Typical Cohesion Modes of Foreign Long-Term Power Market with Spot Market and Implications for China

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Abstract. Since the 9th document issued by the Government, China's power market construction process speeds up. Long-term trading and spot trading are both important components of a complete market system. This paper summarizes the cohesion methods and coordinated operation mechanisms of long-term trading and spot trading in typical foreign power markets. This paper also analyzed the advantages, disadvantages and applicability of the cohesion methods of different types of long-term transactions and spot transactions, and propose suggestions for China. It can provide technical support and decision-making reference for relevant government departments to formulate long-term and spot trading rules, and promote the scientific and orderly development of power market.

1. Introduction
At present, China's power market reform has been going on for four years. The construction of the power market already had some effect. The power market system based on mid- and long-term trading and supplemented by spot trading has begun to take shape. In terms of long-term transactions, the scale of direct power transactions in various provinces has further expanded, and some provinces have launched regular monthly centralized bidding transactions. In terms of spot market, the National Energy Administration has promoted the power spot markets pilots throughout the country. The first batch of pilot provinces included Shandong, Shanxi, Zhejiang, Fujian, and Sichuan. As of October 2019, the first batch of pilot provincial spot market trials have all started settlement trials[1].

With the development of the spot market pilots, China's electricity market will have co-existence of electricity generation plans, long-term transactions, and spot transactions for long time. There is an urgent need to carry out related research on the connection of electricity generation plans, long-term transactions and spot transactions. In this paper, the in-depth systematic research on the cohesion mode between national long-term transactions and spot transactions is conducted, and different models between different countries or regions isdisguised. This paper summarize the different cohesion methods of medium and long-term transactions and spot transactions and their enlightenment to China.

2. PJM electricity market

2.1 Bilateral transaction
In the PJM market, market members can sign bilateral physical and financial bilateral trading contracts in various cycles from day to day to mid-to-long term to avoid the risk of day ahead and real-time market price fluctuations. For physical bilateral contracts, market members need to decompose the trading contract into a power curve by themselves, and report the power and priority to PJM in a period of day ahead. In the unified security check, if a congestion occurs, the PJM can be adjusted in
accordance with the priority order. Generally, the bilateral contract has a higher priority. Although bilateral contracts do not participate in the recent market quotation, PJM will uniformly consider this part of the contract when it is cleared. The final implementation of the bilateral contract will affect the clearing price, especially when it is affected by transmission congestion. And it needs PJM to carry out overall optimization to determine the final unit combination and generating scheme.

The amount of physical bilateral contracts in PJM is few. There are more financial bilateral contracts, which do not need to be reported to PJM, and the contracts are not physically executed\(^\text{[2-3]}\).

2.2 Day ahead market

Before 12:00, PJM received market members’ recent market quotes. Power generation companies reported information on unit start-up and shutdown costs, no-load costs, and multi-segment quotation curves. Electricity retail companies submit multi-segment purchase quotation curves on behalf of power users, or they can only declare purchased power and accept market clearance prices. Each market member can also choose a bus node that meets the conditions and apply for a virtual power generation or power purchase quote.

From 12:00 to 16:00, PJM will calculate the day ahead market clearing. According to quotes from market members, PJM runs a safety-constrained unit commitment and economic dispatcher, performs market clearance calculations, and issues clearance results. Some companies that have signed bilateral contracts or own power plants can submit self-schedule declarations. PJM will prioritize self-planned power generation under conditions that meet grid security constraints. When grid security constraints are not met, they will adjust the curve.

Beginning at 18:00, PJM optimized and adjusted the unit commitment. Due to the existence of a large number of virtual power generation and loads in the market, which cannot represent the actual situation of the power grid on the day of operation, the market clearing results cannot be implemented as a dispatch plan. After the day ahead market is cleared, PJM will remove the virtual power generation and virtual load, and adjust unit commitment based on the next day’s load forecast, with the goal of minimizing the cost of power generation, and considering security constraints. Then PJM will notify the power generation enterprises that need to increase the start-up group.

Figure 1 Day-ahead market time line of PJM

*All times are Eastern Prevailing Time*
3. Australian power market

Australia adopts the mandatory power pool model, which is a typical centralized market. All electrical energy transactions must be conducted through the centralized trading platform of Australian Energy Market Operator (AEMO). Market entities are not allowed to sign physical bilateral contracts, and prices and production methods are all determined by AEMO. The market can be divided into real-time electricity market and electricity finance market\(^5\).

3.1 Real-time market

All power plants in the Australian, regardless of the type of property rights forms and the type of technology, must bid the electricity market. AEMO's real-time dispatching is based on market member quotes, with the goal of maximizing the spot market transaction value for each dispatching period. AEMO determines the power price of each state and the output of each unit, while satisfying the power generation and supply balance of the power grid. And the power grid security and the frequency control and auxiliary services are required to be globally optimized. The entire market is cleared every five minutes, and the generated electricity price is not the electricity price that is actually used for settlement. The average value of clearing prices every half hour is the settlement price of half an hour of electricity.

3.2 Electricity financial market

In order to reduce the risk of price fluctuations in the spot market, generators and retailers can choose to participate in the financial contract market. Power generators and retailers can sign long-term or short-term bilateral trading contracts (contracts for difference) based on the performance price negotiated by both parties outside the spot market, or they can trade in the government-approved securities and futures exchanges. The electricity financial market provides real-time electricity price risk aversion products for the real-time electricity market entities.

The amount of electricity agreed on the CFD contract is a commercial term settled on a quarterly or annual basis and it does not involve physical power transactions. There are many types of contracts. The more important ones are two-way CFDs and one-way CFDs.

4. British electricity market

The UK market is mainly based on bilateral transactions, supplemented by real-time balance mechanisms. Bilateral transaction contracts are an important basis for grid dispatch. They are physical contracts that need to be executed, accounting for 95\%. The balance mechanism accounts for a small proportion of electricity. It is believed that the British market is based on decentralized decision-making and decentralized balance of market members, highlighting the general commodity attributes of electrical energy, advocating the free sale and purchase of electrical energy, and the system operator has less effect on production arrangements\(^6\)–\(^7\).

4.1 Bilateral transaction

Bilateral transactions in the UK market include OTC (Over the Counter) transactions and on-premise standard contract transactions, which are carried out in trading centers. Bilateral transactions do not have a fixed trading cycle. Market members can flexibly sign various types of contracts. The deadline for contract signing can continue to the Gate Closure time. That is, one hour before the real time.

Market members form their own power generation curves by signing many different types of contracts. Due to the need to accurately adjust the power generation and consumption curves through the signing of bilateral contracts, both the power generators and the electricity retailers must accurately predict the required electricity generation plans, and the requirements for the electricity retailers are relatively high.

Market members need to decompose trading contracts into power curves by themselves, and use the balance mechanism unit (BMU) as the main body to superimpose all trading contracts in the same BMU into a power curve, and report it to the system operator before 11:00 every day. If there is a
deviation between the declaration curve and the actual power generation, market members need to bear the risk of price fluctuations of the balance mechanism, so they will try to sign a bilateral transaction to make the transaction accumulation curve consistent with the actual output curve.

4.2 Day-Ahead Market and Day-Ahead Scheduling
The calculation of day-ahead market clearance in the UK does not take into account the actual network conditions or the physical parameters of the unit. The clearance price is the system's marginal electricity price.

Due to the lack of consideration of grid security constraints in bilateral transactions and the day-ahead market, the system operator must conduct a large number of analysis and calculations in the day-ahead period, to timely discover balance and grid security problems and guide market members to adjust transactions. The system does not arrange production by dispatching orders, nor does the unit commitment. The system operator announces load forecasts for the entire power grid and districts every day at 9:00. At 11:00, the next-day system balance margin analysis and grid security analysis are performed based on the initial power curve submitted by market members.

At 16:00, the system operator releases the system's balance margin and the next day's power generation plan according to the latest declaration curve. When there is insufficient power supply, the system operator promptly issues an insufficient power warning and a load limit warning, and through the expectation of rising electricity prices, guides generators to postpone maintenance and guides adjustable loads to reduce power demand. When grid congestion occurs, market members are guided to adjust their trading plans to avoid excessive deviations between the contract cumulative curve and actual output.

5. Summary of foreign experience

5.1 Necessity of long-term transactions and spot transactions
Long-term trading and spot trading are important components of a complete market system. Most electricity markets are dominated by long-term trading. Long-term transactions play an important role in protecting the income of market members, avoiding market risks, and attracting investment in power generation. Spot transactions can form and reflect real prices, balancing the deviation between long-term transactions and actual loads.

5.2 Typical cohesion model for long-term with the spot market
At present, there are two most typical models, one is decentralized model represented by the United Kingdom, the other is centralized model represented by the Australia and PJM.

The UK model (decentralized model) emphasizes on the common commodity attributes of electricity. The core of the market is various types of bilateral transactions. Market members can arrange unit start-stops and power generation plans by signing bilateral contracts and participate in the centralized trading spot market and financial market. UK establishes a real-time balancing market (or balancing mechanism) to ensure that transactions meet the requirements of system scheduling security.

The Australia and PJM (centralized model) emphasize the physical characteristics of electricity, and establish markets based on the different functions of electricity products in the system, including electricity markets, capacity markets, different types of auxiliary service markets, and transmission rights markets. The electricity market adopts the decision-making method of full electricity bidding, unified optimization of the entire network, and consideration of security constraints. The power generation plan is determined by the clearing results of the spot market. Bilateral transactions exist as financial instruments for market members to avoid spot market price risks, and have only settlement significance.

The decentralized mode is suitable for the situation where the power grid structure is strong and less blocked; the centralized mode is suitable for the situation where the network constraints are complex and the market maturity is high.
6. Implications for China's market construction

First, the social, economic, political, and historical conditions of typical foreign power markets are quite different from those in China. Therefore, in the initial pilot phase of the power market in China, the market model cannot copy the foreign market, but they can be used as a reference for China's market construction.

The second is that provinces in China need to fully adapt to the specific conditions of each province when choosing a decentralized or centralized model. For example, in the provinces with severe congestion, if the decentralized model is adopted, it will place higher requirements on the physical implementation of long-term contracts by market operating agencies. The centralized mode is better for provinces with complex grid constraints. Except decentralized and centralized, an intermediate model may be designed for the co-existence of electricity generation plans and power market for now.

Third, in the process of ensuring the balance of the power system, promoting competition, and reducing system operating costs, innovative trading varieties can be created in accordance with regional characteristics. For example, the United States CAISO and the surrounding non-market areas have launched an EIM balancing market, which is a new attempt by the United States in conjunction with national conditions.

Fourth, China's current wind and solar energy curtailment problem is prominent. How to consider ensuring clean energy consumption during market construction will be one of the key issues. China can give special consideration to clean energy during making market rules and plans.

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