy regulators are developing unified rules and regulations for the Nordic electricity market to achieve a common Nordic retail market. The network regulatory working group within the Nordic union of energy regulators, collects and analyses the network regulatory information of the Nordic countries, and issues the Nordic market report each year. In addition to introducing the current situation and development of the Nordic electricity market, the Nordic market report focuses on the generation, consumption, transmission, wholesale and retail markets of the Nordic market. Its evaluation dimensions mainly include:
2.3. Electricity market evaluation in Australia
The National Electricity Law (NEL) requires the Australian Energy Authority (AER) to assess the national wholesale electricity market at least every two years. The evaluation criteria mainly include: 1) whether there is "effective competition" in the market; 2) whether or not the market characteristics have negative effect for competition; 3) whether or not the market characteristics have negative impact on the effective operation of the market and the realization of the national energy target.

Based on the above criteria, AER also uses the SCP analysis model to comprehensively evaluate its electricity market according to the principles of verifiability, stability, readability and practicability:

- Market structure: market concentration, barriers for market entry and exit;
- Market behavior: generation capacity retention, market manipulation;
- Market effectiveness: market competitiveness and efficiency.

2.4. Discussions of market evaluation methods in typical countries
Comparing the market evaluation methods above, three features could be identified here:

Firstly, specialized organizations are required for the evaluation and analysis of the electricity markets. In the United States, the independent electricity market regulator IMM is responsible for monitoring and statistical analysis of the market; ACER in Europe cooperates with the European Commission in regulation of the market; the Australian Energy Authority is responsible for the evaluation of the market.

Secondly, most of the above markets are evaluated in terms of market structure, market behavior and market efficiency according to SCP model. The PJM market evaluation, Australian market evaluation both adopted SCP for their market assessment, and the evaluation for Nordic market also applies indexes reflecting SCP concept.

The design of electricity market evaluation index should be adapted to local conditions. The Nordic electricity market involves a large number of cross regional transactions, so the cross regional transaction volume and tie line channel are evaluated; the Australian national electricity market has designed a lot of indicators to assess the barriers for market entry and exit due to the increasing market concentration in recent years.

3. Design of China's electricity market evaluation system

3.1. Progress of China's electricity market
Since the new round of China's electric power system reform in 2015, the construction of electricity market has been continuously promoted. At present, the connection of among and within province market has been initially formed, and the electricity market covers a time scale from long term to short term.

For inter provincial spot market, State Grid Corporation of China (SGCC) has continued to carry out cross regional and spot market for incremental renewable energy. In 2019, the total trading quantity was 5.245 billion kWh, including 4.936 billion kWh of renewable energy, and the renewable energy accommodation rate was increased by 1.1%. The spot market in eight pilot provinces has been generally carried out. Up to May 2020, Shanxi, Gansu, Shandong, Fujian and other provinces have completed the third settlement of trial operation.
3.2. Target of China’s market evaluation
The main targets of the market evaluation include:
- To test whether or not the market structure is reasonable;
- To monitor whether or not the market is fully competitive;
- To monitor the efficiency and security of the market operation;
- To revise and improve the rules of the market based on the evaluation results.

According to the SCP model in the classical theory of industrial economics, which is also widely applied for the market evaluation systems in typical countries, this study of China’s electricity market evaluation is suggested to include market structure, market behavior & operation, and market performance.

3.3. Design of China’s electricity market evaluation system
Based on the SCP model and referring to the evaluation design methods of typical electricity market countries and regions, China’s power market evaluation system is established as shown in the table below:

| SCP dimensions         | 1st level indicator | 2nd level indicator | illustration                                      |
|------------------------|---------------------|---------------------|--------------------------------------------------|
| Market structure       | Supply & demand     | Bidding space in peak load period |                                                     |
|                        |                     | Bidding space in valley load period |                                                     |
|                        |                     | Supply & demand ratio in peak load period |                                                     |
|                        |                     | Supply & demand ratio in valley load period |                                                     |
| Market concentration   | HHI index           | Square sum of market shares of all generators \( HHI = \sum_{i=1}^{n} s_i^2 \) |                                                     |
|                        | TOP-p% of generation| Number of power generation enterprises to supply specific load rate |                                                     |
|                        | Residual supply index (RSI) | The sum of the market shares of the power generation enterprises taking out a certain power generation enterprise (\( q \) is the generation value, and \( D \) is the sum of load) \( I_{RSI} = \frac{\sum q_i - q}{D} \) |                                                     |
| Generation types       | Generation diversity | The smaller the index value is, the smaller the seasonal influence would be on the electric power output (\( p \) is the share value for one generation type) \( FDI = 1 - \sum_{i=1}^{n} p_i^2 \) |                                                     |
| Market declaration     | Quantity value of quotation |                                                     |                                                     |
|                        | Market participation in generation side |                                                     |                                                     |
|                        | Market participation for retail companies |                                                     |                                                     |
|                        | Market participation for large consumers |                                                     |                                                     |
| Malicious competition  | Number of quotations contrary to regulations |                                                     |                                                     |
|                        | Malicious capacity held by generators |                                                     |                                                     |
|                        | Rate of extreme quotation | The electricity quantity rate for the generators with low quotation, and for the consumers with high quotation |                                                     |
| Market clearing        | Clearing electricity quantity |                                                     |                                                     |
|                        | Average price of the market |                                                     |                                                     |
|                        | Spot market share    |                                                     |                                                     |
Market activity

| Index                                                                 | Description                                                                                      |
|----------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|
| Turnover ratio of electricity trading contract                       | In the electricity financial market, the larger the ratio of the total contract to the executed quantity, the more turnover times |
| Consistency between market supply demand ratio and market price      | If the consistency is high (i.e., the price is low when the market supply exceeds the demand, and the price is high when the supply is less than the demand), the market mechanism is effective |
| Market participation rate                                            |                                                                                                 |

Market efficiency

| Index                                                                 | Description                                                                                      |
|----------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|
| Profit and loss of generation enterprises                           |                                                                                                 |
| Changes in electricity purchase cost of consumers                   |                                                                                                 |
| Producer and consumer surplus                                       | The additional benefits brought by the difference between the bidding price and clearing price for market entities |
| Average Markup index                                                | Profit level of all generation enterprises in the market                                         |
| Market efficiency index                                             | The closer the clearing price is to the marginal cost, the more competitive the market is.       |
| Rate of clearing price reaching the limit                           |                                                                                                 |

Clean energy accommodation

| Index                                                                 | Description                                                                                      |
|----------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|
| Generation of hydropower, wind power and photovoltaic power         |                                                                                                 |

Unbalanced fund

| Index                                                                 | Description                                                                                      |
|----------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|
| Unbalanced fund for market and non-market coordination             | Such as fee for ancillary services                                                               |
| Unbalanced fund in the market                                      |                                                                                                 |

4. Cases of evaluation index design adapted to China's specific conditions

4.1. Index design case considering differences between provinces

Chinese provinces have great differences in energy resource, economic conditions, generation type and supply & demand situation. Taking the market concentration evaluation in the generation side as an example, if the traditional top-N (i.e. the proportion of the largest N generators in the market share) index is used, it is difficult to reflect the actual situation of the market in different province. Therefore, the method of top-p% is adopted instead to evaluate the market concentration for generation.

The local generation enterprises are ranked from high to low according to the generation share until the sum of which satisfies p% of total load in this area, and the number of generation entities is the value of top-p%. The higher top-p% is, the less the market is concentrated. In this index, p is determined by market operators or regulators according to many factors like inter provincial input or output situations.

Top-p% can be calculated with static and dynamic modes: the static top-p% is determined by the installed capacity and peak load, which can be referred to in a long-term period with a fixed value; the dynamic top-p% can be calculated by the available generation capacity and real-time load at a certain time.

4.2. Index design case considering market maturity

When the market is not designed perfectly, the market participants will take advantage of rules to participate in the market in an extreme way. Taking the quotation as an example, if the floor price (generation side) or ceiling price (consumer side) takes up a large proportion, it indicates that there is an excessive game phenomenon. Under this situation, the market participants do not formulate the quotation curve according to their actual demand. Market rule makers can set the proportion limit of extreme quotation to see if it is necessary to make constraint for each quotation segment.
5. Conclusions
The evaluation system of typical electricity markets such as PJM, northern Europe and Australia, generally include three aspects: market structure, market behavior and market performance. Therefore, referring to foreign experience, China’s market is suggested to build an evaluation index system based on the SCP model. Considering China's electricity market is facing the challenges of China's special national conditions, in the process of specific index design, such as the differences among provinces, imperfect rules in the initial stage of market construction, the coexistence of non-market and market. The specific features in China’s market should be considered in market evaluation design. The usage of the evaluation system and the market adjustment form a closed-loop interaction for the continuous process of market establishment.

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