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Application and Prospect of Blockchain Technology in the Energy Internet

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Abstract Blockchain is booming as a new generation of information technology. The basic features of blockchain technology, including decentralization, fairness, and expansibility, are consistent with the construction of an Energy Internet. According to the technical characteristics of blockchain and the development direction of the Energy Internet, this chapter analyzes the technical architecture of the energy blockchain. This chapter outlines the current situation of blockchain technology in the application of the Energy Internet using four typical application scenarios. Moreover, it identifies the key scientific problems to be solved in the application of energy blockchain technology and looks toward the development vision of an Energy Internet–based blockchain. Finally, this chapter provides guidance for promoting the application of blockchain technology in China's Energy Internet construction.

Keywords Blockchain technology · Energy Internet · Energy blockchain · Scientific problems · Prospect forecast

1 Introduction

At the general debate of the 75th Session of the United Nations General Assembly on 22 September 2020, President Xi Jinping solemnly announced that China would strive to achieve a peak in carbon dioxide emissions by 2030 and carbon neutrality by 2060. This means that China's economy will officially enter the path of low-carbon transformation. In the coming years, China will continue to adjust its economic growth, industrial structure, technological path, business model, and even the lifestyle of its residents [1]. The energy industry accounts for more than 80% of the country's total carbon dioxide emissions, which is a key area necessary to achieve the carbon

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peak and carbon–neutral goals [2]. Against the backdrop of low-carbon transformation of energy structure, the Energy Internet industry and technology have ushered in significant development opportunities.

The core of the Energy Internet is electricity, which can organically combine energy technology, information technology, and intelligent management technology. This effort has achieved the coupling and complementarity of various energy sources, including electricity, gas, oil, and coal, and thus meets the diversified energy demand of electricity, heating, and cooling [3]. Under the guidance of the carbon peak and carbon–neutral goals, the installed capacity of wind power and solar power has continued to rise. A large number of unstable power supplies connected to the Energy Internet has made the coordinated and optimal operation of energy an increasingly urgent task. In addition, the carbon peak and carbon–neutral goals have accelerated the large-scale development of the Energy Internet. This development requires an energy system with a complex structure, extensive equipment, and complex technology. This structure also has typical nonlinear random characteristics and multiscale dynamic characteristics. The traditional energy dispatching, trading, and management methods do not meet these new requirements for Energy Internet planning, construction, and operation management [4].

In his speech on promoting the innovation and development of blockchain technology and industry. President Xi Jinping stressed that "we should promote the combination of blockchain underlying technology services and new smart cities, and explore the application of information infrastructure, smart transportation, energy and power." The president's guidance necessitates the joint development of blockchain technology and industrial innovation and development, and promotes the need for accelerated integration and functional expansion of blockchain technology and an Energy Internet. In this chapter, we analyze the application mode and basic architecture of blockchain technology for the construction and development of an Energy Internet. We introduce the application status of blockchain technology according to four typical scenarios of energy supply, energy consumption, energy trading, and energy data management. Finally, we identify the key scientific problems facing energy blockchain and propose suggestions for the development of an Energy Internet based on blockchain technology.

2 Background Information

2.1 Energy Internet

Based on the existing energy supply system and distribution network, the Energy Internet has adopted advanced power electronic technology and information technology. The smart grid, thermal power network, natural gas network, hydrogen energy network, and other energy networks have been integrated to realize energy interaction and network sharing with a two-way flow of energy, information, and value [5]. In

2011, U.S. scholar Jeremy Rifkin in his publication *The Third Industrial Revolution* proposed the idea of an Energy Internet as a new energy utilization system characterized by an in-depth combination of energy technology and information technology. At the United Nations Development Summit in September 2015, President Xi Jinping proposed a China initiative to "Explore building a global Energy Internet to meet global electricity demand in a clean and green way." In 2016, the Chinese government noted in its "Guiding Opinions on Promoting the Development of Internet + Smart Energy" (FGAI Energy [2016] No. 392) that the Energy Internet is a new form of energy industry development with the deep integration of Internet access and energy production, transmission, storage, consumption, and energy market [6].

Against the backdrop of the low-carbon transformation of the energy industry and the development and progress of information technology, the development pace of Energy Internet technology is constantly accelerating. At present, the Energy Internet is based on extensive access to renewable energy generation, which covers various types of energy supply facilities in different regions. The Energy Internet connects micro energy networks consisting of distributed power generation, energy storage, intelligent power transformation, and energy saving equipment through Internet access and information technology to create multi-energy complementarity of energy sources [7]. As an intelligent energy system supporting clean and low-carbon transformation of energy and electricity, comprehensive utilization of energy, and flexible and convenient access of multiple subjects, the Energy Internet is an important extension of the power system in the energy field. In addition to providing traditional power transmission and distribution functions, the Energy Internet also has established an energy-sharing and service platform to better support energy nodes, such as low-capacity distributed power generation, electric vehicles, and smart home appliances, which can join the Energy Internet in a plug-and-play way [8]. In addition to the deepening of the concept of energy saving, low-carbon, and sustainable development, the coupling of energy interaction and carbon emissions has become an urgent issue affecting society. Understanding how to integrate carbon emission verification and carbon emission trading into the Energy Internet is an essential problem to be considered in the development of this power system [9].

2.2 Blockchain Technology

Blockchain is a decentralized distributed ledger database, which is a string of data blocks associated with cryptography. Within each data block, information that has been effectively confirmed by multiple businesses is arranged through time series and formed in a chain structure. According to the "White Paper on China's Blockchain Technology and Application Development" issued in 2016 by the Ministry of Industry and Information Technology, blockchain technology includes the use of the chain to verify the data structure and data storage, distributed node consensus algorithm to generate and update the data, cryptography to ensure the security of data transmission and access, and intelligent automation of script code contracts to

program and operate data in a new kind of distributed infrastructure and computing paradigm. Decentralization, security, and reliability are typical characteristics of block chain technology.

According to different ways to participate, blockchain technology can be categorized in three forms: public chain, alliance chain, and private chain. Among these chains, the public chain is the earliest form of blockchain. It follows the principle of complete decentralization and complete peer of nodes. Any node can participate in record maintenance, but the transaction volume is limited. The alliance chain is used primarily for specific organizations, and the predetermined nodes participate in record maintenance. The consensus process is completed by a group of trusted nodes with a certain number of nodes, and the internal nodes are not completely equal. Private chains run only in an internal environment, and only a few internal users can record and access these chains. Internal rules can be easily modified, and restrictions on transaction volume and transaction speed are relatively low, while a-Nodes are quite limited [10].

The characteristics of blockchain technology, including decentralization, openness, transparency, and sharing, are consistent with the construction direction of holographic perception, open sharing, and integrated innovation of the Energy Internet. This technology can effectively solve the problems of data integration, network security, multiagent coordination, and other aspects in the construction of the Energy Internet system. Hence, this work analyzes the application of blockchain technology in the Energy Internet and discusses the application mode and future development direction of blockchain technology in various scenarios.

3 Blockchain Energy Internet Technology Architecture

The application of blockchain technology in the Energy Internet field is in its infancy. With the core idea of blockchain decentralization and distributed data structure, it will be helpful to build the information platform of an energy system. Through the effective integration of information flow and energy flow, the energy interaction and utilization efficiency of the Energy Internet can be improved. Carbon emissions of the entire energy system can be effectively reduced, which will further optimize the value stream flow within the energy system. The Energy Internet technology architecture based on blockchain technology is shown in Fig. 1.

With the development of the new energy industry and the progress of energy science and technology, the Energy Internet has gradually formed an operation mode of horizontal multi-energy complementarity and vertical source network load storage coordination. On the energy supply side, the Energy Internet gives priority to the development and utilization of renewable energy, such as wind power, solar power, and hydropower. It relies on fossil fuel to alleviate the pressure of large-scale unstable power on the operation and dispatching of the energy system and reasonably allocates energy storage facilities to ensure the stability of the energy supply. On the energy demand side, the diversified energy needs of different users for electricity, heating,

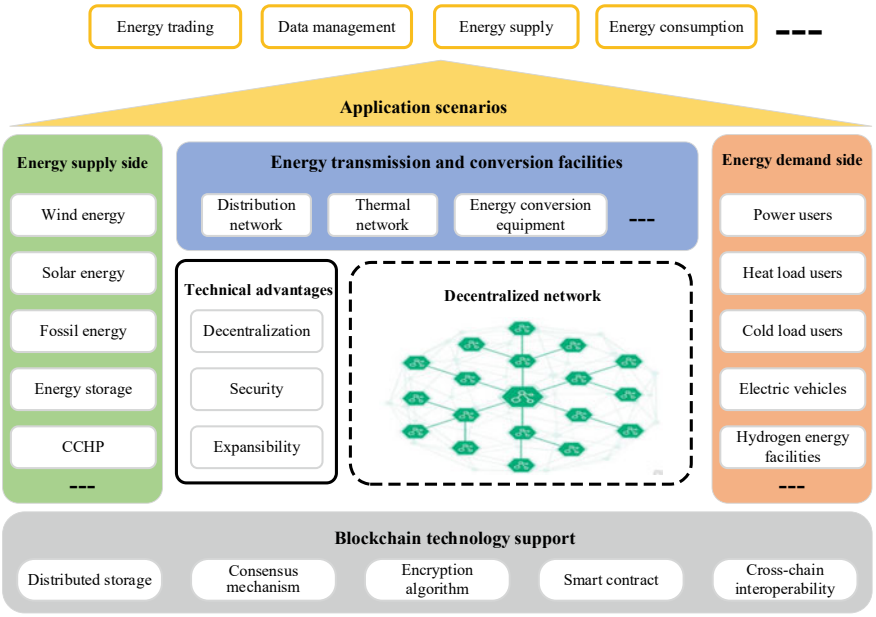

Fig. 1 Energy Internet technology architecture based on the blockchain

and cooling can be met through advanced energy scheduling and management means. Innovative application scenarios, such as charging and discharging of new energy vehicles and hydrogen energy production, have been actively expanded [11]. By connecting energy transmission and conversion, reliance on new technologies, such as an intelligent distribution network and thermal and cold power transmission, it is possible to establish efficient transmission channels at both ends of energy supply and demand. Combined with various energy conversion equipment, including heat pumps and phase change energy storage, the Energy Internet can promote the interaction and optimization of different energy flows [12]. In terms of energy data management, the Energy Internet relies on information technologies, such as big data analysis, machine learning, and prediction. It also integrates internal operational data, meteorological data, power grid data, and power market data of energy. In addition, big data analysis, load forecasting, and power generation forecasting can be carried out to realize the efficient recycling of data flow.

Blockchain technologies, such as distributed data storage, consensus mechanism, encryption algorithm, smart contract, and cross-chain interoperability, have played a key supporting role in the information interaction of the Energy Internet. Unlike traditional ways of storing all data of the energy system in one center, distributed storage allows all nodes in the system to store and manage data, and thus can form a distributed ledger maintained by multiple parties. The consensus mechanism is the key element needed to ensure that all participants in the energy system can form a

unified account record. At present, the common consensus mechanisms include workload proof, rights and interests proof, agency rights and interests proof, and Byzantine fault-tolerant mechanisms. Hash algorithm and asymmetric encryption technology constitute the encryption algorithm technology of the blockchain network. With the help of modern cryptography, the trusted interaction of multiparty subject information can be guaranteed [13]. Smart contracts enable blockchain applications to expand from simple transfer transactions to other fields, such as energy and electricity. This technology can be used to deploy all terms and logical processes related to energy contracts. The automatic execution of the contract code is realized through event triggering, which avoids the low efficiency and potential safety hazards of human control. Cross-chain interoperability is an emerging technology in the blockchain. It can enable different blockchain networks to communicate or share information with each other. It is consistent with the characteristics of wide area interconnection and multisystem interaction of the Energy Internet. Cross-chain interoperability has become one of the key technologies of the future [14].

With the technical support of the blockchain, a decentralized network platform can be built. The energy supply side, demand side, transmission and conversion, data management, and other subjects can participate in the network platform as independent nodes. This ensures that the Energy Internet can offer technical advantages, such as decentralization, security, and expansibility. Decentralization is the most typical feature of an energy blockchain network. As the number of participating nodes in the energy system increases, the credibility of the system also increases [15] to form an energy interaction system of multilateral trust. The security of the energy blockchain is reflected in its ability to prevent forgery and tampering. The blockchain validates the transaction data occurring in a certain period of time and packages it into data blocks. Each block is linked in an orderly way with the previous block through cryptographic algorithm. The flexible expansibility of blockchain technology makes its integration with the Energy Internet possible. The distributed operation mode can be used to build a flat network platform and break the inefficient modes of centralized operation, control, and operation. Blockchain technology improves the interaction efficiency of energy flow, information flow, and value flow in all links of the Energy Internet. On the basis of the technical advantages of the energy blockchain, blockchain technology has been applied in many Energy Internet scenarios. The specific conditions are described in the next section.

4 Application of Blockchain Technology in the Energy Internet

The Energy Internet based on blockchain technology has adopted a midsize desktop interface design and has carried out relevant applications in energy supply, energy consumption, energy trading, and data management. This technology provides strong support for various energy businesses.

4.1 Energy Supply

The wide access to distributed renewable energy has promoted the point-to-point interaction between multilateral power trading and energy. The distributed energy management mode has some problems, however, such as high management cost, low operation efficiency, opaque data, and difficulty protecting privacy. At the same time, the energy and power industry has actively participated in carbon emission trading to realize low-carbon transformation and development. The carbon market still has problems in data collection, credit supervision, information circulation, and other aspects [16]. Blockchain technology is integrated into the energy supply side to build an equal, trustworthy, safe, and efficient network platform. The supply of information of the energy enterprises and equipment is linked for storing relevant product and service information through chain authentication. The time stamp recording and allocation mechanism can be used to address real-time queries for relevant information, such as an energy scheduling and management business. This improves the energy management efficiency of multiple energy coordination and complementarity. In addition, the blockchain can track and record the carbon emission data generated in the process of energy supply, which uses the blockchain data structure and distributed ledger technology. This carbon emission verification and trading information will be broadcast and stored throughout the network, which then provides support for the verification and supervision of carbon emission data. The structural diagram of an energy supply platform based on blockchain technology is shown in Fig. 2.

Many countries and regions have carried out energy supply management projects based on blockchain technology. Globally, the United States is one of the most active countries in the development and application of energy blockchain technology and developed the world's first energy blockchain project in 2016. This project collects

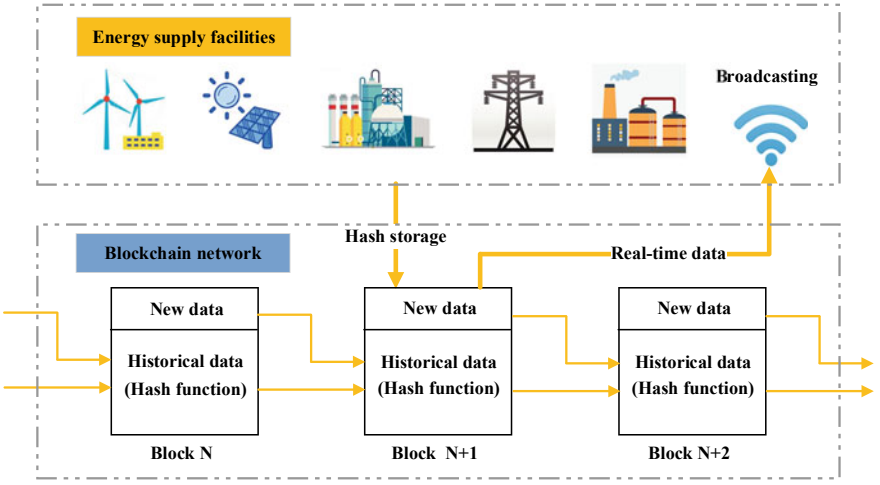

Fig. 2 Structural diagram of an energy supply platform based on blockchain technology

the power supply information of distributed photovoltaics in Brooklyn, New York, and uses blockchain technology to distribute surplus power to energy users in need. In 2017, WePower UAB in the United States established the WePower platform. This blockchain token technology virtually maps renewable energy electricity into energy tokens that can be circulated efficiently. It has improved scheduling efficiency and flexibility on the energy supply side [17]. The practice of an energy blockchain in China started a few years later. In July 2020, the Beijing Electric Power Trading Center launched the trial operation of a voucher trading system based on blockchain technology. The blockchain fully supports the implementation of a renewable energy consumption guarantee mechanism. The Haishu District in Ningbo officially launched a carbon housekeeper platform in July 2021. By relying on the digital economy portal, a data connection between the government and enterprise was realized. Full coverage of carbon emission data monitoring of industrial enterprises was achieved, and thus provided a data basis for the issuance of carbon quotas for industrial enterprises.

4.2 Energy Consumption

The demand-side response is an important means of Energy Internet supply and demand interaction. This response can optimize the resource allocation at both ends of energy supply and demand, alleviate demand for electricity from peak load, and improve the overall operation efficiency of the energy system [18]. Although China launched a series of demand-side response demonstration projects in 2012, the effectiveness of the project implementation was insufficient because of the cumbersome active response process at the energy consumption end, the low level of fine management, and the difficulty of information interconnection and sharing. As shown in Fig. 3, using blockchain technology, the supply and demand ends of the energy system have been connected directly to form an interconnected network platform. Energy consumers, service providers, government agencies, regulatory authorities, and other nodes are connected and share the information of the energy system in real time. This provides a basic information guarantee for active response and regulation on the energy consumption side [19]. In addition, energy consumers can find suitable energy suppliers by accessing the information of relevant blocks. The smart contract in the platform will match the appropriate supply and demand sides to ensure real-time confirmation, real-time execution, and automatic clearing of energy transactions to simplify the process of energy consumption.

To improve the convenience of energy consumption and guide energy users to actively consume clean and low-carbon renewable energy, Germany's Innogy Innovation Hub company launched the Share&Charge project. This project integrates the information of electric vehicle users and charging piles on the chain, and users can find a charging pile that is powered by renewable energy to charge the vehicle using a mobile phone program [20]. BittWatt of Singapore has established an intelligent

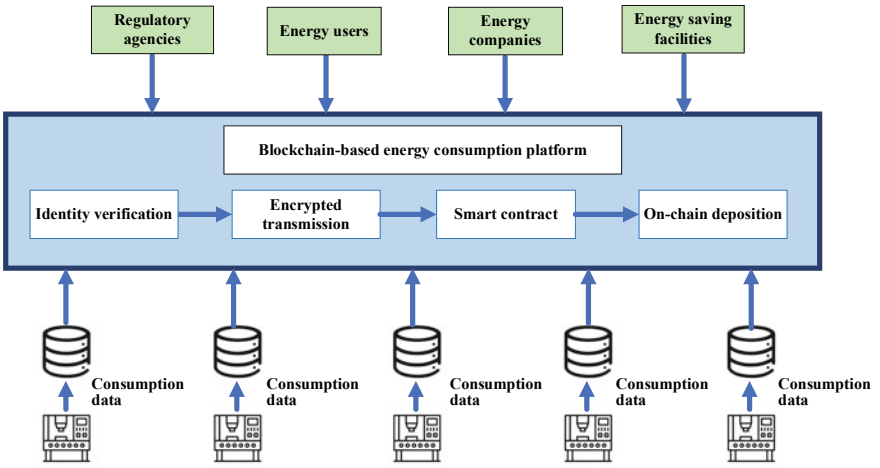

Fig. 3 Structural diagram of an energy consumption platform based on blockchain technology

energy consumption platform based on blockchain technology to solve the problems of delay and inefficiency in the interconnection of energy supply and demand. This program has achieved the real-time matching of energy supply and demand and the automatic transfer of digital assets. China's Shenzhen Zero Carbon Technology Co., Ltd. (Xarbon) has combined blockchain technology and carbon sink business. Different types of energy consumption data are intelligently analyzed to develop a "carbon sink chain" intelligent platform to encourage the public to consume green energy [21].

4.3 Energy Trading

The diversification of the main participants in the Energy Internet has driven the need for higher requirements for information transparency and transaction efficiency of energy transactions. The traditional electricity trading mode no longer meets the diversified needs of the energy market. As shown in Fig. 4, in the energy-trading platform based on blockchain technology, energy producers and sellers can encrypt and transmit the quotation to the blockchain system before the beginning of the trading cycle. Through a two-way auction, the supplier and the demander can reach the transaction intention, and the transaction contract will come into force after being signed digitally by the buyer and the seller and the power grid enterprise. Smart contracts will automatically perform energy scheduling, expense settlement, and other businesses, reduce personnel workload, and save labor costs [22]. At the same time, the blockchain system can set a reputation value list to exclude malicious nodes that have low value from energy transactions. This approach reduces the security risks

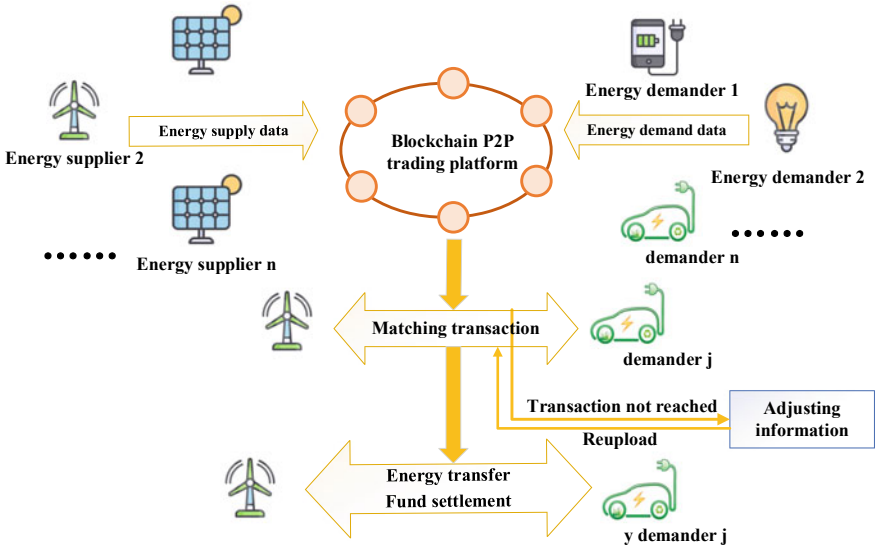

Fig. 4 Structural diagram of an energy-trading platform based on blockchain technology

of the Energy Internet and blockchain systems and ensures the normal progress of energy transactions.

The Piclo project in the United Kingdom is an earlier energy-trading blockchain platform, which provides direct energy interaction services by matching transactions according to the needs of users and suppliers. The Australian power ledger project has made full use of local lighting resources to build a P2P solar power-trading system based on blockchain technology. This project has solved the problem of mutual trust between energy supply and demand [23]. In China, the Shekou energy blockchain project launched by the China Merchants Charity Foundation will connect clean power located in Shekou Nanhaiyiku to participate in the virtual transaction of clean power. The smart contract in this project has been used to enable the supply and demand sides to complete energy transactions [24]. State Grid Shandong Electric Power Company has created an intelligent distributed energy-trading platform based on blockchain technology, which realizes the purchase and sale of electricity among photovoltaics, energy storage, and users in a microgrid to improve the transparency and operation efficiency of energy trading.

4.4 Energy Data Management

The open sharing of energy data can promote the revolution of energy production and consumption with digital assets. This ability to share big data plays an important role in improving the energy utilization efficiency and operation management efficiency

of the Energy Internet. The disclosure of valuable information, however, poses many problems, such as the diversification of data structure, the risk of privacy disclosure, and the difficulty of ensuring information security [25]. The trusted mechanism of blockchain technology can build a highly secure data management platform for the Energy Internet. This technology supports the safe interaction and open sharing of diversified data at different levels. At the micro level, users can view their energy data anytime and anywhere and release energy demand information. In addition, energy suppliers can manage energy supply information through an integrated information platform and use various decision support systems to formulate energy supply plans. At the macro level, the distributed blockchain network stores energy supply and demand information that does not involve privacy, which can be extracted and utilized by all kinds of participants. Massive amounts of actual data are necessary for the research and development of renewable energy, energy conservation, and consumption reduction. Thus, building a data management platform based on blockchain technology can better provide a strong data foundation for Energy Internet science and technology research and technological innovation [26]. The structural diagram of a data management platform based on blockchain technology is shown in shown in Fig. 5.

To strengthen the data management of the energy industry, the Filament Company of the United States proposed Blocklet chip hardware and blockchain software solutions in 2018. The company applies these solutions to machines, instruments, or other edge equipment to realize the functions of safe transaction, real-time monitoring, asset tracking, and management of embedded energy equipment. PONTON of Germany launched a Gridchain for the real-time management of power grids. This system improves coordination among power generation, transmission, distribution, and dispatching and also provides a solution for power grid congestion management [27]. In China, the State Grid credit investigation company uses blockchain technology to integrate internal power data, e-commerce data, industry and commerce,

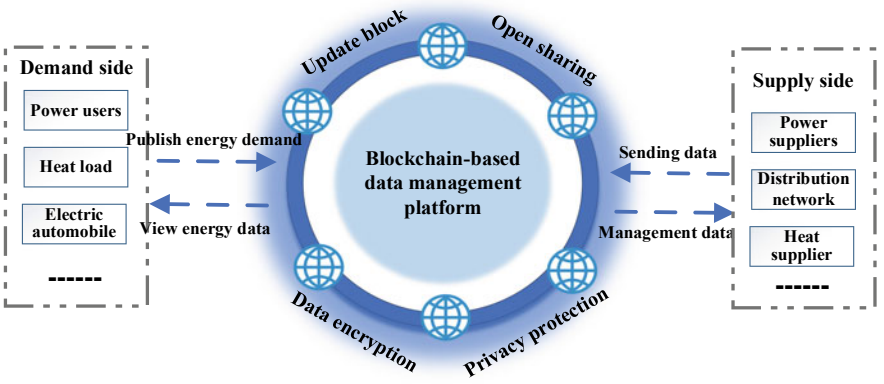

Fig. 5 Structural diagram of a data management platform based on blockchain technology

justice, and other external industry data of the State Grid Corporation of China. More than 10,000 pieces of black-and-white list data are stored and shared by encryption, which optimizes the management mode of credit data. China Southern Power Grid Corporation also invested in and built a green certificate trading platform. The blockchain distributed ledger function is used to manage user account information and transaction information in real time. This function is used to avoid violations such as artificially modifying parameters and tampering with transaction data.

5 Scientific Problems in the Application of Energy Blockchain Technology

The theoretical research of energy blockchain has achieved considerable research results, and relevant demonstration projects have been preliminarily put into practice. Because of the characteristics of blockchain technology and the physical characteristics of the Energy Internet, the application of blockchain technology in the Energy Internet still requires some adjustments. These key scientific problems are as follows:

1. Blockchain technology still faces a series of bottlenecks. First, the blockchain consensus mechanism poses the problem that it is difficult to balance the node size, operation efficiency, and fault tolerance [28]. The workload proof mechanism offers significant advantages in node size and fault tolerance, but it takes too long to reach a consensus and cannot meet the operational requirements of the energy system. Although Byzantine and proxy proof of rights and interest mechanisms can improve operational efficiency, some nodes are excluded from information consensus verification, resulting in reduced fault tolerance. Second, the current application of blockchain technology has focused primarily on business scenarios that do not require high real-time management and throughput. At present, the ability of blockchain technology to mine innovative business scenarios is relatively insufficient. Therefore, the maturity of blockchain technology needs to be improved, and continuous technical iteration is needed to meet the application needs of practical projects.
2. The application of blockchain technology in the field of energy and power also faces limitations. First, under the guidance of the goal of carbon peak and carbon neutralization, the installed scale of new energy power, such as wind and light, continues to rise, and the intermittence and volatility of new energy power generation have formed a more complex way to supply energy [29]. Second, the Energy Internet will open up the energy interaction throughout the source network load storage. The Energy Internet also can integrate the application of energy-saving and consumption-reducing equipment, such as absorption heat pumps and waste heat recovery. This integration could solve the diversified energy demand of electricity, heating, and cooling as well as the complex physical structure of the energy system, which may make it difficult to integrate various information in the

blockchain. In addition, the construction cost of the energy blockchain network platform is high. If the existing energy supply and demand equipment and transmission and conversion systems are transformed and updated comprehensively, significant investment costs will be required. This introduces further challenges to the large-scale application of blockchain technology in the field of energy.

3. The promotion and application of energy blockchain technology faces problems, such as difficult supervision and blame. The blockchain data structure can ensure that the information on the blockchain network can be traced but not be tampered with. When it comes to offline execution, real-time energy interaction, and other scenarios, however, online records cannot cover all business processes, and may pose problems with the data on the chain being inconsistent with energy information off the chain. Therefore, when trying to reduce human intervention, it remains difficult to ensure that the energy information outside the chain is truly and reliably digitized on the chain. The Energy Internet also is related to all aspects of the national economy and to people's livelihood. Especially in regard to the development trend of energy conservation and low carbon, the requirements of energy scheduling and trading have become increasingly strict. At this stage, the energy blockchain system has been dominated by an alliance blockchain that generally excludes regulators. This system cannot be used to guarantee the legality and compliance of blockchain technology application. Therefore, it is essential to establish an energy blockchain supervision mechanism that is suitable for future development [30].

6 Prospect of Energy Internet Based on Blockchain Technology

In light of the key scientific problems faced by the application of blockchain technology to the Energy Internet, the theoretical research and technological innovation of energy blockchain in the future may focus on the following three aspects: high operational efficiency, high scalability, and effective supervision.

6.1 High Operating Efficiency

The energy system has the characteristics of instantaneous response and real-time balance. It is necessary to solve the performance problem of the blockchain. Only by improving the operation efficiency of the energy blockchain network can this technology be applied to the construction of the Energy Internet on a large scale [31].

First, starting from the underlying architecture of blockchain, a consensus mechanism has been actively explored to meet the needs of the Energy Internet. A consensus verification method with both fault tolerance and response efficiency should be

designed to meet the actual scenario of large-scale access of energy supply and demand nodes. Second, by continuously improving and optimizing the encryption algorithm of the blockchain and by using the latest research results of modern cryptography, we can reconstruct the formation mechanism of data blocks and improve the asymmetric encryption efficiency during energy information interaction. This mechanism would enable more efficient storage as well as the management of massive amounts of energy data. In addition, the effective integration of energy blockchain with artificial intelligence, 5G communication, Internet of things, and other information technologies has been accelerated. A low-cost and efficient communication system that is widely applied using 5G should be arranged at the terminal of energy facilities. This system would be able to effectively manage all kinds of data at both ends of the energy supply and demand and transmission system and thus would improve the circulation efficiency of energy information.

6.2 High Scalability

With the diversified and large-scale development of the Energy Internet, higher requirements will be needed for the scalability of energy blockchain technology. Therefore, operational characteristics should be the focus of the future development of the Energy Internet. By optimizing the platform architecture, improving the smart contract, and taking full advantages of cross-chain technology, the applicability and practicability of blockchain technology in the Energy Internet can be effectively improved.

For the energy blockchain network platform, the open-source structure and technical advantages of the public chain should be fully utilized. The underlying architecture to meet the multitype application scenarios of the Energy Internet has been studied. The modularization of new energy power generation facilities, energy-saving and consumption reduction equipment, and an intelligent regulation system have been embedded into the blockchain platform architecture to achieve the autonomous cooperation and cascade utilization of multi-energy networks. Regarding smart contracts for the energy blockchain, the operation mechanism of various energy equipment should be studied extensively. The energy flow and information flow of energy production, transmission, transformation, utilization, and other links must be effectively integrated. With the help of a high-performance, programmable development language and computing engine, a modular energy management intelligent contract can be constructed. This would shorten the development cycle of energy blockchain smart contracts and reduce the cost of contract deployment and transfer [32]. In terms of cross-chain technology utilization of the blockchain, cross-chain interoperability technologies, such as notarization mechanism, side chain relay, and hash lock, should be adopted to break the "data islands" of different energy systems and different energy attributes. The information interaction between heterogeneous energy subsystems has promoted energy interaction, which can be used to balance the energy-wide area of the Energy Internet.

6.3 Effective Supervision

The development of the energy industry is closely related to the national economy, energy conservation, and low carbon emissions. It is necessary to introduce a practical and effective regulatory mechanism to ensure the safety and credibility of energy information. Only in this way can we widely promote and apply energy blockchain technology and support the high-quality and sustainable development of the Energy Internet.

Furthermore, we should strengthen the supervision and accountability of all participants in the energy blockchain through technical means. In a decentralized, collaborative, and autonomous network platform, a high-security encryption algorithm should be introduced to improve data security and privacy protection of the system. With the help of blockchain cross-chain interoperability and other technologies, the key information that does not involve privacy can be packaged into blocks and sent to the supervision node regularly. While protecting the privacy of energy interaction subjects, additional supervision of energy trading, carbon emission trading, and other markets is needed. The entire management process of the Energy Internet should be realized by penetrating the supervision mechanism. Multiple subjects involved in energy dispatching and trading should be strictly reviewed, and entity mapping between real identity and virtual network should be established. Active verification, tracking, and authentication of the uplink data can prevent in-process stop loss and accountability for all kinds of Energy Internet businesses [33].

7 Summary

As a decentralized, open, transparent, and fair emerging technology, blockchain plays a fundamental and leading role in promoting data sharing, optimizing business processes, reducing operating costs, and improving coordination efficiency. The application of blockchain technology has been widely recognized and valued. It has become an emerging technology direction in the key areas of the strategic layout of many countries and has opened up a new track for national competition. The Energy Internet is a typical example of the deep integration of the energy industry and information technology. Its basic characteristics of openness, interconnection, and peer-to-peer sharing are highly consistent with the basic design of the blockchain, making the Energy Internet one of the more important fields in blockchain integrated application. The Energy Internet based on blockchain technology has revealed a unique technical advantage in energy supply, energy consumption, energy trading, data management, and other aspects, and as such, has provided new ideas for the development of Energy Internet technology and the energy industry.

Because the integrated application of blockchain in the energy field is still in the exploratory stage, the Energy Internet based on blockchain technology still faces problems, such as technical bottleneck, difficult expansion, and weak supervision. We

need to accelerate theoretical research and technological innovation, strive to improve the operational efficiency of the energy blockchain, and enhance the applicability of blockchain technology in the energy system. In addition, independent technological innovation and mechanism reforms can improve the effective supervision of energy blockchain projects. In the future, blockchain technology should be combined with the energy industry to build an integrated Energy Internet system that is suitable for China's sustainable economic and social development. This development will greatly promote the transformation and upgrading of China's energy structure and contribute to the realization of China's strategic goal of reaching its carbon peak and carbon-neutralization goals.

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