Research on key issues of power spot market construction

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Abstract. Power spot market is the key link of the power market system. It plays a fundamental role in supporting the opening, competition and orderly operation of the power market. It is also the key to coordinate market transactions and system security. Based on the comprehensive comparison and analysis of the construction practice of power markets in different countries, this paper analyzes and studies the key issues in the organization and operation of the power spot market, such as market operation organizers and their responsibilities, market price and clearing mechanism, and puts forward some innovative suggestions for the construction of power spot market.

1. Introduction

The spot market usually refers to the real-time market for physical delivery of goods. Considering the characteristics of instantaneous supply-demand balance of power commodity delivery, the time range of power spot market is often extended to several hours or even one day before real-time delivery. Therefore, the time range of spot electricity market discussed in this paper covers the period from the day before the real-time operation of the system to the real-time operation.

The significance of power spot market can be summarized as follows: (1) it can form an optimized trading plan which is suitable for the physical operation of the power system and reflects the wishes of market members in a suitable time advance; (2) it promotes the full competition of electricity trading by means of centralized clearing, and realizes the efficient and optimized allocation of power resources; (3) it provides a trading platform for market members to modify medium and long-term generation plans, so as to reduce the system security risk and financial risk of transaction.

2. Comparison of electric power power spot market at home and abroad

The power spot market of PJM in the United States is composed of day ahead and real-time markets. The trading targets of all levels of markets include electric energy and auxiliary services (reserve and frequency modulation). PJM power spot market adopts "full power optimization" mode. In the day ahead market, the power generation companies need to declare all their generation resources and trading willingness. The market matches them with the load demand of the whole network, forms the day ahead trading plan of the generation companies through clearing calculation, and carries out full settlement according to the day ahead node marginal price. The real-time market also adopts the mode of "full power optimization". Before the real-time operation, according to the latest forecast and system operation information, the power generation resources of the whole grid are re allocated (based on the transaction declaration information sealed in advance). There will be difference between the real-time trading plan and the day ahead trading plan. For the electricity with this deviation, the incremental
settlement will be made according to the marginal price of real-time node. Both the day ahead market and the real-time market of PJM adopt the node marginal price mechanism, while the auxiliary service adopts the pricing mechanism of marginal clearing price of the whole network.

The UK power spot market is composed of day ahead electronic trading and real-time balancing mechanism, and its trading target is electricity. The auxiliary services are mostly carried out in a long time (from months ago to days ago), which are purchased by the dispatching center of the British Grid Corporation, and can be implemented by signing bilateral contracts or centralized bidding. The electricity exchange is responsible for the organization of electronic trading in the UK power spot market. The clearing calculation does not consider the actual network conditions or the physical parameters of the unit. Therefore, the clearing method is essentially a centralized auction in general sense, which does not consider physical constraints and does not need to conduct security check.

The Nordic power spot market consists of three parts: day ahead market, intra-day market and balanced market, and its trading target is electric energy. The transaction mechanism of ancillary services is roughly the same as that in the United Kingdom, which is purchased by transmission operation agencies of various countries, and can be implemented by signing bilateral contracts or centralized bidding. The Nordic power market has also carried out large-scale medium and long-term bilateral transactions, mainly in the form of OTC. The bilateral transactions signed need to be physically delivered during actual operation. In addition to bilateral trading, electricity is traded in the power spot market, mainly in the day ahead market, while the trading volume in the intra-day market and the equilibrium market is relatively small. Nordic day ahead market adopts the price mechanism of regional marginal price. On the other hand, the intraday market adopts the price matching mechanism.

Specifically, the comparison of power spot market modes among PJM, UK and Nordic electricity markets is shown in Table 1.

Table 1. Comparison of power spot market architecture among major electricity markets

| Country or region | Market system          | Transaction target          | Clearing mode                        | Price mechanism                  | Transaction size/% |
|-------------------|------------------------|------------------------------|--------------------------------------|----------------------------------|--------------------|
| America PJM       | Day-ahead market       | Electric energy + Spare      | Physical network model and unit operation parameters | Node marginal price             | 100 (22.3)         |
|                   | Real-time market       | Electric energy + Spare + Frequency modulation | Physical network model and unit operation parameters | Node marginal price             | 1.0 ~2.0           |
| Britain           | Day ahead electronic transactions | Electric energy | Unrestricted liquidation | System marginal price | 26.5               |
| Balance mechanism | Power and ancillary services (contract) | Physical network model and unit operation parameters | PAB                               | 2.0                 |
| Northern Europe   | Day-ahead market       | Electric energy | Transmission limit of tie line in price range | Regional marginal price         | 83.7               |
|                   | Intra-day market       | Electric energy | Transmission limit of tie line in price range | Matching pricing                | 0.8                |
3. Overall analysis of power spot market construction

Power spot market is an important platform for market members to conduct electricity trading, and its trading scale is mainly affected by the trading volume of bilateral contracts (including self-supply contracts) signed by market members in advance. In fact, the trading scale of power spot market may be affected by market rules, transaction costs and other factors. For intra-day market and real-time market, the trading scale is relatively stable. The main role of the day market is to support market members to fine-tune their power generation and consumption plans, while the main role of the real-time market is to ensure the real-time balance of the system. Therefore, their trading scale is relatively small, about 1%-2% of the total trading volume.

In the clearing calculation of power spot market, especially the day ahead market, market members are often required to report their signed bilateral transaction volume (market members can choose whether it is physical execution or financial settlement) to the market organizer. The market organizer optimizes and matches the generation resources and electricity demand of the whole network. Although there are still some sporadic discussions, both academic and industrial circles have gradually recognized the superiority of nodal marginal price in power spot market, because it can better reflect the scarcity of power goods at different times and places, release price signals with guiding significance, realize efficient congestion management, and guide market members to actively participate in system peak shaving, release more clean energy consumption space. However, in the actual operation of the market, whether to adopt the nodal marginal price often depends on the severity of the grid congestion and the certainty of the occurrence of the congestion.

4. Key issues of market organization

Who will organize the construction and operation of the power spot market for electricity sales? This is a problem that needs to be clarified first. The operation of power spot market mainly includes market data, economic dispatch and security check, and transaction settlement. The operation of the power spot market shall be organized by the cooperation of trading institutions and dispatching agencies. The transaction is reported to the trading institution, which makes a basic analysis and judgment on the volume and price, and then gives it to the dispatching agency, which performs SCED (safety constrained economic dispatch), SCUC (safety constrained unit combination) and safety check, and then returns the results to the trading institution, and finally the trading institution settles the transaction. In the initial stage, the responsibilities of the trading center and the dispatching organization in the market organization that are difficult to be clearly defined can be gradually clarified according to the market construction and operation.

Market entities include power generation enterprises, power supply enterprises, power sales enterprises and power users. In the early stage, power generation enterprises only have coal-fired units. After the market is mature, wind power, photovoltaic and other new energy units can enter the power spot market. In addition to the traditional power grid enterprises, there are also newly established independent distribution companies. Power selling enterprises are new enterprises registered in power trading institutions and have the qualification of power sales business. At the beginning of the market, the power users are 110kV users. After the maturity of the market is high, the users of other voltage levels will be released step by step to enter the power spot market until the market is opened to all users.

Power spot market is an important platform for market members to conduct electricity trading, and its trading scale is mainly affected by the trading volume of bilateral contracts (including self-supply contracts) signed by market members in advance. At the initial stage, the scale of power spot market still needs to follow the path of domestic power market construction, and adopt the way of gradual
liberalization. For example, the 110 KV users are allowed to participate in the spot trading, so the initial scale may be small. However, with the gradual liberalization of customer voltage level, the proportion of spot electricity trading will gradually increase. As the medium and long-term trading can reduce the risk, when the spot transaction reaches a certain scale, it will gradually stabilize in a small range.

5. Key issues of market operation
Market model can be divided into decentralized and centralized. The two modes are mainly based on the different contract basis. The decentralized mode is mainly based on medium and long-term physical contracts. The power generation and consumption curves are determined by both parties in the day ahead stage, and the deviation of electricity is adjusted through day ahead and real-time balanced transactions. Centralized management of market risk is mainly based on the medium and long-term price difference contract, and the electricity market mode of full power centralized bidding is adopted in combination with power spot market.

In the initial stage of China's power spot market, the two modes are allowed to coexist. Each pilot province can fully consider the factors such as power grid, power supply structure and power supply and demand environment in the selection of market mode, and make overall decisions to select the market mode suitable for itself. Among these factors, the most critical determinant is the network congestion. If the network congestion is heavy, the centralized mode should be adopted; if the network congestion is light and the market maturity permits, decentralized mode can be considered.

Chinese power spot market of electric power can build day ahead market first, and then develop day market and real-time market on the basis of mature day ahead market. Although the real-time market can not be carried out temporarily, it needs to adopt a certain balance mechanism to ensure the settlement of unbalanced electricity.

The clearing result of spot transaction is related to scheduling. Day ahead market clearing directly generates Pre-scheduling plan, and real-time market clearing determines real-time scheduling arrangement. Therefore, clearing model mainly depends on quotation factors and system physical model. According to the quotation curve, trading institutions can get the total power generation and total electricity consumption curves. The focus of the two curves is the market inventory, and the transactions on the left side of the clearing point are all closed. Both decentralized market and centralized market are constrained by the most accurate system physical model and cleared according to the principle of the lowest price.

There are three main price mechanisms in spot electricity market: uniform marginal price, node marginal price and regional marginal price. The unified marginal price mechanism is mainly used in the system without network congestion. All transactions in the system are completed according to the corresponding price of the inventory, and the electricity price does not change with space. The node marginal price is mainly used in the system with serious network congestion. The district marginal price is mainly suitable for the system with definite network congestion.

6. Conclusion
Power spot market is an important part of electricity market. This paper first analyzes the construction of foreign power power spot market, then summarizes the framework of power spot market construction, and finally studies the key issues of power spot market construction. On this basis, this paper proposes that the operation of the power spot market should be organized by the cooperation of trading institutions and dispatching agencies. The construction of power spot market generally includes day ahead market, intra-day market and real-time market. The research results can provide a reference for the construction and designers of power spot market, and realize spot trading as the "last step" of power trading as soon as possible.
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