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Application of Blockchain Technology in Energy Trading: A Review

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As blockchain and energy trading have become hot topics in industry and academia, this paper presents a brief literature regarding the blockchain-based energy trading in the fields of energy trading with blockchain. At first, the background and development process is presented, and then the applications of blockchain in energy trading are surveyed and analyzed. Finally, conclusions are summarized and important directions are highlighted in this field.

Keywords: energy trading, blockchain, review, transaction mechanism, platform construction

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INTRODUCTION

At present, as the environmental pollution issue is becoming more and more serious, the disadvantages of the centralized energy system, such as the heavy loss of energy in the long-distance transmission and distribution process, and the low fault-tolerant ability of the system, are becoming prominent. The development of decentralized renewable energy technology has gained attention; however, its storage and redistribution process can not be satisfied through the current centralized system. Meanwhile, some researchers put forward the idea of blockchain-based energy trading (Zhang et al., 2017; Pee et al., 2019), and some projects have been successfully implemented (Laszka et al., 2018b; Mengelkamp et al., 2018). The construction of an energy trading platform and trading mechanism based on blockchain has become a hot topic. This paper presents a systematic literature review of studies and projects based on blockchain-based energy trading, as proposed in papers published in recent years. Considering that energy trading based on blockchain is still at an early stage, this paper divides the current research focus into four aspects: (1) construction of trading platform; (2) economy, privacy, and security of transaction mechanism; (3) redundancy and scalability of trading platform; (4) implementation of the specific technology of trading platform.

The rest of this paper is organized as follows. In section The Background and Development Process, the background of the research problem and the development process are introduced. Section Application of Blockchain in Energy Trading describes four key issues and analyzes the corresponding research status. Conclusions and future development trends are explained in section Conclusion.

THE BACKGROUND AND DEVELOPMENT PROCESS

Microgrid Energy Markets

Renewable energy plays an important role in reshaping the future of energy industry, which can be integrated into power systems, in various forms, such as active distribution networks

(Li et al., 2018a), integrated energy systems (Li et al., 2020), and microgrids (Li et al., 2018d). In this context, how to maximize the utilization of renewable energy by managing micro-grid markets is becoming a hot topic from academia to industry. Papaefthymiou and Dragoon (2016) elaborated on how to transform the traditional power systems into systems with 100% renewable energy. Similarly, Hanna et al. (2017) stressed the importance of policy support; to find the optimal operation mode to model the microgrid, Hanna et al. (2017) found that only with the support of policies, the microgrid will be able to achieve the lowest cost operation and environment friendly factors. Li et al. (2018c) presented a scheduling scheme of microgrids with an electric vehicle battery swapping station, taking into consideration, the real-time pricing mechanism. Li et al. (2019) put forward a multi-objective microgrid dispatch strategy considering the user experience. To ensure the benefit of microgrid participants, Kuznetsova et al. (2014) put forward the individual goal of stakeholders to optimize microgrid energy management framework. Furthermore, in terms of economic efficiency optimization, Montuori et al. (2014) proposed the optimization model, hybrid optimization of multiple energy resources (HOMER), to evaluate the economic efficiency of the microgrid with a biomass gasification power plant. Demand response management (DSM) has experienced a renaissance since microgrids require a flexible demand-side to simplify system operations (Palensky and Dietrich, 2011), but the use of DSM in microgrids does not take the advantage of the development of renewable energy sources in the long run, and reflects the needs of socio-economic development. An improved scheme based on the blockchain was put forward by Noor et al. (2018).

Li and Li (2019) proposed a microgrid dispatch strategy taking into account, the demand response of electric vehicles. By combing the advantages of DSM and blockchain technology, Li and Li (2019) presented a game-theoretic model for DSM within microgrid networks that were enhanced by blockchain, and which realized payment mechanisms and intelligent decentralized control.

Blockchain Technology

Blockchain technology provides a powerful tool for implementing energy trading. In 2019, Nakamoto (2019) presented a peer-to-peer (P2P) network, which employed proof-of-work to record a public history of the transaction, and this consensus mechanism can enforce any needed rules and incentives. That was the beginning of the blockchain-based research. Dong et al. (2018) described the blockchain as a distributed, redundant, chain-connected, ledger-sharing database, in which each node in the network is fault-tolerant and can achieve point-to-point communication.

There are four key characters of blockchain: (1) decentralized distributed nodes and storage; (2) consensus, smart contract, and asymmetric encryption, which enable it to have huge potential in many domains, such as finance, computer software, and computer applications; (3) the information economy and postal economy, such as investment and securities; (4) the shared health-care data framework, generation, and distribution in the citizen-level microgrid which may benefit from the widespread dissemination of blockchain transactions (Giungato et al., 2017).

Andoni et al. (2019) presented an overall review of blockchain technology, which involved 140 blockchain research projects and initiatives. However, most of the related studies are still in their infancy. Some social factors, such as laws and policies will also have an impact on the later development of blockchain technology. More specifically, Ali et al. (2018) presented an extensive survey of the application of blockchain in the internet of things (IoT), demonstrating the potential advantages of blockchain in some aspects, such as privacy, secured communications, identity, and data management as well as monetization of IoT data and resources. Fan et al. (2018) modeled the pricing and transaction of energy-internet electricity, based on the blockchain and big data, which provided a reference for the parties involved, including producers, consumers, and managers.

APPLICATION OF BLOCKCHAIN IN ENERGY TRADING

Since most studies related to energy trading based on blockchain are still in the initial stage, according to different research focuses, this paper divides relevant studies into the following four aspects: (1) construction of trading platform; (2) study on the economy, privacy, and security of transaction mechanism; (3) the latency and scalability of trading platform; (4) implementation of the specific technology of trading platform.

Design and Construction of a Trading Platform

Integrated demand response (IDR) has been proven to be effective in improving the operating flexibility of the system and energy utilization efficiency through optimization of the operations of flexible loads, energy conversion, and storage equipment on the demand side (Li et al., 2021). To make the full use of the integrated scattered IDR resources, Zhao et al. (2018a,b) presented an energy transaction mechanism based on the blockchain technology. Moreover, Mannaro et al. (2017) have launched the Crypto-Trading Project, where, they highlighted the key role of blockchain technology and smart contracts in the management and control of innovation typology of the energy market.

Privacy, Security, and Economy of Transaction Mechanism

To solve the privacy problem of energy transactions, Zhou et al. (2018), Laszka et al. (2018a), and Tan et al. (2019) proposed different solutions, respectively. Aiming at the security and privacy issues of large scale vehicle to grid (V2G) energy trading, Zhou et al. (2018) developed a consortium of blockchain-based energy trading mechanism and an edge computing-based task offloading for V2G and local energy aggregators (LEAGs), respectively, and the validation of the proposed framework was proved from the perspectives of task offloading and security. Laszka et al. (2018a), considered not only privacy but also resilience problem, and they provided a novel distribution application platform. Tan et al. (2019) designed a model for privacy-preserving energy scheduling based on the energy blockchain network in which they solved the problem by using Lagrangian relaxation and smart contracts.

In terms of the economy of the trading platform, Park et al. (2018) suggested a blockchain-based P2P energy transaction platform and provided simulation results that calculated and compared the economic benefit of the platform. Considering the huge operational overhead resulted from a high-frequency transaction, Hou et al. (2019) designed a scheme that enabled nodes to satisfy their power loads through locally stored energy (self-sufficiency), before participating as sellers, if they still had considerable surplus electricity. Alcarria et al. (2018) presented a blockchain-based authorization system for trustworthy resource monitoring and trading.

Latency and Scalability of Trading Platform

To solve the issues of latency resulted from processing the energy trading decisions at remote control centers and the security concerns, while trading the energy, Jindal et al. (2019) proposed a blockchain-based edge-as-a-service framework, which used a software-defined network (SDN) architecture to reduce the latency and secured the underlying trading transactions by blockchain. Blom and Farahmand (2018) modeled a local energy market using Ethereum platform and concluded that the given market with 600 participants and a trading frequency of one transaction every 5 min can be processed by the Ethereum protocol. Besides, Liu et al. (2019) provided the off-chain energy trading method and asynchronous transaction recoding mechanism, which are supported by a local energy trading cyber-physical system.

Implementation of Specific Technology of Trading Platform

In addition to the research and analysis of the characteristics of blockchain, the implementation of the algorithm is also the focus of the current research problem. Kang et al. (2018) exploded a renewable energy trading platform using smart contract of Ethereum, proved its scalability and adaptability utilizing coding transaction process and contents of smart contracts, and presented a simple scenario for two nodes. Pipattanasomporn et al. (2018) presented the laboratory scale implementation of the blockchain network for the exchange of solar energy. Tai et al. (2016) provided an improved algorithm of distributed security checking and proved the feasibility by a case consisting of six nodes.

However, all the schemes mentioned above are in the initial exploration stage, and the verified schemes and scale are in an ideal environment or laboratory environment. Therefore, there is still a way to go before the blockchain-based energy trading platform can be widely used in practical applications.

CONCLUSION

As an emerging and powerful technology, energy trading based on blockchain has attracted a growing attention of many scholars. After studying the existing literature, this paper summarizes the key issues into the following four points: (1) construction of trading platform; (2) economy, privacy, and security of transaction mechanism; (3) redundancy and scalability of trading platform; (4) implementation of the specific technology of trading platform.

Since most studies are in the primary stage, the construction of an energy trading platform and efficient algorithm implementation will be important research directions in the future. Another interesting topic is to apply machine learning to blockchain-based applications (Shi et al., 2008; Li et al., 2018b; Tanwar et al., 2019).

AUTHOR CONTRIBUTIONS

HL, FX, and LY contributed to conception and design of the study. HL and FX performed the statistical analysis. HL wrote the first draft of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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