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To cite this article: Xingxiong Zhu 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **592** 012159

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Application of Blockchain Technology in Energy Internet Market and Transaction

Xingxiong Zhu^{1,2}

¹ State Grid Power Finance and E-Commerce Laboratory, 100053 Beijing, China

² State Grid Electronic Commerce Co., Ltd., 100053 Beijing, China

zhuxx@pku.org.cn

Abstract. Based on the blockchain technology, important datas such as transactions, scheduling, finance, and energy contracts are distributedly recorded, various resources such as distributed energy generation, energy transmission, energy consumption, and energy storage are aggregated for collaborative optimization control and market trading. In this paper, we build blockchain-based new generation energy Internet with extensive interconnection, intelligent decision making, real-time interaction, and open sharing. The application of blockchain technology in energy Internet includes photovoltaic energy microgrid, blockchain-based energy Internet entities, blockchain-based power trading, and energy asset securitization. Technical frameworks for energy Internet market trading system based on blockchain technology are proposed. Distributed energy ledger and energy trading smart contract are utilized. Distributed trading rules, algorithms and processes of energy system and microgrid are established. Energy Internet transactions and payment settlement system are constructed. Energy producers and consumers trade peer-to-peer on the platform to improve system efficiency and security.

1. Introduction

Energy Internet is a network that integrates power technology, electronic technology, information technology and intelligent management technology to achieve energy exchange and sharing [1]. The traditional energy market trading mechanism and technical system are designed according to the centralized power supply mode. However, with the advancement of the new energy system reform, it is a new trend to open up the electricity selling market and encourage distributed clean energy to participate in market competition.

At present, the development of blockchain technology is changing with each passing day, distributed ledger technology and smart contract technology are gradually applying [2]. Technical frameworks for energy Internet market trading system based on blockchain technology are proposed, and distributed trading rules, algorithms and processes such as distributed energy and microgrid to provide core technology solutions for energy trading in the new situation are established.

The advantages of blockchain applications gradually emerge in the fields of new energy trading, financial services, and supply chain management in the energy sector.

2. Method

The data in the blockchain system is extremely difficult to tamper with. If the attacker attempts to tamper with the transaction data in the block, the attacker success probability calculation formula [3] is as follows:



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$$P = 1 - \sum_{k=0}^{z-1} \frac{\lambda^k e^{-\lambda}}{k!} \left(1 - (q/p)^{(z-k)}\right) \quad (1)$$

Where, p is the probability that an honest node finds the next block, q is the probability that the attacker finds the next block, z is the number of blocks behind the block which includes the transaction, and λ is the expected value of Poisson distribution of attacker's potential progress [3]. When q equals 0.3, and z equals 50, 50 blocks have been linked after the block which includes the transaction, the attacker success probability P equals 0.0000006, less than one in a million. The probability is extremely low. When the number of z blocks increases, the probability of success of the attacker decreases exponentially.

Based on blockchain technology, the system records important data such as transactions, scheduling, finance, and contracts in the energy blockchain. Based on the blockchain, various resources such as distributed energy, energy storage, and load are aggregated, and smart contracts are used for collaborative optimization control and market transactions.

In this paper, we build blockchain-based new generation energy Internet with extensive interconnection, intelligent decision-making, real-time interaction and open sharing. The application of blockchain technology in the energy Internet includes photovoltaic energy microgrid, blockchain-based energy Internet entities, power trading, and energy asset securitization.

Energy Internet transactions and payment settlement systems are constructed, using energy distributed ledgers and energy trading smart contracts. Energy producers and consumers directly trade peer-to-peer on the platform to improve system efficiency and safety.

3. Application of blockchain technology in energy Internet

Internet of Energy is a complex multi-network system based on the power system and modern information communication technology [4]. The application of blockchain technology in energy Internet can be deepened and expanded in the following aspects.

- Blockchain technology is used in scenarios where there are many participants and many processes, and ensure that the information cannot be tampered. In response to the problems of multiple types of participants, lack of trust, and transaction friction in the energy Internet, the blockchain does not rely on the center or third-party organizations to ensure the authenticity of data, greatly reduce the trust cost of energy transactions, and accelerate the energy flow of the energy Internet and the flow of information and capital.
- The underlying platform of the energy physical information system is constructed through the blockchain [5]. The blockchain distributed system is a natural multi-live system. When some servers fail, and the number of failed servers does not exceed the consensus mechanism limit, the system operation is not affected, and energy system operation is continuous.
- Blockchain provides intelligent on-demand automatic triggering of tasks by smart contracts. Smart contracts provide energy Internet autonomy management scenarios for energy consumption payment settlement, demand side response, energy autonomous control, etc., to meet the intelligent Internet energy needs.
- The timestamp mechanism and chain storage structure of the blockchain completely reflect the process of data from generation to entire process, and cannot be destroyed or tampered [6], which brings convenience to the supervision of transactions. Retroactive energy equipment and monitor energy trading are realized.
- The energy Internet contains a large number of market entities and equipment entities. The normal operation of the energy Internet requires monitoring and control of massive equipment and entities [7]. At the same time, it is very difficult to coordinate and control the massive entities. The market behavior of the entities make the problem more complex and changeable.
- The Internet of Things, combined with blockchain smart contracts, democratic autonomous management is enabled. The intelligence level and execution capability of energy equipment are improved.

4. Blockchain-based energy Internet system framework

The Trusted blockchain alliance chain provides energy distributed ledger and energy trading smart contract services. Energy Internet aggregates energy resources, energy transmission, energy distribution, energy consumption, energy storage, and other distributed resources, supports coordinated control and market trading [8].

The specific application scopes of energy blockchain include blockchain-based energy generation, transmission, consumption and storage, electricity trading, photovoltaic energy microgrid, energy asset securitization, energy financing, energy market trading, energy resource organization and collaboration, energy measurement, energy authentication, payment clearing and settlement, and etc.

The energy blockchain application architecture is shown in Figure. 1.

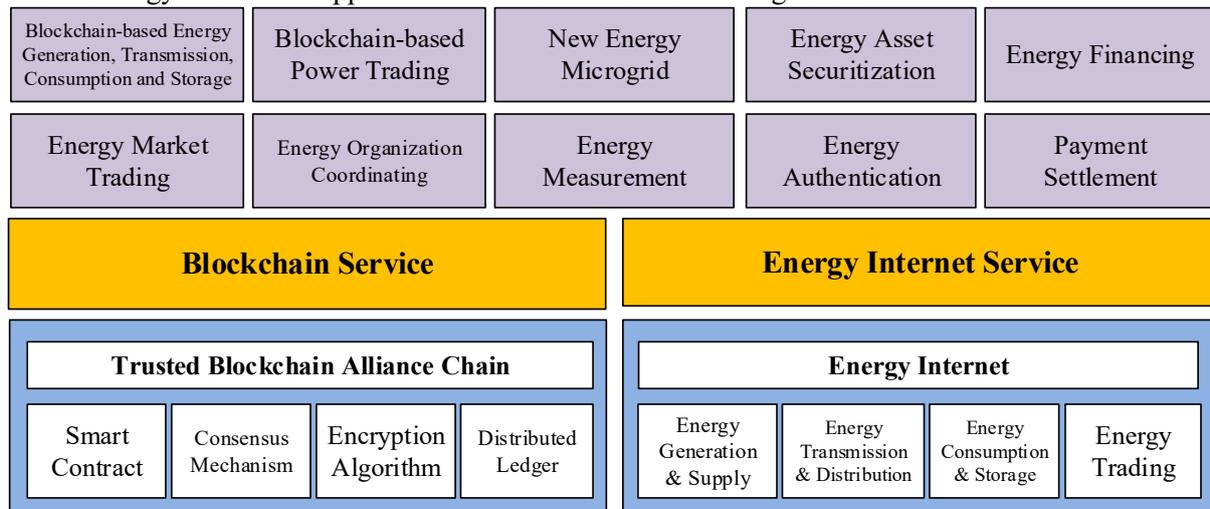


Figure 1. Energy blockchain application architecture

Energy blockchain is peer-to-peer, interconnected, and value driven. It satisfies the value transfer and sharing of large-scale decentralized multi-agents. It automates and intelligently implements protocol execution through smart contracts. The automatic execution of the trading of energy systems is guaranteed through series of intelligent contracts.

5. New energy microgrid

Blockchain promotes peer-to-peer transactions in a decentralized manner [9]. Enterprises and even ordinary households sell their own surplus electricity to other companies and households. The transaction is connected by blockchain network and managed without the involvement of intermediaries.

Participants in photovoltaic energy trading can be either producers or consumers. Residents or small-scale photovoltaic power plants conduct transactions through blockchain trading and dispatching. The smart meter records the amount of electricity, the blockchain distributed ledger records the electricity transaction, and the smart contract performs payment clearing and settlement.

Microgrid power transactions are mainly multilateral trading, include multi-party participation such as power generation, electricity consumers, power distribution agencies, etc. When blockchain is the base platform and provides technical support, energy operation efficiency is improved. And the costs of power transmission, distribution and storage are saved for all parties. The number of power transactions is large, trading time is not fixed, and transaction amount is random, which also imposes a burden on financial institutions in the settlement process. Real-time clearing can be achieved through smart contracts to increase the speed at which companies and individuals can withdraw bankroll.

In this paper, we utilize the trustworthy and traceable characteristics of blockchain to reduce fraudulent behaviors of buyers and sellers, set up a good credit bridge, and achieve the purpose of reducing costs and increasing efficiency.

6. Blockchain-based energy generation, transmission, consumption and storage

As a distributed data processing technology, blockchain has the characteristics of high transparency, decentralization, and collective maintenance. It is suitable for the coordination of energy generation, transmission, consumption, and storage to optimize operational needs. Alliance chain architecture improves system security. A reasonable supervision mechanism in the alliance chain structure, coordinate management and control are introduced, to improve the efficiency of system.

All the flexible load is recorded in the form of blocks, and adjustable load is used as transaction entity. The flexible load control strategy is optimized through multi-party coordination to improve accuracy. Through the characteristics of smart contracts, accurately and automatically, and avoiding human factors and external factors, the process of load flexible control is safe and credible.

All the user data involved in load control on blockchain is recorded, to support the data security of energy generation, transmission, consumption, and storage, and to improve efficiency through distributed processing.

In the distributed charging system of electric vehicles, blockchain technology is used to manage billing, charging and settlement. Blockchain technology is used as the basic platform to coordinate the source to construct distributed trusted energy transactions, scheduling, and financial settlement.

7. Blockchain-based power trading

In the electricity trading market, the roles of users participating in transaction can be divided into four categories:

- Producers: traditional power plants, and new energy plants;
- Production consumers: home photovoltaic users, communication base stations, data centers, and commercial buildings including uninterruptible power system;
- Ordinary consumers: ordinary household users, and ordinary commercial buildings;
- Public facilities maintainers: State Grid.

Blockchain technology is combined with distributed power to build a peer-to-peer power trading and settlement system [10]. Blockchain, as a basic technology, supports multiple procedures in the power trading process. The specific solutions are as follows.

7.1. Power transaction billing medium

There is a core component in the system, the trading medium, which is bitcoin in the bitcoin system. In order to promote blockchain power trading [11], a trading medium, power token, is used in various business activities such as transferring value and recording transactions in the trading system.

7.2. Power registration and issuance

Since the production and use of electric energy are real-time, the registration and circulation of electricity are actually a commodity registration and issuance process. Users buy electricity just like buying an actual item for use in the future. The power registration and issuance indicate how much electricity the power plant will be able to produce at some point in the future.

7.3. Electricity trading transactions

Power producers trade electricity by issuing it to the blockchain. Users, individuals or companies, trade electricity through a power trading platform or directly peer-to-peer. The transactions contain information about buyers and sellers as well as electricity prices, which are recorded in blockchain. Therefore, there will be no denial of electricity transactions.

7.4. Electricity bill collection and subsidy payment

The collections of electricity charges are an important task of the traditional power system. The multi-transaction systems based on the blockchain easily realize the task of collecting electricity charges. When actual using of electric energy, the collection of electricity charges are completed in real time. The collections of electricity charges system use blockchain smart contracts to assign the input and

output of each transaction to different objects, such as power plants and transmission and distribution networks.

At the same time, in order to encourage the production and consumption of environmentally-friendly electric energy, the government's subsidy policy needs to be accurately and timely distributed to the hands of electric energy producers and consumers. The blockchain-based power trading medium is a good solution. The trading medium has a clear accounting function, it clearly records the trading behavior and clearly distinguish which electric energy is environmentally friendly. Therefore, it accurately uses the trading smart contract to distribute the subsidies to the beneficiaries, minus the complicated procedures in the middle process.

7.5. Power payment settlement

The use of trading distributed ledger to record electricity transactions and consumption effectively alleviates the liquidation and settlement pressure of electricity payments. The value transfer of electricity is realized by the blockchain multi-transaction system, and which realizes real-time clearing and settlement.

8. Energy asset securitization

At present, in the process of asset securitization of new energy business, the following problems are faced. It lacks of credit risk pricing technology. For new energy projects, such as distributed photovoltaic power plants, there is still no effective evaluation technology to solve reasonable pricing of assets. It is difficult to monitor the operation of energy asset securitization. The operation and management of existing securitized assets are mainly based on centralized management, and face a series of shortcomings such as data being easily falsified.

The distributed ledger technology of blockchain has the advantages of data disclosure and transparency, which helps the securitization initiator to effectively identify the asset quality and accurately predict the future cash flow of the asset. On the other hand, it effectively supervises the follow-up of the asset, and avoids the moral hazard of the asset owner after the security.

In the distributed storage and peer-to-peer transmission, through the decentralization method, the system decides whether to enter the securitization plan. It classifies and manages the assets of the asset pool through a unified evaluation standard, separates operational rights and ownership, and ensures waterfall cash flow through smart contracts.

Based on the blockchain asset securitization, the distributed ledger, the open transparent and non-deformable of data are fully utilized. Blockchain-based data also provides a more informed basis for subsequent asset management.

Through the incentive mechanism, all the node members in the chain, including asset node, securities initiator node and investor node, participate in accounting and supervise the operation of data flow. That effectively prevents the moral risk of the asset operator, and ensures the security. In addition, time-stamped data generated by blockchain technology is used to facilitate mutual supervision of asset nodes.

9. Conclusion

In this paper, we build blockchain-based new generation energy Internet with extensive interconnection, intelligent decision making, real-time interaction, and open sharing. The application of blockchain technology in energy Internet includes photovoltaic energy microgrid, blockchain-based energy Internet entities, blockchain-based power trading, and energy asset securitization.

Technical frameworks for energy Internet market trading system based on blockchain technology are proposed. Distributed energy ledger and energy trading smart contract are utilized. Distributed trading rules, algorithms and processes of energy system and microgrid are established. Energy Internet transactions and payment settlement system are constructed. Energy producers and consumers trade peer-to-peer on the platform to improve system efficiency and security.

Acknowledgment

This work was supported by grants from the e-commerce science and technology project of State Grid Corporation of China (No. 5100/2019-72005B), Research on Key Technology Application of Trusted Blockchain Basic Service Platform.

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