Research on Carbon Emission Management of Electric Power Enterprises Based on Blockchain Technology

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Abstract: As a high energy-consuming industry, it is especially important for electric power companies to manage carbon emissions well. This study analyzes the main problems of electric power companies in carbon asset management, and investigates the methods of intelligent, digital and transparent management of carbon emission situation using intelligent Internet of Things and blockchain technology. Carbon emission management based on blockchain technology can improve the accuracy and openness of carbon asset data and promote electric power companies to move forward to the low-carbon ecological era.

1 Introduction

One of the greatest challenges to human development today is global climate change, and a report released by the IPCC (Intergovernmental Panel on Climate Change) in October 2018 concluded that keeping global temperature increases to 1.5°C would help avoid the deterioration of the Earth's climate, human health, and ecosystems, and that achieving this goal would require net-zero global greenhouse gas emissions by the middle of the 21st century [1]. China accounts for 28.8% of global energy carbon emissions, and therefore, the effect of China's carbon reduction has an extremely important impact on global carbon peaking and carbon neutrality [2,3].

According to the guidelines issued by China, electric power, petrochemicals, chemicals, building materials, iron and steel, non-ferrous metals, paper, and civil aviation are the eight high-energy consuming industries included in the national carbon market. Electric power companies are required to disclose their carbon emissions regularly every year. In the future, with the increasing number of subjects involved in carbon emissions and the expanding scope of the carbon trading market, it is especially important for the power enterprises that are included in the management of carbon emission allowances to manage their carbon emissions [4,5].

Blockchain, as one of the emerging digital technologies in recent years, has gained increasing attention due to its technical advantages in safeguarding data authenticity and integrity and improving data transparency [6,7]. The distributed data interaction and real-time data iteration of blockchain technology as well as the secure storage and tamper-proof function of quantum blockchain [8] can meet the personalized demand of carbon emission management, avoid the generalized measurement of marginal clearing price, implement the fine management of carbonization of power trading emissions, and improve the security of carbon market transactions and the privacy of retailers' information. Therefore, coupling carbon emission management with blockchain technology is a sure way to optimize the ecological environment.

2 Problems in traditional carbon asset management

Large power companies have many subsidiaries around the country, and each subsidiary collects, manages and stores its own carbon emission data, but the data management is not transparent and prone to tampering, and the centralized storage of data by different subsidiaries creates data "silos". In addition, the quality of carbon emission data collected by different subsidiaries varies, and there are problems such as difficulty in tracking and integrating key information, difficulty in reading relevant data, various data collection methods, and inconsistent data. Therefore, the centralized database of each subsidiary increases the difficulty of carbon emission report preparation for the parent company, and at the same time, it also leads to the lack of unified and credible carbon emission base data, which is detrimental to carbon trading [9].

Each subsidiary of a power company varies in terms of technical process, equipment level, energy utilization level, energy consumption measurement level, and product transportation method. Moreover, the amount of greenhouse gases emitted by each subsidiary varies from high to low when producing the same amount of electricity, due to the fact that some units optimize the production process of a certain segment and some units use cleaner energy for power supply, heating or transportation, which results in different units having different emission reduction capacity for the same production segment [10].

At the end of each compliance year, power companies are required to write off a certain amount of carbon

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allowances based on their carbon emissions. If there is a shortage of carbon allowances, they need to go to the market to purchase the corresponding carbon allowances and CCERs (nationally certified voluntary emission reductions) for compliance. If the cost of purchasing carbon allowances is much higher than the cost of emission reduction, the profit of the power company will be squeezed [11]. Therefore, for the key emitters of electric power, proper management of carbon assets can significantly reduce the operational input costs, improve competitiveness and increase their profitability; improper management and operation may eventually lead to significant loss of carbon assets, increase the overall operation and maintenance costs of the company, reduce market competitiveness and affect the healthy and sustainable development of the company [12].

Therefore, building a decentralized, non-tamperable and traceable super carbon ledger will facilitate companies to track, reward and punish the carbon footprint of each link and optimize the path, thus reducing operating costs and improving low-carbon competitiveness. An accurate and granular carbon emission data is the foundation and prerequisite for companies to manage their carbon assets, and adds consistency and credibility to carbon trading.

3 Carbon emission accounting methods and data collection

To solve the carbon asset management challenges of power companies, this paper conceptualizes a carbon asset management blockchain that includes power companies, local carbon emission management departments, and third-party technical verification agencies.

3.1 Carbon Emissions Accounting Approach

In traditional power companies, greenhouse gas emissions mainly come from fossil fuel combustion emissions. The current carbon emission data are mainly accounted and measured by manual accounting method and continuous carbon emission monitoring technology.

The manual accounting method is costly, data collection is complicated, and the data collection and confirmation period is long, which is not conducive to the real-time grasp of carbon emissions in all aspects of the plant, and increases the difficulty of carbon emission preparation reports and verification by third-party institutions. At present, the international common practice is to adopt CEMS (carbon emission continuous monitoring technology) [13]. CEMS is a trend of future carbon emission measurement, which is conducive to the intelligent and digital management of carbon emission. Therefore, this paper adopts the accounting method of CEMS.

3.2 Carbon emission data collection

For direct carbon emissions, a carbon emission meter certified by the national or local environmental protection department can be installed at the carbon emission outlet to calculate the carbon emissions from that outlet in a continuous time interval. For the method of uploading data to the blockchain by the carbon emission meter, there are two options as follows.

3.2.1 Option 1

Using wireless communication module, a wireless communication module is installed at each carbon emission port. The wireless communication module receives the carbon emission data through the communication interface of the carbon emission measuring instrument, and then uploads the collected data to the cloud server of a node in time through the nearby wireless network or the traffic card in the module; the node that receives this carbon emission information will broadcast this information to other nodes, and the nodes on the chain will carry out technical verification of this information together, and if more than half of the valid nodes pass, all nodes will record this carbon emission If more than half of the valid nodes pass, all nodes will record the carbon emission information into their own carbon ledgers. It is easy to install, only need to install a wireless communication module next to each carbon emission meter, and the data is directly uploaded to the cloud server without the need to go through the third party equipment. However, the equipment is more expensive to build and maintain, and the data cannot be uploaded at high frequency. The high cost is due to the fact that each carbon emission port needs to install a wireless communication module and a traffic card, which makes the management of many traffic cards complicated and brings high cost. This solution is suitable for scenarios where there are few carbon emission ports and the frequency of uploading data is low, where the communication module is easier to manage and the maintenance cost is low.

3.2.2 Option 2

Using edge devices, each edge device receives carbon emission data sent by dozens of carbon emission meters. The edge device uploads the carbon emission data to the cloud server via wireless network or traffic card. This device can store and package and upload the data of dozens of carbon emission ports, and also make prediction based on the historical carbon emission data of each carbon emission port. The solution has lower equipment construction and maintenance costs, lower total power of the equipment, can use LAN for data transmission, and can also automatically control the collection frequency, process data, and collect data centrally for packaging and uploading. The same transmission of carbon emission data from dozens of carbon emission ports only requires the installation of 1 edge device and 1 traffic card or the use of a network port, so the cost and total power consumption are lower. Wireless edge devices can use Lora or Zig Bee for wireless networking [14], and in places where there is no network, the edge devices can also upload data by means of satellite communication. However, scalability is poor, and edge computing must add or physically upgrade devices for the organization to gain more computing power or storage space. This solution is suitable for scenarios with more carbon emission ports and frequent data uploads, and is more suitable for the application scenario of carbon emission of power companies.

4 Construction of PBFT (Practical Byzantine Fault Tolerance Algorithm) Blockchain Federation Chain

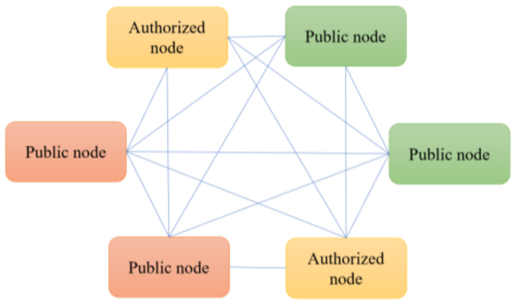

Figure 1. league chain

A Byzantine consensus-based blockchain 3.0 federated chain is constructed within the blockchain with a total of n (n=3 f+1) different subjects as nodes, and the fault tolerance of this blockchain does not exceed (n-1)/3 nodes [15].

Taking f=2 as an example, these 7 nodes have the same status, and 7 subjects whose interests are as unrelated as possible, such as power companies (2 internal nodes), local carbon emission management departments (2 internal nodes), third-party verification companies (1 node), local environmental protection departments (1 node), and carbon trading centers (1 node), are selected. Each subject is equipped with a cloud server to store its own carbon ledger data, and a carbon asset blockchain client software is installed in their respective offices. On the client, the node holder can see the carbon dioxide or methane emissions uploaded by the carbon emission collection point in time for each link.

There are 7 nodes in this blockchain and it is acceptable from the security and activity point of view that at most 2 nodes are failing and 2 nodes are malicious nodes at the same point of time. The failed node is unresponsive, i.e., suddenly disconnected or delayed in communication or deliberately not communicating, while the malicious node is maliciously controlled. Suppose in the worst case scenario, there are 2 honest nodes on this blockchain that are failing and 2 nodes that are malicious but still responsive, under the principle of majority rule and satisfying the block activity, the honest node can still beat the malicious node and successfully get out of the block. Even if the malicious node does not put the block on the ledger, but there is actually a consensus endorsing the block record, if the honest node goes to the malicious node to check the block, it can know whether its ledger has been tampered with by hash verification.

After the blockchain is constructed, each node can see the carbon ledger of the power company, and different application modules can be developed for different nodes.

5 Smart Contracts and Application Modules

5.1 Smart Contracts

In the above federation chain, the contract layer only contains the data verification smart contract, i.e., each node verifies the format of the received carbon emission data (technical verification). In this smart contract, the input is "a certain uploaded carbon emission record", and each node checks whether there is any problem with the format of the carbon emission record or whether there is any abnormality with the recorded data. If more than half of the valid nodes pass, then the transaction will be recorded in each node's book at the same time.

5.2 Application Module

In the application layer, some application modules can be developed according to the needs of power companies, such as carbon emission query module, carbon emission structure module, carbon emission reward and punishment module, one-click carbon emission report module, path optimization module, carbon emission forecast and carbon trading price forecast module, etc.

6 Conclusion

In this paper, we have studied how power companies can use IoT and blockchain technologies to build an intelligent, automated and transparent super carbon ledger. Based on the trusted carbon ledger, the company can know the carbon emission records of each department and each link at any time, and can make targeted optimization of the carbon emission situation. At the same time, the traceability feature of blockchain also makes the carbon emission report automatically generated by the company highly credible, which is convenient for verification by carbon emission management departments and third-party verification agencies. Based on the credible carbon emission data, companies can set their own emission reduction targets and plans.

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