Research and Implementation on the Operation and Transaction System Based on Blockchain Technology for Virtual Power Plant

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***Abstract*—Virtual power plants are among the promising ways that variable generation and flexible demand may be optimally balanced in the future. The virtual power plant is an important branch of the energy internet, and it plays an important role in the aggregation of distributed power generation resources and the establishment of virtual power resource transactions. However, in the existing virtual power plant model, the following problems are becoming increasingly prominent, such as safeguard, credit rating system, privacy protection, benefit distribution. Firstly, the operation and transaction mechanism of the virtual power plant was introduced. Then, the blockchain technology is introduced into the virtual power plant transaction to make it more conducive to the information transparent, stable dispatch system, data security, and storage security. Finally, the operation and transaction system based on blockchain technology for the virtual power plant was design**.

Keywords-virtual power plant; blockchain;transaction system.

I. INTRODUCTION

With the rapid development of renewable energy such as wind turbines and photovoltaics, the trend of distributed energy access to the distribution network is increasingly developing towards high penetration and high density. However, the randomness and uncertainty of the access of a large number of renewable energy sources will have an important impact on the operation and dispatch of the power system and the transactions in the power market. The virtual power plant (VPP) technology is one of the important methods to aggregate many distributed energy sources (DERs), such as distributed power sources, energy storage systems, controllable loads, and electric vehicles, to participate in the operation of the power market and promote the consumption of renewable energy.

The most attractive function of the VPP is that it can aggregate DERs to participate in the operation of the electricity market and ancillary service market, and provide management and ancillary services for the distribution network and transmission grid. In order to achieve its best benefits, many studies have been carried out, such as establishing distributed generator (DG) and controllable loads to participate in the operation framework and model of the day-a-day power market, applying power matcher technology to VPPs, etc.

Literatures [1-2] studied the characterise and issues during the VPP operation. There are various problems in the current VPP operation process. The trust issue of the power supplier in the VPP operator is manifested in the reliability of energy information and revenue settlement. Literatures [3-5] studied the operation and transaction model of VPP. However, the current DG settlement cycle is long, and the investment enthusiasm of renewable energy owners is affected. At present, the VPP information and data are stored in the control center of the VPP operator. There are user identity disguise or data leakage problems caused by hacker intrusion, which poses a threat to the safe operation of the VPP.

The blockchain is a distributed database based on internet foundation and cryptography. The encrypted data is integrated and packaged in the form of blocks, and connected in the order of actual generation time, forming a kind of joint maintenance by multiple parties, using cryptography The accounting technology that guarantees the security of transmission and access, and can achieve consistent data storage, hard to tamper with, and non-repudiation, also known as distributed accounting technology. Literature [6] analysed the value, application scenarios and applicability of blockchain in energy industry. In this paper, the operation and transaction framework based on blockchain technology was proposed to solve those problems.

II. THE OPERATION AND TRANSACTION SYSTEM BASED ON BLOCKCHAIN TECHNOLOGY FOR VPP

Based on the characterises the operation and transaction strategy of the VPP, the VPP needs to aggregate DERs in different regions. Therefore, VPPs need to deal with the random, volatile, and intermittent. It is difficult for VPPs to achieve the ideal utilization rate and overall benefits when the dynamic combination of distributed energy is carried out. In the existing system, the VPP uses two-way communication technology to realize the dispatch of information and data on the power generation side, the demand side, and the power trading market. However, there is no guarantee system for the trusted terminal access and information security of VPPs. Thus, the identity authentication technology of terminal sensing equipment, shared data privacy protection technology, and credit rating were studied.

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A. The Operation and Transaction Strategy of the VPP

According to different functions, VPPs can be divided into two major modules, commercial virtual power plants (CVPP) and technical virtual power plants (TVPP) [3]. The CVPP plans power generation plans, load forecasts, and realizes market transactions, while the TVPP integrates DER input, provides power generation management, online optimization and coordination of DER, etc [7-9]. The basic operating structure of VPP is shown in Figure 1. the CVPP and TVPP could be incorporated in an operation and transaction system in actual application scenarios.

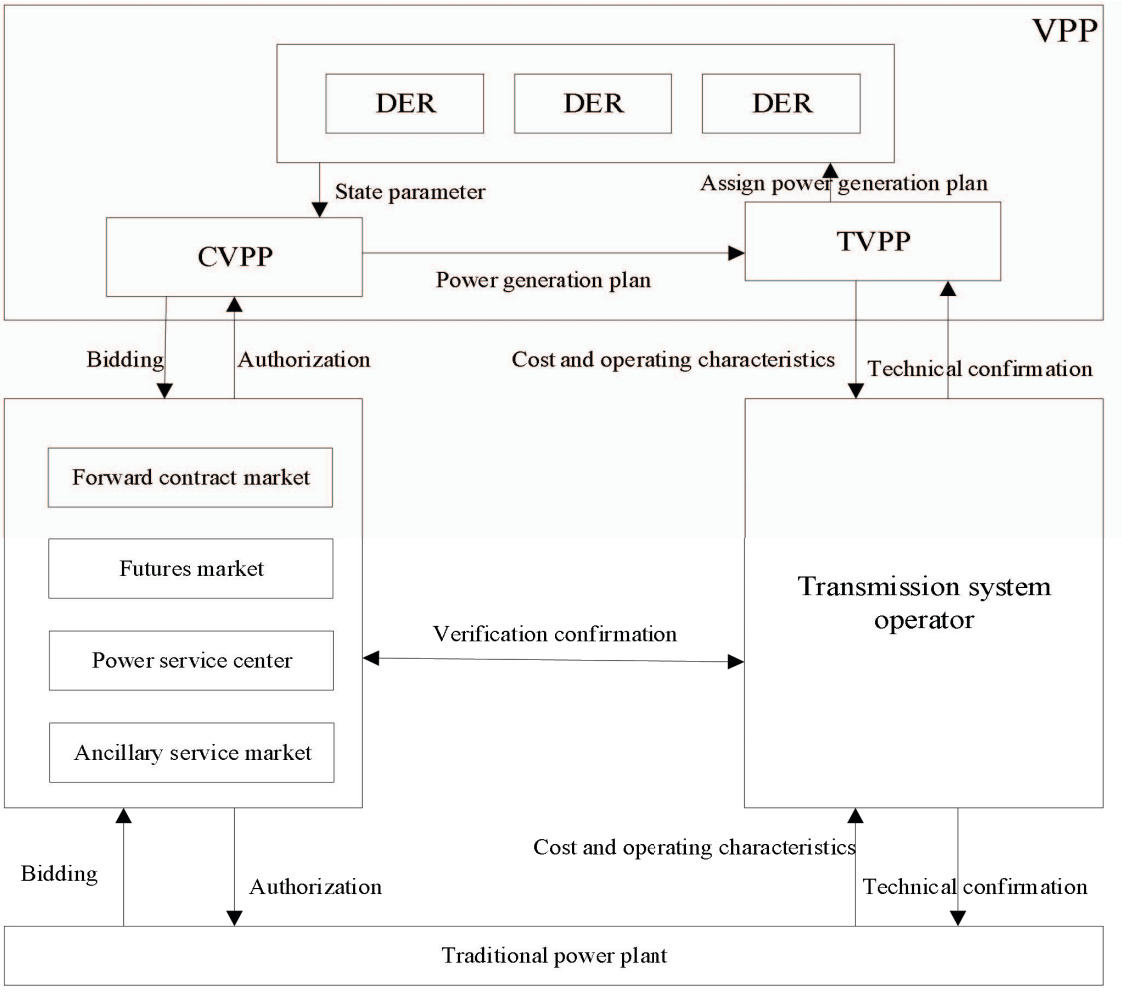

Figure 1. The basic operating structure of VPPs

B. The Blockchain based Identity Authentication Technology of Terminal Sensing Equipment

In the VPP system, the alliance chain model was a prioritized option. The consensus mechanism of the alliance chain can provide high transaction concurrent processing capabilities when the total number of nodes is small and the network scale is not too large. However, VPPs have information collection requirements for a large number of distributed node devices [10-11]. As the number of nodes increases, due to the increase in information that needs to be exchanged, the increase in system load and the increase in network communication, the performance degradation will be obvious.

The hierarchical and classified management of blockchain nodes, break through node types in addition to consensus nodes and non-consensus nodes, and explore lighter nodes such as collection nodes and edge nodes as the tentacle for data acquisition was proposed. And the following researches were studied on the light node identity management model components that support identity authentication, role division and responsibilities of management nodes, identification and rapid query of identity information of massive terminal devices that support national secret algorithms, and ensure the integrity and reliability of data from the source of terminal sensing equipment. To ensure that the data from terminal sensing equipment is credible and identifiable, and to lay a foundation for the confirmation of data rights.

C. The Blockchain based Shared Data Privacy Protection Technology

Taking advantage of cryptographic tools such as secure multi-party calculations, zero-knowledge proofs, and smart contracts combined with oracles is to study data ownership, use rights, processing rights, and subsequent authority control to prevent data owners from privacy losing data control over the data after it is shared [12-13]. Thereby dispelling the worries of data sharing parties, improving data utilization and scope of

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application, and enhancing data value density. Combing blockchain technology with privacy protection technology is to break the dependence on the platform and environment while maintaining high computing efficiency to meet business needs.

The privacy protection technology could be combined with cryptography in the blockchain network, such as data filtering and safe calculation. In the entire data market system and the transaction process within the market system, the data market should not disclose any additional information about users and their data. The role of secure computing is to complete various computing tasks while protecting features such as privacy and fairness. In different fields, achieving goals in different degrees and perspectives.

D. The Blockchain based Credit Rating System Construction

An open and transparent comprehensive credit rating system for VPP operators and users were constructed to stimulate the enthusiasm of VPPs operators and users [14-15].

Determining the parameters and indicators that can be collected in actual scenarios that contribute to the credit rating system. Then, influencing task quota allocation through ratings, and building a multi-level rating system were studies. Scientific and reasonable rating rules through evaluation indicators, incentive measures, and punishment mechanisms were generated to achieve a standardized market.

To achieve standardization of market behaviours of market entities, reduce risks, safeguard the legitimate rights and interests of all parties involved, and provide guarantees for the standardized operation of VPPs, the credit rating rules were design into smart contracts and automatically adjust them based on true and credible data on the blockchain. Source storage and load users, VPP operators, trading centers and other parties can read the credit rating rules and indicator score increase and decrease records, as well as their own and others' ratings, and can improve their behaviour according to the rules to obtain higher credit rating and earnings.

The blockchain based operation management system of VPP is shown in Figure 2. Each VPP could utilize light node for DERs and is responsible for the terminal sensing equipment. As a stakeholder, the VPP should be consensus node during power system operation and transaction.

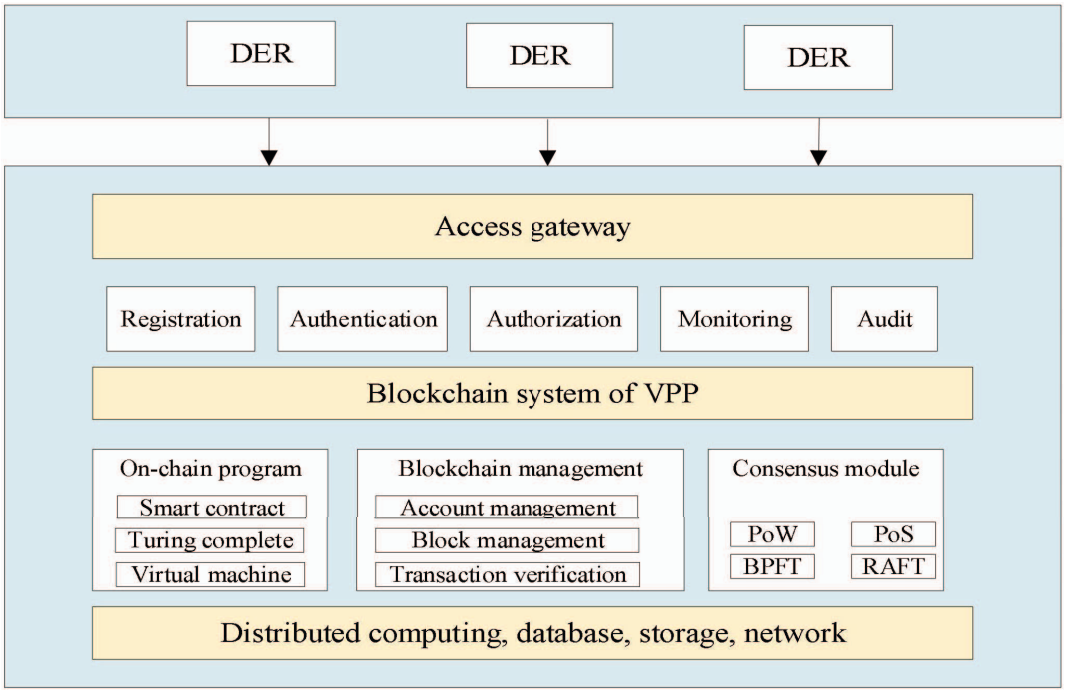

Figure 2. The blockchain based operation management system of VPPs

III. Design of Operation and Transaction System based on Blockchain for the VPP

A. Design of Operation and Transaction Strategy of the VPP

The method to confirm the identity of massive edge devices is a big problem for CA management, and the inability to confirm the identity will directly affect the credibility of the data. Turning the terminal equipment into nodes and making the terminal equipment an integral part of the blockchain can greatly improve data credibility and data security. The identity authentication module of the device terminal based on blockchain management can ensure that the data source is credible and identifiable, and solve the problem of credibility and confirmation of edge terminal data. The electronic authentication technology is supported by the public key infrastructure (PKI) system, which ensures the confidentiality, integrity and non-repudiation of the information transmitted on the network by encrypting, decrypting, digitally signing and verifying the information transmitted on the network, and ensuring the security of network applications.

The design of KPI of the operation and transaction system based on blockchain for the VPP, as shown in

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Figure 3. The complete PKI system is as follows. Security server: For ordinary users, the security server is used to provide security services such as certificate application, browsing, certificate revocation list, certificate downloading, etc.. The users need to obtain the certificate of the security server, and the certificate is issued by the certificate of authority (CA); Registration Authority(RA) server: It plays a role in the CA system structure. On the one hand, it forwards the certificate application request transmitted by the security server to the CA, and on the other hand, it forwards the digital certificate and certificate revocation list (CRL) issued by the CA to the LDAP server and the security server. Lightweight Directory Access Protocol (LDAP) server: It provides directory browsing services, is responsible for adding user information and digital certificates transmitted from the registration authority server RA to the server. Users can obtain digital certificates of other users by accessing the LDAP server; CA server: It is the core of the entire certificate authority, and is responsible for the issuance of certificates. The CA first generates its own private key and public key, then generates a digital certificate, and transmits the numbers to the secure server normally. The CA is also responsible for generating digital certificates for security servers and RA servers; Database server: It is the core part of the CA, and is used for the storage and management of data (such as keys and user information), logs, and statistical information in the CA.

The CA could be a consensus node in the alliance chain, and the data of the individual terminal equipment could be stored in a blockchain light nodes.

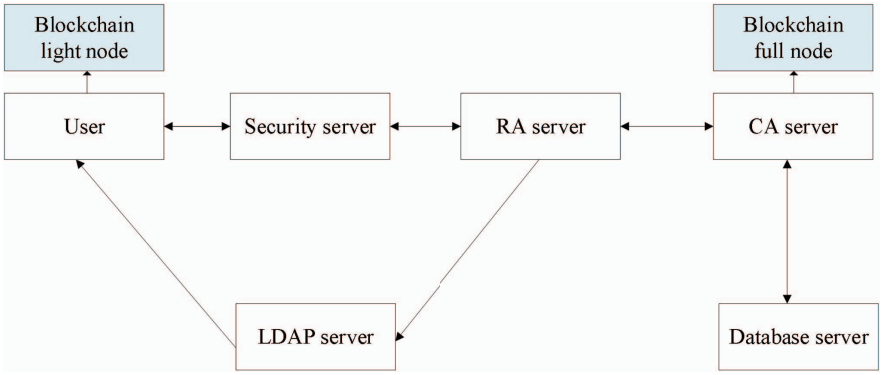

Figure 3. The blockchain based PKI system of VPPs

In the term of shared data privacy protection technology, the on-chain information records all the information of the transaction, forming an operation mechanism with efficient and transparent processes, high data security, and multi-party trust collaboration, which is conducive to solving the privacy protection problem in the power industry chain, and promotes the improvement of production efficiency and the reduction of operating costs. The digital fingerprint technology and Hash value on the chain to ensure that the data is true and complete, but the data is not on the chain. The transmission of support data is restricted to specific authorized nodes. Supporting the use of encryption and decryption methods to control user data access. The cross-chain technology further eliminates privacy concerns of external chain applications.

In the term of credit rating system, the system was design through several indicators, covering the main participants in the VPP ecology, from basic management capabilities to control of power service quality, the establishment of an assessment system to conduct a comprehensive credit evaluation of the participants, as shown in Figure 4. The credit rating system will be written into smart contract and as a measure of electricity trading.

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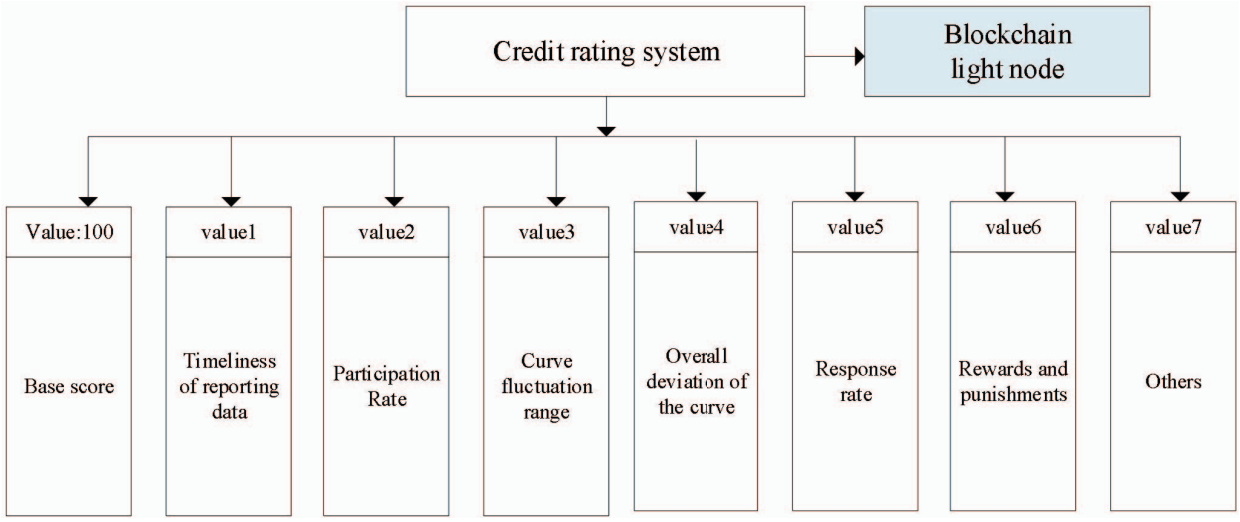

Figure 4. The blockchain based credit rating system of VPPs

B. *Future Implementation of Operation and Transaction Strategy of the VPP*

Combining the traditional VPP operation and transaction system and the mentioned above ideas, the data storage, information security, and data interoperability were effectively introduced into the blockchain system. The blockchain system is divided into two types, full node and light node. The data of the DER could be store on the blockchain system, and not participate in consensus. The full node deals with important information and participates in consensus, such as CVPP node, transaction node, control center node, and supervision node, as shown in Figure 5.

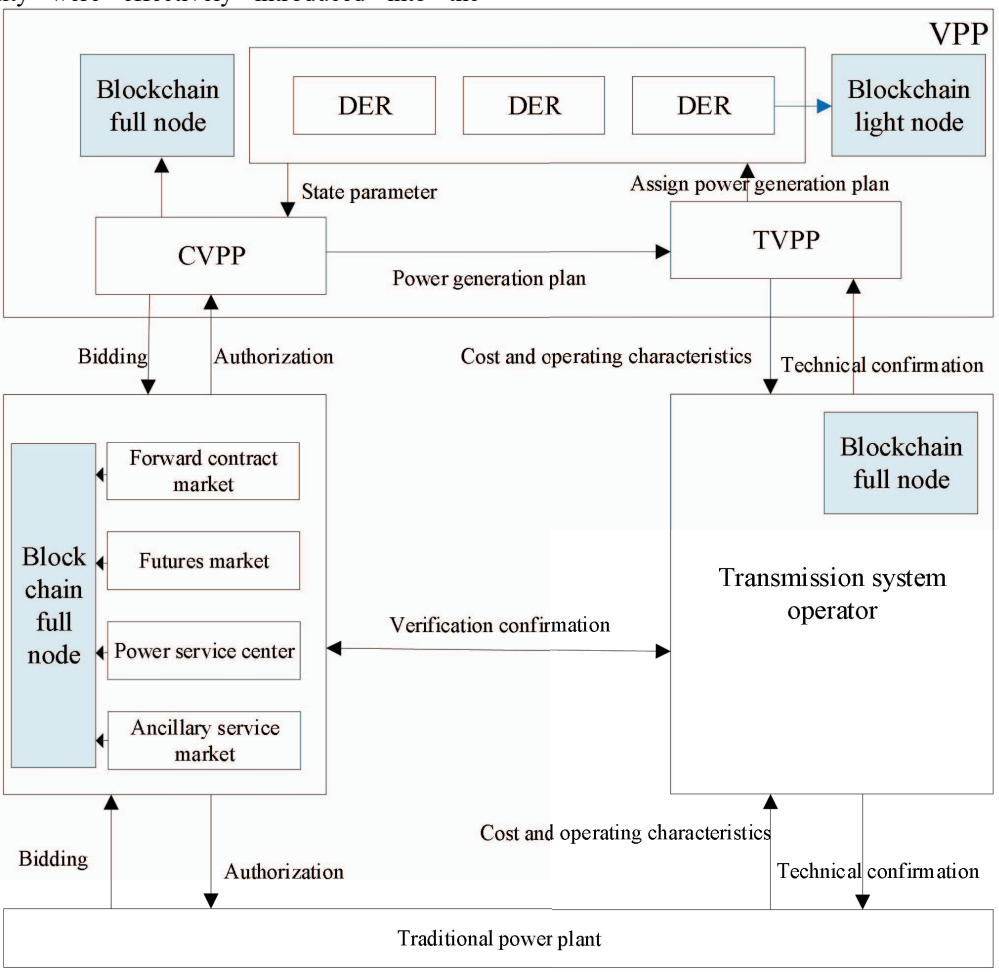

Figure 5. The proposed blockchain based operation and transaction system of VPPs

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IV. CONCLUSIONS

The exploration of terminal sensing equipment data collection methods based on blockchain can enhance the credibility and accuracy of data, provide precise and accurate rights for data, and help ensure the security of data information, thereby reducing investment for data collection and verification, providing a credible foundation for data-based business. The privacy protection of shared data based on the blockchain can refine the granularity of data sharing while protecting the privacy of individuals, institutions, and enterprises, increase the willingness of data sharing, and at the same time increase the collaboration of all parties to increase the overall value density of data. The shared data will be improved in the term of digitization and intelligence of various businesses. Through smart contracts and on-chain data, the transparency and authority of all links of the VPP is enhanced, and an open and transparent comprehensive credit rating system is built for VPP operators and users. The construction of the system is conducive to the self-discipline of the participants and improves the effectiveness of the credit rating system.

Currently, the operation and transaction system based on blockchain technology for VPP is in the research and discussion stage. In this paper, the operation and transaction framework of VPPs based on blockchain technology was proposed. By utilizing the blockchain technology in terminal sensing equipment, shared data privacy protection and credit rating system in the proposed framework, the blockchain node was design into two types. Light nodes are used for storage certificates and full nodes are used for consensus to make ensure efficiency and save investment of the blockchain. In the next implementation process, specific smart contract and node layout should be the key consideration.

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REFERENCES

[1] N. Zhang, Y. Wang, C. Kang, J. Cheng and D. He, "Blockchain technique in the energy internet: preliminary research framework and typical applications," Proceedings of the CSEE, vol. 36, 2016, pp. 4011-4023

[2] Q. He and Q. Ai, "Application prospect of block chain technology in virtual power plant," Electrical & Energy Management Technology, vol. 3, 2017, pp. 14-18.

[3] W. She, Y. Hu, X. Yang, S. Gao and W. Liu, "Virtual power plant operation and scheduling model based on energy blockchain network," Proceedings of the CSEE, vol. 37, 2017, pp. 3729-3736.

[4] W. Shao, W. Xu, Z. Xu, N. Wang and J. Nong, "Study on virtual power plant model based on blockchain," Computer Science, vol. 45, 2018, pp. 25-31.

[5] G. Zhou and G. Li, "Research on distributed scheduling strategy of virtual power plant considering blockchain," Computer Engineering and Applications, vol. 56, 2020, pp.268-273.

[6] X. Shen, S. Chen, Z. Yan, J. Ping and B. Luo, "Analysis on value, application scenarios and applicability of blockchain in energy industry," Automation of Electric Power Systems, vol. 45, 2021, pp.18-29.

[7] B. Wang, Y. Li, S. Zhao, H. Chen, Y. Jin and Y. Ding, "Key Technologies on blockchain based distributed energy transaction," Automation of Electric Power Systems, vol. 43, 2019, pp. 53-64.

[8] J. Ping, Z. Yan, S. Chen, Z. Shen, S. Yang, J. Li and H. Qu, "Credit risk management in distributed Energy resource transactions based on blockchain," Proceedings of the CSEE, vol. 39, 2019, pp. 7137-7145.

[9] H. Zhou, S. Yu, Bai J, Wei Z, Sun G, Zang H and Qian W 2021 Research on trading pattern of virtual power plant based on blockchain technology[J], Power Demand Side Management, 23, pp72-76

[10] X. Chen, Y. Zhu, K. Feng and T. Yu, "Identity authentication of power system safety and stability control terminals based on blockchain," Journal of Guangxi Normal University (Natural Science Edition), vol. 38, 2020, pp. 8-18.

[11] X. Jiang, L. Luo, Z. Yu, X. Fu, G. Sheng, Y. Liu and Y. Qian, "Technologies and solutions of blockchain application in power equipment ubiquitous internet of things," High Voltage Engineering, vol. 45, 2019, pp. 3393-3400.

[12] P. Gao, Z. Chen, L. Yan, J. Xuan, W. Wang, X. Shen and R. Shi, "A new generation of power data security protection technology for zero-trust environment," Electric Power Information and Communication Technology, vol. 19, 2021, pp7-14.

[13] W. Ding, G. Wang, A. Xu, H. Chen and C. Hong, "Research on key technologies and information security issues of energy blockchain," Proceedings of the CSEE, vol. 38, 2018, pp. 1026-1034.

[14] B. Wang, Q. Wang, Y. Li, S. Zhao and M. Wu, "Transaction mechanism of demand response resource considering credit in blockchain environment," Automation of Electric Power Systems, vol. 45, 2021, pp. 30-38.

[15] S. Cui, Y. Li and X. Chang, "Research on model of blockchain-enabled power carbon emission trade considering credit scoring mechanism," Electric Power Construction, vol. 40, 2019, pp. 104-111.

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