



Design and Implementation of Green Power Traceability System Based on Blockchain Technology in the 2022 Beijing Winter Olympics

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Abstract. The Beijing Winter Olympics Organizing Committee has set a low-carbon goal for the 2022 Beijing Winter Olympics to ensure that the venues use electricity to achieve green power supply. However, the green power has special physical properties of electricity, which makes it difficult to trace its source. In this paper, by combing and analyzing the Winter Olympics green power transaction process, relying on blockchain technology, designing a green power traceability mechanism covering the five links of “generation-transmission-distribution-transaction-consumption” to realize the key information of the whole process on the chain. Distributed storage of certification and core data, effectively maintaining data security, and ensuring the authenticity and credibility of key information throughout the entire Winter Olympics green power process. The system operation test shows that the system can realize the effective inspection of green power traceability information and improve the traceability ability of the Winter Olympics green power.

Keywords: Blockchain · Distributed Ledger Technology · Green Power · Traceability

1 Introduction

Energy is an important material basis for national economic and social development, including renewable energy and non-renewable energy. Renewable energy refers to non-fossil energy such as solar energy, hydro power, wind energy, and biomass energy. It is a green and low-carbon energy source. Since the reform and opening up, China's energy industry has developed rapidly and has become the world's largest energy producer and energy consumer. On September 22, 2020, Chinese President Xi Jinping announced at the General Debate of the Seventy-fifth United Nations General Assembly that he will strive to achieve carbon neutrality by 2060, which means that China's energy clean and low-carbon transition will take more active steps [1]. The Beijing Winter Olympics Organizing Committee has set a low-carbon goal for the 2022 Beijing Winter Olympics, and strives to achieve green power supply for venues.

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Green power is beneficial to environmental protection, and therefore also has the special physical properties, that is, from the power generation side to the power consumption side, it is difficult to trace its source. Blockchain has many technical characteristics such as tamper resistance, traceability, openness and transparency, and many fields have carried out research on the traceability of commodities based on blockchain technology. The literature [2, 8, 9] designed a commodity traceability system based on blockchain technology to realize the production of commodities in response to the problems of centralization and easy tampering in the operation of conventional logistics commodities such as food and medicine. The traceability system could realize the traceability of the whole process of production, logistics and use information of goods. There are relatively few explorations on the traceability of unconventional commodities based on blockchain technology. The literature [4] sorted out and analyzed the current status and problems of ship pollutant management, and used blockchain technology as a basis to explore the establishment of a ship pollutant tracking and tracing mechanism to provide information for ship pollutants. Traceability provides new methods and directions for unconventional commodity traceability. The literature [3] explored the feasibility of blockchain technology in the traceability system of factory pollution emissions. By using the technical characteristics of blockchain traceability, combined with the pollution emission monitoring and management of chemical plants, it clarified the mainstream direction of the traceability system. The application of blockchain in the energy field has also been studied in recent years. The literature [6, 7, 10] analyzed the relationship between energy transition and application of blockchain technology, and introduced application of blockchain technology in China's energy industry in recent years, which involves the use of blockchain in electricity trading, high-quality services, and new energy clouds and other scenarios. However, the application of blockchain technology in green power traceability scenarios has not yet been covered in relevant literature.

In order to ensure the green power supply to the Beijing Winter Olympics venues and improve the traceability and supervision capabilities of the green power, this paper designed the traceability mechanism of the Winter Olympics green power based on the characteristics of blockchain technology such as multi-node maintenance, distributed storage and difficult data tampering to complete the green power. In the chain of core data of power generation, transmission and distribution, transaction and consumption, the evidence and sub-item traceability were stored, and the green power traceability verification design was combined to realize the traceability of the green power consumption of the Winter Olympic venues.

2 Design of Green Power Traceability Mechanism for Winter Olympics

Due to the special property of electric power, it is impossible to conduct traceability and product property certification for green power in the conventional sense. This paper utilized the verification method to verify that the electric energy used by all venues in the Beijing Winter Olympics is green power. Firstly, the basic property of green power was clarified, the entire business process of the Winter Olympics green power

was analyzed, and the basis for the research on the traceability mechanism of the green power was formed; secondly, the core data and key node data required for the green power traceability of the Winter Olympics was sorted out to form the core data table, the data source was clarified; finally, the core data and key node data was extracted, calculated and compared to complete the verification of the green power consumption of the Winter Olympic venues.

2.1 Green Power Trading Process of the Winter Olympics

In order to ensure the stability and continuity of the green power transaction of the Winter Olympic venues and ensure that the electricity purchased by the Winter Olympic venues fully meets their own green power demand, the electricity power users of the Winter Olympic venues will annually determine the electricity consumption in the coming year based on the actual electricity consumption of the venues. The electricity consumption in the coming year on a monthly basis was estimated, and was submitted it to the power company, and an agency contract would be signed. As the agent of the Winter Olympics venues, the electricity power company is listed in the power trading center, and the renewable energy power generation company is delisted to achieve the green power transaction [11].

The power company determines the list of renewable energy power plants that will ultimately participate in the green power transaction and the amount of power supply based on the power transaction rules (such as time and electricity price requirements) and the actual power generation capacity of each renewable energy power plant (such as unit capacity), and signs the power supply contract. After the power supply contract is completed, a green power transaction commitment letter, transaction announcement, and transaction result are formed in the power trading center to complete the green power transaction. In the following year, in accordance with the green power supply contract, the power companies continue to supply power to the Winter Olympic venues. The whole business process of the Winter Olympics green power transaction is shown in Fig. 1.

2.2 Core Data Combing of the Green Power Traceability System

Combining the whole business process of the Winter Olympics green power, from the perspective of “generation-transmission-distribution-transaction-consumption”, the data required for the green power traceability system of the Winter Olympics based on



Fig. 1. The whole business process of the Winter Olympics green power transaction (Photo credit: Original)

Table 1. THE CORE DATA LIST OF THE GREEN POWER TRACEABILITY SYSTEM FOR WINTER OLYMPICS

Business process	Corresponding system	Core data
Power generation process	Power dispatching system	Real-time output and actual power generation of renewable energy power stations
Transmission and distribution process	PMS System, GIS System	Geographic location information data of major infrastructure
Transaction process	National unified electricity market trading platform	Electricity purchase and sale contracts, transaction undertakings, transaction announcements, market entities in the transaction results, transaction time, transaction methods, transaction electricity
Power consumption process	Use and acquisition system, marketing system, Integrated dual-core system	User information, real-time electricity load, over-standard information

blockchain technology mainly includes four categories, namely renewable energy power plant data, main distribution network structure data, Winter Olympic venue electricity consumption data and green power transaction data correspond to five links, forming the core data list of the green power traceability system for Winter Olympics, as shown in Table 1.

2.3 Green Power Traceability Mechanism for the Winter Olympics Based on Blockchain Technology

The blockchain technology can provide a collaborative environment with strong external confidentiality and internal transparency. The blockchain technology also can ensure the authenticity and reliability of the data on the chain. Its anti-counterfeiting, anti-tampering, and traceability characteristics ensure that the data is between multiple parties. Those characteristics provide a solid foundation for its application in the energy field [5]. In the blockchain network, all nodes jointly abide by specific rules and supervise each other to build a network of cooperation, mutual trust and multi-party governance.

The transaction process of the Winter Olympics green power was sorted out, a traceable core data list was formed, and the core data of green power generation, power consumption, settlement power and transaction power was put on the chain for certification, and power generation, power consumption and transaction data, and real-time monitoring of the flow of electric energy was compared to achieve the verification of the green power supply of the Winter Olympics venues. Based on the multi-party maintenance and hard-to-tamper characteristics of blockchain technology, the Winter Olympics

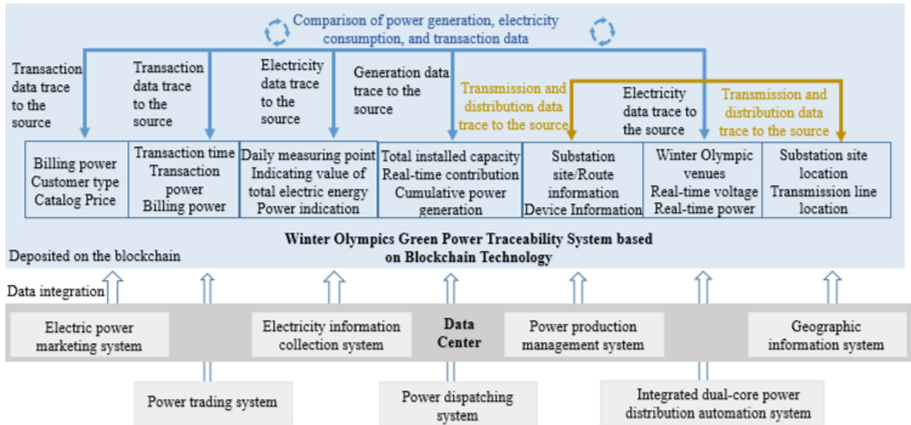


Fig. 2. The green power traceability mechanism for the Winter Olympics based on blockchain technology (Photo credit: Original)

green power traceability mechanism based on blockchain technology is designed. As shown in Fig. 2, the traceability core data is stored for endorsement, and multi-node consensus is carried out to enhance the credibility of the green power traceability mechanism for Winter Olympics.

- Traceability of green power generation information: Through docking with the national unified power market trading platform, obtaining transaction vouchers for Winter Olympic venues and renewable energy power generation companies, analyzing and forming a list of renewable energy power generation companies participating in the Winter Olympic green power transactions, and clarifying the power generation companies' affiliation administrative regions. Further docking with the power dispatching system of the region where the renewable energy power generation company belongs to obtain real-time output and actual power generation data of the renewable energy power plants participating in the Winter Olympics green power supply. Statistics on the above data, the cumulative total power generation data, monthly power generation data and total real-time output data of renewable energy power plants participating in the Winter Olympics green power transaction are obtained, and they are recorded on the chain.
- Traceability of green power transmission and distribution information: From power generation to power consumption, green power needs to pass through the power grid infrastructure such as the distribution network, substations, and converter stations. By connecting the power dispatching system and the GIS system, the key converter station and substation name and geographic location information in the transmission process of the renewable energy power generation company could be obtained, and the Winter Olympics green power transmission main network architecture diagram could be constructed, and the distribution network architecture diagram, forming a considerable the flow of electric energy is traceable to the source of information on the "network" side.

- Traceability of green power transaction information: Connecting to the corresponding power trading system to obtain information on the purchase and sale contracts of the Winter Olympic venues, transaction commitments, transaction announcements, market entities, transaction time, transaction methods, transaction power, etc., to form Winter Olympic venues and the endorsement of the power generation-sales-purchase-utilization relationship between renewable energy power generation companies proves that there is a transaction relationship between the Winter Olympics venues and renewable energy power generation companies, and the core transaction data obtained at the same time is used for multi-node consensus.
- Traceability of green power consumption information: docking with the State Grid Beijing Electric Power data center station utilization and acquisition system and marketing system to obtain the meter reading information of the Winter Olympic venues and basic user information, and obtain the real-time power load of the Winter Olympic venues, and at the same time according to the meter reading data calculated by the cumulative power consumption of the Winter Olympics venues, and at the same time use blockchain technology to realize the on-chain storage of the power consumption information of the Winter Olympics venues, and realize the credible storage and traceability of the information on the “consumption” side of the Winter Olympics green power.
- Traceability verification of green power: Based on the non-tamperable core data on-chain deposit certificate, the core data is calculated and analyzed, and the cumulative total power generation data of renewable energy power plants, the cumulative power consumption of the Winter Olympics venues, and the settlement power and settlement types are calculated. For comparison, when power generation is larger than power consumption, and power consumption is equal to settlement power, and the power flow of the transmission main network and distribution network structure is stable and continuous, the green power supply of the Winter Olympic venues can be verified.

2.4 Design of the Green Power Traceability System for the Winter Olympics Based on Blockchain Technology

In the green power traceability for the Winter Olympics scenario, the non-tamperable and traceable features of the blockchain are used to realize the collection of core data through the docking with power-related systems, and the key data and vouchers of the whole process of the Winter Olympics green power transaction and power consumption on-chain storage certificate, using electronic signature, time stamp, hash value verification and other technologies to confirm the source and time of the green electricity data, carry out the originality and authenticity of the electronic data, and realize the data level through technical means trust. In addition, the green power traceability system based on the energy blockchain is cross-chain docking with the judicial chain built by the Beijing Internet Court, by the node consensus to realize the judicial-level, further improving the security and credibility of the green power data.

2.5 The Design of System Architecture

The green power traceability system based on blockchain technology uses a micro-service architecture, and business data is stored on the information intranet. Through

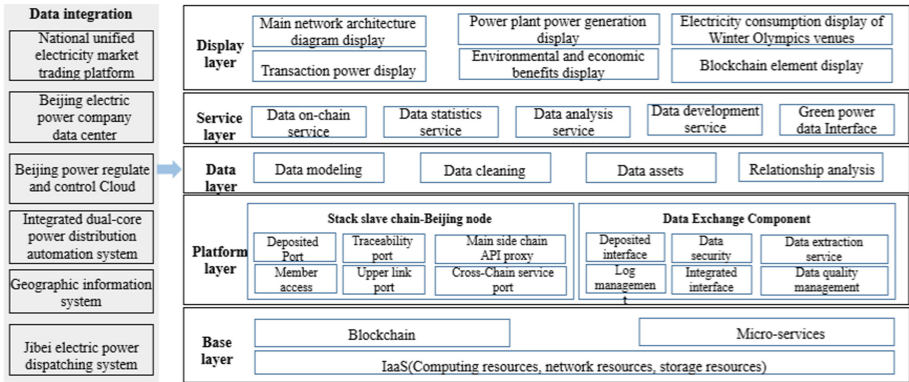


Fig. 3. The overall architecture of the Winter Olympics green power traceability system based on blockchain technology (Photo credit: Original)

the internal and external network isolation device, the data information can be stored on the external network. The whole system includes 5 layers: the base layer, platform layer, data layer, service layer and display layer. The system completes the acquisition of business data by integrating with external systems, and performs data calculation through algorithm analysis. Finally, the system displays the output results on the visual interface in the form of graphics, real-time data etc. The architecture of the system is shown in Fig. 3.

- Base layer: the system is built based on the cloud environment, based on advanced technologies such as blockchain and microservices.
- Platform layer: based on the energy alliance chain, data exchange services are encapsulated. Through the stack slave chain Beijing node, complete system member access management, provide system members with data on-chain, certificate storage, and traceability interfaces. It connects to the judicial chain, government affairs chain, central enterprise e-commerce alliance chain and other alliance chains through cross-chain service interface. It sets up data exchange components to integrate, extract and quality management of paired Winter Olympics green electricity data, thereby ensuring the integrity, security, reliability and transmission performance of the data in the transmission process.
- Data layer: directly connect to the business system where the core data is located, complete the collection of power plant, dispatch, transaction, and consumption data collection, then use data modeling to complete green current direction, green power structure, and cumulative power consumption analysis etc., send the data analysis results to the service layer as standard data.
- Service layer: provide green electricity data on-chain, statistics, analysis and development services. The system uses the business table of the original business system database where the green electricity data is located as the carrier, and obtains from the business system according to the predefined library, table structure definition, authority configuration, and directly connects with the data extract business data from business systems in a way to achieve various data on the chain. Structured storage

based on Merkle tree and stand-alone Key-Value unstructured LevelDB data storage based on log sorting and consolidation, complete data analysis and data development services of data assets, and through the data interface to complete the flow of internal data.

- Display layer: the core data is displayed on a large visual screen, which mainly includes: main network architecture display, power generation display, venue power consumption display, transaction power display, blockchain element display, etc.

2.6 Test Results

- Through the docking with the data integration system in Fig. 3, the system completes the acquisition of business data, combines algorithm analysis to complete data statistics and calculations, and finally displays graphics and real-time data results on a visual interface.
- The system obtains and updates the power generation, transaction and settlement data of renewable energy power generation companies at a monthly frequency. It obtains regulation data through FTP transmission every 5 min, reads PMS data and usage data through MaxCompute space using data models. Calculate the green power traceability verification data such as total power generation, consumption, settlement, and display the relevant data on a visual interface.
- Functionality: The system has the functions of green current direction analysis, green power structure analysis, cumulative power consumption analysis, and graphical display of green power traceability information. Since the system was tested and launched, nearly 300 blockchain accounting has been completed every minute, with a total of more than 50 certificate deposit transactions and settlement data. The accumulated transaction power of the chain deposit certificate is 318 million kWh, which reduces the burning of standard coal by 100,000 tons. Reduced 250,000 tons of carbon dioxide, improved the traceability and supervision of green power, and realized the supply of green power to the Winter Olympic venues.
- Security: using distributed databases, combined with sharding, clustering and other technologies to achieve the security and reliability of data storage; using channel encryption, transmission encryption, and data encryption to achieve security protection for data collection and transmission; in data processing, In the sharing link, two-level desensitization, service access control, dynamic behavior tracking and other technologies ensure the safe and reliable sharing of data.

3 Conclusion

The article mainly analyzes and sorts out the status of the Winter Olympics green power trading, and studies the process and core data of the traceability of the green power, designs the traceability mechanism of the Winter Olympics green power based on blockchain technology, and develops a blockchain-based technical Winter Olympics green power traceability system software and realizes the chain storage and multi-point query of key data in power generation, transmission, distribution, transaction, and consumption. Through the test operation of the system, the following main conclusions are

drawn: System green power transaction data has judicial-level effectiveness, improves the credibility of the data, guarantees the authenticity and credibility of the key information in the whole process of the Winter Olympics green power, is conducive to the government and society's supervision of the use of green power transactions, and provides theories and principles for achieving carbon neutrality practice basis.

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