Design of Wind Farm Information System Based on Blockchain Technology

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Abstract. The current wind power operation and maintenance management has difficulties in data storage, insufficient security, and weak sharing. Therefore, this paper proposes to use the blockchain to build a wind farm information system to solve these problems. This paper analyzes the applicability of blockchain and wind farm information system, and designs the functional modules of the wind farm information system and the corresponding system framework.

1. Introduction

With the deterioration of the environment and the reduction of fossil fuel reserves, countries around the world are paying more and more attention to the development of renewable energy. As early as the beginning of the twentieth century, there were already applications of wind power generation in the world. The "Renewable Energy Law of the People's Republic of China" passed in 2005 clarified the legal status of renewable energy and promoted the development of renewable energy. As of the end of 2019, China's cumulative installed capacity reached 210 million kW, and the cumulative wind power generation reached 405.7 billion kWꞏh[1]. Wind power has become one of the important energy sources in our country. The rapid development of the wind power industry has also exposed many problems. For example, failure of wind farms cannot be detected and dealt with in time, which can easily cause wind turbines to shut down, which will not only bring great economic losses to enterprises, and even affect the safe and stable operation of the grid. Therefore, whether it is from the perspective of enterprises or power grids, it is necessary to ensure the normal operation of wind farms. However, current wind farms have problems such as difficulty in data storage, insufficient data utilization and sharing[2]. The conventional centralized monitoring system for wind farms can no longer meet the requirements, so the operation and maintenance management of wind farms needs to be improved.

The current improvements to the operation and maintenance management of wind farms are mainly from the perspective of project management. Chen[3] analyzed from the perspectives of spare parts management, occupational health management, and risk management, and gave suggestions on quality management and safety management. Yang[4] carried out an integrated operation and maintenance design from three aspects: human resource management, wind farm site management, and spare parts management, and redesigned relevant evaluation and assessment standards. Zhang[5] proposed a new training method for wind power operation and maintenance personnel, which reduces costs and improves efficiency through intelligent training of operation and maintenance personnel.

With the development of technology, scholars have gradually proposed that emerging technologies such as cloud computing, blockchain, and the Internet of Things can be used to build a new operation and maintenance management model. Zhang[6] discussed the necessity of operation and maintenance
management informationization from the aspects of accident management, problem management, configuration management, etc. Zhang\cite{7} proposed a smart wind farm operation system, which uses technologies such as smart wind turbines and big data analysis to achieve cloud analysis and a new operation and maintenance model for centralized monitoring and repair. Wang\cite{2} proposed that the effective utilization and sharing of wind power operation and maintenance data can be realized through blockchain. However, the current application of blockchain technology in the energy field is mainly focused on the study of traditional power market transactions and the problems of distributed new energy power transactions. Li\cite{8} designed in detail the system architecture of a blockchain-based power purchase and sale platform, and designed a complete transaction process and its smart contract. Wang\cite{9} introduced blockchain technology to the electricity market transaction that includes microgrids, and at the same time used carbon emission factors to correct the quotation to complete the electricity transaction between power plants and factories. Liu\cite{10} proposed to partition nodes with different transaction frequencies to form multiple local blockchains, and cross-chain transactions can be carried out between adjacent local blockchains to meet the needs of flexible energy transactions. Gai\cite{11} proposed a privacy-protecting blockchain transaction model, which realizes privacy protection by covering up inactive accounts. Li\cite{12} proposed a demand-side energy management strategy for blockchain for a small distributed energy system including residential, commercial, and industrial sectors, realizing time-sharing power consumption based on renewable energy generation.

At present, there are few researches on the operation of wind farms in terms of blockchain. This article proposes that blockchain technology can be used to construct an information system for wind farm operation and maintenance management. The system integrates equipment monitoring, data storage, spare parts management and other functions. It uses the decentralization and non-tampering characteristics of blockchain technology to ensure the safe storage of operating data, improve data utilization and sharing, and realize regional management of wind farm.

2. Blockchain technology
Blockchain technology is a creative integration of old technologies such as asymmetric encryption algorithms, consensus mechanisms, and smart contracts. The asymmetric encryption algorithm is composed of a pair of public and private keys, and can generally be used to encrypt data, digital signatures, etc. in the blockchain. The public key is public, while the private key is only known to the holder. After one of the keys is used for encryption, only the other key of the corresponding key pair can be decrypted. The consensus mechanism is a key technology that can be realized by the blockchain. It enables distributed nodes to reach a consensus on transactions across the network without trust, thereby forming a new block of consensus transaction data and linking it to the district. Block chain. Currently commonly used consensus mechanisms mainly include workload certification mechanism, equity certification mechanism, and authorized share certification mechanism. A smart contract is essentially a piece of machine code that is automatically triggered and executed when certain conditions are met, and transactions can be automatically completed under decentralized conditions. It changes the part executed by humans to machine code, which has higher credibility and gives the blockchain the characteristics of openness, transparency, and non-tampering. The most basic unit of the blockchain is a data block. The structure of the block is shown in Figure 1. Simply put, the blockchain is to form a distributed database in a chain structure according to the time sequence of generation of consensus data blocks.
3. Applicability analysis of blockchain and wind farm information system

3.1. Development status of wind farm information system

At present, most wind farms choose the mode of regional management. Regional management is to implement remote equipment monitoring and unattended functions for all wind farms in a certain area through information technology. Regional management requires a good wind farm information system, but the current wind farm information system still has problems such as difficulty in summarizing a large amount of data, and difficulty in sharing and effective use of high-value data [2].

3.2. Applicability analysis of blockchain and information system

Blockchain technology and wind farm information system have certain similarities in the following four aspects, and their characteristic comparisons are shown in Table 1.

(1) Decentralization: All nodes in the blockchain are distributed, and each node has equal rights and obligations. It does not require the existence of a central organization to guarantee. Any node failure will not affect the normal operation of the blockchain, and wind power The wind turbine nodes in the farm are also distributed, and each wind turbine node bears the same utility, and any wind turbine node will not affect the operation of other wind turbines;

(2) Collaborative autonomy: All nodes in the blockchain jointly participate in the generation and maintenance of the data blocks of the entire blockchain. Through a set incentive mechanism, it can be ensured that all nodes spontaneously participate in the consensus and maintenance of the blockchain, while the wind farm runs In the process, all wind turbine nodes collect data by themselves and upload them to the centralized control center for storage and processing, and no incentive mechanism is required. All wind turbine nodes will spontaneously maintain the normal operation of the blockchain network;

(3) Consensus mechanism: Blockchain uses a consensus mechanism to ensure decentralization and ensure the authenticity and reliability of transaction information, and wind farms can also reach a consensus on all operating data through all wind turbine nodes using the consensus mechanism to achieve safe and reliable storage of wind turbine operating data;
(4) Traceability: Each node in the blockchain uploads all transaction information in the current period to the blockchain. The data of the entire network can be traced and the security is high. The operation of wind farms currently needs to improve data security and sharing. The use of blockchain is just right Can improve the degree of data sharing, and there is no risk of leakage.

Table 1. Comparison of the relationship between blockchain and wind farm information system.

| Characteristic          | Blockchain technology                                                                 | Wind Farm Information System                  |
|-------------------------|---------------------------------------------------------------------------------------|------------------------------------------------|
| Decentralization        | Distributed peer-to-peer network, each node has equal rights and obligations          | The wind turbines are scattered                |
| Cooperation Autonomy    | All nodes participate in network maintenance                                          | All wind turbines participate in data upload and maintenance |
| Consensus mechanism     | Trust mechanism without third party guarantee                                          | wind turbines can reach a consensus on the uploaded data through mutual verification |
| Traceable               | The transaction information of each node is uploaded to the blockchain, and the entire network data can be traced and cannot be tampered with | Increased sharing of data collected during wind turbine operation without risk of leakage or modification |

4. Design of Wind Farm Information System Based on Blockchain

4.1. System function design

Wind farm information system is to manage the whole process of wind farm operation through the use of information equipment. The function of the wind farm information system designed in this paper is shown in Figure 2, including six modules including basic authority, equipment information, maintenance, equipment monitoring, technical data, and spare parts.

Basic authority management: divided into department information settings, user information and authority information. This part divides the rights of different blockchain nodes. Each wind turbine node only has the right to view the information uploaded by it. Viewing the operating data of other nodes requires permission from other nodes.

Equipment information management: divided into equipment information entry and equipment information query. This part is used to view and manage basic information such as the model and power of each wind turbine node.

Maintenance management: divided into maintenance plan, maintenance record, and maintenance query. When each wind turbine node is regularly maintained, the signal of this regular maintenance is uploaded to the blockchain. Every regular maintenance can be traced and cannot be tampered with, which helps to promote the normal implementation of the regular maintenance plan.

Technical data management: divided into data entry and data query.

Spare parts management: Divided into location query, warehouse entry and exit operations, and warehouse entry and exit query. In this part, the inventory information of all spare parts in the area is managed uniformly through the blockchain to reduce personnel management and personnel corruption.

Equipment monitoring and management: The most important function of this system is the equipment monitoring and management module, so this module will also be designed with emphasis. This module is divided into fault alarm and maintenance records. It is mainly responsible for processing and analyzing the signals uploaded by the wind turbine nodes, and alarming the fault signals. After receiving the alarm signals, the personnel on duty in the centralized control center will repair them and record the maintenance. Upload to the blockchain. Its working process is shown in Figure 3. That is, after each wind turbine node collects the signal, it performs filtering processing to reduce the noise of the signal, and then extracts the principal components of the signal and calculates the real-time $T^2$ and SPE statistics ($T^2$ represents a number of principal component pairs The influence of the system model, the SPE statistic represents the influence of the comprehensive error of the process quantity), and compare it with the upper limit of the $T^2$ and SPE statistic calculated under normal operating conditions. Once the limit is found, the smart contract will be called to perform the
fault analysis, determine what kind of failure is and give an alarm, and upload the diagnostic information to the blockchain; if it does not exceed the limit, it will prompt that everything is normal, and upload the operating data to the blockchain. This can realize the effective storage and utilization of data, especially the fault data can be used by the whole network, and the use of fault data can continuously improve the effectiveness of diagnosis.

Figure 2. Functional structure diagram of wind power information system

Figure 3. Flow chart of equipment monitoring management

4.2. System framework design

According to the similarity between the blockchain and the wind power information system analyzed in the previous section, this paper constructs a five-layer system basic framework as shown in Figure 4. This framework is slightly different from the six-layer framework of the traditional blockchain, the most obvious is that the incentive layer is missing. Because wind turbines have a mandatory obligation to maintain the normal operation of the wind farm, there is no need for an incentive mechanism.

Among them, the physical layer is the many wind turbine nodes that constitute the bottom layer of the blockchain and the corresponding data-collecting sensors, acquisition cards and other physical devices. This layer is mainly responsible for collecting data during the operation of the wind turbine.

The data layer is the underlying data structure of the blockchain. This layer includes block information, hash functions, merkle trees, asymmetric encryption algorithms, timestamps, and chain
structures. It uses hash functions and merkle trees to record block information and asymmetric encryption. The algorithm encrypts the data, and the blocks that record block information are formed into a block chain through a chain structure. This layer records the data uploaded during the operation of the wind turbine, which can realize distributed storage of data.

The network layer includes P2P network, propagation mechanism and verification mechanism, and data transmission in blockchain is realized through P2P network. This layer mainly establishes a safe and reliable connection between blockchain nodes, so that information can be reliably stored.

The algorithm layer is the core of the blockchain and the core of the system, including consensus algorithms, algorithm mechanisms, and smart contracts. The consensus algorithm is a verification mechanism for all parties to ensure the authenticity of the data. The smart contract is a section that meets specific conditions. Automatically executed machine code, consensus algorithm, and smart contract are the foundation and key to achieve blockchain decentralization and trustlessness.

The application layer is the terminal realization of the wind power information system, and the centralized control center and wind turbine nodes realize the call of the corresponding functional modules through the application layer.

5. Conclusion
Blockchain technology can be used in all walks of life in a broad sense. This article analyzes its feasibility in wind farm information systems based on the characteristics of blockchain technology itself. From the analysis results, it can be seen that blockchain technology and wind farm information systems fit well and can solve the problems encountered by the current wind farm information system. The features of blockchain, such as decentralization, traceability, and non-tampering of information, can effectively enhance the authenticity and effectiveness of information in spare parts.
management and maintenance management, and will also make information transmission in the equipment monitoring process safer and more efficient.

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