Research on Energy Trading Mechanism of Zero carbon Park Based on Blockchain Technology

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Abstract. In the context of global climate change and various environmental problems, stabilizing the global average temperature, implementing near zero carbon emissions, and finally achieving absolute zero carbon emissions in the future have become an important task of China's ecological civilization construction. As an important population and industrial cluster, the park is the carrier of important economic and social activities, so the park is the most important form to achieve the dual carbon goal. Based on blockchain technology, this paper comprehensively uses carbon neutral mechanisms such as zero carbon energy substitution, low carbon technology, carbon sequestration and carbon sink, and purchase of voluntary emission reductions to gradually reduce the carbon emissions in the park to zero, and finally realizes intelligent and automatic management of carbon emission reduction management in the park.

1. INTRODUCTION

In September 2020, China clearly put forward the goals of "carbon peak" and "carbon neutral", which pointed out the direction for the development of various industries1. In March 2021, the government work report listed "doing a good job in carbon peaking and carbon neutralization" as one of the key tasks, and pointed out that the action plan for carbon emission peaking by 2030 will be formulated, the industrial structure and energy structure will be optimized, and new energy will be vigorously developed2. The park is a special regional structure created by the government, enterprises or other organizations in order to achieve functional goals such as industrial development. It is the most important population and industrial cluster, the most important spatial carrier of economic and social activities, and an important spatial form for regional economic development, industrial transformation and upgrading, and functional realization. More than 90% of urban residents work and live in the park, and more than 80% of GDP and more than 90% of innovation are generated in the park, so the park is the most important form to achieve the dual carbon goal3. Building a zero carbon park plays a vital role in realizing the national dual carbon strategy. The zero carbon smart park is built on the basis of a digital smart park that is fully empowered. Digital means run through the whole process of the construction and operation of the zero carbon park, promoting the realization of low-carbon energy supply, low-carbon economic development mode, further reducing carbon emissions, and improving industrial competitiveness.

Blockchain is a distributed shared ledger technology based on a variety of technologies[4]. In essence, it is a distributed database that is jointly maintained by multiple parties. The decentralized or polycentric data management mode relies on participating nodes to jointly maintain the growing data chain and decentralized consensus mechanism, ensuring the credibility of data based on verification. The technical features of the blockchain include collective maintenance, transparency and trustworthiness, non counterfeiting and anti tampering, high reliability, etc56.Cross chain refers to the circulation of value and information between different blockchains through technical means. At present, cross chain technologies include notary mode, side chain relay mode, hash locking mode, and distributed private key control78.

Blockchain originated from Bitcoin and is a supporting technology in the field of cryptocurrency. In recent years, many researchers have applied blockchain to the energy field, such as green power trading, green power traceability. These studies have promoted the development of energy with the support of a new generation of information technology.However, for building a zero carbon smart park, the management of multiple energy sources in the park and the information interaction between different energy sources pose challenges to the application of the blockchain. To achieve the carbon emissions of the industrial park close to zero or even zero emissions, not only the information transparency of the internal energy carbon emissions data is required, but also the information interaction with the green power market and the carbon emissions trading market outside the park is required to achieve the dynamic balance of zero carbon emissions of the entire industrial park.

This paper proposes an energy trading system for a

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near zero carbon emission park based on the blockchain, including the park regional chain and the energy supply blockchain. The park regional chain and the energy supply blockchain process the energy trading data based on the cross chain interaction model constructed by the consensus of the ant colony algorithm, and finally achieve the "zero carbon emission" of the park.

2 OVERALL STRUCTURAL SCHEME OF ZERO CARBON PARK

This paper proposes an energy dispatching method and system for the zero carbon smart park, which involves the blockchain field and is used to solve the carbon emission reduction management problem of the smart park. Technically, it is to use blockchain technology to establish the connection between the park's regional chain, green card market chain and carbon market chain, establish heterogeneous energy sub chains within the park, and achieve rapid transactions of different energies through smart contracts to improve energy utilization efficiency. First of all, from the perspective of energy input of the smart park, when the distributed renewable energy in the park, such as photovoltaic power generation and wind power generation, cannot provide enough power to maintain the normal operation of the park, it is necessary to purchase green certificates from the green certificate trading market to ensure 100% green power supply for the entire park. At this time, a cross chain interactive management scheme between the two regional chains is designed to achieve rapid circulation between the park and the green certificate market; Secondly, for the internal part of the smart park, there are many different energy sources, such as electricity, heat, gas, etc. If the single chain structure is used between different energy sources, it will cause data structure expansion, large concurrent transactions, heavy network server burden and other problems. Therefore, this paper uses heterogeneous energy sub chains to achieve transactions between comprehensive energy sources in the park, improve transaction efficiency, reduce energy waste and reduce carbon emissions; Finally, the smart park will inevitably produce a large amount of carbon

dioxide emissions, such as fuel vehicles, gas, oil plants and buildings. In addition to some necessary means of carbon capture and utilization, carbon sink and negative emission technology, carbon quota and carbon trading will be used to offset carbon emissions, so as to achieve zero carbon emissions in the whole smart park, Use blockchain technology to achieve transaction management between the park's regional chain and the carbon market chain.

Through the above three ways to control the carbon emissions of the entire park from the source to the output, it is known that the park achieves 100% green power supply from the input side, including distributed photovoltaic, wind power, biomass power generation, energy storage and photovoltaic wind power purchased from the green card market in the park, as shown in the following formula. Therefore, it is only necessary to consider controlling carbon emissions and offsetting the carbon dioxide generated in the park in a certain period by means of carbon capture, carbon sink, carbon trading and other means. In fact, it is a mathematical optimization problem. The optimization goal is to minimize or even close to zero carbon emissions in the park in a certain period.

$$P = P_f + P_g + P_s + P_c + P_l \tag{1}$$

$$C = C_1 - CCUS - C_2 + \eta \tag{2}$$

P represents the total electricity required by the park in a certain period of time，P_f、P_g、P_s、P_c、P_l represent wind power, photovoltaic, biomass wind power, energy storage and green power purchase respectively. C refers to the carbon emissions of the park, C_1 refers to the carbon emissions generated by various activities in the park, including the amount of carbon dioxide excluded from the burning of fossil fuels, the use of fuel vehicles, etc.,η refers to the errors caused by measurement errors, and C_2 refers to the amount of carbon offset, including carbon quotas, carbon trading, carbon capture, etc.

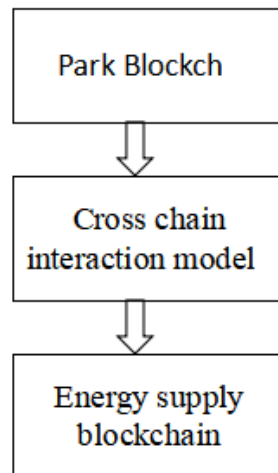The specific steps of energy trading in the park are:

Figure 1 Construction process of zero carbon park

3 PARK ENERGY TRADING SCHEME BASED ON BLOCKCHAIN TECHNOLOGY

3.1 Cross chain method of blockchain

3.1.1 Cross chain Exchange Model Based on Ant Colony Algorithm Consensus

Because the energy types and blockchain network topology are different, the blockchain system has problems such as low consensus computing efficiency, limited trading capacity per unit time, and compatibility and interoperability between different blockchain systems. This paper proposes a consensus cross chain interaction model based on ant colony algorithm. The model divides the nodes in the blockchain system into consensus service nodes, cross chain exchange nodes and application nodes. Connect the consensus service nodes with efficient computing capability together through high-speed network to form a blockchain P2P network serving the energy field, and provide consensus computing services for the application nodes in the blockchain network; Connect the cross chain exchange node to different blockchain networks at the same time, synchronize the block data of different blockchains, form the state database of different blockchain networks on this node, and provide cross chain access services for different blockchain network application nodes based on the P2P protocol blockchain exchange network between exchange nodes; Application nodes can synchronize data, access cross chain exchange nodes, and send intra chain or cross chain transactions from their own blockchain network consensus service nodes.
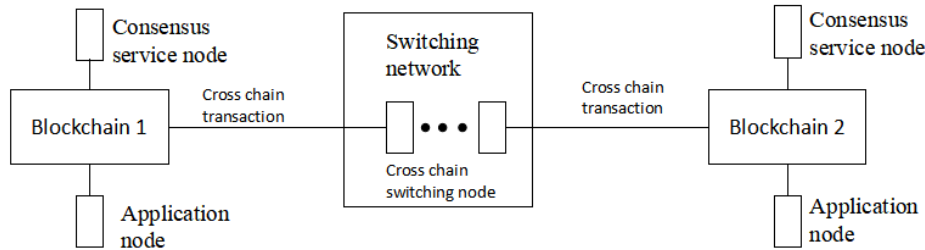

Figure 2 Cross chain overall architecture

Deployment revolves around consensus service nodes and cross chain switching nodes, which is actually an optimization problem. Given the sample application node application node $F = \{x_1, x_2, \cdots, x_m\}$, k is the number of consensus service nodes. The set of consensus service nodes is C={C1, C2,..., Ck}. Consensus cross chain exchange:

$$E = \sum_{i=1}^{k} \sum_{x \in C} \|x - \mu_i\|_2^2 \qquad (3)$$

$\mu_i = \dfrac{1}{|c_i|} \sum_{x \in C} x$ is the mean vector of c_i, and the smaller the E value is, the smaller the cost is. In the case of fixed application nodes, reasonable consensus and cross chain switching node settings can minimize the cost of network transmission and achieve the optimal situation, so that the efficiency of transaction and consensus will reach the highest.

Since consensus nodes and exchange nodes need to be selected, greedy algorithm can be used to find the optimal consensus service and exchange node, but the algorithm complexity is too high, and the accuracy is not as good as ant colony algorithm when the amount of data is too large, so ant colony algorithm is used to select. This algorithm is mainly based on the mutual cooperation of groups, forming a positive feedback mechanism through "pheromone", and finally finding the global optimal solution, The algorithm is mainly based on the pheromone between application nodes for indirect communication, and finally finds consensus nodes and exchange nodes. When selecting the next transition node, the node is selected according to probability, which is determined by pheromone and node visibility between two nodes. Assume that at time t, the ant will choose to transfer to the next node j at the current node i, where the probability is9:

$$p_{ij}^k = \begin{cases} \dfrac{\tau_{ij}^{\alpha} \eta_{ij}^{\beta}}{\sum_{s \in O} \tau_{is}^{k} \eta_{is}^{\beta}}, & j \in O \\ 0, & \text{, otherwise} \end{cases} \qquad (4)$$

O represents the node set to which the ant will go next, τ_{ij}^{α} represents the pheromone factor on node edge e_{ij}, and η_{ij}^{β} represents the visibility between nodes i and j. The corresponding edge e_{ij} pheromone increment between any two nodes is as follows10:

$$\begin{cases} \tau_{ij}(t+1) = \rho \tau_{ij}(t) + \Delta \tau_{ij}(t, t+1) \\ \Delta \tau_{ij}(t, t+1) = \sum_{k}^{m} \Delta \tau_{ij}^{k}(t, t+1) \end{cases} \qquad (5)$$

$\Delta \tau_{ij}^k(t, t+1)$ is the pheromone increment contributed by ant k to edge e_{ij}, $\Delta \tau_{ij}(t, t+1)$ is the pheromone contribution of all ants passing through the edge to edge e_{ij}, and ρ is the pheromone residual coefficient, $\Delta \tau_{ij}^k(t, t+1)$ is adjusted by ant density model:

$$\Delta\tau_{ij}^{k}(t,t+1)=\begin{cases}Q,e_{ij}\\0,otherwise\end{cases} \quad (6)$$

When each ant passes through nodes i and j, the pheromone increment contributed to the edge e_{ij} is constant, and the length of each unit is Q. The parameters are set according to the scale of the blockchain network node, and the optimized search is carried out through the above formula to finally obtain the desired node.

3.1.2 Privacy protection

Due to the openness and transparency of blockchain data, users' privacy is challenged. In particular, each energy supplier has a strong demand for energy data. Based on this, a transaction module is arranged on the cross chain exchange node for the above cross chain scheme. The transaction module is built with an information transmitter and a verifier to protect data security. The method of shell proof with zero knowledge range is adopted here. The shell proof is composed of inner product range proof and improved inner machine parameter protocol. The inner product range proof is to blindly add the inner product of random numbers. The inner product here is represented by the range of secret values. On this basis, the inner product parameter protocol combines polynomials. The role of the verifier is to verify whether the polynomials are correct, and thus obtain the legitimacy of the secret values. The improved inner product parameters are demonstrated as follows[11]:

$$z = g^{a} \cdot h^{b} \cdot \mu^{c} \quad (7)$$

Compress the parameters in dimensions, and split the vector protocol n-dimensional vectors a and b and n-dimensional elements g and h into half, as shown below[12]:

$$\begin{cases}a'=xa_{[1:n/2]}+a_{[n/2+1:n]}\\b'=b_{[1:n/2]}+xb_{[n/2+1:n]}\\g'=g_{[1:n/2]}\cdot g_{[n/2+1:n]}^{x}\\h'=h_{[1:n/2]}^{x}\cdot h_{[n/2+1:n]}\end{cases} \quad (8)$$

The improved parameter vector is as follows:

$$\begin{cases}a=(a_{[1:n/2]},a_{[n/2+1:n]})\,b=(b_{[1:n/2]},b_{[n/2+1:n]})\\g=(g_{[1:n/2]},g_{[n/2+1:n]})\,h=(h_{[1:n/2]},h_{[n/2+1:n]})\end{cases}$$

(3) System functions and cross chain processes

In this paper, the blockchain divides nodes into three categories: application nodes, consensus service nodes, and cross chain switching nodes. The nodes have multiple built-in modules, such as data synchronization module, data access module, and transaction sending module. For cross chain switching nodes, the transaction verification module is added to achieve data privacy protection. When the broadcast module is added, it can provide the government and other regulators with regulatory channels during cross chain transactions to achieve compliance and legalization. The system function diagram is as follows:
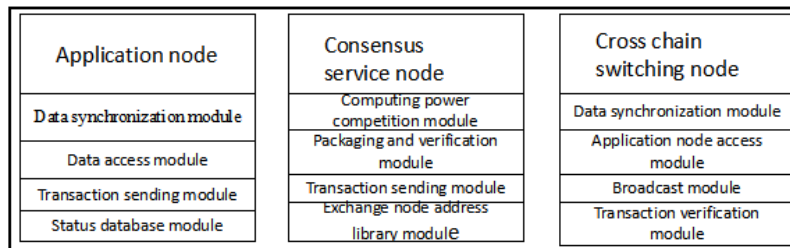

Figure 3 System Function

Cross chain process:
1. The application node initiates cross chain requests;
2. Cross chain nodes query the target blockchain transaction format and feed it back to the application node;
3. The application node sends transactions;
4. Cross chain nodes send messages to the destination, verify the correctness of the data, and broadcast to the supervisor at the same time;
5. After receiving the target blockchain consensus node, it will join the new block through computing power competition.

3.2 Transaction between zero carbon smart park and green power market

In order to reduce the carbon emissions of the smart park, the interaction between different chains is realized based on the blockchain cross chain technology. From the perspective of energy input, in addition to distributed renewable energy such as photovoltaic, wind energy and bioenergy in the park, external green power supply is also required to achieve 100% green power supply in the park.
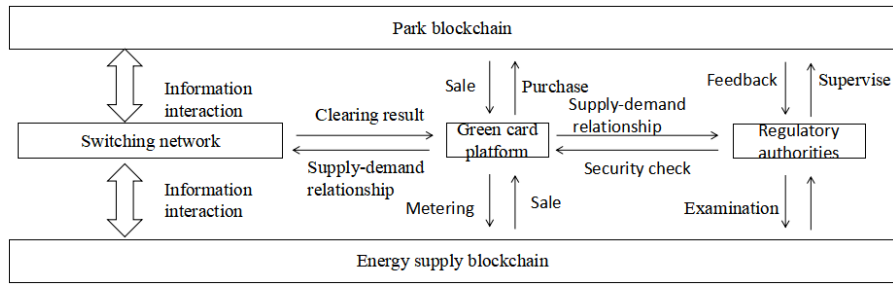
Figure 4   Schematic Diagram of the Park— Green Power Market Transaction

It can be seen from the above figure that green power transactions involve both zero carbon smart parks and new energy power generation manufacturers. The new energy power generation manufacturers represent the new energy regional chain, and the smart parks represent the regional chain of smart parks. A cross chain interaction model is designed to coordinate the information and capital exchange between the two chains. While producing green electricity, new energy power generation manufacturers have been certified by the green certificate platform, and can sell the green certificate to the green certificate platform; The government supervision department plays the role of review and supervision; The zero carbon smart park triggers the smart contract on the chain by purchasing the green certificate of the green certificate platform, and automatically signs the green electricity purchase agreement. That is, the green certificate can also be transferred to the smart park immediately.

3.3 The transaction between zero carbon smart park and carbon trading market

From the perspective of carbon emissions, in order to minimize the carbon emissions in the park, carbon monitoring devices are used to monitor the total carbon emissions in the hospital area at all times, and CCUS carbon capture, utilization and storage and carbon sink are used to absorb some carbon dioxide. In addition, quota system and carbon trading are used to trade with the carbon market to further control carbon dioxide emissions from the output. The carbon quota is the quota issued by the government to each unit in the park free of charge. The industrial park converts the carbon emissions into the actual carbon emissions through the detection of carbon emissions and uploading them to the chain. The chain smart contract realizes automatic deduction of the quota, automatic declaration of enterprise emission reductions, etc; The park can also conduct two-way transactions with the carbon market to sell the remaining carbon emission rights; When the carbon quota is exceeded, purchase carbon emission rights through the carbon trading market.

The following figure describes the transaction process between the smart park and the carbon trading market. The smart park represents the regional chain of the smart park, the carbon trading market represents the carbon market chain, and the exchange network is responsible for the information asset interaction between the two regional chains; In a certain period, when the total carbon emissions of the smart park are less than the quota, the carbon balance can be traded across the chain to the carbon market through the smart contract on the chain; When the total carbon emission of the smart park is greater than its own quota, it needs to purchase the carbon quota of enterprises with surplus quota in the carbon emission market, or the CCER of enterprises with voluntary emission reduction, that is, to certify voluntary emission reduction. The smart park has zero carbon emissions through two ways of trading.
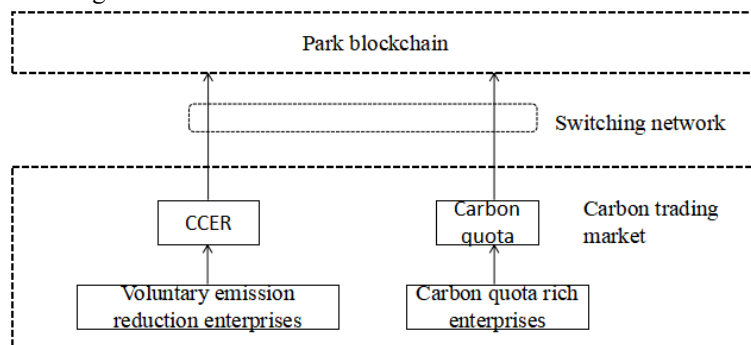

Figure 5   Park Carbon Market Transaction Chart

3.4 Transactions between integrated energies within the zero carbon smart park

From the perspective of the internal energy utilization efficiency of the park, on the one hand, the data structure and transaction type of various energy data are different, on the other hand, the data in the energy transaction process is also not shared and disclosed by power grid, natural gas and other manufacturers, for example, the natural gas data is generally in the hands of natural gas manufacturers. Therefore, each service provider establishes its own energy heterogeneous sub chain, and each energy sub chain selects the alliance chain structure. The use of energy heterogeneous sub chain can greatly reduce the construction cost of users, improve data security and transmission speed, and improve energy

utilization efficiency. By allocating a large amount of complex work in each energy field to each heterogeneous energy sub chain, the main chain in the park area only records the final data of each transaction and verifies whether it is correct.

Figure 3 details the transaction process between integrated energy sources in the park. The energy sub chains realize bilateral transactions through smart contracts. The smart contracts deployed in the blockchain can act as market makers for both parties to achieve equal status and transparent information. The comprehensive energy in the park includes photovoltaic, wind energy, biomass power generation, energy storage and other power chains, and gas, refrigerator and other energy chains. Each energy sub chain realizes the purpose of convenient transaction, optimal price and optimal efficiency through cross chain transactions.
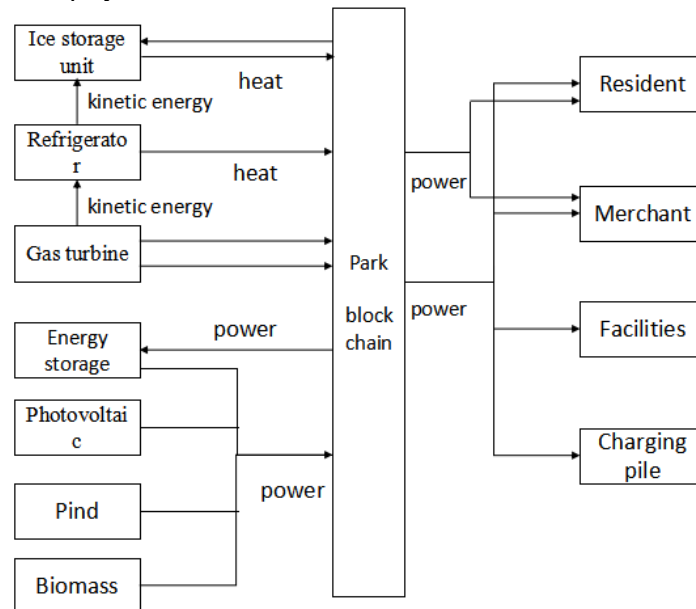

Figure 6　Comprehensive Energy System of the Park

4 CONCLUSION

This paper solves the problem of comprehensive emission reduction in smart parks and the problem of difficult interaction between different energy blockchains. To solve these problems, we use blockchain technology to design a cross chain exchange model based on the consensus of ant colony algorithm, considering privacy protection and government regulation; The cross chain method based on the consensus of ant colony algorithm is adopted to realize the information interaction between the park regional chain, green power market and carbon trading market, and the optimization of comprehensive energy is realized based on the cross chain comprehensive application of the energy sub chain in the park; On this basis, considering the carbon emissions of the entire park, the system optimization has been carried out from the generation, utilization and control stages, which will enable the smart park to truly achieve the zero carbon goal.

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