Research on market trading mechanism of distributed photovoltaic and electric heating load

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Abstract. Based on the analysis of the electricity sale mode of distributed photovoltaic and the electricity consumption trading mode of electric heating load, a market-oriented trading mechanism model of distributed photovoltaic and electric heating load is proposed, which provides a theoretical basis for the online analysis and operation control of distribution network under the market-oriented trading.

1. Introduction
With the implementation of energy conservation and emission reduction strategy, large-scale access of distributed photovoltaic and electric heating load has become an important trend of distribution network operation. In the market-oriented environment, the demand of distributed photovoltaic output and electric heating load is affected by the incentive measures and peak valley electricity price, and there is a big difference with its inherent characteristics. For example, distributed photovoltaic power plants use the configured energy storage device to allocate the on grid power in real time according to the change of the on grid electricity price, while some electric heating load users use the electric heat storage boiler to achieve the heating and heat storage during the low price period. In order to actively deal with the technical challenges brought by the above changes to the operation and control of distribution network, power supply enterprises need to first study the market-oriented trading mechanism of distributed photovoltaic and electric heating load, and clarify the behavior characteristics of distributed photovoltaic and electric heating load in the context of market-oriented trading.

At present, the research on the market-oriented trading mechanism of power suppliers and power users at home and abroad mainly focuses on the establishment of the mathematical model of power users’ response to electricity price. The modeling methods can be roughly divided into three types: based on the price elasticity matrix of power demand [1-3], based on consumer psychology [4], based on the statistical principle [5]. However, these models only consider the unilateral interests of power users, not the balance of interests between power suppliers and power users.

Firstly, this paper analyzes the online trading mode of distributed photovoltaic and the electricity consumption trading mode of electric heating load, and then puts forward the market-oriented trading mechanism model of distributed photovoltaic and electric heating load, which provides theoretical basis for online analysis and operation control of distribution network under the market-oriented trading.
2. Distributed photovoltaic online trading mode

2.1 Distributed photovoltaic bidding model in contract market
In the contract market, all kinds of power producers submit the contract electricity quantity and contract price to the trading center, and participate in the contract market in two main ways: bilateral negotiation and competitive auction. Under the bilateral negotiation mode, the power producer and the grid company or the user directly reach the medium and long-term or short-term contract through negotiation and negotiation, and determine the contracted trading power and the contracted trading price. Under the mode of competitive auction, the power producer submits the contract electricity quantity and its price in a certain period of time in the future within the specified time. The power market dispatching center determines the contract transaction electricity quantity and its price generated by the competitive auction in the contract market according to the principle of minimum total power purchase cost and non-blocking system. In the performance stage of the contract, the specific content of the default treatment shall be clarified, including the economic responsibility of the power generation side or the power purchaser, so as to reduce the economic loss caused by the default event to the other party.

In addition, although the operation of distributed generation agent reduces the impact of single distributed generation instability, its overall stability is still lower than that of conventional generation. In view of this situation, first of all, from the perspective of the market, it is necessary to limit the proportion of grid connected electricity of distributed generation in the contract market, so as to reduce the impact on the power grid in case of unstable power supply of distributed generation; second, from the perspective of the regulator, it is necessary to reasonably determine the conventional generation reserve capacity of distributed generation, which is highly dependent on some external environment and has relatively high generation cost. High distributed power (such as wind power, photovoltaic power, etc.) provides appropriate tariff subsidies or corresponding energy storage equipment subsidies to distributed power providers.

2.2 Distributed photovoltaic online bidding model in the day ahead Market
In the day ahead market, all kinds of power producers determine the bidding power and price according to the forecast power of the next day published by the trading center and their own contract power. The trading center determines the market clearing price of the day ahead market and the output size and order of different power producers according to the power and price submitted by each power producer, and defines the compensation mechanism for power producers when the demand of the next day is insufficient.

Considering the diversity of distributed power generation types, some distributed power sources (such as wind power, photovoltaic power generation, etc.) are greatly affected by the external environment. Under the unified management of the agent operators, they can achieve the power supply effect corresponding to the complementary wind and solar power. At the same time, they can cooperate with stable distributed power sources such as gas power generation, biomass power generation, small hydropower, etc., effectively avoiding the large scale of distributed power generation fluctuation, but DGA operators still need to predict their own output, determine the stable output they can provide the next day and the time period of possible large fluctuation, and consider the signed contract power to develop a reasonable day ahead market trading volume and trading price. In addition, in the transaction price submitted by the DG agent operator, the tariff subsidy enjoyed by some renewable energy DG should be taken into account.

2.3 Distributed photovoltaic online bidding model in real-time market
The real-time market is open in a short time from the end of the day ahead market to the operation. Each power producer submits the up and down adjustable capacity of the unit participating in the real-time transaction and its quotation. The transaction center adjusts the real-time transaction plan in consideration of the market demand, contract power and day ahead transaction volume, and
determines the optimal adjustment scheme, including the real-time market transaction volume and market clearing price.

Real time transaction is an important means to ensure the balance of power supply and demand. When the real-time power demand fluctuates greatly, the distributed generation on the distribution network side can effectively adjust the impact of demand fluctuation on the power market by using its own flexible start-up and stop characteristics, so as to achieve peak and valley regulation on the supply side. In particular, the distributed power supply with stable output is easier to realize the advantages of flexibility and low cost in peak load regulation. At the same time, from the perspective of distributed generation companies, the formulation of reasonable peak load electricity price will be conducive to improving their market competitiveness; from the perspective of market regulators, in order to encourage distributed generation to actively participate in the regulation of real-time market power supply and demand, it is necessary to improve the corresponding regulations on grid connection of distributed generation, and clarify the compensation and incentive mechanism of distributed generation participating in peak load regulation.

3. Trading mode of electric heating load

3.1 Centralized matching transaction mode
A set of electronic trading system for direct power purchase shall be built in the power trading center led by relevant government departments, and large customers and power production enterprises with access qualifications shall carry out direct power purchase related transactions on the platform. According to the demand of different trading periods, the large power users provide the electronic trading system with two trading parameters, i.e. electricity price and purchasing power, while the power production enterprises also provide the system with these two trading parameters, i.e. electricity price and selling power. Then, the trading system integrates the purchasing and selling power curves provided by all parties and adds the consideration of transmission loss to these customers and power. The social welfare of production enterprises (i.e. the price difference provided by the two parties) is calculated separately. On the basis of ensuring the power grid security constraints, the two parties of the transaction with the best social welfare are matched first, so as to form a transaction with high matching degree [6]. Based on the quoted price of electricity customers and power production enterprises, the social welfare is divided equally as the basic criterion to obtain the final transaction price. When the social welfare is negative, the whole transaction ends.

3.2 Centralized bidding mode
The concept of centralized bidding transaction is that in order to carry out the centralized transaction of direct power purchase, an electronic trading system is constructed by the power trading center. The power consumers and power production enterprises who have obtained the access qualification are all concentrated on this platform to directly carry out the bidding and transaction of direct power purchase. According to the demand of different trading periods, the power consumption customers declare the required purchasing power to the trading system, and the power production enterprises declare the specific price and the saleable power. The trading system will carry out sorting after deducting the network loss, and then select a consistent marginal clearing price through the security check, which is the final price of this transaction. After that, the trading system will notify the parties who have finally reached the transaction, inform the power dispatching center of the specific situation of the transaction, and finally the power dispatching center will arrange the dispatching plan according to the situation and finally implement it.

3.3 Centralized listing trading mode
Large users will publish the data such as the required electricity quantity or the specific quantity and price of electricity that can be provided, and make an offer. After that, the power production enterprises that meet the requirements of these information will show to them that they can respond to
the offer, and apply for it, and then carry out the safety check and the approval of the relevant parties, and finally conclude the transaction. Power users put forward power purchase demand, including electricity quantity, electricity price information, etc. The transaction center summarizes the demand, considers the regional grid electricity fee, forms the power purchase demand curve (segmented volume price curve), and issues it to the power generation enterprises. The power generation enterprises on the electricity selling side declare their willingness to trade (segmented volume price curve) to the trading center, and the trading center summarizes the quotations of power generation enterprises to form a centralized quotation curve. The trading center shall determine the bid winning result according to the quotation situation, and deal with the electricity quantity in the low price segment first. If the declared electricity quantity in the low price segment is less than or equal to the listed electricity quantity, the declared electricity quantity shall be the bid winning electricity quantity. If the declared electricity quantity is greater than the listed electricity quantity, the declared electricity quantity shall be distributed according to the proportion of the declared electricity quantity. Then deal with the electricity quantity in the next low price segment. If the remaining declared electricity quantity in the previous low price segment is not traded, deal with priority For the remaining electricity in the last low price segment, the transaction price is the listing price of this segment, and the remaining electricity after the transaction is the listing electricity of this segment. The trading center shall determine the winning power generation enterprise according to the bid winning situation and application situation[7].

At present, the centralized matchmaking transaction mode is the best mode to match the current large-scale direct power purchase transaction in China.

4. Market-oriented trading mechanism model of distributed photovoltaic and electric heating load

Adopt the medium and long-term contract market to carry out centralized clearing n days before the t day of the contract delivery start date. The contract market in the transmission network market generally includes annual contract, monthly contract, etc. Considering the fluctuation of the distributed generation and the higher prediction accuracy of the closer to the actual operation, the contract advance of the distributed generation can be appropriately reduced, such as monthly contract and weekly contract. The specific transaction model is as follows:

(1) N days before the contract delivery start date, the distributed power supply and electric heating load shall respectively report the predicted generation capacity, electricity sale price and load range to the market organizer.

(2) The market organizer calculates the prediction accuracy and correlation based on the historical data of the distributed generation prediction. Through the power purchase cost optimization model proposed in this paper, the power purchase with each distributed generation is determined, and the power purchase through the transmission network contract market is determined according to the power balance in the region.

(3) Through the allocation algorithm of power purchase cost, the power purchase price of each heating load is calculated and the power supply contract is signed.

(4) The delivery of electricity starts on the t day of the starting date of contract delivery. In case of deviation of electricity during the delivery, market participants can trade in the real-time market.

5. Summary

Based on the analysis of the online trading mode of distributed photovoltaic and the electricity consumption trading mode of electric heating load, this paper puts forward the market trading mechanism model of distributed photovoltaic and electric heating load. The model comprehensively considers the maximization of the respective interests of distributed photovoltaic and electric heating loads. For distributed photovoltaic power plants, the model can provide reasonable trading strategies and improve the rate of return on investment; for electric heating load users, the model increases the possibility of reducing the cost of power purchase. It has guiding significance for the operation control
of distribution network under the background of market-oriented trading of distributed photovoltaic and electric heating load and market-oriented trading.

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