Research on the Mechanism of Aggregate and Distributed Generation Participating in the Power Market

Yongliang Li¹, Zhenhua Yan¹, Xuwei Xia¹, Junwei Ma², Dongge Zhu¹, Shaoyong Guo³

¹ Electric Power Research Institute of State Grid Ningxia Electric Power Co., Ltd
² State Grid Shanxi Electric Power Company
³ Beijing University of Posts and Telecommunications

*Corresponding author’s e-mail: lifeifeiyongliang@163.com

Abstract. In recent years, distributed power generation has made great progress, but it is still restricted by factors such as low marketization, lagging public services, and incomplete management systems. This paper studies the trading mechanism of distributed power participation in the market. First, it studies the participation of aggregated distributed power generation resources in the market; then based on the model of distributed power generation resources that participating in the market through aggregated agents based on this article, the market mechanism is designed. Finally, a calculation example is adopted and the proposed method is verified.

1. Introduction

Distributed power generation (DG) utilizes clean energy resources, and electricity production and consumption are completed nearby. It has the advantages of high energy utilization and low pollution emissions, and represents a new form of power generation and electricity consumption. In recent years, distributed power generation has been achieved. Great progress has been made, but it is still restricted by factors such as low marketization, lagging public services, and imperfect management systems. This paper studies the trading mechanism of distributed power participation in the market. First, it studies the participation of aggregated distributed power generation resources in the market; then based on the model of distributed power generation resources that participating in the market through aggregated agents based on this article, the market mechanism is designed. Finally, a calculation example is adopted and the proposed method is verified.
the power market; then, based on the model of distributed power generation resources participating in the market through aggregated agents constructed in this paper, design the market mechanism; finally, use calculation examples to illustrate and verify the proposed method.

2. Aggregation classification of market entities for distributed power generation resources

Because distributed transactions have the characteristics of small scale and scattered distribution, multi-point aggregation has become one of the development trends of distributed transactions. Distributed transaction resource aggregation forms can aggregate any form of distributed resources, such as power generation, energy storage and/or demand-side resources, and become a research hot spot. For the aggregation of distributed energy resources, there is no limit to the number of individual resources that can be aggregated, and it can include one or more resource types. The resources in an aggregation can span multiple pricing nodes, but they must be within a single sub-load aggregation point, that is, on the same side of a clear transmission congestion in the regional trading center. The aggregation classification of distributed transaction resources is given below:

1) Distributed resource suppliers

The owner or operator of distributed energy aggregation is called a distributed resource provider (DERP) and can participate in the energy and auxiliary service market of the regional trading center. To become a market participant, DERP must: (1) sign an agreement with the regional trading center, indicating that it accepts and abide by the agreement; (2) provide the regional trading center with a copy of the distributed resources that constitute one or more of its aggregations List; (3) Notify the public utility distribution company or metering subsystem in the service area where the distributed resources are located; (4) Obtain a letter of consent from the public utility power distribution company or metering subsystem; (5) Complete the new regional trading center The resource development process, including a 10-day trial operation period. Like other market participants, DERP can only bid through the dispatch coordinator in the wholesale energy market and ancillary service market.

2) Micro-grid aggregation integrator

In recent years, with the continuous development of smart grids, the ability of micro-grids to participate in demand-side interaction has been gradually discovered. Micro-grids themselves contain power generation devices, energy storage devices, and even electric vehicle charging stations. At the same time, the level of automation and intelligence is relatively high. Compared with ordinary users, they can deeply participate in demand response with the internal power production, transmission, transaction and use of an overall organization. They can purchase electricity from the grid or sell electricity to the grid, which means they are more capable of passing price signals, incentives, etc., to change its short-term and long-term power consumption patterns, which can have a significant impact on the power demand side market.

Interactive mechanism. When the micro-grid is only a simple price receiver, it obtains real-time electricity price information through smart meters, adjusts internal electric energy production and use, and automatically responds. The incentive effect of the price signal is reflected in the economic dispatch of the unit that takes into account the elasticity of demand. Network optimal power flow and other models. On the whole, the essence of the interaction between the micro-grid and the grid under real-time electricity prices is still the economic self-dispatch of the micro-grid. However, the power and load components in the micro-grid system are complex, and even contain multiple types of energy such as heat, electricity, and hydrogen at the same time, and there are energy couplings. The problem will be further complicated after combining the system power flow constraints and expanding the scale of the micro-grid. Therefore, when the micro-grid participates in the grid dispatching as a relatively passive demand-side price receiver, how to accurately describe the demand elasticity of the micro-grid under a given external incentive and carry out effective risk management is a combination of the micro-grid and the real-time electricity price. The key and difficult points of power grid interaction research. When the micro-grid penetration rate in the distribution network is high, the regional micro-grid group composed of adjacent micro-grids will have an impact on the existing electricity market transaction mode. On the one hand, individual micro-grids can exchange power nearby to form an internal trading market within
the micro-grid group; on the other hand, the micro-grid group can conduct energy transactions with the upper-level distribution network through an aggregation agent. At this time, the micro-grid group market power is sufficient to affect market electricity prices, and there is a complicated competitive relationship between aggregation agents and other market participants.

3) Virtual power plant aggregation

As a virtual main body, the virtual power plant has its external characteristics as virtual power up-regulation and down-regulation capabilities. As a whole, it participates in the regulation of the power market and distribution system operators externally, and realizes the coordinated operation and control of various distributed resources internally, and interact with participants such as users and equipment maintenance managers. The virtual power plant realizes the management of distributed resources and the interaction between upstream and downstream through software. The virtual power plant software platform needs to have the basic functions of forecasting, optimizing decision-making, and real-time monitoring. The virtual power plant database is used to process and store distributed resource output/load historical data, user information, electricity market price information, meteorological data, etc., and can support the prediction and optimization decision-making of the virtual power plant.

3. Aggregate and distributed power generation to participate in the design of the power market mechanism

Based on the model of distributed power generation resources participating in the market through aggregating agents constructed in this article, the following market mechanism is designed:

1) Market access

In the transaction mechanism designed in this article, unlike Bitcoin and other block-chain applications that only transfer the value of funds, it also involves the transfer of actual power and energy. In order to ensure that the identities of the parties to the transaction are true and valid, before using the system for the first time, users need to register with the aggregation agent and log on to the chain in advance. To ensure privacy, the user's information should not be known to other users in the block-chain network. The SHA256 algorithm can be used to encrypt user-related information, and the resulting hash value is used as the user's unique identification. The encryption algorithm is as follows:

\[ \text{SHA256}(\text{UserInfo}) = \text{UID} \]  

(1)

User Info includes the user's name, home address, phone number, smart meter number, user's Ethereum account address, etc. After verifying that the user information is accurate, the aggregation agent will call the user registration function in the smart contract to create an account for the user registration to form a user information structure, including the user information unique identifier UID and the Ethereum address Address. The encryption operation only needs to be registered, the stage is carried out once, after which the user uses the UID as the identity identifier, and the block-chain node only needs to verify whether the UID corresponds to the Address.

2) Pre-Trading stage

Before the transaction, in addition to the funds for the sale and purchase of electricity in the accounts of users with distributed generation, a certain amount of deposit must be pre-stored for the final penalty and incentive stage. In a transaction cycle, the distributed power generation party can publish a piece of electricity sales information on the block-chain network, which mainly includes information such as estimated electricity sales, quotations, and margins. Electricity users can publish a piece of electricity purchase information on the block-chain network, including information such as intention to purchase electricity, quotation, and margin.

3) Transaction settlement stage

The system automatically matches transactions based on the quotation information released by the seller and the buyer. The aggregation agent receives transaction requests from all parties as shown in Table 1.
Table 1 Electricity Sale and Purchase Request Form in the Transaction Matching Process

| serial number | Seller | Power purchaser |
|---------------|--------|-----------------|
|               | Electricity Sales/(kWh) | Pre-sale price/ (RMB/kWh) | Electricity Sales/(kWh) | Pre-sale price/ (RMB/kWh) |
| 1             | 100    | 0.66            | 1                     | 90                      | 0.67                      |
| 2             | 100    | 0.67            | 2                     | 85                      | 0.66                      |
| 3             | 90     | 0.63            | 3                     | 85                      | 0.65                      |
| 4             | 80     | 0.67            | 4                     | 75                      | 0.64                      |
| 5             | 50     | 0.65            | 5                     | 60                      | 0.63                      |
| 6             | 60     | 0.60            | 6                     | 80                      | 0.63                      |

For each power purchaser's quotation, traverse all power sellers' quotations. If there is an equal quotation, the transaction will be matched directly to form a transaction contract. The transaction power is the smaller value of the two parties, and the transaction price is the quotation of both parties. That is, the two parties in the transaction with the same quotation are first matched. If the quotations of multiple power purchasers are consistent, the large customers with large electricity purchases will be given priority to trade. If the quotations of multiple power sellers are consistent, the large customers with large electricity sales will be given priority to trade. The remaining transaction request example after matching is shown in Table 2.

Table 2 Electricity purchase request form for easy matching process

| serial number | Seller | Power purchaser |
|---------------|--------|-----------------|
|               | Electricity Sales/(kWh) | Pre-sale price/ (RMB/kWh) | Electricity Sales/(kWh) | Pre-sale price/ (RMB/kWh) |
| 1             | 1->285 | 0.66            | 1                     | 2->190                  | 0.67                      |
|               | Remaining15 | 0.66            |                       |                         |                           |
| 2             | 2->190 | 0.67            | 2                     | 1->285                  | 0.66                      |
|               | Remaining10 | 0.67            |                       |                         |                           |
| 3             | 3->680 | 0.63            | 3                     | 5->350                  | 0.65                      |
|               | 3->510 | 0.63            |                       | Still need35          | 0.65                      |
| 4             | 80     | 0.67            | 4                     | 75                      | 0.64                      |
| 5             | 5->350 | 0.65            | 5                     | 3->510                  | 0.63                      |
|               | Still need50 | 0.63            |                       |                         |                           |
| 6             | 60     | 0.60            | 6                     | 3->680                  | 0.63                      |

After that, the remaining requests are sorted. The power sales requests are first sorted in ascending order of power price, and requests with the same power price are sorted in descending order of power sales; at the same time, power purchase requests are first sorted in descending order of power purchase price, and requests with the same power purchase price are sorted in descending order. Sort in descending order of power purchase, and the sorting results are shown in Table 3.
Table 3 Electricity Sale and Purchase Request Form in the Transaction Matching Process

| Serial number | Seller | Pre-sale price/(RMB/kWh) | Seller | Pre-sale price/(RMB/kWh) |
|---------------|--------|--------------------------|--------|--------------------------|
| 6             | 60     | 0.60                     | 3      | 35                       |
| 1             | 15     | 0.66                     | 4      | 75                       |
| 4             | 80     | 0.67                     | 5      | 50                       |
| 2             | 10     | 0.67                     |        |                          |
| 3             | make a deal |              | 2      | make a deal               |
| 5             | make a deal |              | 6      | make a deal               |

After that, transaction matching is performed, and each power purchase request is traversed in order, and it is matched with the lowest quotation request in the current quotation table to form a transaction contract. The transaction price in the final transaction contract is the power seller and the power purchaser. The average value quoted by the parties, and the final transaction power is the smaller value of the power declared by both parties. The results after the matching are shown in Table 4.

Table 4 Transaction matching result table

| Serial number | Seller | Pre-sale price/(RMB/kWh) | Serial number | Seller | Pre-sale price/(RMB/kWh) |
|---------------|--------|--------------------------|---------------|--------|--------------------------|
| 6             | 6->335 | 0.625                    | 3             | 6->335 | 0.625                    |
|               | 6->425 | 0.62                     |               | 6->425 | 0.62                     |
| 1             | 1->415 | 0.65                     | 4             | 1->415 | 0.65                     |
| 4             | 4->435 | 0.65                     | 5             | 4->545 | 0.65                     |
|               | 4->545 | 0.65                     |               | 2->55  | 0.65                     |
| 2             | 2->55  | 0.65                     |               |        |                          |
| Remaining 5   | 0.67   |                          |               | make a deal | make a deal               |
| 3             | make a deal |              | 2             | make a deal               |
| 5             | make a deal |              | 6             | make a deal               |

If the electricity seller declares less electricity than the electricity purchaser, the electricity seller concludes a transaction with the electricity purchaser to match the transaction contract. At this time, the demand of the power purchaser has not been met, and the next power seller will continue to conduct matching transactions with the power purchaser until this power purchaser meets the demand. If the electricity seller declares more electricity than the electricity purchaser, the electricity seller concludes a transaction with the electricity purchaser to match the transaction contract.

After successful matchmaking, the two parties sign a smart power purchase contract. The contract includes expected transaction power, transaction price, execution time, margin amount, etc. Both sellers and purchasers need to reserve corresponding margins in their respective accounts and freeze this part of the funds. When the contract is reached, the power purchase contract is automatically executed. During this period, the smart meter information of both parties to the contract is automatically collected.

4) Punishment incentive stage

Aggregation agents take corresponding penalties and incentives based on the deviation between the forecast electricity sales of distributed power generation and the actual electricity sold. The distributed generators will strive to improve their own power generation forecasting ability to obtain greater
economic benefits. If the actual power generation of the distributed power generation party is greater than or equal to the power declared in the transaction request, the aggregation agent will give economic rewards to the distributed power generation account through the smart contract to encourage it to truthfully declare the power generation. If the actual power generation of the distributed power generation is less than the transaction request power generation, the aggregating agent will replenish the power users from the external purchase of power, and the funds for purchasing supplementary power will be deducted from the distributed power generation's security deposit, and the extra security deposit will be deducted as a penalty.

4. Conclusion
Building a distributed power transaction model and mechanism based on block-chain technology will help integrate large-scale distributed power generation resources, provide conditions for the realization of auxiliary services with large grids, expand additional revenue channels for distributed power generation, and increase comprehensive revenue. National industry policy formulation and implementation create favorable conditions, which are conducive to complementing the current centralized trading system and improving the efficiency of all parties in power transactions. At the same time, it is conducive to building a distributed power industry by balancing the needs of multiple parties in the transaction. Chain and ecosystem, and then derive a richer platform operation model and auxiliary service model. The with H-type main steel beams and steel channels, lightweight precast panels set upon the steel skeleton, shear keys connected to the main steel beams and post-pouring concrete layer.

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