Study on the connection and settlement of forward electricity market and spot electricity market

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Abstract. In recent years, China's electricity market construction has gradually accelerated. Provincial medium and long-term electricity markets (forward market) have been established. Spot electricity markets have been established and have been in the trial operation stage in several pilot provinces in China. This paper introduces the connection and settlement of the forward electricity market and the spot market. The paper mainly discusses the contract for differences mechanism between the forward electricity market and the spot market when the forward bilateral contract are a financial contract. The strategy of forward bilateral contracts is studied according to the price expectations in the spot market.

1. Introduction

The electricity market mainly includes electricity energy market, ancillary service markets, and capacity markets. The electricity energy market mainly includes medium and long-term markets (forward markets) and spot markets [1]. In the medium and long-term electricity market, bilateral medium and long-term bilateral contracts are signed between power customers (or electricity retail companies) and power producers. Generally, medium and long-term bilateral contracts are annual, monthly or weekly agreements. Since the power demand curve of power customers is uncertain, it is not possible to meet their own needs simply by purchasing power only in the medium and long-term market. Power customers also need to purchase electricity by participating in the spot electricity market [2]. The spot electricity market mainly includes day-ahead electricity market, intra-day electricity market and real-time electricity market.

From the perspective of electricity consumption, electricity customers purchase electricity mainly through medium and long-term electricity trading, supplemented by spot electricity trading. Electricity customers can avoid price risks and stabilize their own electricity purchase cost expectations through medium and long-term bilateral contracts. Spot electricity trading are based on the organization of supply and demand, renewable energy consumption demand, transmission congestion, and market entities bidding to ensure the power balance.

Since 2015, China's electricity market construction has accelerated [3][4]. China's electricity market is mainly established by provinces. Within the province, there are medium and long-term electricity markets and spot electricity markets. So far, the medium and long-term electricity markets in the provinces have been basically established. The eight pilot provinces in China, i.e., Shanxi, Gansu, Zhejiang, Fujian, Sichuan, Shandong, Inner Mongolia and Guangdong have also established electricity spot markets. This paper mainly discusses the connection and settlement of the medium and long-term electricity market (forward market) and the spot market, which could be a reference for the construction process of the electricity market in China.
2. Connection of medium and long-term electricity market and spot electricity market

2.1. Physical contracts and financial contracts
Medium and long-term electricity trading and spot electricity trading are important components of a complete electricity market system. Medium and long-term electricity trading (forward bilateral contracts) are generally divided into physical contracts and financial contracts (contracts for difference, CDF), which can help market entities avoid price risks and lock in revenue. Among them, medium and long-term financial contracts can be decoupled from spot electricity trading organizations and power dispatch operations because they do not require physical execution. As medium and long-term physical contracts are required to be physically executed, they need to coordinate with spot electricity trading in terms of functional positioning, trading sequence, and market space to achieve efficient and orderly operation of the electricity market.

2.2. Perspective of function
From a functional point of view, medium and long-term electricity trading are positioned to promote clean energy consumption and a wide range of optimized allocation of energy resources, form a stable power flow, stabilize market supply and demand, and help market entities avoid price risks. Spot electricity trading is positioned to balance the deviation between medium and long-term electricity trading and actual loads, and to improve the efficiency of competition in the electricity market.

2.3. Perspective of trading sequence
From the perspective of trading sequence, medium and long-term electricity trading are organized before the spot electricity trading. After medium and long-term electricity trading closing, medium and long-term electricity trading contracts on the execution day of each market entity will be aggregated to form the settlement basis for medium and long-term electricity trading and spot electricity trading.

3. Contract for difference mechanism for forward electricity market and spot electricity market
The amount of electricity in the spot market by electricity consumers is the sum of the electricity in the medium and long-term electricity market (forward electricity market) and the deviation electricity in the spot market, i.e., the deviation electricity is defined as the electricity in the spot electricity market minus the electricity in the medium and long-term market. In the electricity market, power producers, electricity retail companies, and electricity consumers use contract for differences (CFDs) for settlement [5]. The same part of the spot electricity curve as that of the medium and long-term bilateral contract is settled at the medium and long-term trading price. The deviation power (the spot curve minus the medium and long-term curve) is settled using spot trading prices, as shown in the following formula:

\[ f_t = c_{\text{con,t}}p_{\text{con,t}} + c_{\text{sp,t}}(p_{\text{sp,t}} - p_{\text{con,t}}) \]

(1)

where \( f_t \) is the electricity revenue of power producer or electricity charge of electricity consumer; \( p_{\text{con,t}} \) and \( c_{\text{con,t}} \) is the power and its corresponding price of bilateral contract, respectively; \( p_{\text{sp,t}} \) and \( c_{\text{sp,t}} \) is the power and its corresponding price in the spot electricity market; \( p_{\text{de,t}} \) is the deviation power and \( p_{\text{de,t}} = p_{\text{sp,t}} - p_{\text{con,t}} \), as shown in Fig.1.
3.1. From the electricity consumers’ perspective

Total cost of electricity purchase by consumers (or electricity retail companies) is equal to the integral of the electricity purchase cost over time at a time.

The cost of purchasing electricity at a certain moment is equal to the medium and long-term electricity times the medium and long-term price \( (c_{\text{t,} \text{con}}, p_{\text{t,} \text{con}}) \) plus the product of deviation electricity and the spot price \( (c_{\text{t,} \text{sp,t}}, p_{\text{t,} \text{sp,t}}) \).

3.1.1. When the medium and long-term power is less than the spot power. When the medium and long-term power is less than the spot power, the cost of purchasing electricity from the power producer at a certain time can be understood as: purchasing a part of the electricity in advance through the medium and long-term price. The remaining part (spot electricity minus the medium and long term) is supplemented by spot price purchases, as shown in (1).

3.1.2 When the medium and long-term power is greater than the spot power. When the medium and long-term power is greater than the spot power. That is, at a certain time, the customer purchases too much power in advance through the medium and long-term price and cannot use up. The cost of purchasing electricity from the power producer at a certain time can be understood as shown in the following formula:

The cost of purchasing electricity at a certain moment is equal to (spot power minus deviation power) multiplied by the medium and long-term price plus the product of the deviation power and the spot price, i.e.:

\[
f_t = c_{\text{t,} \text{con}}(p_{\text{t,} \text{sp,t}} - p_{\text{t,} \text{de,t}}) + c_{\text{t,} \text{sp,t}}p_{\text{t,} \text{de,t}}
\]

\[
= c_{\text{t,} \text{con}}p_{\text{t,} \text{sp,t}} + (c_{\text{t,} \text{sp,t}} - c_{\text{t,} \text{con}})p_{\text{t,} \text{de,t}}
\]

(2)

Then the cost of purchasing electricity at a certain moment is equal to the spot power times the medium and long-term price plus the product of the value in brackets (the spot price minus the medium and long-term price) and the deviation power.

Note that the deviation power is negative, that is, the spot power is met in advance through the medium and long-term price. The absolute value of the deviation electricity (that is, the electricity purchased in the medium and long term minus the spot power) is sold back to the market at the spot price minus the medium and long term price. Thereby reducing power purchase costs.

3.1.3 Another understanding of the power purchase cost formula. The cost of purchasing electricity at a certain moment is equal to the medium and long-term power multiplied by the value in brackets (medium and long-term price minus the spot price) plus the product of the spot electricity and the spot price. Then as for the above formula, there is another way to understand it: medium and long-term
trading are settled based on the difference between the contract price and the spot market clearing price, as shown in (3). This is stipulated in the spot electricity market in many provinces (e.g., Zhejiang Province) in China.

$$f_t = (c_{cont,t} - c_{sp,t}) p_{cont,t} + c_{sp,t} p_{sp,t} \quad (3)$$

3.2. From the power producers’ perspective

The power purchase cost at a certain moment is the revenue of the power producer at a certain moment. It is only needed to change the cost of purchasing electricity at a certain moment on the left side of the above formula to a certain moment of revenue for the power producer.

4. Challenges in the initial phase of China’s forward electricity market

In order to stabilize market supply and demand and help market entities avoid price risks, it is hoped that in the electricity market, electricity will be mainly based on medium and long-term electricity trading. That is, electricity market operators prefer that consumers and power producers will sign bilateral contracts as much as possible.

However, judging from the trial operation of the spot electricity market in eight pilot provinces in China, the bidding strategy is to use a low price because power producers compete for power during the trial operation. Note that since the optimization of forward bilateral contracts is a linear programming in (1). If the price expectations in the spot market is lower than the forward market, electricity consumer would not want to sign forward bilateral contracts. To minimize the electricity cost, electricity consumers would purchase power only in the spot market. This situation is a challenge of the bilateral contracts between electricity consumers (including electricity retail companies) and power producers.

5. Conclusion

This paper focuses on the connection and settlement of medium and long-term electricity market and spot electricity market. The contract for difference mechanism for medium and long-term electricity market and spot electricity market is discussed from the electricity consumers’ perspective and power producers’ perspective, respectively. Finally, the challenges in the initial phase of China’s medium and long-term electricity market is introduced.

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