Blockchain-based Economic Evaluation System for Environmental Equipment Operation

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Abstract. The operation economy of environmental protection equipment for thermal power units is one of the key indicators for promoting ultra-low emission and energy-saving advanced technologies. At present, the economic evaluation methods mostly use off-line data for statistics. The risk of data tampering is high, and the evaluation results can not guide the production and operation in time. Based on the blockchain technology, this paper designs an economic evaluation system for the operation of environmental protection equipment, saves the key data on the chain, uses artificial intelligence technology to establish a prediction model for the emission reduction effect of desulfurization and denitrification equipment, generates the economic operation evaluation results of the unit based on the smart contract technology, develops a verification system, and demonstrates the technical route. Experiments show that the system can provide strong support for power generation enterprises to improve the economy of equipment operation, and has certain reference value for the government to promote more reasonable carbon reduction paths and technologies.

Keywords: thermal power unit, economic evaluation, environmental protection, blockchain

1 Introduction

Thermal power plants are the main sources of smoke, SO2, NOx and other air pollutants. In order to cope with global climate change and achieve the strategic goal of "carbon peaking and carbon neutralization", in recent years, China has vigorously promoted the implementation of ultra-low emissions and energy-saving transformation projects in domestic power generation enterprises. The state has formulated a series of laws and regulations, plans and technical policies to promote the implementation of ultra-low emission transformation of qualified coal-fired units in service. At the same time, in order to achieve the balance between environmental protection and benefits, the state has also formulated a number of supporting policies such as electricity price, power generation, pollution discharge fee, etc., and has given electricity price subsidies to new units and active units that have reached ultra-low emission levels. In order to achieve ultra-low emission targets for a long time, power generation enterprises not only sacrifice the service life of equipment, but also increase additional costs through long-term overload operation of environmental protection equipment. Whether the

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operation cost of ultra-low emission technology is covered by electricity price subsidies is one of the important factors to promote ultra-low emission technology.

The economic index of ultra-low emission coal-fired power equipment is considered to be one of the key indicators for the promotion and application of ultra-low emission coal-fired power equipment and advanced energy-saving technology. In terms of economic evaluation, the Ministry of ecological environment issued the technical manual for cost-benefit analysis (CBA) of ultra-low emission transformation in the industrial sector, constructed the technical framework for the cost-benefit evaluation of ultra-low emission in the industrial sector, and conducted an in-depth analysis of the implementation effect of the ultra-low emission measures from the perspective of cost and benefit [1]. Zhang Yi et al. studied the emission standards and economic incentives for different units of coal-fired power plants in China, the United States and Europe, and explored the path to reduce emission reduction costs [2]. Luo Cong et al. established the cost assessment model of pollutant control technology to explore the impact of unit capacity, coal quality, operation time and the strategy of "increasing the size and reducing the size" on the operation cost [3]. Niuyongjun through DCS data analysis, the operation and economic indicators of desulfurization system were studied [4]. Gaomingkai et al. proposed the application of artificial intelligence technology to the optimization of the complexity of flue gas desulfurization process and the use of life cycle assessment (LCA) evaluation method, and compared the economy of environmental protection system under typical load conditions from the perspective of operation cost [5]. Lin Lin used artificial intelligence technology to comprehensively evaluate the operation of flue gas desulfurization and denitrification equipment from the operation level, coal consumption for power supply and emission [6]. In terms of data quality, the authenticity of economic evaluation data will have a significant impact on the actual value of evaluation results. Wang Jing studied the problem of data validity caused by pollution data falsification and non-standard operation of monitoring data, and put forward measures to curb data falsification [7]. Huqing and others believe that the data of environmental monitoring and economic operation indicators are faced with problems such as credibility and artificial fraud, and put forward a solution based on blockchain technology [8].

According to the literature research, the existing evaluation methods and models mainly use off-line data for statistics and formula calculation. With the continuous growth of new energy installed capacity and the change and fluctuation of load faced by thermal power units participating in peak shaving, the traditional evaluation method can not guide the production and operation in time. At present, it is urgent to consider carbon reduction and economic operation costs as a whole, and improve the comprehensive benefits of ultra-low emissions. Therefore, how to use advanced technologies such as artificial intelligence and blockchain to establish a credible intelligent evaluation system for the operation economy of environmental protection equipment, use the real-time data of unit operation to generate economic evaluation results, improve the economic indicators of equipment operation, and then bring economic benefits to the power plant is an urgent problem to be solved.

2 Technologies Status and Problems

2.1 Ultra-low emission technology of flue gas

At present, China's coal-fired power plants have achieved stable ultra-low emissions. Compared with conventional pollution control facilities, the cost of equipment investment and operation costs for ultra-low emission reduction has basically increased by about 30%, and some enterprises are closer to the level of "near zero emissions" [2]. The common desulfurization technologies mainly include dry desulfurization, wet desulfurization and semi dry desulfurization. The wet desulfurization technology has low cost, high efficiency and is widely used. The domestic denitration technology mainly uses SNCR denitration, SCR denitration and low-carbon combustion method for denitration. With the continuous reform of the national NOx emission standard, the simultaneous treatment of SNCR and SCR method for denitration is a trend in the development of Denitration Process. Desulfurization and denitrification are demanding in terms of technology and process. Pollutant emissions are related to unit capacity and coal type. The larger the unit size, the greater the emission reduction potential. In the process of unit emission reduction, it is found that the ultra-low emission units with the same technical route have large differences in pollutant emission levels, which indicates that the operation specifications and operating standards of environmental protection facilities in various power plants are inconsistent, and the economy of the units is also inconsistent. As a result, enterprises are facing different economic benefit pressures.

From generation to use, the online monitoring data of environmental protection is often collected by the continuous monitoring system (CEMS) to the distributed control system (DCS) of the power plant, and then transmitted to the storage device on the application side through the real-time monitoring information system (SIS). The data transmission chain is long and easy to be tampered with, which is specifically reflected in the mismatch of the logical relationship between the data, data loss Distortion or deviation from the normal operation level makes it difficult to trace the problem in the actual process, which affects the accuracy and reliability of the statistical analysis results.

2.2 Blockchain and smart contract technology

Blockchain technology originated from bitcoin. In "bitcoin: a peer-to-peer e-cash system" published by Satoshi Nakamoto, the concepts of P2P network technology, encryption technology, timestamp technology, block technology and so on are elaborated, marking the birth of blockchain technology. Blockchain technology has the characteristics of decentralization, transparency, openness, data non modifiability and traceability. The blockchain is stored through the chain structure of blocks. The block header of each block saves the state information of the blockchain itself and reflects it to the Merkle root of the block header to ensure that the information is not tampered with. The block body stores the transaction record information. All the information on the chain is encrypted asymmetrically and confirmed many times by each block, so as to ensure the safety, accuracy and reliability of the data on the chain. After more than a decade of development, blockchain technology has been not limited to the field of Finance and virtual currency, but has been widely used in many fields of the real economy [9-13].

Smart contract is a computer protocol deployed in the blockchain to form, verify or execute contracts in the form of code without the participation of a third party. The integration of smart contract technology and blockchain technology has increased the flexibility of transactions. By defining the transaction logic and access rules on the blockchain, it has changed the sequential execution mode of the traditional transaction system, greatly simplified the transaction and supervision process, and is more suitable for the actual complex transaction application scenarios [14]. Zhang Ning et al. proposed a distribution network transaction mechanism based on smart contracts, established a distribution network transaction mechanism model without central institutions, and designed a smart contract for multilateral power trading [15]. She Wei et al. proposed that the intelligent operation of the energy network system can be realized through the blockchain intelligent contract technology, and violations can be avoided without manual participation by enforcing the contract [16].

In the economic evaluation business of environmental protection equipment operation, the smart contract is not only responsible for storing the flue gas emission data of environmental protection equipment, unit status data and economic operation index data, but also can evaluate and score each unit according to the set time rules according to the economic evaluation rules of the unit operation. Through openness, transparency and smart contract technology, the non repudiation of original evaluation data and the objectivity and impartiality of evaluation scores are guaranteed.

3 System Design Based on Blockchain Technology

The economic evaluation system of environmental protection equipment operation based on blockchain technology proposed in this paper is a key data storage and contract evaluation system of flue gas emission based on blockchain technology, as shown in Figure 1. It records the key data of environmental protection equipment operation by using the characteristics of blockchain technology, such as decentralization, detrust, information transparency, data tamper ability and traceability, and reduces the risk of data falsification. The reliability of the original evaluation data cannot be guaranteed and the problem tracking is difficult due to problems such as working condition management and economic index management. At the same time, the evaluation rules are made into executable contract codes to maximize the fairness and impartiality of economic evaluation. The participants of the system include group units, regulatory units, secondary companies and power plants. The pollutant emission model is built based on the machine learning algorithm of artificial intelligence. The original data and calculation results of the model also ensure the data traceability of the evaluation system through the blockchain.

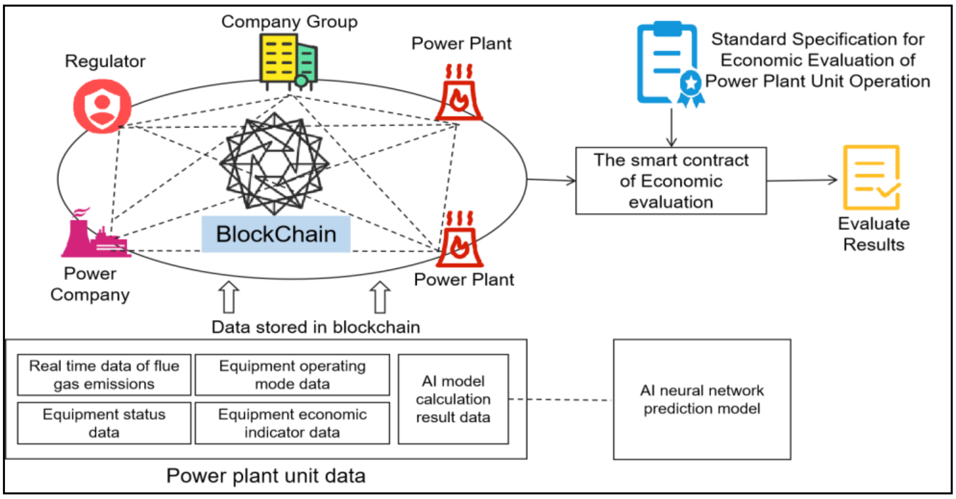

Fig. 1. System design chart.

3.1 Overall system design

The platform architecture can be divided into three layers, including data storage layer, platform support layer and business service layer from top to bottom, as shown in Figure 2.

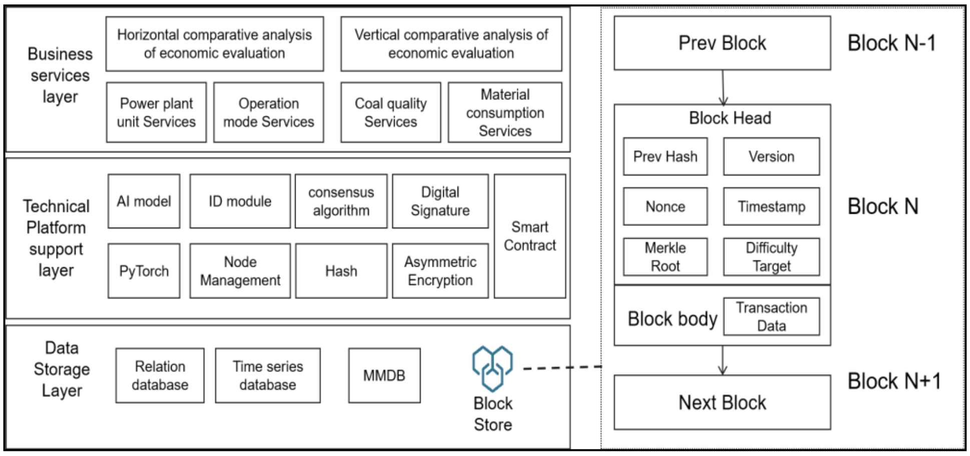

Fig. 2. System framework chart.

Data storage layer: according to different types of data, it includes time series database for storing flue gas emission data, relational database for storing structured data such as unit information, working condition information and coal quality information, cache library for storing login information and permissions during system operation, and block chain block storage for storing transaction records.

Platform support layer: the platform layer includes blockchain module and artificial intelligence module. Blockchain module includes identity management, blockchain node management, PBFT algorithm, smart contract management, digital signature management and asymmetric encryption algorithm. The artificial intelligence module includes the algorithm based on machine learning and the generated prediction model.

Business service layer: including unit management, working condition management, coal quality management, material consumption management, horizontal comparison of unit economic evaluation and vertical comparison of unit economic evaluation.

3.2 Design of prediction model for desulfurization and denitrification

The platform cleans the original data of desulfurization and denitration through machine learning algorithm, extracts the massive operation data of each unit to be mined, and uses machine learning algorithms such as neural network, deep learning and Bayesian network to establish multiple prediction models of pollution reduction effect, which can capture the generation concentration of NO_x and SO_2 with typical characteristics under specific working conditions.

3.3 Business data credibility design

According to the characteristics of desulfurization and denitrification business, the data of unit economic evaluation includes real-time data, structured data and unstructured data of flue gas emission. According to the management and control experience of desulfurization and denitrification and the characteristics of the blockchain platform, it is necessary to classify the data, and different types of data adopt different uplink strategies. For real-time data, the certificate is stored in the chain on an hourly basis. For manually registered data, the certificate is stored in the chain after the business occurs, as shown in Table 1.

Table 1. Data classification table.

Data type	Data content	Up Chain period
Registered data	Coal quality data, material consumption data, unit startup and shutdown, working condition data, equipment startup and shutdown data, etc	After business
File data	Contract text, etc	After business
Time series data	Operating data such as load, pollutant concentration at inlet and outlet	Per hour
Model calculation data	Model calculation results	After business
Economic operation index data	Calcium sulfur ratio, ammonia nitrogen molar ratio, ammonia escape, humidity, etc	Per hour

When the business data is stored and certified by the blockchain, the data cannot be tampered with. Since the blockchain ensures the security of data through distributed consistent storage, transaction consensus, digital signature and other mechanisms, its efficiency and throughput are bound to be affected. In order to ensure the efficiency of the application system, a dual storage mode is adopted in the system, that is, the business data fingerprint information is stored on the blockchain and the business data is stored in the database. If the business data is maliciously tampered with, the forged data behavior can be identified only by using the data of the blockchain for verification. The verification process is shown in the following figure 3.

When accessing the business data, the fingerprint information is obtained by decrypting the blockchain data, and compared with the fingerprint information of the business data. If the two are consistent, the business data is credible.

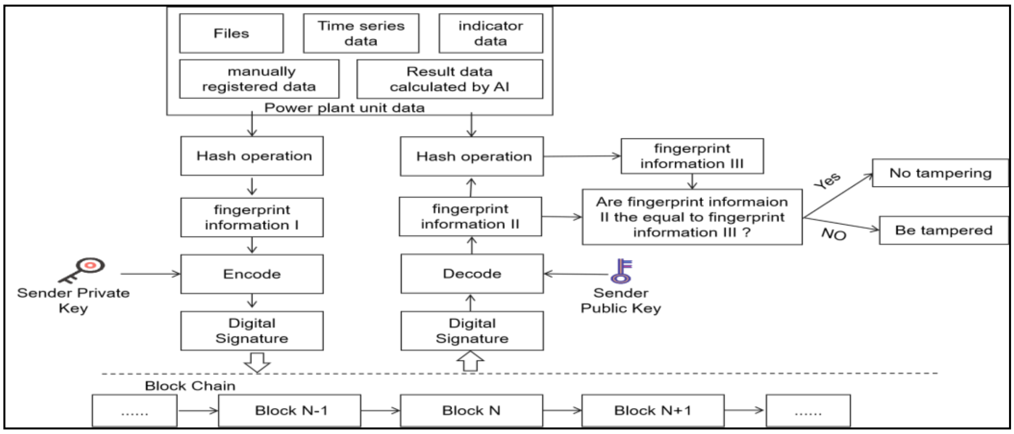

Fig. 3. Data credibility verification flowchart.

3.4 Design of smart contract for economic evaluation

According to the environmental protection policy and the operation data of each unit, calculate the operation economic indicators of desulfurization and denitrification, including the calcium sulfur ratio of desulfurization system, ammonia nitrogen molar ratio of denitrification system, ammonia escape, standard ratio, reductant and adsorbent consumption, unit operation status and other data, and generate a comprehensive index evaluation coefficient.

X=F(calcium sulfur ratio, ammonia nitrogen molar ratio, ammonia escape, ratio to standard, material consumption, unit operation status data)

According to the comprehensive economic evaluation standard, write the smart contract code and deploy it on the blockchain. Through system operation, users can get the economic report of environmental protection equipment operation of the unit, including the vertical comparative analysis report of different units and the horizontal comparative analysis report of the same unit at different times.

4 Evaluation and Verification Based on Smart Contract

Ten 300MW, 600MW and 1000MW coal-fired power generation units from five home appliance plants in Northeast, North and South China were selected to study the operation data of limestone gypsum wet flue gas desulfurization and SCR denitration system. The unit operation economy was evaluated through smart contract technology.

For power generation enterprises, according to the evaluation results provided by the system, on the premise of meeting the national ultra-low emission requirements, dynamically adjust the material balance, save the use of desulfurization adsorbent and denitration reductant, and bring economic benefits to the enterprise. For the group, the control and supervision personnel of the group company are assisted to master the performance of desulfurization and denitrification systems of different units, track the operation change trends such as material consumption and ratio to standard, develop more refined operation economy assessment methods, and reasonably plan the environmental protection investment of the group. For the society, the systematic scoring results provide a credible data basis for the country to formulate various environmental protection norms and standards, further reduce the potential of greenhouse gas emissions through technical measures, and provide a reference for the scientific promotion of more reasonable carbon reduction paths and technologies.

Based on the operation and maintenance experience and research results of the online monitoring platform for thermal power units, an environmental and economic operation and control evaluation model is established based on emission reduction technology. The pollutant reduction indicators of desulfurization and denitrification facilities in power plants are accurately calculated, and the material consumption for the current month is predicted based on the unit consumption of the previous month, with an accuracy rate of over 90%, as shown in Table 2.

Table 2. Data Accuracy of unit consumption prediction table.

Unit Name	Monthly average of unit consumption	Counting term	Accuracy of unit consumption prediction	Type
North Company # 1	5.88	3	94.16	Desulfurization
North Company # 1	9.83	3	92.12	Denitrification

5 Conclusion

This paper analyzes the current situation of ultra-low emission technology and the research results of economic evaluation in the previous literature, points out that the credibility of data is an important factor in economic evaluation, and puts forward that using real-time data of equipment operation for evaluation can help power plants improve economic benefits. Based on blockchain technology, this paper designs the economic evaluation system of environmental protection equipment operation, uses artificial intelligence technology to build the prediction model of desulfurization and denitrification effect, and uses intelligent contract technology to generate the economic evaluation report of unit operation. Finally, it summarizes that the system can bring economic benefits to the power plant, provide more refined management means for the group, and provide a reference for the country to promote the operation stability and economy of air pollutant control equipment in key industries by standardized means.

Blockchain technology can ensure the credibility of blockchain data, but the authenticity of data before entering the blockchain cannot be verified. In the later stage, it is necessary to integrate trusted edge gateway devices to develop sensor data directly on the chain technology, ensuring the credibility of data from the source.

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