Research and Application of Renewable Energy Power Consumption Certificate Based on Blockchain

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***Abstract*—With China's steady progress in the development and construction of renewable energy, the proportion of renewable energy in China is increasing, and the willingness of market players to purchase renewable energy power is increasing. However, the existing technical means have single tracking indicators, low reliability, difficult supervision, and can not track the consumption of users safely, transparently and efficiently. The paper introduces blockchain technology into renewable energy consumption voucher transaction. Firstly, it introduces the problems faced by renewable energy power consumption vouchers; Secondly, it studies the key technologies of blockchain to meet the power consumption demand of renewable energy; Finally, a renewable energy power consumption voucher management method based on blockchain technology is designed.**

***Keywords*-renewable energy power ; blockchain technology; consumption certificate**

I.Introduction

At present, the development of renewable energy has become an important measure for countries all over the world to ensure energy security, strengthen environmental protection and deal with climate change. Vigorously developing and utilizing renewable energy can reduce the dependence on petrochemical energy, and will play a very important role in ensuring China's energy security. With the steady progress of the national development and construction of renewable energy, the proportion of renewable energy in China continues to increase, and the user side adjustable load and energy storage are more and more involved in the interaction with the power system. The access to a high proportion of renewable energy makes the operation mode of the power system more diversified and the AC/DC connection of the power grid more complex. Under the new quota system, it will face serious challenges in establishing and improving the trading mode of renewable energy consumption market, strengthening scientific and technological support means and optimizing the market trading mechanism[1-3].

Domestic scholars have done a lot of research in relevant directions. Literature [4-5] established a two-stage joint equilibrium model considering green certificate trading market and power wholesale trading market to study the strategic behavior and mutual influence of power producers in the two markets under different quota requirements; Literature [6-8] analyzes the current situation and current supporting policies of trading systems at home and abroad, and then analyzes the interaction mechanism between internal factors and external environment through system dynamics model according to the trading situation of carbon emission and green certificate market, and carries out scenario simulation and deduction of carbon emission and green certificate trading market. Literature [9-11] designed the national renewable energy market based on quota system and its coordination mechanism with the provincial day ahead market, the national green certificate market and the deviation electricity settlement mechanism to encourage renewable energy to accurately predict its own output. Literature [12-13] designed a power market system suitable for renewable energy quota system. The implementation mode of renewable energy trading based on curve is proposed, which solves the problem that China's current renewable energy quota system only considers the consumption and does not evaluate the user's friendliness to renewable energy power generation, and encourages market members to actively consume renewable energy to complete their own allocation.

This paper mainly studies the whole process management method of renewable energy power consumption certificate based on blockchain. Aiming at the problems and difficulties existing in the current green power certificate in the renewable energy power consumption system, this paper establishes the whole process control, tracking and accounting management of renewable energy transaction, so as to ensure the transparency, security and traceability of the transaction, Solving the problem that the power trading center platform lacks corresponding mechanisms and technical means in the monitoring and measurement of renewable energy consumption.

II.Problems faced by renewable energy power consumption certificate transaction

A.Green card problem

Green certificate is the abbreviation of green power certificate. It is an electronic certificate with unique code identification issued by the state for the on grid power of non-aqueous renewable energy per megawatt hour of power generation enterprises. In January 2017, the notice on the trial implementation of renewable energy green power certificate issuance and voluntary subscription trading system (FGGY[2017] No.132) was issued, marking the formal trial implementation of China's green power certificate system. The buyer of the green certificate actually obtained the declaration right, that is, claimed to use green energy.At present, China's green card adopts the system of voluntary subscription[14-15]. Any enterprise and the public can voluntarily subscribe for the green certificate as a proof of consuming green power and supporting the development of green power.

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The establishment of green power certificate system in China is mainly due to two considerations. On the one hand, the current new energy price system is more and more difficult to adapt to the development of green power. At present, China implements the fixed on grid price mechanism of "benchmark price of coal-fired units and financial subsidy" for new energy, and the financial subsidy is equivalent to paying the environmental benefits of new energy. On the other hand, the voluntary subscription transaction of green card also lays the foundation for the compulsory transaction of quota system in the future[16-17]. The green card voluntary subscription transaction can accumulate working experience in certificate issuance, transaction organization and fund supervision for the green card compulsory quota transaction, and lay a working foundation for the future renewable energy compulsory quota transaction. Since the voluntary subscription of green certificates was launched on July 1, 2017, the development of green certificates has been hot before cold. After the green card just went online, its development soon entered a bottleneck period. Platform statistics show that at present, China's nuclear wind power and photovoltaic green certificates have accumulated more than 21.8 million, and the actual trading volume of 27185 accounts for only about 0.12% of the nuclear issuance volume.

B.Excessive consumption of renewable energy

The concept of excess consumption was put forward in the new quota policy in 2019. It is the second renewable energy power consumption mode in addition to issuing green certificates[18]. Excess consumption is the excess consumption that the market subject can trade after completing its own consumption task. The notice of the new quota system specifies that the relevant responsible institutions are responsible for organizing the account creation and transfer of consumption, but does not describe the specific method. Secondly, the record of consumption is generated with the actual power use of power trading, so it also needs to be combined with the power trading market. It is necessary to explore the management methods that can ensure the credibility of consumption certificates, certificate storage, statistics and the whole process cycle.

C.Blockchain helps renewable energy power consumption certificate transaction

As a new distributed ledger technology, blockchain can not only "increase credit" for the development of renewable energy power consumption certificates, but also find more diversified application scenarios for renewable energy power consumption certificates. It is expected to provide a new and feasible solution to solve the current dilemma of green card and excess consumption management.

Blockchain technology introduces renewable energy consumption certificate transaction, turns consumption certificates into digital assets registered on the chain, transfers the value of digital assets in the point-to-point network, increases the liquidity of certificate assets, realizes the whole process traceability, and the transparency and controllability of the whole process of generation, circulation and transaction of renewable energy power consumption certificates, Solve the problems of cumbersome certificate issuance process, "credit enhancement" and "efficiency enhancement", and solve the problems of excessive certificate price and insufficient liquidity; The government, the trading center, other entities responsible for consumption and other parties witnessed together to realize the "several verifiable" of each renewable energy power consumption, save costs and improve the efficiency of renewable energy trading.

III.Research on Key Technologies of blockchain adapting to renewable energy power consumption demand

Blockchain technology has the technical characteristics of open mutual trust, multi-party consensus, tamper proof and whole process traceability, and has a high demand resonance and technical fit with renewable energy consumption responsibility weight business. Firstly, the multi-party consensus and tamper proof characteristics of blockchain are applied to realize the authenticity, reliability, tamper proof or repudiation of the whole process of consumption distribution and bookkeeping. It has technically guaranteed the credibility of all work. Secondly, apply blockchain smart contract technology to realize the operation of certificate transaction declaration and clearing on the whole chain, and support the flexible and reliable operation of large-scale point-to-point transactions. Thirdly, the blockchain chain storage structure is applied to track the source of renewable energy consumption throughout its life cycle, so as to eliminate omission and tampering. Fourthly, apply blockchain identity authentication technology to realize cross domain unified security management of renewable energy consumption identity, reduce key management cost and improve user experience.

A.High-speed hierarchical asynchronous consensus mechanism

The consensus mechanism is responsible for coordinating and ensuring the consistency of data records at all nodes of the renewable energy power market trading network. Under the coordination of the consensus mechanism, the account books of each node are shared together, so as to realize the functions of node election, data consistency verification and data synchronization control. As a data structure that stores data in chronological order, the blockchain can support different consensus mechanisms. The implementation of consensus mechanism should comprehensively consider many requirements such as application environment and performance. The specific implementation scheme is shown in Figure 1.

This paper Adopts the fragmentation technology supporting high-speed transactions, improving the large-scale transaction throughput of the blockchain, and supporting the hierarchical topology in a variety of physical networks between transaction subjects in multi-form distributed energy transactions, so as to improve the ability and efficiency of reaching consensus on the multi-level architecture of the blockchain and ensure the security of the system architecture. The consensus algorithm, which couples the distributed power transaction business logic in the partitioned network, takes both or more parties as the consensus subject, simplifies the consensus process and improves the consensus efficiency. The high-speed hierarchical asynchronous consensus mechanism between slices is adopted to reduce the coupling degree of

consensus reached between slices on the time scale, ensure the consensus between blockchain nodes without accurate time synchronization, and support the integration of reliable new energy transactions and the underlying platform of blockchain.

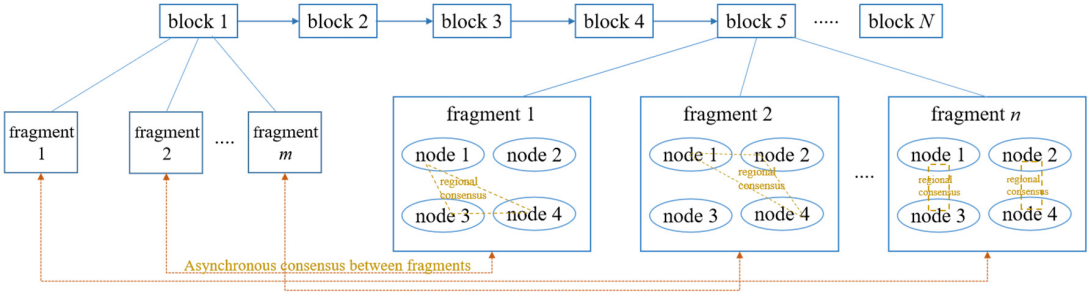

Fig.1 Implementation scheme of high-speed hierarchical asynchronous consensus algorithm

B.Atomic intelligent contract based on business rules

Atomic contract is a modular and single function tool program without business attributes. It is usually divided into signature type, certificate type, query type, etc. Disassembling smart contracts into simpler atomic contracts can improve contract processing speed and reduce development workload.

In a variety of transaction processes, authentication and signature verification are the basic functions required in various transaction scenarios. Atomic contracts with independent functions, based on the characteristics of agile development, rapid evolution, convenient fault tolerance and elastic scalability of microservice technology, can provide event monitoring function for consistency reconciliation during smart contract operation, and decouple the deployment of some application scenarios and contracts while improving contract service efficiency. In the transaction process, different atomic contracts are called each other to form a smart contract with complex transaction functions. The schematic diagram of atomic contract call is shown in Figure 2.

At the development level, some general atomic contracts do not need repeated development. When a new transaction scenario or mode appears, the existing atomic contract is called and combined through the interface to form the basic service for the new scenario service; Or customize and develop personalized contracts based on existing services to adapt to different transaction scenarios, which can reduce the workload of contract development.

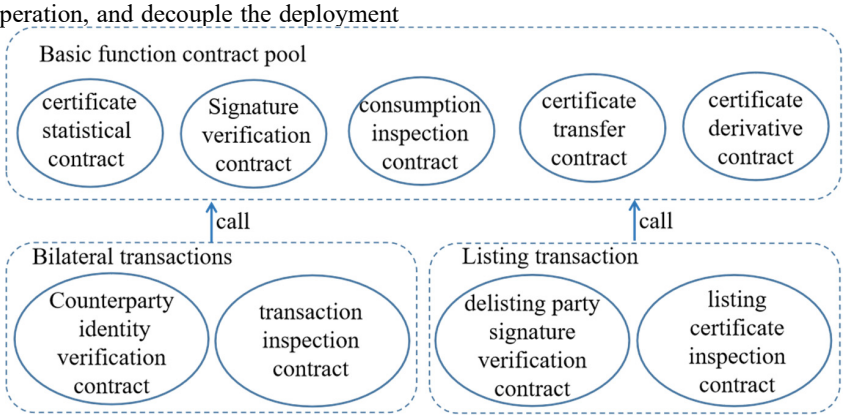

Fig.2 Schematic diagram of atomic contract call

C.Blockchain storage optimization scheme

With the increasing amount of stored data, blockchain storage is facing new challenges: one is capacity expansion. The blockchain storage application system requires each node to store a complete data, which requires high storage space for nodes and is also a waste of storage resources. The other is storage structure expansion. Relational database can design the data type and size according to the needs of business applications, but blockchain can not meet the management of personalized business data. Therefore, blockchain storage optimization has attracted more and more attention.

At present, there are two ways to optimize the storage of blockchain nodes. One way is to change the existing blockchain system architecture. The other way is to delete old data. Changing the existing blockchain system architecture will require the consent of most nodes, which will face security risks such as system hard bifurcation. Deleting old data is to directly delete the historical data of the blockchain, which will cause the loss of data and the traceability of the blockchain. Therefore, how to reduce the storage overhead of nodes without reconstructing the existing blockchain and losing its traceability is a problem worthy of study.

Among the methods to reduce data redundancy in blockchain, the methods of pruning data and reconstructing system architecture are more popular. Pruning data is a way to delete old data directly. Pruning data will lose the traceability of the blockchain. The blockchain that loses traceability will lose many application scenarios, such as audit, product

traceability, etc. The way to reconstruct the blockchain is to modify the existing blockchain system architecture, such as fragment system. Slicing system is to store data in different memory chips to reduce redundancy. The partitioned blockchain system modifies the original blockchain protocol to process and verify transactions in pieces, and the data stored in each piece is different, so different sub committees need to constantly interact to verify new transactions.

D.Blockchain cloud lightweight identity authentication technology

At present, most of the business systems in the power industry use the centralized identity authentication system. However, the centralized identity authentication server is vulnerable to malicious attacks and risks such as single point of failure. The distributed architecture of blockchain technology meets the needs of identity authentication. Multiple organizations build trusted alliance networks, and decentralized nodes run on multiple servers, eliminating the dependence on centralized servers. The blockchain based lightweight identity authentication system proposed in this paper does not rely on digital certificates and special media, and highly matches the trusted identity confirmation requirements in the renewable energy consumption scenario.

Taking the key segmentation of public key cryptography SM2 algorithm as an example, the application and implementation process of key segmentation in digital signature is studied and developed. The interaction of Internet data mainly comes from between the client and the cloud. Key segmentation divides the private key into two parts, one is stored in the client and the other in the cloud. The private key component of the user is directly stored in the mobile terminal, and the private key component of the cloud is kept by the server. When the user is executing the digital signature requirement, The user calculates the private key component of the client by calling the private key component of the client. The cloud uses user name, password and gesture verification to authenticate the user's identity. After calling the private key component of the cloud, the signature component of the cloud is calculated with the signature of the signature data, and the final signature component is generated after the computation of the private key component of the client end and the cloud. The process and technical principle of blockchain based lightweight identity authentication is shown in Figure 3.

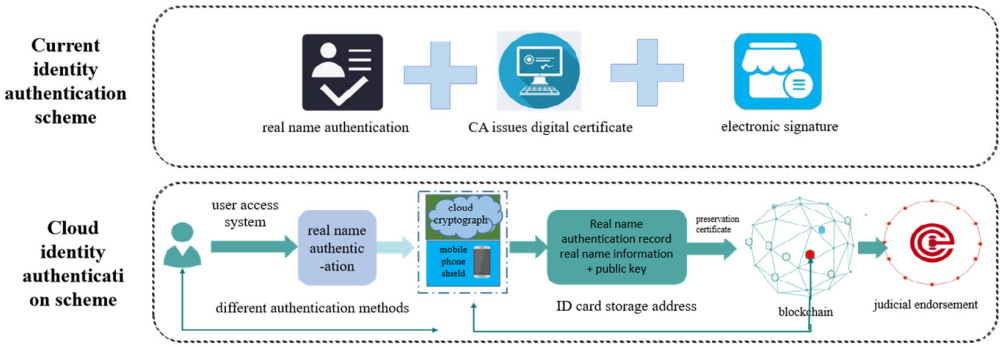

Fig.3 Blockchain based cloud lightweight identity authentication

IV.Management process of renewable energy power consumption certificate based on blockchain

A.Issuance of consumption certificate

The anti-counterfeiting issuance of renewable energy power consumption certificate is completed by the renewable energy power consumption certificate management smart contract. In order to ensure the credibility of the issuance link, the issuance of certificates will be recognized throughout the network as a transaction in the blockchain network, in which the type of renewable energy, consumption of renewable energy, certificate holder and other information will be permanently stored in the blockchain and cannot be tampered with.

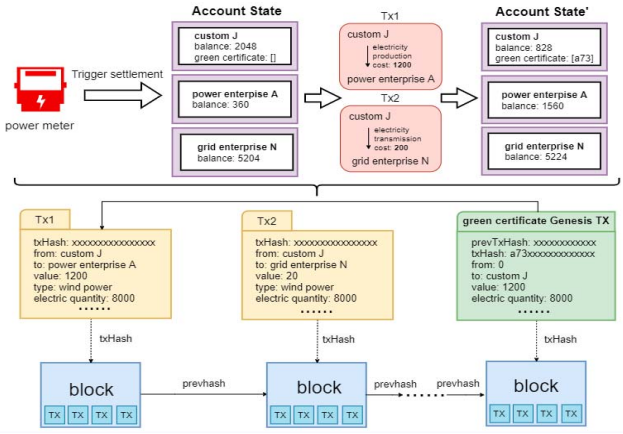

Fig.4 Examples of fee clearing and green card issuance transaction process

The issuance of consumption certificates is jointly endorsed by highly trusted authoritative nodes and verified by all participants. After consensus on the chain, a digital excess

consumption certificate is generated, which breaks the original double entry bookkeeping mode, ensures that the data can not be tampered with and forged, greatly improves the authority of the certificate, and lays a solid foundation for the nationwide renewable energy consumption certificate transaction.

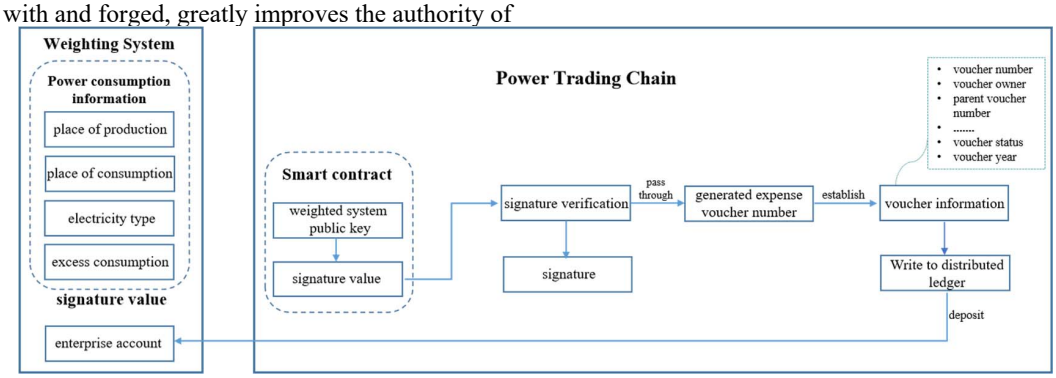

Fig.5 Blockchain certificate issuance flow chart

B.Consumption receipt transaction

The renewable energy certificate transaction processis shown in Figure 6. The main processes are described as follows:

(1) The buyer and the seller of the renewable energy consumption certificate submit the consumption quantity and quotation to be purchased / sold to the blockchain node in the form of a power of attorney, and freeze the corresponding amount in the buyer's account.

(2) After the blockchain node verifies the user's identity information, the consensus stores the corresponding entrustment form.

(3) The matching node in the blockchain regularly triggers transaction matching by using the entrustment form, and returns the matching result to the buyer and the seller after the consensus is stored.

(4) After the blockchain is verified, transfer the frozen purchaser's funds to the seller's account and complete the transfer of ownership of renewable energy consumption certificates.

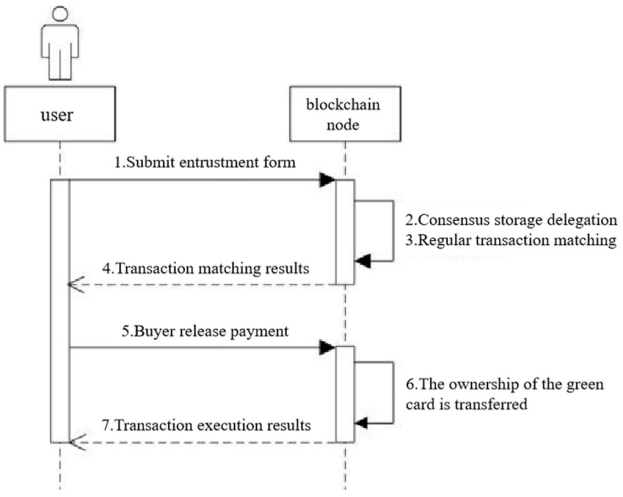

Fig.6 Sequence diagram of renewable energy certificate transaction

C.Consumption certificate accounting

The calculation of consumption is shown in Figure 7. The measurement of electricity purchased by market entities, the transaction of excess consumption and the green certificates subscribed by market entities are all stored in the chain. The consumption in the above three aspects is counted and calculated in the annual accounting stage, and the total consumption responsibility weight and non-water consumption responsibility weight of each provincial administrative region are issued accordingly. Due to the use of blockchain for energy transactions and excess consumption transactions, the power, time and energy type of each transaction can be traced to the source. The accounting can be handled separately by the authority indicated in the notice of the new quota system, or directly connected to the power trading blockchain and excess consumption trading blockchain system as a supervision node to intelligently complete the information summary and accounting through smart contracts.

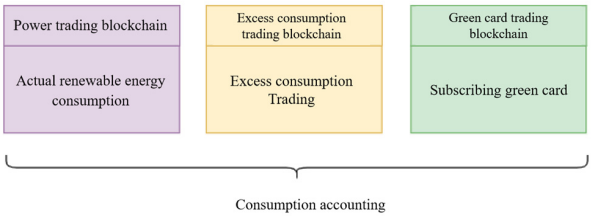

Fig.7 Consumption accounting

D.Traceability of consumption certificate

All consensus nodes of the blockchain participate in the transaction data recording, and the characteristic data such as issuance information, circulation information and derivative information of certificates are registered on the blockchain without tampering, so as to realize permanent storage. Each transaction record is connected to generate data blocks in the form of time stamps, which completely tracks the flow chain of transaction information, solves the problems of information island, poor information flow and lack of mutual trust, and realizes the traceability of the whole life cycle of certificates.

The matching transaction contract of renewable energy consumption certificates is triggered and executed regularly

by the matching node of the blockchain. Each transaction records the identity, quotation, selling price, transaction price and trading volume of the buyer and the seller in detail, and forms a transaction chain in the form of blocks. All data can be traced and effectively prevent data tampering. Through the design of query interface, each provincial administrative region can accurately grasp the current consumption of renewable energy in their respective responsible areas and carry out effective control.

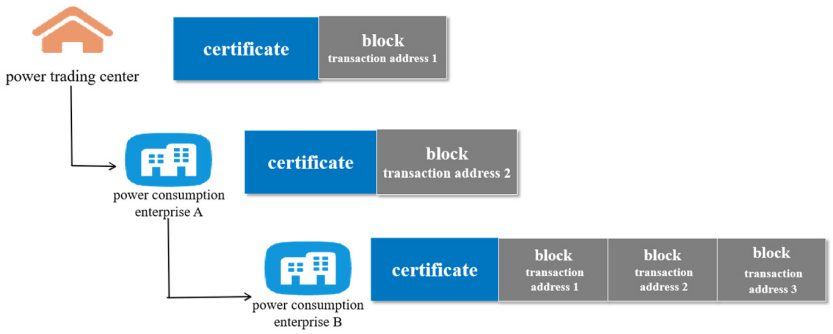

Fig.8 Certificate traceability based on blockchain

V.Conclusion

In this paper, blockchain technology is introduced into renewable energy consumption certificate transaction, which turns the consumption certificate into a digital asset registered on the chain, transfers the value of digital assets in the point-to-point network, increases the liquidity of certificate assets, realizes the whole process traceability, and the transparency and controllability of the whole process of renewable energy power consumption certificate generation, circulation and transaction, Solve the problems of cumbersome certificate issuance process, "credit enhancement" and "efficiency enhancement", and solve the problems of excessive certificate price and insufficient liquidity; The government, the trading center, other entities responsible for consumption and other parties witnessed together to realize the "several verifiable" of each renewable energy power consumption, save costs and improve the efficiency of renewable energy trading.

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