Research on Distributed Power Market Trading Mechanism Considering Distributed Power Sources

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Abstract. This article analyzes the current situation of distributed power generation construction and participation in the power market, sorts out the problems faced by distributed power generation participation in the centralized power market, and proposes a distributed power market trading framework based on blockchain technology. It designs a trading mechanism and process based on blockchain technology, and proposes a market clearing mechanism for centralized matching in the day ahead market and continuous matching in the real-time market, It can effectively solve the problem of distributed power sources participating in the electricity market.

Keywords: Distributed power supply, Electricity market, Blockchain technology, Real time market

1   Introduction

With the proposal of the dual carbon target, China is vigorously developing renewable energy. According to statistics. With the increasing proportion of renewable energy sources such as wind power and photovoltaic connected to the grid year by year, the power grid needs more flexible resources for regulation[1]. The electricity market is an effective method to optimize the allocation of various resources[2].

From the perspective of the electricity market, distributed energy has certain particularities compared to traditional energy, and the relevant institutional details for distributed energy participation in the electricity market, such as admission mechanisms, bidding cycles, pricing methods, and participation processes, are not perfect. From the perspective of the power supply side, distributed energy has a relatively scattered spatial distribution, most of which are small in scale, and have high randomness in output. Compared with traditional energy, the above characteristics of distributed resources make them less competitive and difficult to participate in the centralized power market. Moreover, the scale of distributed power generation is relatively

small, and the generation uncertainty is high. Therefore, most of the participating users are residential users or small industrial and commercial users. At the same time, the market needs to have strong flexibility to balance the power supply and demand under large power fluctuations[3].

In summary, Distributed power sources have the characteristics of large quantity, small capacity, low voltage level, high output fluctuation, and scattered distribution, making them unsuitable for participating in traditional power wholesale markets. Therefore, it is necessary to explore the establishment of a new electricity market trading mechanism that adapts to the characteristics of distributed power generation.

This article proposes a distributed electricity market trading framework based on blockchain technology, designs a trading mechanism and process based on blockchain technology, and proposes a market clearing mechanism for centralized matching in the day-ahead market and continuous matching in the real-time market.It can effectively solve the problem of distributed power sources participating in the electricity market.

2   Current Status of Distributed Power Supply Participation in the Market

2.1   Problems in the participation of distributed power sources in the market

- The low accuracy of distributed photovoltaic forecasting affects the clearing price of the spot market. At present, some spot pilot areas use estimation methods to predict distributed photovoltaic output, which has a low accuracy and has a certain impact on market clearing prices.
- The fluctuation of distributed photovoltaic output results in insufficient frequency modulation capacity, leading to increased human intervention in the market situation. The distributed photovoltaic output has not yet fully achieved "observable and measurable", and the power generation output is subject to significant fluctuations due to weather conditions, resulting in the frequency regulation capacity cleared in the market not meeting the system's regulatory needs. Therefore, human intervention is needed in the frequency regulation market clearing results.
- After large-scale distributed photovoltaic grid connection, it will cause frequent changes in the forward and reverse directions of the trend, affecting the accuracy of safety verification and market clearance results.

Due to the small capacity and random output of most distributed resources[4], it is difficult for them to participate in the electricity market alone. Overall, the participation of distributed energy in the electricity market in China is still in its early stages, and there is still a lot of need to improve the relevant implementation methods and systems for distributed resource participation in the electricity market.

2.2   Market participation methods for distributed power generation

Distributed renewable energy generation does not have the ability to directly participate in current electricity market transactions due to small capacity and high power fluctuations. Currently, there are four main modes for distributed generation to participate in the electricity market[5], which are participation through distribution companies, P2P market transactions, microgrids, and participation through virtual power plants[6-8]. Its profit model can only be achieved through policy subsidies or through third-party integrated agents for trading. However, the prices provided by third parties are lower than the actual market prices, and long-term policy subsidies are not conducive to the technological progress and sustainable development of distributed renewable energy. Therefore, it is necessary to establish a market model suitable for free trading of distributed electricity at the distribution network level, and integrate and coordinate a large number of dispersed distributed power sources and users with demand side response capabilities through market-oriented means.

3   Formatting the title, authors and affiliations

3.1   Distributed transaction mode based on blockchain technology

Blockchain is a technology that utilizes computer technology to achieve secure and reliable value transfer. Essentially, it is a distributed ledger with multiple nodes participating, with each node synchronously backing up data. According to the conditions of node participation, it can be divided into three types: public chain, alliance chain, and private chain. Blockchain is a technology that utilizes computer technology to achieve secure and reliable value transfer. Its essence is a distributed ledger with multiple nodes participating, with each node synchronously backing up data. The data structure of blockchain is chain like, with the front and back data connected by hash values. The newly generated data is added to the original data chain and synchronously updated across all network nodes.

3.2   Feasibility analysis of blockchain for distributed transactions

The distributed ledger characteristics of blockchain will enable a series of new market models and trading mechanisms[9]. Blockchain technology can not only provide security for market transactions, but also reduce communication costs[10], improve the interoperability of market transactions, and enable small energy suppliers and users to quickly and easily conduct network transactions and settlements, increase the weak centrality of the energy industry, improve transaction efficiency and security, and lower energy consumption prices.

3.3 Design of Distributed Transaction Framework Based on Blockchain Technology

3.3.1 A Distributed Transaction Mechanism Model Based on Blockchain.

Based on the characteristics of distributed energy trading and blockchain technology, this article designs a distributed trading mechanism model. In Model China, users can choose to join the distributed electricity market trading market based on their electricity production and consumption situation. At the same time, according to electricity market theory, bidding strategies are written into smart contracts to provide users with reference prices and maximize the benefits of the distributed energy trading network. The trading model is shown in Figure 1
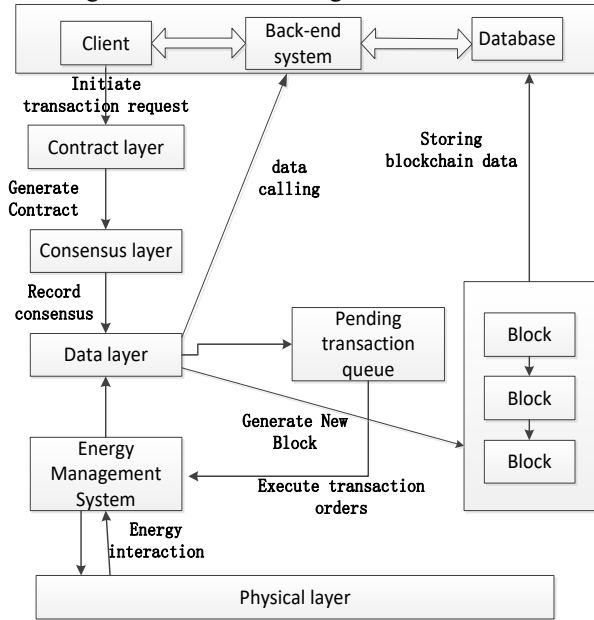

Fig. 1. Distributed Energy Trading Model

3.3.2 Distributed transaction process based on blockchain.

The distributed transaction process design based on blockchain technology is as follows:

- Each market entity has a distributed electricity market trading platform network service interface, through which the trading platform publishes information, and users can upload their own quotation information through this interface. After the market starts, each entity in the market acts as a common node in the blockchain system to send purchase and sales orders corresponding to the transaction period to the network through a service interface to form an order book table.
- Various types of transaction methods and clearing mechanisms are programmed to form smart contracts. Each market entity selects corresponding trading methods

based on their own needs, and then the order book automatically programs market clearing based on the clearing mechanisms corresponding to different trading methods in the smart contract.

- The clearance results are further confirmed and verified through authorized nodes and security checks, ultimately completing transaction matching and transmitting the clearance results to users through the service interface.

- After the actual delivery, the measured energy flow is uploaded to the trading platform through the service interface by the smart meter to ensure the accuracy of the measurement, and then the transaction settlement is carried out. The value corresponding to the transaction will be automatically settled and paid between successfully matched transaction users.

- The transaction record is added to a new block by the authorized node, packaged and linked, and the viewing permissions are publicly disclosed to the relevant nodes.

- A deviation assessment and guaranteed power supply mechanism need to be established, and corresponding trading contracts and prices should also be embedded in the market mechanism in the form of smart contracts.

3.3.3 Distributed Power Market Trading and Clearing with Multiple Time Scales.

This article designs a distributed electricity market trading process based on the trading time scale of the centralized electricity market, in order to achieve the goal of connecting the trading time between the distributed market and the centralized market. This article only considers the two markets of distributed power generation, day-ahead trading and real-time trading, with centralized matching adopted for day-ahead trading. The real-time market adopts a bidirectional auction continuous matching mechanism.

3.3.4 The mechanism of centralized matching in the day-ahead market and continuous matching in the real-time market.

The current market adopts a centralized pricing and matching mechanism, with the trading form of two-way quotes from both buyers and sellers of electricity, with both prices and quantities reported. After participating in electricity trading in the day-ahead market, there may be a certain gap between the trading and actual electricity quantities due to plan changes and prediction errors. To meet orders, users can send scattered electricity demand in the form of orders to the real-time market of the day. The real-time market mainly plays a role in balancing the market. The clearance of the real-time market is achieved through a continuous matching mechanism of bidirectional auctions. The orders of both the buyer and seller are sorted by price and time, with the seller's orders sorted in ascending order of price and those with the same price being prioritized by the declaration time; The buyer's orders are sorted in descending order of price, and those with the same price are prioritized according to the declaration time. The continuous matching clearance process diagram is shown in the following figure 2.
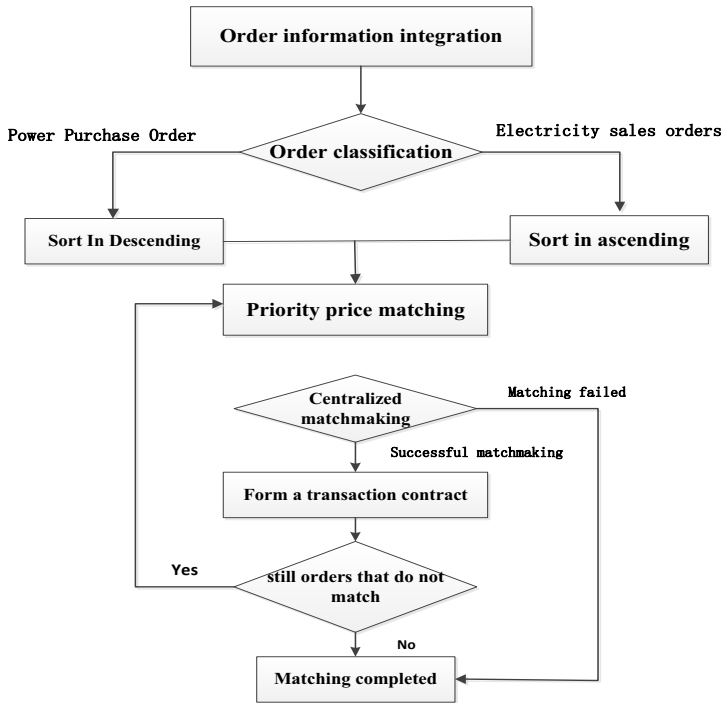
Fig. 2. Continuous matching clearance flowchart

4   Summary

This article analyzes the current situation of distributed power generation construction and participation in the electricity market, outlines the problems faced by distributed power generation participation in the centralized electricity market, and introduces the current methods of distributed power generation participation in the electricity market. Based on the characteristics of blockchain technology, its applicability for distributed transactions was analyzed, and a distributed electricity market trading framework based on blockchain technology was proposed. It can effectively solve the problem of distributed power sources participating in the electricity market.

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