Research on Blockchain Technology-based Electricity Retail Market Management Model

Yan Li[1,a], Yujia Li[1,b], Yaheng Su[1,c], Houjing Guo[1,d], Xiao Meng[2,e], Hankui Tian[2,f] and Yongli Wang[2,g]
[1]*Inner Mongolia Electric Power Economic Technology Research Institute, China*
[2]*North China Electric Power University, China*

Keywords: Blockchain, Electricity Retail Market, Smart Contracts.

Abstract: In order to solve the supervision and accounting problems of electricity retail market, improve the operation efficiency and reduce the transaction risk, the article proposes the architecture and business process of electricity retail market management system based on the alliance chain. Firstly, it designs the operation and management model of electricity retail market, establishes the retail market model based on the coalition chain technology, and designs the retail package and transaction process; then it proposes the settlement mechanism of electricity retail market transaction based on smart contract, designs the settlement process and cost calculation method; on this basis, it constructs the framework of electricity retail transaction based on the coalition chain technology by combining the characteristics of electricity retail market, and explains how the overall architecture, technical It explains how blockchain technology can be applied to the electricity retail market from three aspects: overall architecture, technical architecture, and functional architecture.

1 INTRODUCTION

With the continuous promotion of the new round of power reform, the electricity retail market will be gradually liberalized (National Development and Reform Commission, 2020), the development scale of the electricity retail market will be further expanded, and the role of the market in the optimal allocation of resources will be further highlighted. More and more trading entities are involved in the market. However, unlike the wholesale electricity market, users in the retail electricity market tend to be more dispersed and less capable of grasping information, and electricity sales companies are prone to use the asymmetric information generated in complex electricity spot transactions to engage in unfair price competition and harm the rights and interests of other market players. Therefore, it is necessary that there are still difficulties in regulation and accounting in the early stage of the development of the electricity retail market (Tan, 2021). In order to solve the information security problems of traditional centralized trading architecture and improve the transparency of market transactions, the functional design and implementation method of blockchain-based electricity market trading system are proposed (Ji, 2019, Yu, 2018).

2 BLOCKCHAIN TECHNOLOGY ANALYSIS

2.1 Overview

In essence, blockchain is a distributed ledger with decentralized characteristics. It supports multi-agent participation, stores data in a block chain structure, and uses cryptography technology to ensure the security of data transmission and storage. It has the technical characteristics of difficult tampering and high security (Ouyang, 2017). As shown in Figure 1, the blockchain is composed of a series of blocks arranged sequentially. Each block includes two parts: block header and block body. The block header includes information such as version number, previous block hash, timestamp, difficulty target, random value, and Merkle root. The block body, on the other hand, stores transaction information in the

Li, Y., Li, Y., Su, Y., Guo, H., Meng, X., Tian, H. and Wang, Y.
Research on Blockchain Technology-based Electricity Retail Market Management Model.
DOI: 10.5220/0011359400003440
In *Proceedings of the International Conference on Big Data Economy and Digital Management (BDEDM 2022)*, pages 930-935
ISBN: 978-989-758-593-7

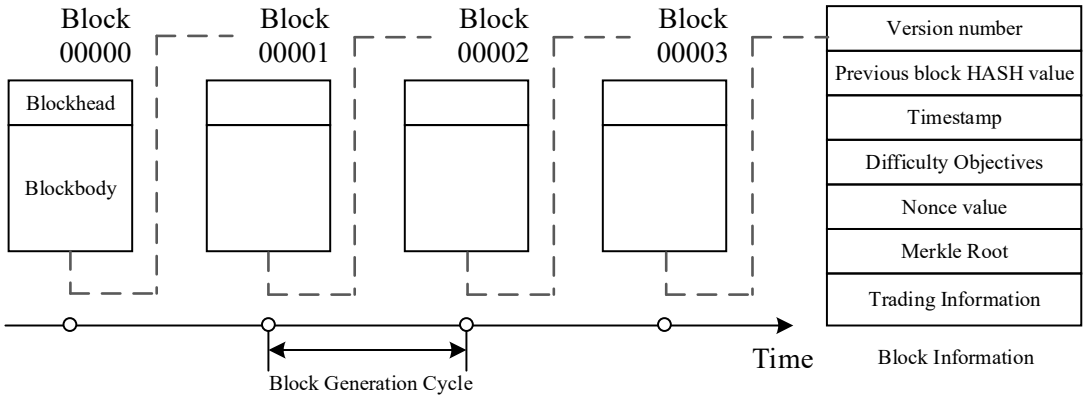

Figure 1: Blockchain and block structure schematic.

form of a Merkle tree. In the block header, the previous block hash ensures both that all blocks in the blockchain are in order and that the blocks are difficult to tamper with. The timestamp, on the other hand, marks the time when the block was formed.

2.2 Blockchain Technology Comparison and Selection

As shown in Table 1, there are significant differences among the three types of blockchain in terms of consensus process, node access, security and efficiency.

Table 1: Comparative analysis of blockchain-like technologies.

Type	Public Chain	Affiliate Chain	Private Chain
Scope of Consensus	All Nodes	Partially selected nodes	Central Node
Read Permissions	Public	Public or restricted	Public or restricted
Security	High	High	Low
Execution efficiency	Low	High	High
Degree of decentralization	Fully decentralized	Partial decentralization	Partially centralized

2.3 Smart Contracts

Each trading node needs to agree on an electronic contract when conducting transactions, including information including signatures of both parties, transaction content (electricity, tariff, etc.), transaction rules, contract trigger conditions, etc. The contract is proliferated through the P2P network and written to the blockchain after being verified by the consensus mechanism, and external data is periodically detected and the contract is executed once the trigger conditions are met. The transaction mechanism of electricity retail trading is embedded in a script in the form of a smart contract to verify each process of electricity trading.

3 ELECTRICITY RETAIL MARKET OPERATION AND MANAGEMENT MODEL

3.1 Electricity Retail Market Model

The retail electricity market needs to operate in a near "fully competitive" environment, where all retail electricity consumers are free to choose their electricity sales companies and grid companies no longer have a monopoly over electricity consumers. Within the limits set by the regulator, the company can adjust its retail package to be more competitive based on its ability to purchase electricity in the spot market. To be truly effective, a transparent and efficient electricity retail trading mechanism needs to be established.

The model describes the sales path of electricity as a commodity in the retail market with the main line of electricity energy flow. In the model, market players can improve their market competitiveness by adjusting their trading behavior, trading channels and other factors independently.

3.2 Electricity Retail Package

The electricity selling company develops and publishes the electricity selling tariff standard called electricity retail package, including the term, electricity price mechanism, electricity deviation handling mechanism, termination clause, and applicable objects.

Table 2: Composition of electricity retail packages.

Package Composition	Content
Period	Define the validity period of the package
Electricity price mechanism	Divided into fixed price, tiered price, variable rate and hybrid
Power deviation handling mechanism	Deviation assessment mechanism can be defined at different granularity such as monthly, daily and time period
Termination clause	Agreement to cancel retail contracts before expiration
Applicable objects	Conditions can be set to restrict retail users, such as annual electricity consumption, industry, etc.

3.3 Electricity Retail Market Trading Process

Market member registration and qualification audit. Market members register according to the requirements of the rules, and the trading center will check the registration information with the qualification information stored in the blockchain, and then they can enter the electricity retail market after passing the audit. Formulation and review of retail packages. The electricity selling company configures the electricity price mechanism, deviation handling mechanism and cancellation clause respectively according to the composition of the package to form the complete package content, sends it to the trading center for review, and after passing it. Generation of retail contract. The retail user views the retail package through the blockchain, selects it according to his electricity consumption characteristics, and sends a request to the package corresponding to the electricity sales company, and after the sales company confirms the package request (Gao, 2020).

4 DESIGN OF SETTLEMENT MECHANISM FOR ELECTRICITY RETAIL MARKET TRANSACTIONS BASED ON SMART CONTRACTS

4.1 Settlement Process and Method

The market players involved in electricity retail market settlement include electricity sales companies, retail users and grid enterprises, and the trading center and regulators supervise the settlement process. Settlement is based on the smart contract formed on the blockchain by the retail contracts signed by retail users, which calculates the electricity tariff and assessment fees of retail users and forms the sales tariff and assessment revenue of the power sales company. The smart contract signed between the retail customer and the power sales company specifies information such as price formation mechanism, deviation handling mechanism and termination clause. The grid company broadcasts the actual electricity consumption of the retail customer every hour, which triggers the retail contract for settlement. Settlement for the previous month is carried out at the beginning of each month, including electricity tariffs, deviation fees and default fees, and the settlement information is recorded as a block in the blockchain and in the full node.

4.2 Settlement Calculation

4.2.1 Calculation of Electricity Consumption Tariff

1)The formula for calculating hourly electricity charges for retail customers who choose fixed-price and stepped-price packages is as follows:

$$F_{\text{Fee}} = P_{\text{Time price}} \times Q_{\text{Time quantity}} \quad (1)$$

$P_{\text{Current price}}$ is the mutually agreed tariff in yuan/kWh in the retail package; $Q_{\text{Time quantity}}$ is the actual electricity consumption of retail customers, in kWh.

2)The formula for calculating the hourly electricity rate for retail customers who choose the market rate type package is as follows.

$$F_{\text{Fee}} = P_{\text{Rate price}} \times k \times Q_{\text{Time quantity}} \quad (2)$$

$P_{\text{Rate price}}$ is the hourly electricity consumption side price in Yuan/kWh before the electricity spot day or real-time market; k is the price adjustment factor.

3)The formula for calculating the hourly electricity rate for retail customers who choose the hybrid package is as follows.

$$F_{\text{Fee}} = P_{\text{Time price}} \times Q_{\text{Time quantity}} \times a\% + P_{\text{Rate price}} \times k \times Q_{\text{Time quantity}} \times (1-a\%) \quad (3)$$

$a\%$ is the proportion of fixed-price electricity implemented in the hybrid package.

4.2.2 Deviation Assessment Cost Calculation

The deviation assessment processing mechanism is divided into: no deviation assessment, deviation assessment by daily period, and deviation assessment by daily/monthly total electricity consumption in the retail package.

1) Deviation assessment by daily time period. The retail customer and the electricity sales company agree on the proportion of over- and under-use of electricity and the deviation tariff for each of the 24 daily periods in the package.

2) Daily/monthly total electricity consumption deviation assessment. The retail customer and the electricity sales company agree on the proportion of over- and under-use of daily or monthly total electricity consumption and the deviation tariff in the package.

4.2.3 Calculation of Liquidated Damages

Liquidated damages are composed of 2 parts in a retail contract: the parties agree to cancel the contract by amicable negotiation and the liquidated damages force the termination of the contract. If there is a termination by both parties, it will be recorded in the blockchain and the contract will expire at 24:00 on the last day of the month. At the time of monthly settlement, the status of the termination is checked and there is a forced termination, then the liquidated damages are added to the monthly settlement fee of the terminated party, and the formula for calculating the liquidated damages is as follows:

$$\begin{cases} C_1 \left(p \neq 0, \mu \leq C_1 \right) \\ \mu = p_{\text{done}} \times b\% \times \dfrac{M_{\text{total}}}{M_{\text{done}}} \left(p \neq 0, C_1 \leq \mu \leq C_2 \right) \\ C_2 \left(p \neq 0, \mu \geq C_2 \right) \\ \dfrac{C_1 + C_2}{2} (p = 0) \end{cases} \quad (4)$$

μ is the default fee payable; p_{done} is the cost of the package for the executed month; b is the default factor; M_{total} is the total number of months of the package term; M_{done} is the number of months of the executed package term; C_1, C_2 is the minimum and maximum amount of the default fee stipulated by the regulator.

5 ELECTRICITY RETAIL MARKET MANAGEMENT SYSTEM DESIGN

5.1 Overall Architecture

The system is built with microservice architecture to achieve state consensus and distributed storage of data among market entities to ensure the validity, integrity, security and non-tamperability of the deposited information. The system architecture is mainly composed of application layer, platform layer and foundation layer. The application layer includes front-end applications such as enterprise market registration and approval, package formulation and release, blockchain electronic contract management, and power settlement basis release. The platform layer demonstrates the main services provided by the blockchain basic service platform and provides effective service support for the application layer. The foundation layer is mainly composed of two parts: blockchain underlying support system and data storage system.

5.2 Technical Architecture

The power retail market management system realizes the node access mechanism of the alliance chain through CA authentication and authorization. When a new member is allowed to join the alliance, it needs to send its public key and necessary identity information to the certificate and visa authority, and the CA authority will issue a certificate for it according to this information. As a license authentication for joining the alliance, CA

authentication can combine the advantages of domestic algorithms of the State Password Administration to improve the system's supervision and credibility. The application architecture is shown in Figure 2.

5.3 Functional Architecture

The front end of the system designs four functional modules: retail market management system information display, power sales company management, retail user management and Trading Center retail management. The functional modules support the power sales companies, the power purchase and sales agency business of retail users and the market management of power trading center. The system functional architecture is shown in Figure 3.

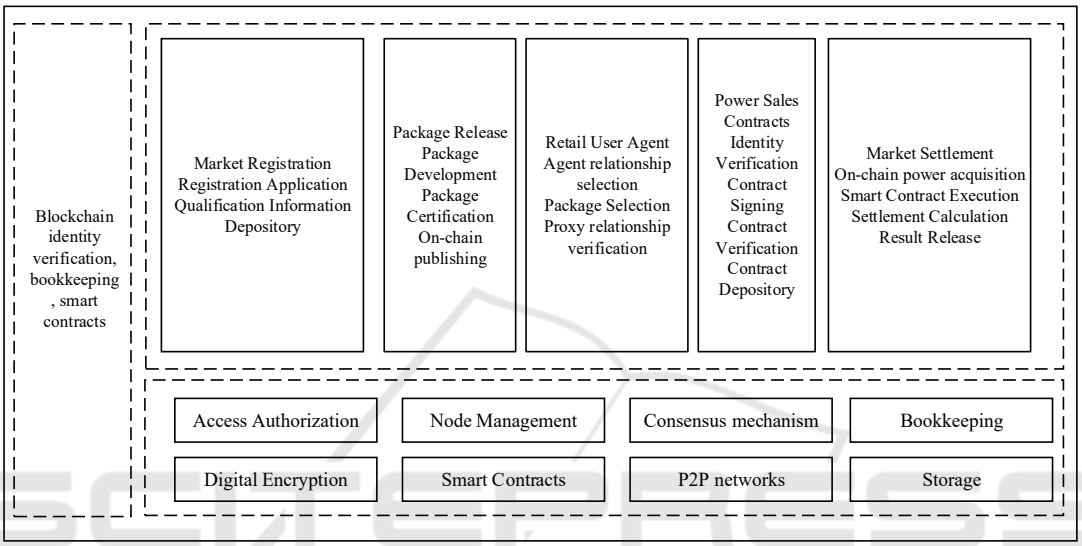

Figure 2: Application Architecture.

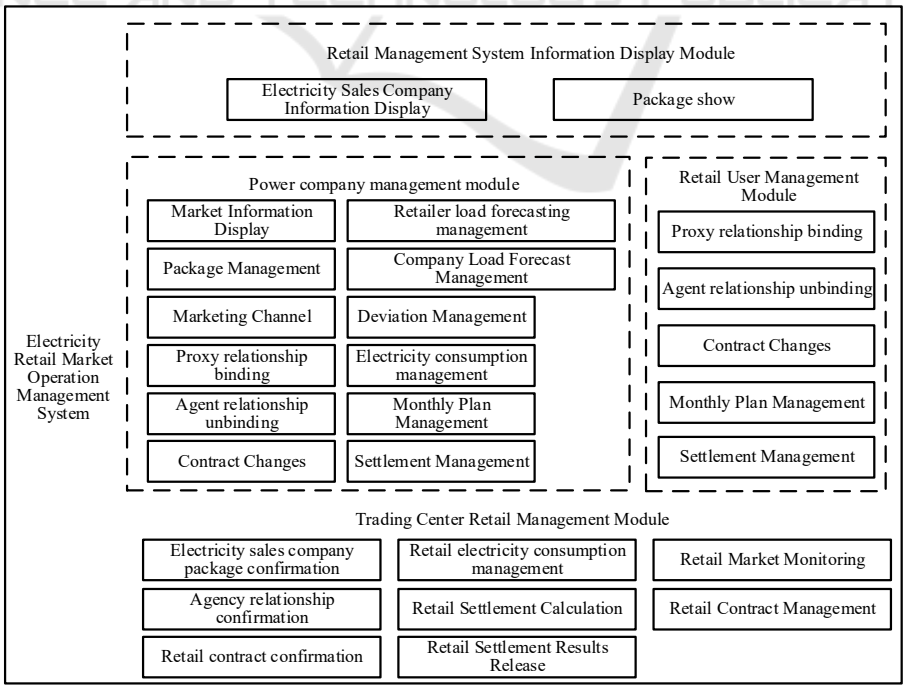

Figure 3: System functional architecture.

6 CONCLUSION

This paper focuses on the application of blockchain technology in electricity retail market management, and proposes a decentralized retail market management model based on smart contracts. Through this management model, the on-chain consensus of participants such as power trading centers, grid enterprises, power sales enterprises, retail customers, and supervisory agencies can be realized. The application of blockchain in the field of electricity retailing is worthy of in-depth study, and the subsequent directions may include the purchase of renewable energy power for retail users and demand-side response of retail users based on energy aggregation.

REFERENCES

Gao Zhengnan, Zhou Feixiang, Li Duo, et al. Design of improved consensus mechanism for blockchain-based power market trading system[J]. Modern Scientific Instruments, 2020(3):134-138.

Ji B. Research on the mechanism and model of electricity retail trading for production and consumption users based on blockchain technology [D]. Guangxi University, 2019.

National Development and Reform Commission, National Energy Administration. Notice on the work related to the pilot continuous trial settlement of electricity spot market [A /OL] (2020-03-26) [2020- 09- 01].

Tan Qiewen, Qin Jianrong, Liang Shengsheng, Xie Tian, Bao Jun, Huang Hongwei. Design and implementation of blockchain-based electricity market trading system[J]. Journal of Electric Power, 2021, v.36; No.164 (05): 466-474. DOI: 10.13357/j.dlxb.2021.055.

Ouyang X, Zhu Qianqiang, Ye L, et al. A preliminary investigation on the application of blockchain technology in the direct purchase of electricity by large customers[J]. Chinese Journal of Electrical Engineering, 2017, 37(13): 3737-3745.

Yu Shaoyuan, Yang Shengchun, Li Yaping, Geng Jian,Shi Fei. Research on market-based trading mechanism of distributed power generation based on blockchain smart contract[J]. Intelligent Power,2018, v.46; No.300(10):43-4.