Architecture Design for Market-oriented Transaction of Distributed Generation Based on Blockchain

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***Abstract*—In the open environment of power market, with the rapid development of distributed generation, traditional centralized transaction faces great challenges in meeting the needs of transparency, timeliness and data security of distributed generation transactions. In this context, this paper proposes an architecture design for market-oriented transaction of distributed generation based on blockchain technology. Firstly, the characteristic matching between distributed generation transaction and blockchain technology is analyzed. Secondly, market-oriented transaction architecture for distributed generation and transaction process based on blockchain is proposed.**

Keywords—Blockchain; Distributed generation; Market-oriented transaction; Architecture Design

I. INTRODUCTION

In an open market environment, the number of producers and sellers in the distributed generation transaction market is huge, but the size of a single transaction is usually small, and each producer can fully control the power generation equipment. At the same time, the self-interest of producers and others makes them more demanding for fairness, privacy and non-discrimination. The traditional centralized transactions faces enormous challenges in meeting the needs of distributed generation transactions in terms of transaction transparency, timeliness, and data security. Market-oriented transaction of distributed generation is a local transaction, which naturally matches the technical characteristics of the blockchain. The application of blockchain technology and ideas in distributed generation transaction can make the transaction based on cryptography rather than trust, make the whole transaction transparent, safe, non-discriminatory and fully automated, and effectively avoid many problems such as low efficiency, high cost and low transparency of centralized transaction. Therefore, the research on the market-oriented transaction architecture of distributed generation based on blockchain technology has certain referential significance within brackets [1].

II. FEATURE MATCHING ANALYSIS BETWEEN BLOCKCHAIN TECHNOLOGY AND DISTRIBUTED GENERATION TRANSACTION

A. Characteristics of Blockchain

As an emerging technology, the development of blockchain has been widely concerned by the whole society, and its application in the energy field has begun to be explored within brackets [2]. A blockchain is essentially an encrypted collection of data blocks, each of which contains all transaction information used to verify the validity of its information (anti-counterfeiting) and to generate the next block. The blockchain replaces the current internet dependency on the central server with data blocks and records data changes and transaction data on the cloud system. Data can be self-certified in transmission, surpassing traditional centrally-dependent information verification methods. In general, the blockchain has four technical features: "decentralized, open and transparent, safe and reliable, and transaction traceable".

1) Decentralized and Synergistic

A blockchain is an end-to-end network composed of many nodes, each of which has the same rights and obligations, with no mandatory control center, no centralized management organization and equipment within brackets [3]. The verification, storage, billing, transmission and maintenance of blockchain data are based on distributed system architecture. Data corruption or anomalies at any node will not affect the operation of the entire data system, making blockchain-based data storage more reliable than traditional data storage. By transforming the central organization into a purely mathematical way to create a trust relationship between distributed nodes, a decentralized and trusted system is obtained.

2) Open and Interconnected.

Any subject can join the blockchain system, and the operational rules of the blockchain system are open and transparent, and each node can obtain a complete copy of the database. Information update requires joint

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authentication of multiple nodes, and each device can act as a node. Failure of one node does not affect the normal operation of other nodes.

3) Transaction, Transparency and Mutual Anonymity

Due to the open and transparent technical rules of the blockchain and the structural features that share all data information, each transaction is visible to all nodes. In addition, each node is trusted, so that the transaction process does not require the node to disclose its identity information, and the data record can be queried through the public interface, and the information is highly transparent within brackets [4]. The transaction process is shown in Fig. 1.

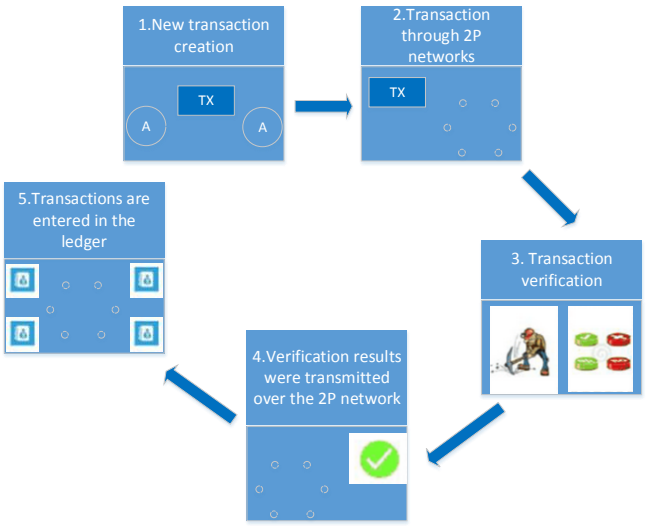


Fig. 1. Blockchain transaction process

4) Non-tampering and Traceable

The blockchain uses a chain structure and a timestamp. Trader information is tied to each transaction record in the blockchain, and the complete delivery path of the transaction target can be fully recorded and tracked and cannot be destroyed or tampered with. Blockchain technology relies on a consensus mechanism to read and write data. Modifying a database by one or more nodes does not affect other node databases unless more than 51% of nodes in the entire network are modified at the same time, but this is almost impossible. Blockchain technology relies on a consensus mechanism to read and write data. On the basis of encryption method, any transaction in the blockchain can be related to two adjacent zones and can be inquired within brackets [5]. Fig. 2 below shows the structure of the blockchain.

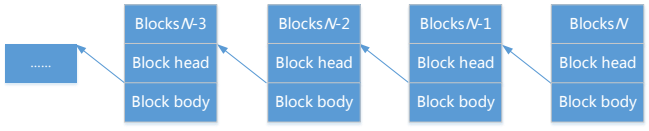


Fig. 2. Chain structure of blockchain

In short, the core function of blockchain technology is to break the trust barriers of both parties without relying on the center and third-party organizations, to ensure the authenticity of the data, and to greatly reduce the trust cost required for the transaction. Efficiently promote transaction.

B. Characteristics of Distributed Generation Transaction

Traditional energy transaction essentially adopts a centralized resource optimization decision-making configuration, but it has the disadvantages of high cost, vulnerability and low security of privacy information. Distributed generation transaction is guided by new connotations, such as open connection, user-centered and distributed peer-to-peer sharing. The energy transaction process also reflects the trend of energy flow, information flow and value flow. Traditional centralized energy transaction relies on centers or third-party agencies to build and maintain transaction credits, resulting in high additional costs. Therefore, it is urgent to develop a distributed market-based transaction model to assist traditional centralized energy transaction and promote the steady development of energy systems in the context of energy Internet. In general, distributed generation transaction has the following four characteristics.

1) Subject Equivalence

The decentralized decision-making of all entities in distributed generation transactions has changed the top-down centralized decision-making approach of traditional energy networks. Each entity in a distributed generation network can independently manage its own energy production, consumption, and transactions, and participate in system decision autonomy.

2) Intelligent Mutual Trust

Energy and information can be fully interconnected between system modules in distributed generation transactions, and each transaction entity can achieve intelligent mutual trust, while at the same time being safe and economical.

3) Transaction Transparency

Distributed generation transaction mainly emphasizes the self-scheduling and ecological operation of the transaction process. Its network structure is open to all kinds of entities, making the transaction process more transparent, providing a platform for information exchange and communication between the energy industry and other industries.

4) Information Sharing

Information on shared system operations and market transactions between distributed generation transaction network nodes can further enhance the ability to optimize resource allocation. In addition, in order to reduce the management costs of central or third-party supervision, distributed generation transaction data cannot be falsified.

In short, participants in distributed generation transaction are characterized as decentralized, peer-to-peer, and co-autonomy, without the need for trust supervision by third-party agencies. Blockchain technology will have a very broad application prospect in distributed generation transaction due to its fairness, transparency and dispersion.

C. Feature Matching Analysis

Blockchain technology has the characteristics of "decentralized, synergy, openness, interconnection, transaction transparency, mutual anonymity, transaction non-tampering as well as traceability". The distributed

generation transaction service model has "subject equivalence, intelligent mutual trust, transaction transparency and information sharing" and other characteristics. Comparing the blockchain technology with the distributed generation transaction service model, the characteristics of the two have similarities within brackets , as shown in the table 1.

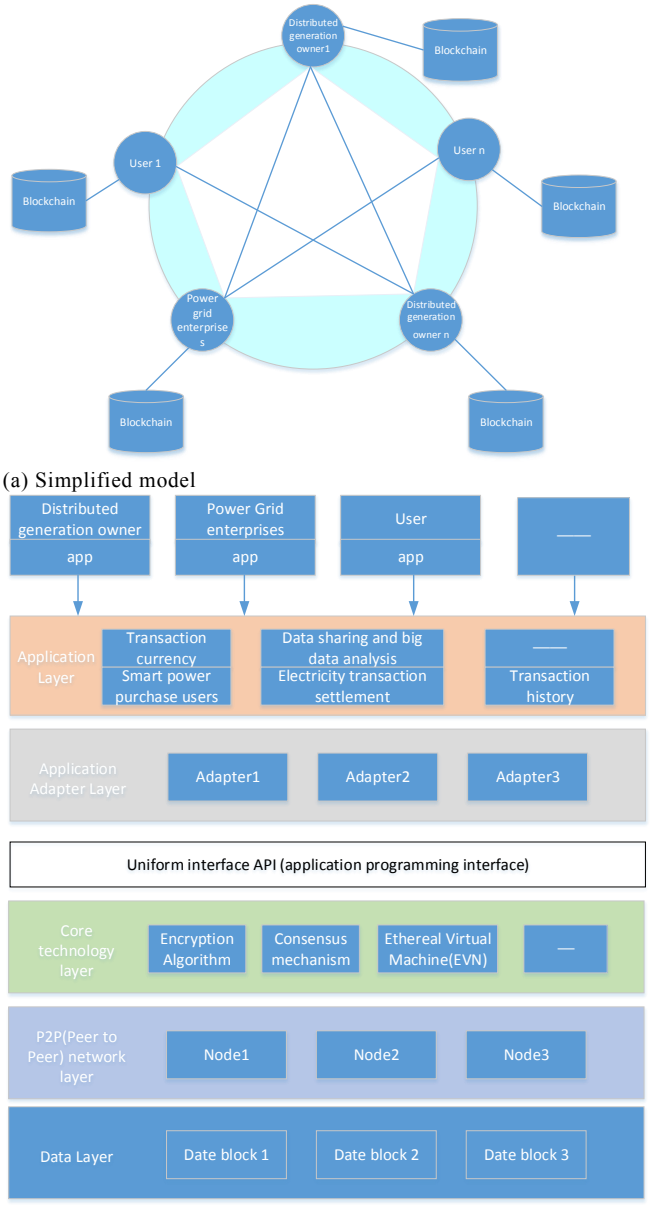
TABLE I. TABLE1. CHARACTERISTICS MATCHING ANALYSIS BETWEEN BLOCKCHAIN AND DISTRIBUTED GENERATION TRANSACTION

Blockchain characteristics	**Distributed generation transaction characteristics**	**Characteristics matching analysis**
Decentralized, synergistic	Subject equivalence	There is a match between the rights and obligations of each node in the blockchain and the equal decentralized decision-making of each entity in the distributed generation transaction.
Open, Interconnected	Intelligent Mutual Trust	Each node of the blockchain has synergistic autonomy, open interconnection and various forms of energy efficient collaboration with distributed generation transactions, and each transaction subject has intelligent mutual trust matching
Transaction Transparency and Mutual Anonymity	Transaction Transparency	There is a matching between open and transparent blockchain operation rules, anonymity of transaction parties and self-scheduling operation and transparency of distributed generation transaction process.
Transaction Non-tampering, Traceable	Information Sharing	There is a match between the inability to modify the blockchain data and the information sharing in distributed generation transactions.

III. THE ARCHITECTURE OF DISTRIBUTED GENERATION MARKET-ORIENTED TRANSACTION BASED ON BLOCKCHAIN

A. The Market-oriented Transaction Architecture Based on Blockchain

The characteristics of decentralized, security, openness and transparency of blockchain can fully meet the demands of market-oriented transaction of distributed generation market-oriented transaction. Therefore, we can rebuild the transaction architecture of distributed generation by using blockchain technology. As shown in Fig. 3, Fig. 3 (a) is a simplified transaction model and Fig. 3 (b) is a market-oriented transaction architecture.



(a) Simplified model

(b) System hierarchy architecture

Fig. 3. Architecture of distributed generation market-oriented transaction based on blockchain

Firstly, the relevant concepts of transaction architecture in Fig. 3 are introduced, including the following seven points:

① The transaction subject in the architecture mentioned in this paper is also called the transaction node, such as power grid enterprises, distributed generation owners, power load users, etc. All transaction data are stored in the transaction node, and are maintained by all nodes together, and the transaction subject is equivalent.

② Transaction method, all transactions are not required to be involved by the intermediary, and are directly completed by both parties.

③Transaction contracts, all transactions are based on smart contracts with pre-defined transaction prices, transaction power and settlement time, etc. The transaction process is transparent.

④The execution method of the transaction, after the conditions are met, any transaction can be automatically executed, so that the transaction is no longer based on trust, improving security and economy.

⑤Transaction information dissemination method, all transaction information is usually broadcasted by means of broadcasting, and information sharing can be realized. To avoid network congestion caused by multiple transactions occurring at the same time, priority can be set for each transaction, then added to the public buffer queue, and finally taken out and broadcast to the network

Secondly, there is a brief introduction to the system hierarchy in Fig. 3. From the bottom up, it is divided into blockchain data layer, P2P network layer, core technology layer, unified interface layer, application adapter layer, application layer, and user APP layer. The blockchain is essentially a database of full backup of transaction data and traceability of transaction records; The P2P network has no central node, and all transaction nodes exchange transaction information through the P2P network protocol, which is highly robust and less affected by single node failures; The core technology layer contains key technologies of the blockchain transaction model, such as encryption algorithms, consensus mechanisms, smart contracts, etc. The interface layer is a set of common APIs including blockchain data read and write; The application adapter is a series of functional components that can provide interfaces and SDKs for upper-layer application development, which greatly reduces the application development difficulty caused by the complex logic of the blockchain; The application layer is the most abundant, including smart power purchase contract, historical transaction audit, big data analysis and other applications; through the installation of client APP, market participants can complete all transaction operations.

B. Distributed generation Transaction Process Based on the Block Chain

In the distributed generation transaction process based on the blockchain, the distributed generation owner and the user can directly conduct peer-to-peer transactions, wherein the transaction processing process is completely automated. Taking transaction between owner A and owner B of distributed generation as an example, the distributed generation transaction process based on the blockchain is shown in Fig. 4.

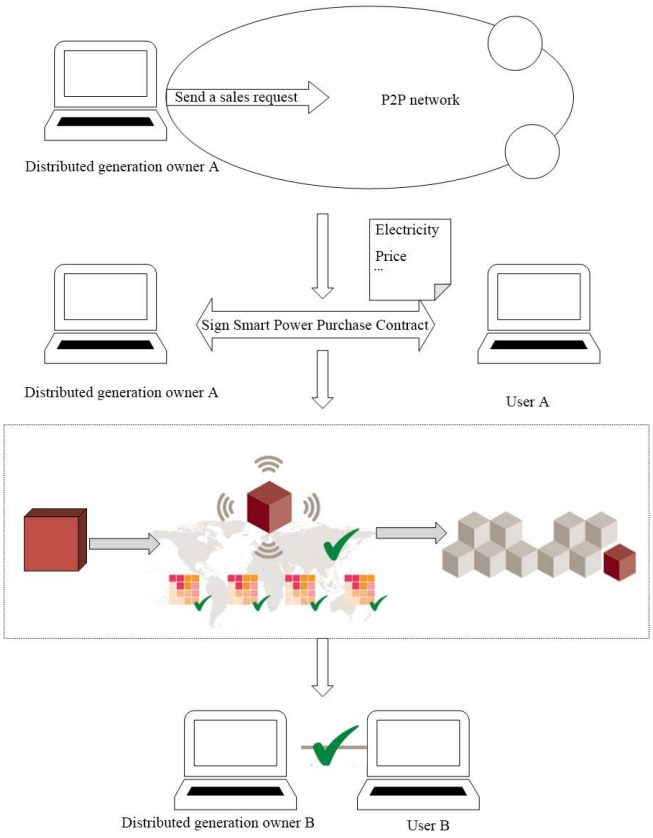


Fig. 4. Distributed generation transaction process based on blockchain

The specific steps of the transaction process are as follows:

①The distributed generation owner A posts the sales information in the P2P network through the client APP, and all nodes will receive this information;

②User B intends to purchase the electricity sold by the distributed generation owner A, and transmits the purchase information to the owner A of the distributed generation;

③Distributed Generation Owner A and User B Sign Power Purchase Contract;

④According to the time specified in the contract, at a certain time, the owner of the distributed generation makes the transaction sheet containing the transaction information and its digital signature, and then broadcasts the transaction to the network.

⑤ All transaction nodes receive transaction information and obtain the right to create transaction block by solving mathematical problems. After a node successfully solves the math problem, it will create a transaction block and time stamp it, and then broadcast the block to the network;

⑥ All nodes in the network verify whether the transaction block is correct. After verification, the block will be added to the local blockchain of the node to form a legal blockchain.

⑦ At this point, the distributed generation owner A and user B complete the transaction, user B uses the digital currency to pay the purchase price of the

distributed generation owner A, while the distributed generation owner A sells the power to the user B;

It can be seen that the entire process of the-based distributed generation transaction is automated.

IV. Risks of the Energy Blockchain Development

The application of blockchain technology in energy transactions is still in the exploratory stage. The energy industry and all related enterprises cannot be rushed. It is necessary to fully grasp the opportunities provided by the emerging market of energy internet and gradually explore its application mechanism and methods. Today, the development of the energy blockchain is mainly faced many risks.

Firstly, the coupling of blockchain technology and distributed generation transaction is based on the physical model of the energy transaction. Blockchain technology is more focused on the financial application of information platform in distributed generation transaction, which is the main reason why its application can't be separated from its own physical model. Especially the current physical model of distributed generation with power system as the core is still weak. It is not possible to blindly exaggerate the application of blockchain technology at the level of distributed generation transactions, and therefore cannot ignore the construction of the physical model of the distributed generation transaction.

Secondly, blockchain technology requires a certain time span in order to be fully applied in a distributed generation transaction. In the initial stage, its application is not fully covered. It is necessary to start with a certain feature of the blockchain technology itself, and analyze the matching of certain technical features of the blockchain with some aspects of distributed generation transaction, so as to effectively deal with the existing problems in regional energy system.

Thirdly, blockchain technology still has room for development and improvement. At present, blockchain technology has shown great application potential in domestic scientific research and commercial financial area. Both the education and business communities have also shown great interest and enthusiasm for blockchain technology. However, the computational efficiency of blockchain technology can't meet the real-time demand of energy system production and sales. Moreover, the fault-tolerant analysis ability of blockchain technology for differentiated networks also has some technical limitations. Therefore, blockchain technology is at present still in urgent need of rapid development.

Finally, there is need for blockchain technology to integrate with big data and cloud computing technologies. At present, the level of information in the production and marketing of energy systems and the analysis and calculation capabilities of massive data are far from real-time requirements. Therefore, it seems necessary for the blockchain technology to deeply integrated with big data, cloud computing technology and information and communication technology, and develop in tandem.

V. Conclusions

Market-oriented transaction of distributed generation is a local transaction, which naturally matches the technical characteristics of the blockchain. The application of blockchain technology and ideas in distributed generation transaction can make the transaction based on cryptography rather than trust, make the whole transaction transparent, safe, non-discriminatory and fully automated, and effectively avoid many problems. This paper designs an architecture for market-oriented transaction of distributed generation based on blockchain technology, and proposes many risks which is faced in the energy blockchain development.

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