Research on the Evolution Path of China's Power Spot Market

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Abstract. Recently, the construction of China's power market is accelerating. With the continuous expansion of market-oriented trading scale and the rapid development of renewable energy, the balance of electric power supply is facing challenges, and all sectors of the society have strong demands to develop the spot market as soon as possible. The government requires that "by the end of 2018, the spot trading pilot should be launched; in 2020, the spot trading market should be fully launched", and 8 spot market pilots have already been launched. By the end of September 2019, 8 provincial-level spot market pilots have completed the continuous settlement trial operation. With the development of spot market pilots and the further improvement of market conditions, it is necessary to gradually promote the integration and opening of provincial markets to enhance large-scale optimal allocation of resources. This paper focuses on the evolution mode and path from provincial market to national unified power market. Two modes are proposed and compared based on the conditions in China. This research is beneficial for the construction of national unified power market and prompting large scale power trading.

1. Experience in large scale power market construction

The United States regional unified market and the European Union cross-border coupling market represent two typical modes of cross regional and transnational large-scale power market respectively[1-4]. The main difference lies in the organization and clearing mode of centralized transaction in the spot market.

1.1. Market Mode Description

1.1.1. U.S. regional unified market. The U.S. has established seven organized regional power markets. In each regional power market (such as PJM), the day ahead and real-time power market is optimized in a centralized and unified way, and the node marginal price mechanism is adopted. There are mainly medium and long-term bilateral transactions among regional markets.

1.1.2. European Union Cross-border Coupling Market. The European Union's day-ahead market adopts the mode of market coupling and zonal power price with basically a country as one/multiple price area. The real-time balance markets are mainly operated by the dispatching agencies of each member country. While the day ahead market jointly clears and ignores the internal transmission congestion of each country (price area), and only considers the capacity limit of transmission lines among countries (price areas). If there is no congestion in the transnational transmission system, the
whole coupling market will form a unified price area; if there is congestion in the system, it will be divided into different price areas.

1.2. Market Mode Analysis
The formation of the two models is related to the power grid structure and market development process of the United States and Europe.

1.2.1. From the perspective of power grid structure. The power grid structure in the United States is complex with congestions occurring frequently, and market transactions need to be optimized considering complete security constraints. The power grid structure in Europe is clear and mature with relatively fewer congestions. So the price zone can be divided in advance according to the network congestion situation, ignoring the power grid congestion within the zone for market coupling calculation.

1.2.2. From the perspective of market development process and motivation. The property right of US electric power industry is decentralized. Driven by the demand of large-scale allocation of resources and opening of power grid, market members spontaneously set up regional electric power market. In the regional electric power market, unified market rules can be adopted to realize the unified optimization of resources. While in Europe, some countries have established domestic electricity market earlier, and there are great differences in market mode, trading varieties and bidding rules among member countries. Thus it is more difficult to achieve unity. Therefore, market coupling is adopted to promote the integration and opening of member countries.

2. Evolution path design for power spot market in China
With the progress of power spot market pilots in China, the market mode, evolution path and technical support systems are widely discussed [5-10]. Based on the international experience and considering the actual conditions of China's power grid structure, dispatching system and administrative management system based on Province, the provincial spot market in China should be opening up and gradually form a national unified power market. The following two modes can be adopted: the inter-provincial unified market mode and the inter-provincial coupling market mode.

2.1. Inter-provincial unified market mode

2.1.1. Mode description. It refers to the gradual integration of provincial markets to form multiple inter-provincial sub-markets. In the sub market, the medium and long-term, day-ahead, intra-day and real-time balance power trading are carried out in a unified way; the medium and long-term bilateral trading are mainly carried out among the sub markets. In the long run, with the development of power grid and information technology, sub markets will be gradually integrated to form a national market.

2.1.2. Transaction sequence. The medium and long-term transactions shall be carried out among the sub markets firstly, and the transaction results shall be decomposed to the sub markets. Then the medium and long-term and spot transactions shall be carried out in the sub markets.

2.1.3. Main features.
- Feature 1: centralized optimization of multi transaction varieties in the sub market. All the market participants in the inter-provincial sub-market conduct transactions on the same platform and the transactions are balanced uniformly.
- Feature 2: in-between the sub markets, the trading variety is mainly medium and long-term trading. The decomposition of the medium and long-term trading results among sub markets serves as the boundary condition of the inter-provincial sub-market organization.
2.1.4. **Sub market scope considerations.**

- Dispatch control area: the sub market is responsible for carrying out various transactions from the year to the real time, and responsible for the power balance. Thus it is necessary to consider the scheduling management system formed in the history, and the sub market scope should be set according to the scheduling security control area.
- Tightness of grid connection: Power grid is the basis and specific carrier of power market. The scale of power grid and the degree of connection determine the size of power market. Therefore, the division of sub market needs to adapt to the characteristics of power grid form and structure in China.

![Diagram for Inter-provincial unified market mode](image)

**Figure 1. Diagram for Inter-provincial unified market mode**

2.2. **Inter-provincial coupling market mode**

2.2.1. **Model description.** The inter-provincial coupling market refers to the joint clearing for the day-ahead spot markets of all provinces; the provincial market is still responsible for the intra-day and real-time balance market organization. Medium and long term transactions can be carried out within or among provinces as required. With the development of spot market in various provinces, all provinces across the country can gradually form a nationwide coupling spot market. With the improvement of the technical support system and the improvement of the calculation level, the market will gradually evolve from taking one province as a price zone to multiple price zones. The consideration of the network security constraints will be gradually refined from only considering congestions among provinces to within provinces, and eventually form a national market in the long run.

2.2.2. **Transaction sequence.** For the medium and long-term power market, the transactions are firstly carried out among provinces, and then the results are decomposed to each province as a boundary for provincial market. For the spot market, day-ahead market coupling is firstly carried out among the provincial markets, and then intra-day and real-time balance markets are organized in the provincial markets.

2.2.3. **Main features.**

- Feature 1: market coupling for day-ahead markets. All units in the country are bidding and clearing on one platform, but only considering the inter provincial transmission line security constraints, and ignoring the internal grid security constraints in the provincial market. If the transmission lines among
provinces are not congested, the entire coupling market will form a unified market price; if there is congestion, the coupling market will be divided into different price zones.

- Feature 2: the intra-day and real-time balance markets are still organized by the province. The provincial system operator is responsible for keeping the balance of power supply in its security control area, and is responsible for organizing intra-day and real-time market transactions.

- Feature 3: simplified network security constraints are considered. A simplified network topology structure is adopted for the optimization of the day-ahead spot market, and each province is equivalent to a node. If the congestion is serious in the province, a province can also be divided into multiple nodes (i.e. divided into multiple price zones) according to the blocking section.

2.2.4. Market operation process.

- Transmission capacity among provinces are calculated.
  - Bidding information of market participants are collected, aggregated and submitted by each province.
  - Inter-provincial coupling market is optimized and transaction results are formed according to the aggregated bidding curve of each province (control area) and the transmission capacity constraints among provinces.
  - Inter-provincial day-ahead transaction plans are formed according to the transaction results, and transmitted to each province for implementation.

Figure 2. Diagram for Inter-provincial coupling market mode
Table 1. A comparison of Inter-provincial unified market mode and Inter-provincial coupling market mode

|                                | Mode 1: Inter-provincial unified market mode | Mode 2: Inter-provincial coupling market mode |
|--------------------------------|--------------------------------------------|---------------------------------------------|
| Medium and long-term power market | Inside or among the sub-markets             | Inside and among the provincial markets      |
| Day-ahead market                | Inside the sub-markets                      | Coupling market among provinces              |
| Intra-day market                |                                            | Provincial markets                           |
| Real-time balancing market      |                                            |                                             |
| Pricing and congestion considerations | Nodal price, considering entire constraints | Zonal price, ignoring constraints inside a province(zone) |

3. Comparison and selection of evolution path of spot market in China

For the comparison of the above two market models, the following factors can be mainly considered:

- Factor 1: Adaptability to the need for optimal allocation of resources. Mode 1 is centralized organization and unified optimization within the unified market, and the efficiency of resource optimization and allocation is high; however, it can only achieve the complementary benefits of resources within the unified market. Mode 2 mainly focuses on centralized optimization in the day-ahead market, and the potential of resource allocation has not been fully explored; however, it can realize the resource complementarity across the country.

- Factor 2: Adaptability to grid structure. Mode 1 has good adaptability to the power grid pattern of our country, and can fully consider the problem of power grid congestion. Mode 2 ignores the power grid congestion inside each province (control area). Due to the prominent problem of power grid congestion inside a province, the actual implementation of market clearing results may be difficult.

- Factor 3: Adaptability to China's administrative management system. Mode 1 has poor adaptability to the provincial oriented administrative management system in China, but it can support the implementation of national regional coordinated development strategy through reasonable division of sub market scope. Mode 2 has a good adaptability to the provincial administration system.

- Factor 4: Adaptability to dispatching management system. In Mode 1, the scope of unified sub market can be divided according to China's dispatching management system to facilitate the organization and management of power market. In Mode 2, the inter-provincial coupling in the whole country puts forward higher requirements for the national dispatching centre.

- Factor 5: Requirements for technical support system. Mode 1 needs a large amount of clearing calculation, and has a high demand for technical support system. In Mode 2, the calculation of clearing is simplified to a certain extent, and the difficulty of technical realization is lower.

4. Conclusions

Generally speaking, the two modes have their own advantages and disadvantages. If Mode 1 (Inter-provincial unified market mode) is adopted, pilot projects may be firstly carried out in some regions consistent with national strategy. With the progress of computing performance and other technologies, several sub markets will be gradually integrated and the scope of unified market will be gradually expanded, and finally transition to the target mode, that is, a nationwide unified market. If Mode 2 (Inter-provincial coupling market mode) is adopted, the coupling can be realized with each province as one price zone firstly. With the improvement of the technical support system, the consideration of the network security constraints will be gradually refined from only considering congestions among
provinces to within provinces, and eventually form a national market in the long run. Besides, the integration and opening-up of provincial markets will involve adjustment of finance and tax management and power grid dispatching of each province, which requires the introduction of relevant policies and supporting mechanisms at the national level.

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