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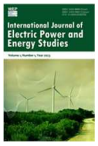

Discussion on the Mechanism of Collaborative Promotion of Smart Grid Development through Energy Storage and Energy Blockchain

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ABSTRACT

With a growing share of renewable sources providing most of our electricity generation, they will introduce many unique challenges for tomorrow's power systems,including important problems of peak load management and scheduling difficulties. Energy storage provides a flexible means to provide energy,plays a key role to solve those problems. Energy blockchain has the characteristics of decentralization, transparency and immutability,provides a new idea for the management of information in energy system, As far as the key problem of how energy storage and energy blockchain could promote the construction of intelligent grid,this work suggests the endogenous relation between energy storage and energy blockchain technology which could be supportive to the evolution of smart grid,and analyses according to its operating mechanism, transaction mode, incentive mechanism and credit mechanism. Soenergy storage and energy block chain can build a grid optimization model combining IoT and data to enhance the flexibility of systems,unleashes the vitality of the distributed power market , fully reflects multi-dimensional values and reduces operation management cost ,and provides novel ideas on how to safely and stably operate smart grids.

KEYWORDS

Energy Storage Technology; Energy Blockchain; Smart Grid; Collaborative Mechanism; Operational Optimization; Distributed Trading.

1. INTRODUCTION

The global energy revolution is ongoing, and the power system worldwide is in a period of great development. The large-scale integration of new energy into the grid has led to increased uncertainty in the operation of the power grid, posing new challenges to the traditional operation of the power system. The smart grid is the foundation platform for future energy transformation and development, and needs to consider issues such as source load bilateral uncertainty, diversified distributed power sources and load access and regulation, and ensuring safety and stability. The development of large-scale energy storage has provided the physical foundation for regulating the power system, but the effective centralized control and efficient utilization of a large number of decentralized energy storage devices still face management challenges and technical obstacles[1]. At the same time, blockchain technology is gradually being applied in the energy field, playing a decentralized, traceable, and tamper proof role in the energy system to solve related trust and cooperation issues. Although energy storage and energy blockchain have different technological attributes, they can complement each other in improving the operation level of the power grid and resource allocation. Analyzing the mechanisms by which both contribute to the construction of smart grids can help achieve energy conservation, emission reduction, and the development of smart grids[2].

2. DEVELOPMENT NEEDS AND CHALLENGES OF SMART GRID

Worldwide, with the development of clean energy and the increasing demand for its applications, the smart grid, as the future trend of power grid development, has been widely recognized and developed for its safety and economy. However, new energy sources such as wind and solar have the characteristics of randomness and instability, which pose great challenges to the stable operation of the system after being connected to the power grid[3]. They also put forward higher requirements for peak shaving and frequency regulation of the system, and can produce significant power changes in some harsh weather environments, thereby affecting the normal operation of the entire system. The improvement of new energy consumption capacity and the guarantee of operational reliability have become the main contradictions faced by smart grids; At the same time, the structure of the power system has undergone significant changes.

The popularization of distributed photovoltaics, user side energy storage and other facilities has transformed traditional power users into integrated producers and consumers, promoting the rapid evolution of the system from a centralized one-way mode to a distributed multi-directional interactive mode. The access of massive dispersed resources not only improves energy utilization efficiency, but also makes the effective aggregation, coordination optimization, and scheduling management of resources exceptionally complex, becoming an important issue in the development of smart grids[4]. Multi party participation in market transactions requires more flexible, transparent, and efficient market mechanisms, but the existing market mechanisms still lack support for distributed trading, real-time pricing, and fair participation of small-scale entities, which is not conducive to the active development of the market; In addition, the smart grid relies on massive data acquisition and transmission, and issues related to data security, trustworthiness, and privacy are gradually being exposed. The integration of a large number of devices and the complexity of device functions also pose new requirements for traditional management methods, urgently requiring the intelligent transformation of device operation and maintenance methods. How to comprehensively solve the multiple contradictions mentioned above is a new topic worthy of in-depth research.

3. TECHNICAL FOUNDATION OF ENERGY STORAGE AND ENERGY BLOCKCHAIN

Energy storage refers to technology that stores and releases energy for the purpose of balancing the spatiotemporal matching between electricity supply side and demand side. At present,the common technologies are pumped storage, electrochemical energy storage, and compressed air energy storage. As technology improves and prices decline,the growing utilization of electrochemical energy storage (especially in the form of lithium ion batteries), and Load Optimization is central to most applications for energy stor-rapid frequency and voltage response; improve power supply reliability; accommodate new energy consumption. It's function would change from auxiliary service to required service of the system[5].

Energy blockchain refers to the technology of using blockchain technology to build a distributed and trustworthy data management and cooperation network in the energy field, using encryption algorithms and chain structures to ensure that information cannot be forged, the source can be traced, and combined with smart contracts for automatic contract fulfillment. It mainly involves P2P energy trading, clean energy tracking, energy data storage, and electric vehicle charging and discharging management. Essentially, it is the construction of decentralized trust relationships, which saves the costs of intermediaries and cooperation communication expenses[6].

From a technical perspective, energy storage and energy blockchain have a natural complementary relationship. The former is a materialized energy storage device that directly regulates the spatial and temporal distribution of energy; The latter is a digital trust carrier that solves the trust coordination problem in scheduling, trading, and management of energy storage resources. Energy storage

provides value landing application scenarios for blockchain, and blockchain provides technical support for trusted aggregation, efficient management, and precise value realization of distributed energy storage resources. The combination of the two is an organic unified system of physical flexibility and information reliability.

On the basis of reaching consensus, some technical difficulties need to be solved: firstly, it is necessary to improve the data docking standards to ensure that data can be quickly and correctly stored in the chain; Then, it is necessary to provide strong security capabilities to avoid security risks during data transmission, storage, and application; Finally, develop corresponding system integration strategies based on different needs, and do a good job in selecting blockchain and designing contracts. Balance safety, efficiency, and cost. The improvement of the above technical details requires joint efforts from both upstream and downstream industries to study and explore.

4. THE CORE MECHANISM FOR PROMOTING THE DEVELOPMENT OF SMART GRIDS THROUGH THE SYNERGY OF ENERGY STORAGE AND ENERGY BLOCKCHAIN

4.1. Operating Mechanism to Enhance the Flexibility and Safety of the Power Grid

The combination of energy storage and energy blockchain can achieve more efficient and flexible regulation of smart grids. Traditional power grid scheduling cannot cope with the situation where a large number of distributed power sources are connected, and although energy storage can be used as a distributed regulation source, it is difficult to effectively aggregate and schedule it in practice due to its inherent distribution. On the blockchain, store data such as the status and available electricity of energy storage facilities, forming a publicly available and reliable energy storage asset ledger[7].

The power dispatch center or resource aggregator can determine the peak shaving capacity of energy storage resources more reasonably based on the trusted information mentioned above, and provide reasonable scheduling strategies; Smart contracts further automate scheduling strategies. In the event of system frequency offset or voltage fluctuations, energy storage batteries that meet certain conditions can be automatically scheduled and assisted in a timely manner. Not only does it improve the timeliness of power grid regulation, but it also reduces human operation costs and the probability of errors. New energy sources such as wind power and photovoltaics have the characteristic of output fluctuations. Energy storage can be stored when there is an excess of new energy output and released when there is a shortage, thereby stabilizing the fluctuations[8].

Due to the stable correlation between energy blockchain and charge-discharge behavior of energy storage,and with the output power from renewable energy, it can reflect the real role of energy storage on consuming renewable energy correctly. On this basis, we could further establish a more reasonable market-based incentive mechanism to motivate energy storage providing services which improve the consumption level of renewable energy.

Meanwhile, energy storage can also be used for building up the electric network security protection system as they can provide fast response support (active and reactive) into the electricity system:which helps reduce the impact of system failures, prevent the escalation of accidents. Energy blockchain stores the running state of the whole power network and the reaction of the energy storage battery,facilitating the post-accident analysis of the reasons for accidents, and this information can not be forged. It is not only convenient to divide the responsibility of the accident,but also to be used as foundation of improving the security barrier. Especially in case of complicated chain failure,relying on the technical features of the blockchain to realize multiple party data information sharing and analysis, it will help operators understand the real situation of the existing system objectively and accurately, and put forward more rational disposal schemes[9].

Traditional mutual assistance between adjacent power grids relies more on pre signed agreements, and there are difficulties in coordination and settlement during the specific implementation process. With the help of energy storage and blockchain technology, cross regional resource regulation can achieve trustworthy sharing. The power grid of each region records the information of its available energy storage resources on the chain. When a certain region is short of electricity, it can automatically and reliably call on the energy storage resources of other regions through smart contracts, and settle automatically after use, greatly improving the speed and convenience of power mutual assistance between regions.

4.2. Activate the Trading Mechanism of the Distributed Energy Market

As one of the development trends of future smart grids, the construction of distributed energy markets faces the problem of small-scale and fragmented resources being difficult to effectively access. The high transaction fees, cumbersome clearing procedures, and unreliable trading entities all severely limit market liquidity. The application of energy blockchain combined with energy storage can effectively solve this series of problems.

A P2P energy trading platform based on blockchain technology is the simplest and most cost-effective way for distributed energy storage resources to participate in market transactions. During this process, energy storage owners can put their surplus electricity or some regulation services they can provide on the shelves for sale, and nearby customers can buy and use them according to their own wishes. The entire transaction is conducted fairly and justly in the blockchain, and all transactions are recorded and cannot be modified.

Smart contracts can automatically complete processes such as transaction matching, electricity calculation, and electricity billing, significantly reducing transaction costs and thresholds, allowing small-scale energy storage owners to more freely obtain their investment benefits. Energy storage can provide multiple types of services at the same time, such as energy services, frequency regulation services, spare parts services, etc. In the traditional mode, transactions need to be conducted on different platforms, and the procedures are cumbersome[10].

Based on blockchain technology, universal smart contracts can be designed to enable energy storage owners to participate in different service market transactions simultaneously on the same system platform, and determine their own operating status based on real-time market clearing price information. Smart contracts will automatically coordinate and settle between different services, greatly improving the marketization level and economy of energy storage utilization. Traditional electricity prices cannot reflect the supply and demand situation of the market in a timely manner. The blockchain trading platform supports a more granular pricing system.

Due to the flexibility of energy storage systems and their sensitivity to prices, charging and discharging decisions can be made based on price information, which can not only obtain corresponding profits but also alleviate market volatility to a certain extent; All transaction and behavioral information stored in blockchain can provide data support for studying market conditions and formulating market electricity prices.

For community level microgrids, this coordination method can improve market transactions within the microgrid. Based on blockchain technology, the internal market can directly complete energy transactions between distributed entities within the microgrid, improving the self consumption level and efficiency of localized energy. Energy storage plays an important role in this process, and smart contracts automatically match supply and demand parties according to pre-set terms and complete the settlement process. Greatly enhancing the autonomy of microgrids. This model can be applied to various occasions such as parks and communities.

4.3. Incentive Mechanism for Achieving Precise Value Traceability and Realization

In the smart grid, the application value of energy storage systems is diversified, and it is difficult to accurately measure and provide corresponding compensation in traditional models, which will dampen investors' enthusiasm. By utilizing energy blockchain technology, it is possible to track the value of energy storage without any tampering, thus achieving precise restoration and monetization of energy storage value, and formulating reasonable incentive plans. In terms of the environmental benefits brought by energy storage, blockchain can achieve traceability authentication of the energy attributes used for charging electricity to determine the difference between green energy and general energy.

When energy storage and discharge replace traditional fossil fuel power generation, corresponding carbon emission reduction or green power certificates can be automatically calculated and generated, making the environmental benefits of energy storage explicit and monetized, bringing additional benefits to investors; The traditional way of evaluating the value of capacity lacks relevant data support. Energy blockchain can record and store information such as actual discharge capacity and duration during peak system load periods, providing an objective and reliable data foundation for accurate measurement and compensation of capacity value. As a result, power grid companies can develop more refined capacity compensation plans, while smart contracts can complete automatic calculation and payment functions for compensation.

The auxiliary service value of ensuring the safety and stability of the power grid can also be achieved through the use of blockchain storage to evaluate the response speed and accuracy of energy storage participation, based on the actual contribution size, and to pay corresponding rewards, thereby incentivizing energy storage to provide better services. For situations where multiple values may arise together, the data traceability of blockchain is beneficial for calculating the degree of correlation between values and for developing more reasonable, non repetitive, or insufficiently complementary overall incentive mechanisms.

4.4. Trust Mechanism to Reduce Management and Operation Costs

The larger the capacity of an energy storage system, the more difficult it is to effectively manage. For massive energy storage devices, the traditional centralized control mode has many drawbacks such as information opacity, high management costs, and low response efficiency. However, a distributed and trustworthy energy blockchain can provide a new path to solve the problems of energy storage lifecycle management and operation. For device status monitoring, blockchain can record the operating status of energy storage devices, and this status information cannot be tampered with once it is on the chain, thus providing reliable information reference for staff.

The above data helps to better analyze the equipment status, identify potential issues with the equipment, and propose corresponding maintenance plans; Using smart contracts to set thresholds for alerting and emergency handling of abnormal situations, making it easier to manage; Treat each battery as an asset node and store all historical data of its production and usage process in the blockchain.

Transparent and traceable asset information greatly improves efficiency and reduces information verification costs in the management process; In the process of asset trading, leasing, or financing, reliable asset history records can effectively reduce transaction risks and costs, and enhance market liquidity; For operation and maintenance activities involving multiple service providers, blockchain can fully record the content, time, and results of each service, objectively evaluate service quality, clarify the responsibilities of relevant parties, and based on this, develop corresponding service evaluation and incentive systems to promote continuous improvement of service quality. It can also automatically pay service fees through smart contracts.

Smart contracts automatically allocate resources, measure usage, and settle fees. While solving the trust and measurement problems in the sharing mode, they also help improve the utilization level of energy storage devices and reduce single household usage costs. In terms of risk management and insurance, the long-term and reliable operational information of blockchain can provide possibilities for insurance companies to conduct risk analysis and provide differentiated insurance services. Of course, while using smart contracts for automatic claims processing, it can also further improve the speed of claims processing.

In addition, as a data intermediary, blockchain helps to promote standardization of data interfaces and communication protocols for devices from different vendors, reduce the cost of system integration and interoperability, and lay the foundation for the large-scale development of the industry.

5. CONCLUSION

Research on the Collaborative Assistance of Energy Blockchain Technology and Energy Storage Technology in Building a Smart Power System. This article studies the mechanism and methods of energy blockchain technology and energy storage technology collaborating to build a smart power system from the aspects of underlying technical support, coordinated control methods, market transaction models, economic incentives, and secure and trustworthy platforms. It also points out that energy storage power stations have the ability to build physical regulation capabilities. Addressing the spatiotemporal imbalance in electricity supply and demand. Energy blockchain provides a digital trust foundation and solves the efficiency problem of collaboration among multiple entities. The fusion of the two can produce a synergistic effect where one plus one is greater than two.Looking ahead to the future, with the continuous maturity of technology and the continuous improvement of mechanisms, the coordinated development of energy storage and energy blockchain will be increasingly widely applied in building a strong smart grid, and may become an effective way to construct a new generation of power systems with new energy as the main body, achieve large-scale clean energy grid integration and consumption, and achieve multi-dimensional source grid load storage friendly interaction, and improve grid security. The above work still needs further research and exploration, and corresponding applications, to promote technological and mechanism innovation and assist in the green and low-carbon transformation of energy.

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