Design of blockchain-based trading mechanism under sharing mode of electric vehicle under smart grid*

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***Abstract*—The P2P energy market represented by electric vehicles will receive more and more attention. Therefore, the P2P energy market platform needs more precise design to ensure that the feedback effect between the transmission and distribution system operation will not reduce the system stability. At the same time, the trading mechanism needs to be redesigned, allowing the platform owner to maximize their own interests by setting prices. Blockchain technology is used to create a shared electric vehicle trading platform, which allows electric vehicles to communicate with the smart grid. The main focus of this paper is to design the combination of blockchain technology and electric vehicles. Blockchain technology has the characteristics of decentralization, distributed peer-to-peer, non-tamperable, consensus trust and economy. From the perspective of feature matching, it can be found that the advantage of the blockchain is actually complementary to the demand of the electric vehicle charging and generating transaction.** (*Abstract*)

Keywords—P2P energy market, blockchain technology, electric vehicle, trading mechanism，smart grid (*key words*)

I. Introduction

As of the end of 2018, the number of electric vehicles in Beijing has reached 187,000. New energy electric vehicles with low carbon, environmental protection and low cost have gradually become the key considerations for users when purchasing cars. What can be found is that the number of new energy electric vehicles will continue to leapfrog, both at this stage and in the future [1].

At present, the proportion of electric vehicles in Beijing is mainly for official use and private use, with the largest quantity and charging demand. There are actually two problems [2]. First, the available charging piles are mainly distributed inside the unit, in public places and in private parking spaces. Only public spaces can be used openly and freely, while internal and private parking spaces are not shared. In many cases, charging piles inside the unit and charging piles in public places are handled by different management operators. The management operator controls the electric piles under its jurisdiction with different cloud platforms as carriers. Even if the physical layer charging interface matches, the actual two are not shared. Second, because the charging pile is close to the transformer access capacity and the number limit, the user often needs to wait for charging at a charging station. However, there are no queues for potentially available charging pile sites in nearby areas. Therefore, inefficient charging pile utilization and grid reliability requirements are in urgent need of business model and technological innovation. The currently implementable method is to build an electric vehicle charging and control platform that is uniformly controlled and can dynamically access the charging pile information at any time.

The blockchain creates a monitorable audit trail that can be applied to any transaction as a digital ledger [3]. Blockchain technology is used to create a shared electric vehicle trading platform, which allows electric vehicles to communicate with the smart grid. During the peak period of power consumption during high-load operation of the power grid, the vehicle owner can transmit power from the vehicle battery to the power grid, thereby obtaining corresponding benefits [4]. This not only improves the security of the system, but also helps consumers buy it when the electricity price is the cheapest or when the grid has the lowest amount of low-carbon electricity.

Foreign research on blockchain technology is mature, and there are many pilots and literatures on the application of blockchains and electric vehicles [5]. In 2018, ElaadNl successfully used the IOTA blockchain technology to settle the first transaction of the electric vehicle charging pilot project for the first time. In 2019, automaker Toyota will pilot a P2P energy trading system driven by blockchain, which will enable businesses, homeowners and electric car drivers to exchange surplus electricity. In order to meet the demand side of a large number of electric vehicle charging / discharging management needs, the literature [6] proposed the concept of introducing blockchain applications in the electric vehicle charging transaction process. The concept advocates the use of decentralized storage and accounting blockchain approach to achieve transactional data records for all electric vehicles and distributed power or grid power transactions first. Literature [7] believes that the combination of electric vehicle cloud, blockchain technology and edge computing will make the future electric vehicle transaction settlement more intelligent and convenient. The literature [8] also believes that the use of blockchain can realize the market-oriented technological innovation of electric vehicles,

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whether it is maintenance cost or the point-to-point transaction settlement of electric vehicles. In short, the combination of electric vehicles and blockchain has been recognized by many scholars and engineering fields abroad.

The main focus of this paper is to design the future combination of blockchain technology and electric vehicles. While supporting the grid to achieve demand side management, we are committed to securing two user transactions. First, electric vehicles can trade with power grid companies through charging piles anytime and anywhere. Second, the demand side can sell distributed power. The purpose of our research is to really promote the marketization of electricity trading.

II. THE MULTI-AGENT MODE OF SHARING ELECTRIC VEHICLE

The final platform will also become a carrier that is highly market-oriented, highly efficient in distributed power consumption, and highly transparent in data sharing. The grid company can directly use the charging pile as the basic data fusion point to obtain different electric vehicle data, including the charging position, the number of charging and the charging duration, and then formulate a reasonable charging plan. In the future, in the way of big data analysis and forecasting, the grid company will guide the charging load of multiple types of electric vehicles in order to avoid the increase of peak-to-valley difference.

A. *Trading Process*

This paper is based on the electric vehicle sharing operation business model that is widely participated by electric vehicle users, electric car rental companies and service providers. We analyzed existing shared transaction processes and built a multi-chain structure for different leasing companies and service providers [9]. From the aspects of user registration and certification, transaction initiation, multi-chain selection, transaction tracking and chain update, transaction execution settlement, and grading judgment of transaction results, we study the transaction and settlement process between users, leasing companies, service providers and other entities in the electric vehicle sharing mode. The shared multi-agent transaction structure diagram of electric vehicles is shown in Fig.1.

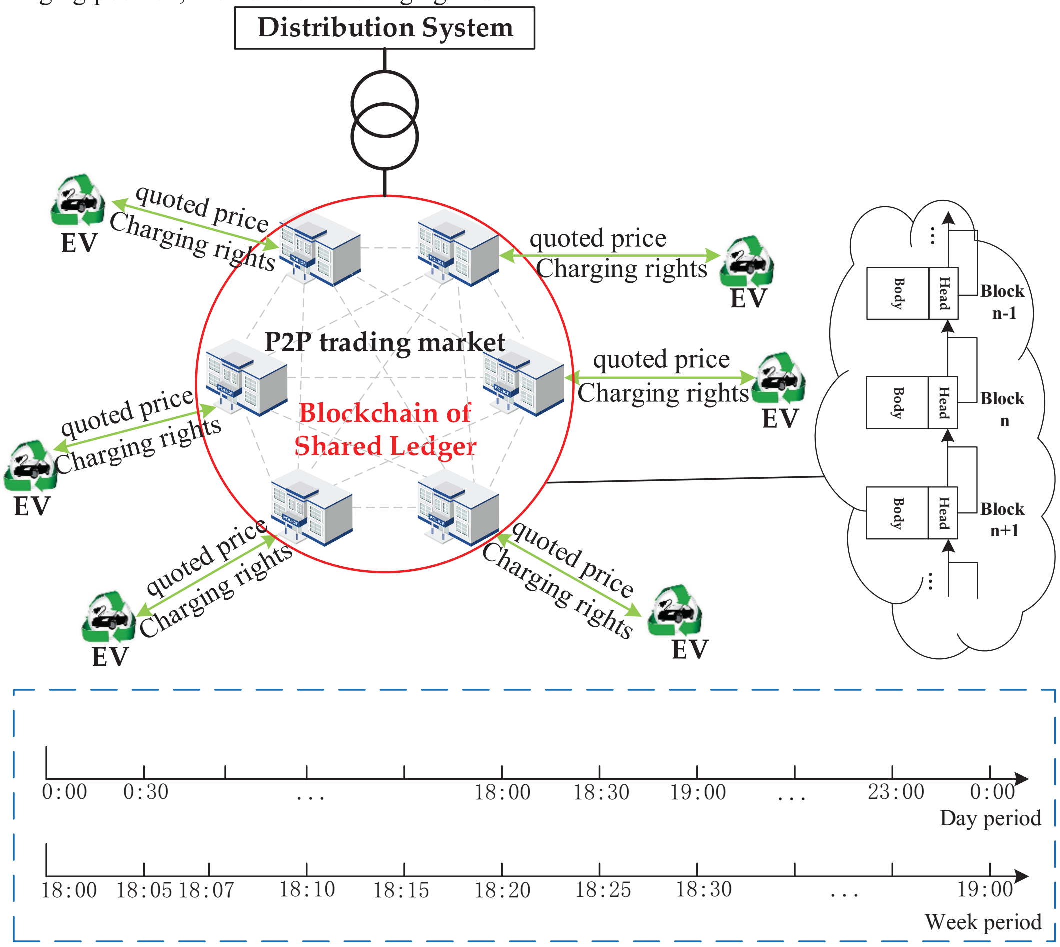

Fig.1. The shared multi-agent transaction structure diagram

- All charging stations submit their own charging power demand in the 18:30-19:00 period to the blockchain within 18:00-18:05 according to their actual needs.
- The grid company submits the request through the smart contract at 18:05, and the blockchain miner determines the total equipment load margin from 18:30 to 19:00 according to the historical data of the normal load and the rated capacity of the equipment, and records all in the area. The charging station is connected to the blockchain.

- The blockchain calculates the charging demand satisfaction rate from 18:05 to 18:07 according to the equipment load margin issued by the grid company and the total charging demand power submitted by all charging stations.

- When the total charging demand power is greater than the equipment load margin, the number and price of charging rights that are desired to be purchased from other charging stations/sold to other charging stations may be submitted according to the degree of flexibility of the self-charging load from 18:07 to 18:10. The charging block service provider's blockchain automatically arranges all bidding information according to the price level, sorting the seller's quotation from low to high, the buyer's quotation is arranged from high to low, and the same price is sorted according to the quotation time.

- After the two-way auction quotation phase, the charging service provider blockchain will clear the bidding queue for buyers and sellers according to the two-way auction rules from 18:10 to 18:15. When the two-way matching is successful, all charging rights transactions will be settled on the blockchain and the number of charging rights will be updated from 18:30 to 19:00 according to the transaction result.

- If there is still an unsuccessful match after the transaction in the two-way auction market, the charging station can conduct P2P transactions between 18:15 and 18:25. If the buyer and the seller do not change the offer in the 18:05 to 18:07, there will be no volume in the P2P market. When the P2P transaction is successfully matched, all charging rights transactions can be settled on the blockchain and the number of charging rights is updated between 18:30 and 19:00.

- All charging stations are required to pay the grid company 18:30-19:00 for the charging fee based on the final allocation and the charging right from the transaction between 18:25 and 18:30. The fee settlement is completed on the blockchain.

- The charging station shall be charged according to the final charging right (charging power quota) between 18:30 and 19:00. Each charging station is equipped with a smart meter that can operate the blockchain node. The smart meter detects the power of the charging station and generates data interaction with the smart contract on the blockchain through the built-in communication module.

B. Settlement process

The blockchain trading platform estimates the current trading period based on the previous trading time, and the trading cycle begins. The platform confirms the reputation values of each node and arranges them in descending order, and divides the reputation value level [10]. It collects the buyer's quotation information and arranges them in descending order, collects the seller's selling price information and arranges them in ascending order, and divides the matchable range of each node according to the reputation value level. Based on the above data, the grid companies speculate that there may be blocked lines and establish congestion costs. After that, the platform broadcasts the sorted list, the matching range of each node, and the corresponding blocking fee. The distributed energy P2P transaction process based on blockchain is shown in Fig.2.

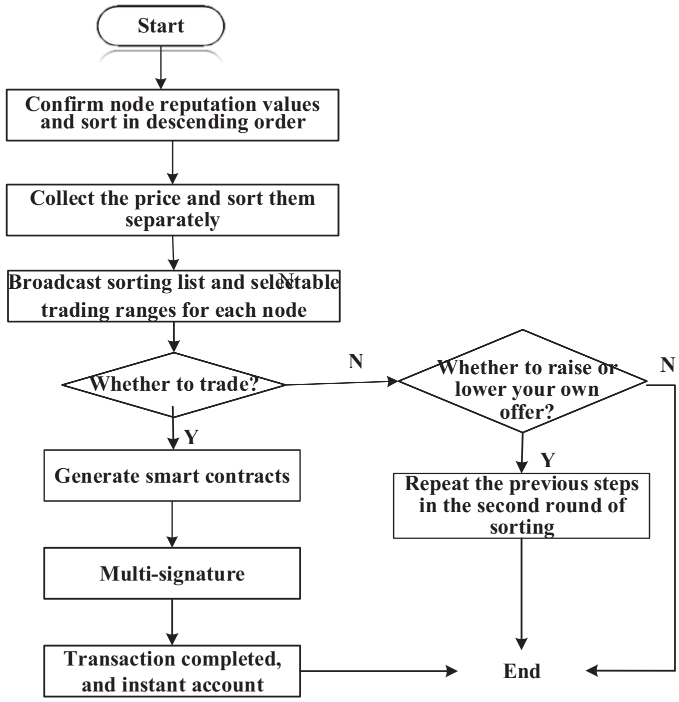

Fig.2. The distributed energy P2P transaction process based on blockchain

The node select whether to trade:

- The node confirms the transaction and the system performs a security check on the transmission line. If the check is passed, a suitable smart contract is generated. The buyer and the seller finally confirm the execution of the contract through multiple signatures, and the money is immediately credited after the transaction is completed. If the check fails, it is determined that the match is unsuccessful and the node enters the next round of quotation.

- The node does not agree with the transaction, and the system again prompts the node whether to adjust the quotation or transaction volume. If the node adjusts the quote or volume, the previous transaction step is repeated until the transaction is completed. If the node does not adjust the quote or the volume of the transaction, the transaction is ended directly.

C. Mode of data interaction

The actual situation of distributed charging pile communication has the following security threats:

- Stealing. Stealing means that illegal users obtain system sensitive information such as user ID, password, charging fee and remaining amount by means of wiretapping and packet capture. Stealing attacks will not directly damage the charging pile itself and the charging pile back-end service management system, but it can lay a certain foundation for tampering attacks and forgery attacks. Stealing an attack is a passive attack. It does not modify the message and is therefore difficult to detect. Therefore, the focus of the attack is prevention.

- Interrupted. An attacker can perform an outage attack on the charging station communication in the following manner. 1) Destroy the charging pile itself, such as the card reader interface, communication module, etc., to block the charging pile communication from the source. 2) Destroy the base station near the charging pile and prevent the charging pile from communicating through the 4G public network. 3) The attack charging pile background service management system is so paralyzed that the information cannot be transmitted normally. From the physical level, the communication network has little possibility of damage, and the attack means is poor and easy to find. It can achieve good protection effect through communication repair and physical redundancy backup. Therefore, this article does not consider the attack of physical interruption.

- Tamper. In combination with the actual communication situation of the charging pile, the tampering attack can modify the stored value data of the charging card, the electric energy data and the electric charging data, or the intermediate file to tamper with the key files in the transmission process. The attack is an active attack, and detecting an active attack is easier than preventing it from launching an attack. Tampering attacks mainly tamper with data through illegal access, so it is impossible to start with data authenticity, and only detect tampering attacks from data integrity.

- Counterfeit. A forgery attack is when an unauthorized person inserts false information during data transmission. In the charging pile communication process, the attacker can charge the electric vehicle by forging the charging card, or pseudo-inducing the charging pile to attack the background service management center.

The information security protection scheme of distributed electric vehicle charging pile designed by the article involves information security protection between service management center (charging pile - background), transaction mode (charging pile - charging card), APP (charging pile - charging pile) and battery management system (charging pile - electric car). It is necessary to meet the requirements of confidentiality, integrity and authenticity. The data encryption algorithm is used to ensure the confidentiality of the data. The Hash-based message authentication code (HMAC) algorithm is used to ensure the integrity and authenticity of the data. In this paper, the authentication-encryption mode is used to design the authentication encryption scheme as shown in the following Fig. 3.

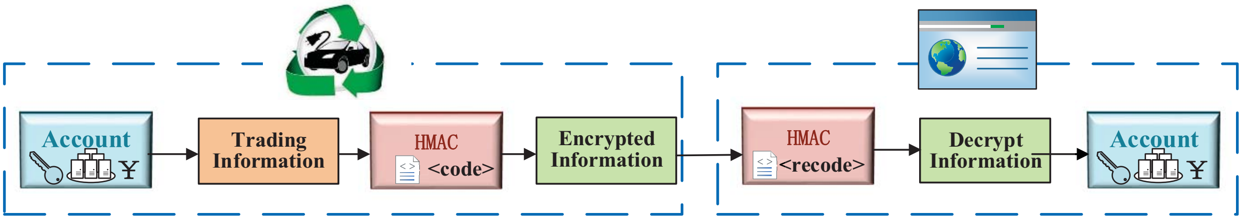

Fig.3. The authentication-encryption mode of authentication encryption scheme

III. MULTI-AGENT TRADING MODE OF SHARING ELECTRIC VEHICLE

The high cost of electric vehicle batteries is a key issue that hinders their industrialization. Therefore, the innovation of sharing mode has become the choice to promote the commercialization and scale of electric vehicles. At present, there are several types of electric vehicle business models that have been practiced in the world: power-exchange mode, battery rental mode, vehicle sales mode, and the latest sharing mode. Based on Section 2.1, this paper designs a multi-agent transaction structure diagram for shared electric vehicles as shown in Fig.4.

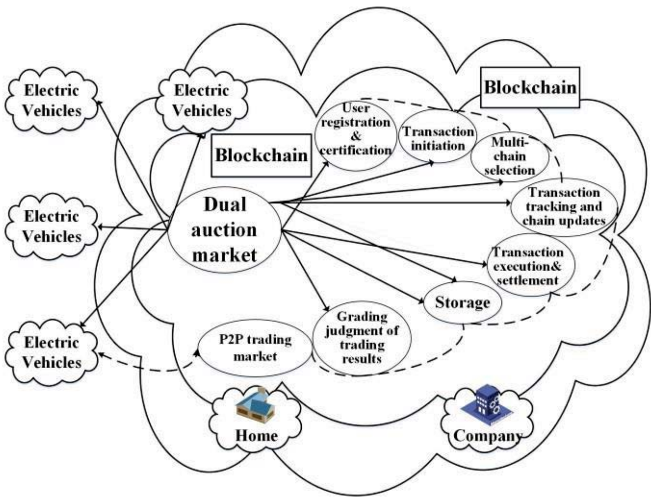

Fig.4 Multi-agent transaction structure diagram for shared electric vehicles

The blockchain transaction process of electric vehicles needs to meet the information constraints of scalability and data privacy. Therefore, this paper envisages a distributed real-time rolling transaction method. The price formation mechanism process is as follows:

- The forecast result of the local electricity price series is released before the trading day.
- Set the initial allocated power, initial price, and send the initial value to each production consumer.
- The producers calculate their net power demand for each energy level over time and send this information to the platform agent.
- The platform updates the current net power of each production consumer and the power imported from the grid by solving the planning problem.
- Platform agents update dual prices.

If a blockage occurs during charging, the method determines the clearing price and coordinates all EVs to reach a new equilibrium point, thereby mitigating blockage. The flexibility of different EVs is determined by their large, low power and price sensitive parameters, and is ultimately reflected as the slope of the bid curve. The charging demand is then redistributed in the future by rolling optimization. However, when the distribution network has a large blocking period, as the departure time approaches, the EV charging urgency accumulation and adjustment flexibility are gradually exhausted. Moreover, due to the concentration of a large number of EVs in the morning, the charging load before leaving is prone to serious "crowding" phenomenon.

The essential reason for the above problems is that each EV makes independent decisions, and the only information shared by it is the main grid price, but the main grid price does not accurately reflect the partial congestion of the distribution network. If the transformer layer can perform blocking prediction for its entire time of day, the price signal can be used to guide the EV to further optimize the charging strategy.

IV. CONCLUSION

The P2P energy market represented by electric vehicles will receive more and more attention. Therefore, it is necessary to design a platform for P2P energy market transactions more precisely to ensure that the feedback effect between the operation of the transmission and distribution system does not degrade the stability of the system. At the same time, the trading mechanism needs to be redesigned, allowing the platform owner to maximize their own interests by setting prices. A promising area of future research may be to use cooperative game theory to design a distribution mechanism to promote mutual cooperation between producers and consumers.

The electric vehicle blockchain platform can rely on the concept of shared economic model to incorporate a large number of scattered distributed power sources on the demand side into the charging transaction. And it ensures that electric vehicle charging users can publish personal information in real time on the same platform, in order to sell and purchase the required power. And, whether it is in the unit, in a public place or in a private parking space that is voluntarily involved in trading, the transaction can be carried out. The platform of the grid company on the platform can guarantee that both the seller and the seller can compete freely in the B2C and P2P trading modes, and absorb the distributed power in an efficient and real-time manner.

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