Research on the Mechanism of Blockchain and Distributed Generation Participating in Provincial Regional Power Grid Electricity Trading

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Abstract. With the acceleration of the construction of new power systems and the implementation of the dual carbon goals, new business types and new modes of power consumption on the user side continue to emerge. Power distributed trading has become an important form of future power energy trading, which is of great significance for promoting safe power supply, promoting energy transformation, innovating energy industries and meeting user needs. This paper analyzes the important mode of distributed power generation participating in market-based transactions, designs the transaction varieties and participation methods of distributed power generation participating in short-term and long-term transactions, and puts forward the key application mode of blockchain in customer side resource interactive transactions based on the compatibility of blockchain technology and distributed transactions.

Keywords: blockchain · distributed generation · electricity trading

1 Introduction

Distributed generation refers to small and medium-sized power generation facilities that are connected to the distribution network for operation and generate electricity nearby. Compared with centralized power generation, distributed power generation is located in or adjacent to power consumption sites, and energy production and consumption are completed nearby [1–3]. It has the advantages of reducing power consumption, high energy utilization rate, and low pollution emissions.

From the perspective of distributed power generation itself, distributed power generation has broken the centralized and centralized power supply mode, and it is an important breakthrough in China's energy and power market to allow customers to interact with resources. Both ordinary people and enterprises can realize the spontaneous self use and free trade of energy and electricity. As far as the current stage is concerned, the market-based transaction of distributed power generation is facing many problems. The transaction model and transaction mode are still immature, there are many distributed

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energy transaction subjects, the transaction mechanism is complex, and the implementation rules of transaction policies in different regions are quite different, which makes the management of distributed energy transaction very difficult. The impact on distributed energy power generation companies is particularly obvious, and information technology is urgently needed to assist transaction decision-making [4–7].

Blockchain is a data structure formed by orderly linking blocks, in which block refers to a collection of data, including relevant information and records, and is the basic unit to form a blockchain. To ensure the traceability of the blockchain, each block will have a timestamp as a unique mark. At present, the application of blockchain in the energy field has begun to take shape. Some European and American developed countries and a few high-tech companies have begun to try to apply blockchain technology to the energy field. At present, the customer side resource interactive transaction has many pain points, such as high frequency of interactive information, heavy workload in formulating strategies, high cost of electronic contracts, difficulty in identifying the main body's electricity quantity, and complex electricity quantity of contract components, which need to be resolved urgently [8–10]. It is possible to apply blockchain technology to distributed energy transactions.

2 Mode of Distributed Generation Participating in Market-Based Transactions

2.1 Current Main Forms of Distributed Generation Participating in Market-Oriented Transactions

Distributed generation (DG), also known as distributed generation, distributed generation, and distributed generation, is a technology and system that uses a variety of small, grid-connected equipment for power generation and energy storage. As the name implies, it belongs to a relatively decentralized power generation mode, and the opposite of distributed power generation is centralized power generation. At present, there are mainly three forms of distributed generation market transactions.

First, the direct transaction mode. Distributed power generation projects directly trade electricity with power users and pay "network passing fees" to power grid enterprises. The transaction scope shall first be realized nearby, and in principle, it shall be limited to the power supply scope of the primary transformer at the access point. The distributed generation project chooses the power users who meet the transaction conditions by themselves, and uses the power grid enterprise as the transmission service party to sign a tripartite power supply and consumption contract, agreeing on the transaction period, transaction energy, settlement method, settlement price, the implemented "grid connection fee" standard and the liability for breach of contract.

The second is to entrust power grid enterprises to sell electricity on a commission basis. The distributed power generation project unit entrusts the grid enterprise to sell electricity on a commission basis. The grid enterprise transfers the remaining electricity sales revenue to the distributed power generation project unit at the comprehensive electricity sales price (that is, the electricity price after the average electricity sales revenue and electricity sales for all users) after deducting the "grid connection fee"

(including network loss). The two parties agreed on the cooperation period, transaction electricity, "network fee" standard, settlement method, etc. of the power transfer. This mode mainly considers that some distributed power sources are very small, such as home (individual) roof photovoltaic power generation (3–20 kW); In addition, some projects have large capacity, but they are unable or unwilling to spend energy to find direct trading partners. They hope that grid companies can sell electricity as agents. As for the comprehensive electricity selling price, the grid enterprises in the pilot areas shall determine the consumption scope of distributed generation based on the actual situation, and consider the price difference of the involved power users and other factors.

The third is the purchase mode of grid enterprises according to the benchmark grid price. For distributed power generation projects that do not participate in market transactions, power grid enterprises shall purchase all on grid energy according to the benchmark on grid price of various power generation approved by the state, and the state's electricity subsidy for power grid enterprises shall deduct the corresponding transmission and distribution price for users with the highest voltage level in the distribution grid area. If the direct trading distributed generation project loses its trading users or there is no eligible trading partner in the nearby area, and there is no power grid consignment mode in the region, then the generation capacity of the distributed generation project should still be purchased by the grid enterprise, which is also a way to cover the cost. This is no different from the current grid enterprises' purchase according to the benchmark grid price; However, for power grid enterprises, the state will deduct the transmission price of the previous voltage level that has not undertaken the transmission business from the subsidy policy, which results in a reduction of the state subsidy expenditure.

2.2 Key Factors of Distributed Generation Market Transaction

- Own electricity demand: that is, the electricity consumption of the main body of the distributed generation market in a certain period of time. During the period when the market price is high, the decision-maker can consider reducing part of his own load demand, thereby either reducing the electricity purchase expenditure or increasing the electricity sales revenue.
- Self generation capacity: For new energy distributed generation with uncertainty and volatility such as wind power and photovoltaic, the output can be predicted according to historical data and weather forecast. In this case, the generation capacity of a certain period in the future is also a range, which can be set according to conservative or aggressive strategies; For other types of power generation, such as gas, coal, cogeneration, chemical energy, the power generation capacity can be relatively determined.
- Power purchase cost: when the self generated electricity is less than the power demand, it is necessary to purchase electricity from the grid or other distributed market entities. If power grid enterprises purchase electricity on behalf, the cost is relatively fixed; If electricity is purchased from other market entities by means of transaction matching, there is a certain space for optimization of electricity purchase price.
- Power generation cost: the power generation cost of distributed power generation is mainly the investment cost of power generation equipment, in addition to maintenance, labor, etc.; For non new energy power generation, fuel cost is also included.

- Electricity selling price: when its own power generation is higher than the demand for electricity, it can sell electricity to the grid or other decentralized market entities. If the power grid enterprise sells electricity on behalf, the electricity price is relatively fixed; If electricity is sold to other market entities by means of transaction matching, there is a certain space for optimization of electricity price.

3 Design of Short-Term and Long-Term Transaction Varieties of Distributed Generation

Distributed generation can mainly participate in power regulation market transactions in the near future. In the future, it can gradually participate in medium and long term (annual, quarterly, monthly, intra-month, multi-day and other days power trading), spot and other electric energy markets and auxiliary service markets with higher technical requirements, as shown in the Table 1.

In the near future, China's distributed generation can mainly participate in the regulatory power market (peak shaving auxiliary service market). Two ways to participate in peak regulation auxiliary services can be considered: one is to conduct centralized bidding with thermal power units on the peak regulation auxiliary service trading platform, and the other is to sign a long-term peak regulation auxiliary service agreement with the dispatching agency. Micro grid participation in peak shaving auxiliary service market is facing market competition with traditional thermal power units. The competition depends on the comparison between the actual regulation cost of microgrid and the increased coal consumption cost of traditional thermal power unit peak shaving.

In the long term, the market transactions that China's distributed generation can participate in include medium - and long-term transactions, spot and more complex ancillary service markets.

3.1 Distributed Generation Participation in Medium and Long-Term and Spot Electricity Energy Market

Distributed Generation Participates in Medium and Long-Term Electric Energy Market

If the distributed generation participates in the medium and long term power energy market, electricity trading contracts will be formed in the medium and long term market through centralized or bilateral forms to meet the basic power generation and electricity demand of the resources aggregated by the micro grid. As a market entity, distributed generation (DG) has the following characteristics in participating in the medium and long-term electricity market.

First, there are many situations of power generation demand and role of distributed generation projects in the medium and long-term market. If the power supply is the main source, the electricity sales transaction will be conducted; If the resources converged by the project are diversified, including distributed generation, energy storage and power users, they can trade in the market the power generation or power consumption demand that is still unbalanced after their internal self use.

Table 1. Suggestions for Distributed Generation to Participate in the Power Market in Phases (owner-draw)

	Market transaction varieties	**Advantages of participation in distributed generation**
The near future	Peak valley price/demand side response	It has strong regulation ability and can give full play to the characteristics of various units such as source, load and storage in distributed power generation projects to adapt to different system requirements by means of marketization
	Peak shaving auxiliary service	
	Capacity market	
	Alternate peak shaving	
Mid and long term	Medium and long-term bilateral and centralized transactions	Compared with other market entities, it has the advantages of complementation, elimination of volatility, coordination and optimization, etc.
	Contract transfer transaction	Compared with traditional thermal power enterprises, it has marginal cost advantage; Compared with new energy power generation enterprises, it has advantages in regulation and prediction
	Spot transaction	It has strong adjustment ability and maximizes the trading and execution space
	Auxiliary services such as frequency modulation and voltage regulation	It can coordinate the rapid response advantages of multiple participating units
	Green card transactions, financial transactions, blockchain based transactions, etc.	Use regulation and better forecasting ability to gain market advantage; Use blockchain decentralization, smart contracts, etc. to carry out market-oriented transactions

Second, it can flexibly adjust the actual power generation demand in a short time to avoid the implementation deviation penalty of medium and long-term curve decomposition. If the penalty unit price corresponding to the penalty energy in the implementation deviation of the medium and long term curve is P1, and the adjustment cost of the resources controlled by the distributed power generation project (increase or decrease of output or increase or decrease of power consumption) is P2, if P1 $>$ P2 is met, the adjustment order can be implemented; if the adjusted energy is $\triangle$ Q, the penalty cost avoided is $\triangle$ Q * (P1-P2).

Distributed Generation Participates in Spot Electricity Market

Distributed generation projects can adjust their declared electricity and acceptable prices according to price expectations when declaring spot goods. Compared with traditional market entities, they have stronger adjustment ability. Because distributed generation has the ability to master all kinds of constraints and regulation performance information of the resources it aggregates, it is more reasonable and optimal in reporting electricity and electricity price strategies; It also has the ability to control and guide the fine adjustment of power generation and consumption by price, so it is more flexible than traditional market players, so it can avoid risks and obtain benefits in the spot market.

If the spot market price of the distributed generation forecast is high near a certain period, the distributed generation will attract its power generation resources to increase power generation, increase declared power generation, reduce power consumption and reduce declared power consumption by providing adjustment compensation price internally. If the spot market price is predicted to be low near a certain period, it will attract its power generation resources to reduce power generation, reduce declared power generation, and increase power consumption and declared power consumption.

3.2 Distributed Generation Participation in Auxiliary Service Market

At present, it is suitable for the auxiliary service market of distributed generation, mainly including real-time balance market, deep peak shaving market, etc. Distributed generation units are small in capacity, large in number and widely distributed, so it is difficult to be directly dispatched by the power grid. At present, it is unrealistic to participate in the auxiliary services of frequency regulation and voltage regulation in the form of individuals. In the future, the distributed generation can be connected to the automatic generation control (AGC) system of the power grid in the form of a cluster through the integrator, and the real-time active power output can be adjusted at a certain regulation rate according to the dispatching AGC command to participate in the FM auxiliary service. The details of AGC is beyond the scope of this thesis.

In the peak shaving auxiliary service market, the distributed power generation project reduces the load on demand, which is equivalent to increasing power generation for the system; Micro grid based on energy storage can be charged and discharged on demand, which is equivalent to adding load to the system or generating distributed power generation. There are usually two ways to obtain returns through participating in system regulation: one is fixed return mode, that is, the main body participating in the peak shaving auxiliary service market is compensated according to the fixed compensation method of kilowatt hour; The second is the way of market bidding, which will be settled

in the order of quotation from low to high, and will be compensated according to the final settlement price.

4 Key Applications of Blockchain in Customer Side Resource Interactive Transaction

Under the demand of clean and low-carbon energy development at this stage, the distributed energy system with renewable energy as the main body is the future development trend. Transactions with one or more of the following characteristics can adopt the distributed transaction method and apply the blockchain technology. 1) Information sharing: multiple trading entities are interdependent and need to share information. 2) De trust: There may be a relationship of interest between transaction subjects and mutual distrust. For example, the user needs the generator to provide enough power to maintain operation within the agreed time; The power generator shall ensure that the users will use as much as they want after power generation. 3) No supervision: no third party is willing or suitable to act as a trusted intermediary. For example, in traditional electric energy settlement, the metering service provider needs to count the energy trading information of the power generation and consumption parties, and the buyer and seller need to have sufficient trust in the metering service provider. Considering that the dispersion and other characteristics of distributed renewable energy are consistent with the openness, transparency and non tampering of blockchain technology, it is feasible and necessary to combine the latter with energy storage equipment, electric vehicles, virtual power plants, auxiliary services, demand response and other aspects. In the current trading mode, in order to deal with the randomness and volatility of distributed energy and improve the system economy, existing literature has studied the combination of these applications and blockchain.

5 Conclusion

The widespread application of distributed generation can not be separated from the gradual improvement of power market mechanism and the progress of transaction technology. Improving the trading capacity and convenience of distributed generation and strengthening the application of blockchain technology in distributed transactions are of great significance for promoting clean energy consumption, promoting energy transformation and ensuring safe and stable power supply. This paper analyzes the important mode of distributed power generation participating in market-based transactions, designs the transaction varieties and participation methods of distributed power generation participating in short-term and long-term transactions, and puts forward the key application mode of blockchain in customer side resource interactive transactions based on the compatibility of blockchain technology and distributed transactions.

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