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Design of Joint Trading Platform for Electricity-Carbon Market Based on Blockchain Technology

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Abstract—The conventional trading platform of the electricity-carbon market trades under the framework of e-commerce, and the transaction cost is relatively high, which affects the economic benefits of electric power enterprises. Therefore, this paper designs a joint trading platform for the electricity-carbon market based on blockchain technology. On the hardware, the ZYNQ-7045 core processor is designed. In the aspect of software, this paper establishes the joint transaction function module and analyzes the software architecture of the platform. Then, blockchain technology is used to design the trading game algorithm in the electricity-carbon market, which can reduce the platform transaction cost and effectively realize low-cost trading in the electricity-carbon market. By testing the platform, it is verified that the transaction cost of the platform is lower, and it can be applied in real life.

Keywords-Blockchain technology; Electricity-carbon market; Joint trading platform; Carbon valence; Electricity price; Transaction

I. INTRODUCTION

The electricity-carbon market is the main environment for green electricity trading and certificate trading. The coordination between the electricity market and the carbon market is very important, which can improve the economic benefits of the electricity market on the premise of realizing low carbon. Currently, the trading platform of the electricity-carbon market has high stability and reliability through the blessing of various procedures. However, the transaction cost increases correspondingly, which leads to the reduction of the economic benefits of the electricity market. To solve the above problems, researchers have designed a variety of trading platforms. Among them, the platform based on PHP technology in the internet + e-commerce framework and the platform based on the WeChat applet are widely used.

The platform based on PHP technology in the internet + e-commerce framework is a trading platform derived from PGP technology under the comprehensive framework of Internet technology and e-commerce. This platform can avoid the problem of users being cheated in the trading process, and it is a trading platform worthy of users' trust [1]. The platform based on the WeChat applet mainly uses the WeChat applet to alleviate the waste of resources in the electricity-carbon market and provide users with a good platform trading experience [2]. However, the high transaction costs of the above two trading platforms have seriously affected the economic benefits of power enterprises [3]. Blockchain technology is a kind of block ledger which can divide relevant information into different blocks for analysis and achieve the purpose of openness and reliability [4]. Therefore, this paper uses blockchain technology to design a joint trading platform for the electricity-carbon market.

II. HARDWARE DESIGN

A. The ZYNQ-7045 core processor

The ZYNQ-7045 core processor designed in this paper contains 350K logic unit, which completes the input and output of power data through a high-speed Ethernet interface so the platform can run at high speed. The peripheral FMC interface can monitor the temperature and voltage changes of the chip and ensure the safe use of the processor [5-7]. Built-in storage module, including 4 DDR3 high-speed particles, with a storage space of 1GB, provided abundant storage and extended storage space for power data. The specific application of the processor is shown in Figure 1 below.

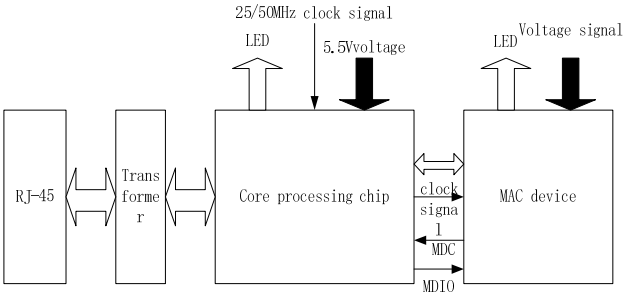

Figure 1 The ZYNQ-7045 core processor application block diagram

As shown in Figure 1, RJ-45 is the processor interface. MDC and MDIO are Ethernet pins. MAC is a signal-processing device. The LED is the indicator of the processor. RJ-45 interface, transformer, core processing chip, MAC device and other components are indispensable [8]. The electric power is accessed through RJ-45 interface, coupled with electric carbon through the transformer, and connected to the platform through MAC equipment, which provides data support for the platform.

III. SOFTWARE DESIGN

A. Establish joint transaction function module

In the electricity-carbon market environment, electricity is traded as pending orders. The user pays the electricity price after the order is pending, and the electricity dispatch is executed after the transaction is completed. In this process, it is necessary to operate on the blockchain. In the form of smart contract calling transaction mode, the transaction will be successful if it is written into the block, and the transaction will

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be rejected if it is not written into the block to ensure the security of the transaction [9]. The trading structure of the platform is shown in Figure 2 below.

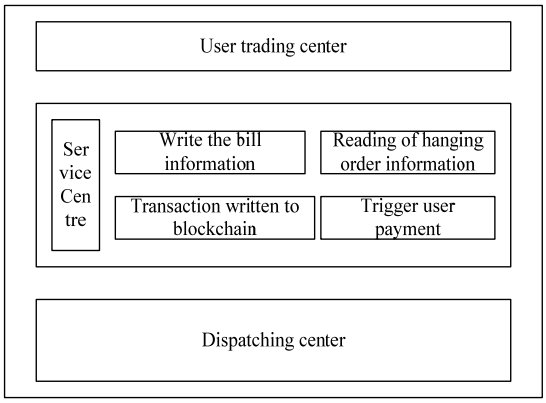

Figure 2 Platform transaction structure diagram

As shown in Figure 2, after the user orders, he enters the trading centre, orders on the service block, and writes the transaction into the blockchain. After the user pays successfully, the power dispatch is carried out [10]. This transaction form can not only improve the transaction security but also the transaction chain, providing security for power enterprises.

B. Design of trading game algorithm in electric carbon market based on blockchain technology

In order to realize the low-cost transaction in the electric carbon market, this paper will maximize the interests of buyers and sellers from the perspective of game theory. Enterprises and users are independent of each other, so a cooperative game model is established, and the expression is as follows:

$$K = \langle (S_i);(B_i) \rangle \tag{1}$$

In formula (1), K is the expression of the cooperative game model; S_i is the i-th electricity sale of electric power enterprises; B_i is the i-th power purchase of users. When S_i and B_i don't meet each other, they need to participate in the second stage transaction. The supplementary conditions of this stage are:

$$\sum_{i=1}^{K} Q_{B_i}(t) \times \sum_{i=1}^{K} Q_{S_i}(t) \neq 0 \tag{2}$$

In formula (2), $Q_{B_i}(t)$ is the amount of electricity purchased by the user at the t-th moment after the end of the first transaction; $Q_{S_i}(t)$ is the amount of electricity sold by the electric power enterprise at the t-th moment after the end of the first transaction. Assuming that the conductivity of carbon price to electricity price is 100%, and the carbon price is completely conductive to electricity price at this time, the transaction cost is:

$$M_j = \sum_{i=1}^{K} Q_{B_i}^{si}(t) \times P_t \cdot Q_{S_i}(t) \tag{3}$$

In formula (3), M_j is the transaction cost; $Q_{B_i}^{si}(t)$ subsidizes the purchase of electricity; $Q_{S_i}^{s}(t)$ is the power generation cost; P_t compensates the average price for the unit of power generation. In the electricity-carbon market, the higher the M_j, the higher the platform application efficiency, and the greater the economic benefits of power enterprises.

IV. PLATFORM TEST

In order to verify whether the joint trading platform designed in this paper has the use value, this paper tests the above platform. After the debugging of hardware and software, make the platform in a normal running state. The final test results are presented by comparing the platform based on PHP technology in the internet + e-commerce framework in literature [1], the joint trading platform of the electricity-carbon market based on the WeChat applet in literature [2] and the joint trading platform of the electricity-carbon market based on blockchain technology designed in this paper. The specific test process and test results are shown below.

A. Test procedure

Before testing, this paper debugs the hardware and software of the platform. After the ZYNQ-7045 core processor is installed according to the instructions, the voltage of the circuit part is 4.5V, and the current is 1.5A, which can ensure the normal installation of the circuit. After the processor is installed, the green indicator lights up, which can ensure that the ZYNQ-7045 core processor is in a normal running state. Set the platform software part as low-level input, with a signal rate ≤4.25GBd, to ensure the normal use of the platform software. After debugging the platform's hardware and software, analyse the trading platform's transaction verification performance, as shown in Figure 3 below.

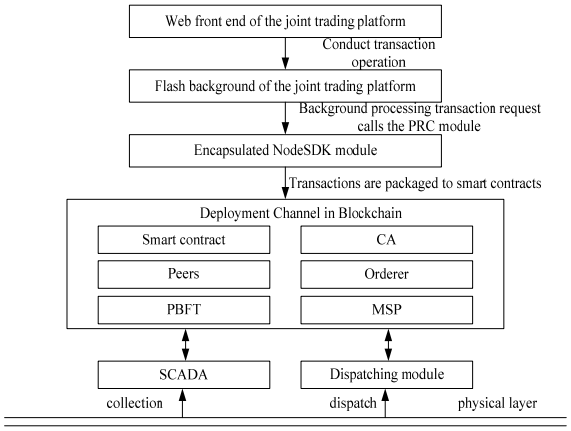

Figure 3 Flow chart of transaction verification of trading platform

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As shown in Figure 3, the Web front end is the operation step of the user's pending order. The Flask background is the processing step of the user's payment transaction. Encapsulate NodeSDK module as the execution step of platform transaction function. The Channel deployed in the blockchain is the scheduling step to complete the transaction. Intelligent contracts, CA, Peers, Orderer, PBFT, and MSP are the operating interfaces for the platform. Such as transaction, consensus, broadcast, authentication, block writing, verification, etc. SCADA is the platform information acquisition step. After the blockchain transaction is initiated, the transaction information is transmitted to the Flash background for authentication through the Web front end. After a series of transaction verification steps, the interface shown in Figure 4 below appears.

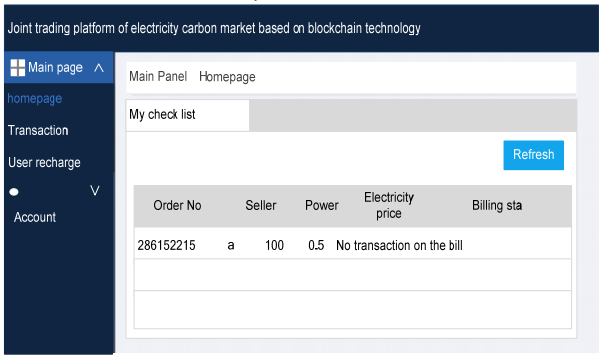

Figure 4 Main interface of the trading platform

As shown in Figure 4, in the trading platform, click on the main page to display the main panel, my pending orders and other information. And upload and process data such as order number, seller, electricity quantity, electricity price and pending order status. In the main interface, the order information is clear, ensuring the platform's normal use.

B. Test results

Under the above test conditions, eight power plants DT_1~DT_8 were selected in this paper, and the conductivity of carbon price to electricity price in the carbon market varied from 65% to 100%. Under the same other conditions, the transaction cost of a PHP technology platform based on the internet + e-commerce framework in literature [1], the transaction cost of a joint trading platform based on the WeChat applet in literature [2] and the transaction cost of joint trading platform based on blockchain technology designed in this paper are compared. The test results are shown in Table 1 below.

Table 1 Test results

Power plant number	Conductivity of carbon price to electricity price in carbon market/%	Literature [1]: The transaction cost of PHP technology platform based on internet + e-commerce framework/10,000 yuan.	Literature [2]: Transaction cost of joint trading platform based on the WeChat applet/10,000 yuan	This paper designs: The transaction cost of the joint trading platform based on blockchain technology/10,000 yuan.
DT_1	65	48.63	40.33	25.92
DT_2	70	52.16	45.67	35.67
DT_3	75	56.42	50.12	40.32
DT_4	80	60.03	55.63	42.76
DT_5	85	75.64	61.61	46.28
DT_6	90	89.99	66.36	48.36
DT_7	95	105.43	72.48	50.69
DT_8	100	128.63	77.23	52.12

As shown in Table 1, the conductivity of carbon price to electricity price in the carbon market is different among the eight power plants randomly selected in this paper. Under the constraint of power plant transactions, the conduction effect of the carbon price on electricity price gradually increases. When the conductivity is 100%, the carbon price is conducive to the electricity price. At this time, reducing the carbon price can achieve the high-efficiency trading goal of the electricity market, lower the transaction cost of the trading platform, and truly realize the long-term goal of carbon trading. All other conditions being the same, the transaction cost is relatively high after using the PHP technology platform based on the internet + e-commerce framework in reference [1]. In the transaction process, the conduction effect of the carbon price on the electricity price cannot be released, which restricts the transaction efficiency. After using the joint trading platform based on the WeChat applet in literature [2], the transaction cost has decreased. In the process of trading, the conduction effect of the carbon price on the electricity price is gradually released, which makes the trading efficiency improve slowly. However, after using the joint trading platform based on blockchain technology designed in this paper, the transaction

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cost is relatively low, the transmission effect of the carbon price on electricity price is high, and the transaction efficiency is high. The platform designed in this paper can meet the needs of trading, improve the economic benefits of the power market, and meet the research purpose of this paper.

V. CONCLUSION

In recent years, blockchain technology has been widely used, and its fairness and reliability have created high value for related technical fields. The electricity-carbon market is a collaborative process between the electricity market and carbon market, which mainly focuses on green electricity, realizes the transformation of low carbon and dual control, and provides higher economic benefits for power enterprises. Therefore, this paper uses blockchain technology to design a joint trading platform for the electricity-carbon market, which can control the transaction cost in blocks and improve the economic value of power enterprises.

REFERENCES

[1] Zheng, S., Li, J., Chen, Y. (2022) An online second-hand car trading platform based on PHP technology under the Internet plus e-commerce framework. Practical Electronics, 30 (02): 39-41.

[2] Zhao, B., Liu, X., Yang, T. (2022) The design and implementation of the campus second-hand idle goods trading platform based on WeChat applet. Computer Knowledge and Technology, 18 (21): 64-66.

[3] Guan, H. (2022) The first prize winning thesis of the 2021 solicitation activity -- Research on the enterprise operation mode of the public resources and factor resources all factor trading platform. Tendering & Purchasing Management, (05): 22-26.

[4] Zhang, C. (2022) Assisting urban green travel to build low-carbon municipal projects - the "PV+urban rail" model was successfully implemented through the property rights trading platform. Property Rights Guide, (02): 54-55.

[5] Xiang, D., Zhou, R., Huang, Z. (2021) Research on key technologies of power market trading platform based on hybrid cloud computing platform. Journal of Shandong Agricultural University(Natural Science Edition), 52 (04): 704-708.

[6] News from our magazine The National Development and Reform Commission and the National Forestry and Grassland Administration jointly issued the Forest Right Transaction Data Specification of the Public Resource Trading Platform System. Tendering & Purchasing Management, 2020 (08): 10.

[7] Li, Y., Zhang, N., Du, E. (2022) Research on the response mechanism and benefit analysis of low carbon demand of power system based on carbon emission. Proceedings of the CSEE, 42 (08): 2830-2842.

[8] Wang, C., Hou, B. (2022) Fuzzy market access policy: game, network structure and implementation mechanism -- an investigation based on policy implementation in the field of public resource trading. Journal of Beijing Administration Institute, (04): 1-8.

[9] Li, X., Liu, Z., Yang, D. (2022) Power Market Efficiency Assessment and Carbon Market Price Design -- Conductivity Estimation from the Perspective of Electricity Carbon Market Correlation. China Industrial Economics, (01): 132-150.

[10] Qin, B., Li, H., Zhang, Z. (2022) Electric power energy system supported by underground space: vision, challenges and prospects. Proceedings of the CSEE, 42 (04): 1321-1332.

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