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Research on the Application of Blockchain Technology in Smart Grid

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Abstract

The massive data of the current era shows that there is no uniform definition of smart grid in the academic world, but people's understanding of smart grid is basically the same. Smart grid is a comprehensive power project that is built on the basis of the existing power supply network and integrates automation technology, information interconnection technology, intelligent communication technology and other technologies. It is for the production and use of electric energy and the development of the national economy and people's lives. All have strategic significance. Smart grids involve modern advanced technologies such as artificial intelligence, big data, and cloud computing. Blockchain technology, as a popular technology at the moment, can also be applied to smart grids. The first part of this article focuses on comparing the advantages of smart grids and the outlook for development trends. The second part is mainly an introduction to blockchain technology, which mainly includes definitions, principles, cryptography and consensus mechanisms. The third part explores one aspect of the smart grid in detail: microgrid, expounds the principle of smart contract, and the real engineering case of applying smart contract to microgrid.

Keywords

Smart Grid; Microgrid; Blockchain; Smart Contract.

1. Introduction

Our country is a big energy consuming country, and is now facing many prominent problems such as low reasonable energy utilization rate and relatively simple energy industry structure. Traditional power grids have difficulties in grid connection, large losses, and low power data utilization in the power energy industry, and grid innovation is imperative. Smart grid research is an inevitable trend in the development of current grid systems.

Distributed energy has quickly become an important energy system in the construction of smart grids due to its reasonable energy efficiency utilization, low loss, and flexible operation. However, compared with traditional electric energy, the difficulty of large-scale grid integration and resource scheduling of distributed energy restricts its further development in the power grid. At the same time, when power companies manage distributed energy sources, it is easy to encounter phenomena such as difficulty in obtaining mutual trust between power transaction parties and inability to supervise power equipment in real time. Electric power companies urgently need a decentralized, safe and reliable technology to establish a power network management system to promote the development of distributed energy.

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As a new application model in the computer field, blockchain technology can establish trust in a distributed system environment without authorization, and data on the chain can be shared in real time. The application of blockchain to the power grid management system can provide new ideas for the dispatch of power resources and the addition and consumption of clean energy. Many experts and scholars at home and abroad have conducted relevant research on this.

Literature [1] puts forward the research on the key technology of blockchain-based decentralized transactions, literature [2] puts forward the research on the data management framework of smart grid based on blockchain technology, and literature [3] discusses the smart grid based on blockchain technology. Distributed resource management has been studied, but it lacks simulation analysis. Literature [4] has studied the privacy protection of smart grid data based on blockchain. Literature [5] proposed a smart grid system based on blockchain.

This article starts from the two aspects of smart grid and blockchain, introduces the concepts and technical principles of smart grid and blockchain, and introduces the application of blockchain in smart grid.

2. Smart Grid

2.1 Definition of Smart Grid

Smart grid refers to a fully automated power supply network in which each user and node is monitored in real time, and the two-way flow of current and information from the power plant to the user-side appliances is guaranteed. The smart grid can ensure the real-time market transactions and the seamless connection and real-time interaction between members on the grid through the widespread application of distributed intelligence and broadband communication, as well as the integration of automatic control systems.

2.1.1 Comparison between traditional grid and smart grid

The characteristics of traditional power grids: 1. For ordinary power grids, they need to find electricians for maintenance; 2. The frequency is unstable and often requires people to dispatch; 3. The system stability and power quality are poor; 4. Most of them are thermal power generation, with low energy utilization. High and pollute the environment.

Smart grid features: 1. It can self-heal when encountering common faults and hidden dangers. If it is unable to self-heal, it can quickly isolate the fault area to avoid a larger area of power outage; 2. Improve the reliability of power supply and power quality; 3. Developed the use of new energy sources, increased the channels of power generation, improved the efficiency of electric energy transportation, and protected the environment while lowering power loss; 4. With the function of self-monitoring, you can better understand the security status of the power grid. The specific comparison is shown in Table 1:

Table 1. Comparison between traditional grid and smart grid

The current traditional grid	The smart grid of the future
Use electromagnetic meter to measure	Use intelligent solid-state meter to measure
No communication between the grid and users	Two-way communication between the grid and users
Centralized power generation	Distributed generation
Radial structure power supply network	Network-like structure power supply network
Manual intervention to restore power supply	Power recovery and self-healing
Power outage due to equipment failure	Power grid adaptive protection
Analyze power grid faults by manual experience	Multimedia technology assists in analyzing faults
Limited service and support for users	Comprehensive service and support for users

From this comparison, it can be seen that under the urging of the various disadvantages of the traditional power grid, people urgently need to innovate the power grid. In this case, the new power grid concept of micro-grid, smart grid and power Internet of things has appeared in the future.

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2.2 Advantages of Smart Grid

The advantages of the smart grid are mainly manifested in:

(1) Security: With a strong grid infrastructure, it can resist all kinds of external interference and attacks.

(2) Failure: Modern technology is organically integrated with the grid infrastructure, and panoramic information of the grid can be obtained, and possible failures can be detected and foreseen in time. When a fault occurs, the power grid can quickly isolate the fault and realize self-recovery, thereby avoiding large-scale power outages.

(3) Operation: The comprehensive application of communication, information and modern management technology will greatly improve the efficiency of power equipment, reduce power loss, and make the grid operation more economical and efficient.

(4) Perception: Through the situational awareness technology, the high integration, sharing and utilization of real-time and non-real-time information can be realized, and a comprehensive grid operation state diagram can be displayed for operation management, and at the same time, corresponding response plans can be provided.

(5) Interaction: Establish a two-way interactive service mode, where users can understand all kinds of information in real time, and rationally arrange the use of electrical appliances; electric power companies can obtain users' detailed electricity consumption information and provide them with more value-added services.

2.3 The development trend of smart grid

Four concepts for the development trend of smart grids:

(1) Sharing: Realize the transparent sharing of information between power sources, power grids and users, and create a friendly and open grid environment.

(2) Green: Based on the concept of green development, the State Grid should change the traditional production mode, improve the energy structure, reduce the emission of pollutants, vigorously develop renewable and clean energy, configure the power supply structure safely and reasonably, and move towards a clean and green power grid.

(3) High efficiency: Energy utilization, transmission efficiency of the grid, and operation efficiency are further improved, making the operation of the grid more economical and reliable.

(4) Innovation: Innovatively combine the smart grid with new technologies such as artificial intelligence, Internet of Things, big data, cloud computing, etc., in order to achieve more powerful functions.

Three stages of the development trend of smart grid:

The first phase will replace repetitive, single, and mechanical working methods with intelligent working methods, reduce labor costs, and improve work efficiency and reliability. In addition, the work at this stage will also provide big data resources, infrastructure support and talent reserves for the next stage.

The goal of the second stage is to use the learning and reasoning capabilities of artificial intelligence technology to analyze various complex problems of the smart grid in the context of big data, so as to obtain prediction and analysis capabilities beyond the intelligence of a single human brain, and to improve the analysis and analysis of professionals. Decision-making ability, and gradually build an artificial intelligence integrated system platform for processing professional field business.

The goal of the third stage is to build a smart energy system, so that the entire energy system has autonomous cognition, can interact with other external smart systems autonomously, and can realize autonomous coordinated control of all links in the system based on the incentives of external environmental factors. To achieve the purpose of improving energy utilization efficiency and saving energy production costs.

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3. Block Chain

3.1 Definition of blockchain

Blockchain technology itself is still in rapid development, and relevant specifications and standards have yet to be further matured. In the definition given on Wikipedia, the blockchain is likened to a distributed database technology. By maintaining a chain structure of data blocks, it can maintain a continuously growing, non-tamperable data record. The definition of blockchain technology can also be viewed from both broad and narrow perspectives: in a narrow sense, a blockchain is a chained data structure with a block as the basic unit, and a digital summary is used in the block to compare the previous transaction history. Perform verification and review the requirements for tamper resistance and scalability in the distributed accounting scenario. In a broad sense, blockchain also refers to the distributed accounting technology based on the blockchain structure, including distributed consensus, privacy and security protection, point-to-point communication technology, network protocols, smart contracts, etc.

3.2 Principles of Blockchain Technology

The principle of blockchain is not complicated, first introduce three basic concepts:

1. Transaction: An operation on the ledger results in a change in the state of the ledger, such as adding a transfer record.

2. Block: Record all transactions and status results that occurred within a period of time, which is a consensus on the current ledger status.

3. Chain: There are blocks connected in series in the order of occurrence, which is a log record of the status change of the entire installation.

If the blockchain system is used as a state machine, each transaction means a state change; the generated block is the consensus of the participants on the result of the state change caused by the transaction. The goal of the blockchain is to achieve a distributed data recording ledger, which only allows additions and does not allow deletion. The basic structure of the bottom layer of the ledger is a linear linked list. The linked list consists of a series of "blocks", and subsequent blocks record the Hash value of the leading block. Whether a block (and transactions in the block) is legal can be quickly checked by calculating the hash value. Nodes in the network can propose to add a new block, but the block must be confirmed through a consensus mechanism [9]. The connection of the blockchain is shown in Figure 1:

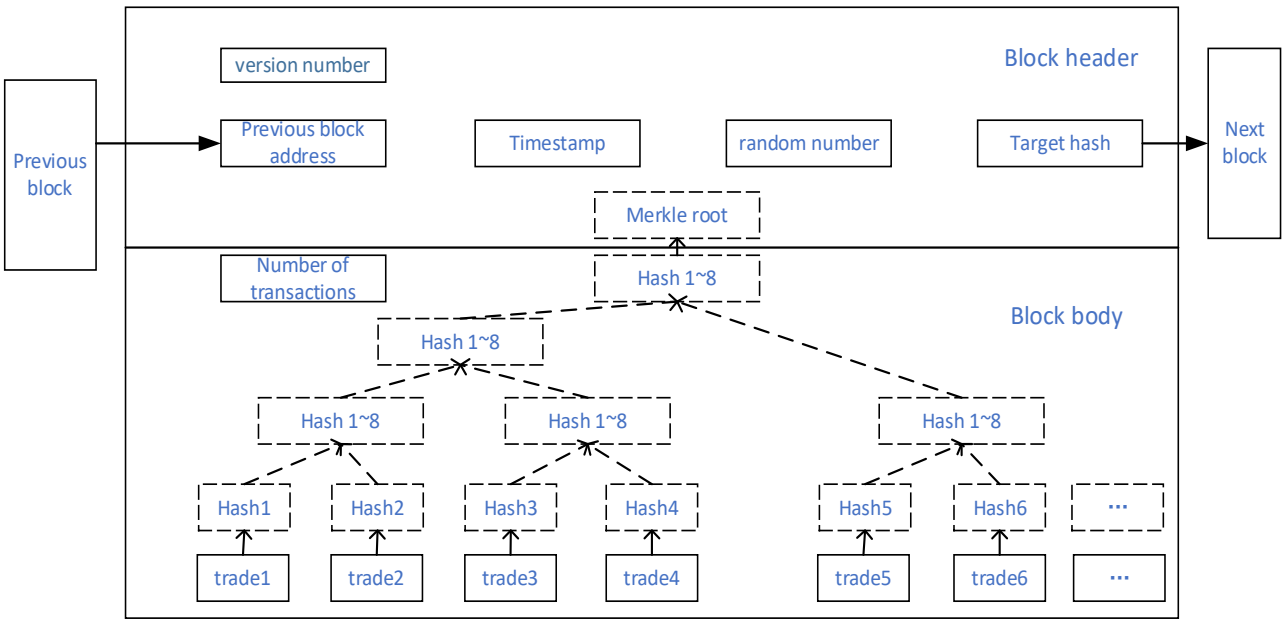

Fig. 1 Blockchain connection structure diagram

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The block of the blockchain mainly includes three parts, namely block size information, block header information, and block body. The blocks are connected through the block header. The block header mainly includes seven parts, which are the version number, the hash value of the previous block header, the hash value of the Merkel tree root, the timestamp, the difficulty index, the nonse value and the counter of the last transaction number. The hash algorithm uses the SHA256 algorithm. The root of the Merkel tree contains the hash value of the root of the Merkel tree of all verified transactions. Nonse represents a temporary value, mostly a random string. The specific block structure diagram is shown in Figure 2.

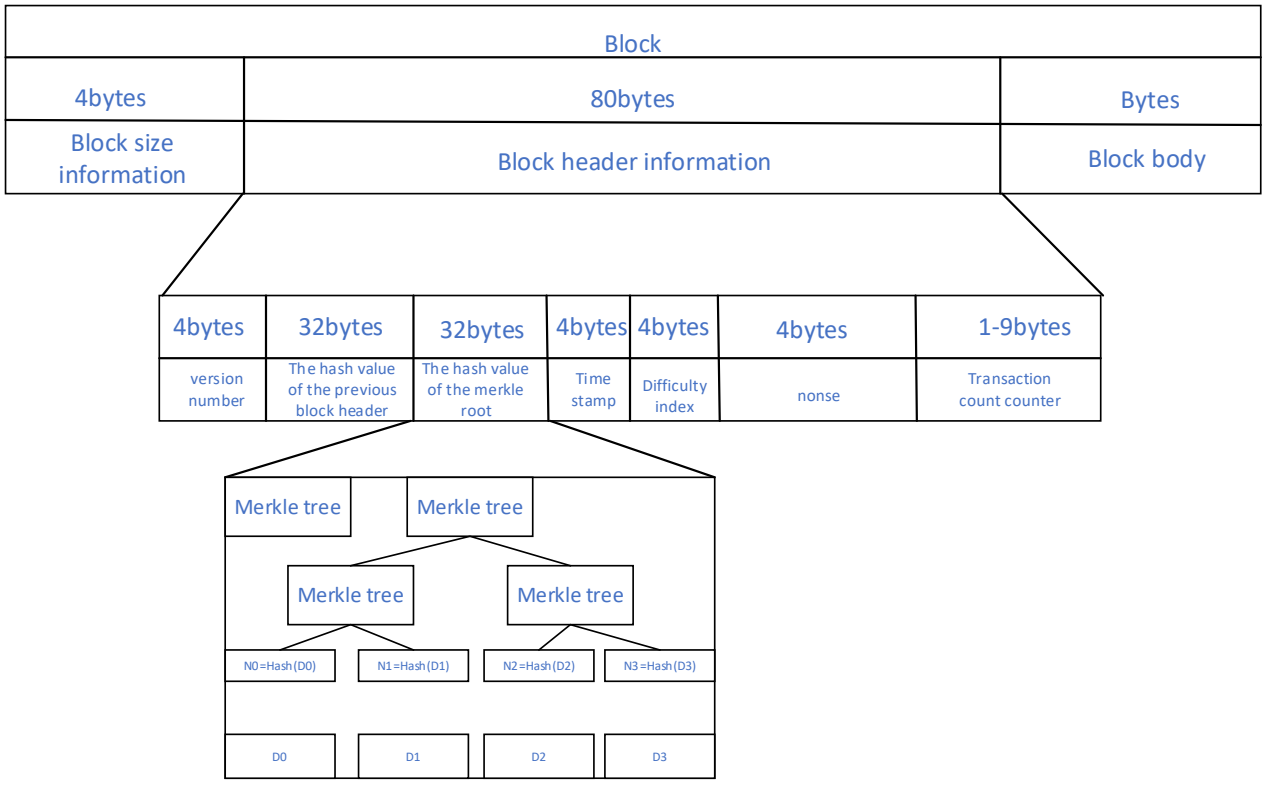

Fig. 2 Block structure diagram

3.3 Blockchain core technology

3.3.1 Hash algorithm

Hash (hash or hash) algorithm, also often called fingerprint or digest algorithm, is a very basic and very important type of algorithm. Binary plaintext strings of any length can be mapped to shorter (usually fixed-length) binary strings (Hash values), and it is difficult to map different plaintexts to the same hash value.

3.3.2 Merkel tree

Merkel tree (also called hash tree) is a typical binary tree structure consisting of a root node, a set of intermediate nodes, and a set of leaf nodes.

Its main features are:

(1) The bottom leaf node contains stored data or its hash value.

(2) Non-leaf nodes (including intermediate nodes and root nodes) are the hash values of the contents of its two child nodes.

3.4 Consensus mechanism

Consistency (Consistency), also called (Agreement) in the early days, in the field of distributed systems means that for multiple service nodes, given a series of operations, under the guarantee of

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the agreed agreement, they can reach a certain degree of processing results. "The synergy. Consistency focuses on the state of the system, not whether the result is correct; for example, it is also a kind of consistency that all nodes reach a negative state for a request.

Consensus refers specifically to the process of reaching a consensus on a certain thing (such as multiple transaction requests, who should be executed first?) among multiple nodes in a distributed system. The consensus algorithm solves the process in which the distributed system reaches a consensus on a certain proposal (Proposal).

3.4.1 POW mechanism

The full name of POW is Proof of Work, which translates to "Proof of Work" or "Proof of Work". How much currency rewards are obtained for mining depends on the effective work contributed by mining, which means that the better the performance of the mining machine and the longer the mining time, the more currency rewards will be obtained.

3.4.2 POS mechanism

POS stands for Proof of Stake or Proof of Stake, the full name is Proof of Stake. The equity proof model is a model in which interest is issued based on the amount and time of currency held. The POS mechanism allows more currency holders to participate in the work of accounting without the need to purchase additional equipment (mining machines, graphics cards, etc.). The computing power of each unit token is positively related to the length of time it holds, that is, the more tokens held by the holder and the longer the time, the greater the probability that it can sign and produce the next block. Once it signs the next block, the "coin age" held by the holder is cleared, and a new cycle is re-entered.

4. Application of Blockchain in Smart Grid

4.1 Microgrid in smart grid

4.1.1 The concept of microgrid

Microgrid is also translated as microgrid, which refers to a small power generation and distribution system composed of distributed power sources, energy storage devices, energy conversion devices, loads, monitoring and protection devices, etc. The proposal of the microgrid aims to realize the flexible and efficient application of distributed power sources and solve the problem of the large number and various forms of distributed power grid connection. The development and extension of the microgrid can fully promote the large-scale integration of distributed power sources and renewable energy sources, and realize the highly reliable supply of multiple forms of energy to the load. Smart grid transition.

4.1.2 Advantages of microgrid

The microgrid has the following advantages:

(1) Contribute to improving the ability of the distribution system to accept distributed power.

(2) It can effectively improve the utilization efficiency of intermittent renewable energy, and realize energy optimization under the premise of meeting the requirements of various loads such as cooling/heating/electricity; it can also reduce the loss of the distribution network and optimize the operation mode of the distribution network .

(3) In the event of a serious grid failure, the power supply of critical loads can be guaranteed and the reliability of power supply can be improved.

(4) It can be used to solve the power supply problem of users in remote areas, islands and deserts

4.2 Classification of microgrids

4.2.1 According to the way of access to the power distribution system

According to different ways of connecting to the distribution system, microgrids can be divided into user-level, feeder-level and substation-level microgrids. The user-level microgrid is connected to the external power distribution system through a common connection point, and the user is generally

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responsible for its operation and management; the feeder-level microgrid refers to the distributed power and load connected to a feeder of the medium voltage distribution system. The microgrid formed by effective management; the substation-level microgrid refers to a large-scale microgrid formed after effective management of distributed power sources and loads connected to a substation and its outgoing line. The latter two are generally owned by power distribution companies and are an important part of smart power distribution systems.

4.2.2 According to the power supply mode of the main network in the microgrid

According to the different power supply modes of the main network in the microgrid, it can be divided into DC microgrid, AC microgrid and hybrid microgrid. In the DC microgrid, a large number of distributed power sources and energy storage systems directly supply DC loads through the DC main grid; for AC loads, power electronic converter devices are used to convert DC power to AC power supply. In an AC microgrid, the output of all distributed power sources and energy storage systems is first converted into AC power to form an AC backbone network to directly supply AC loads; for DC loads, the AC power needs to be converted to DC power through a power electronic converter device Supply power to the load. In a hybrid microgrid, whether it is a DC load or an AC load, it can be directly supplied by the microgrid without power conversion between AC and DC.

5. Application of Blockchain in Smart Grid

5.1 Smart Contract

5.1.1 The concept of smart contracts

A smart contract is a computer protocol designed to spread, verify or execute a contract in an information-based way. Smart contracts allow for trusted transactions without a third party, which are traceable and irreversible.

5.1.2 Smart contract deployment platform: Ethereum

Ethereum is a blockchain development platform that supports smart contracts and lowers the threshold for users to build blockchain applications. Ethereum, like Bitcoin, is an open-source blockchain underlying system. On the basis of Bitcoin, Ethereum encapsulates the underlying technology of the blockchain. Just like an operating system, it provides a very rich external interface. People can quickly develop various blockchain applications without having a deep understanding of the underlying technology of the blockchain. In addition, one of the biggest features of Ethereum is that it is combined with smart contracts. The blockchain is decentralized, trustless, and data cannot be tampered with. It provides a credible execution environment for the operation of smart contracts. It can be said that blockchain technology The smart contract technology has been reborn, and the smart contract technology has also expanded the application range of blockchain technology.

5.1.3 Smart contract development language: Solidity

Solidity is a contract-oriented high-level programming language created to implement smart contracts. This language is influenced by C++, Python and Javascript, and is designed to run on the Ethereum Virtual Machine (EVM). Solidity is a statically typed language that supports features such as inheritance, libraries, and complex user-defined types. Its syntax is close to Javascript, which is an object-oriented language.

5.1.4 Smart contract development environment: Remix

Remix is a compilation environment where smart contracts can be developed online on the web, and smart contracts are developed on Remix.

(1) Write contract code

(2) Compile, link, and generate executable contract bytecode

(3) Execute the contract bytecode on the Ethereum public chain

(4) View the execution results on the Ethereum public chain

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5.2 Examples of the combination of smart contracts and microgrids

In April 2016, US energy company LO3 Energy cooperated with Siemens Digital Grid and Bitcoin development company Consensus Systems to establish the Brooklyn Microgrid-an interactive grid platform based on the blockchain system TransActive Grid. This project is the world's first energy market based on blockchain technology. This micro-grid project realizes peer-to-peer electricity transactions between residents in the community, allowing users to obtain real-time power generation, electricity consumption and other related data through smart meters, and to buy or sell electricity energy to others through the blockchain. Users can complete power and energy transactions without going through a public power company or the central grid. The user issues the corresponding smart contract on the blockchain node of his smart meter through the mobile phone APP. Based on the contract rules, the corresponding link connection is controlled through the grid equipment provided by Siemens to realize energy trading and energy supply. In order to improve the efficiency of the entire system, the platform must not only manage the generated and stored energy, but also deal with the flexibility of consumers' choices.

The Brooklyn microgrid in the United States is based on the Ethereum blockchain. This project allows residents to cross the national grid and directly conduct solar transactions through rooftop solar equipment. The households participating in the project have smart meters connected to the blockchain for To track and record the electricity used by households and manage the electricity transactions between neighbors, each participating household is not only an electricity consumer, but also an electricity producer.

6. Summary

Through the introduction of the first section of this article, we can conclude that our urban development is inseparable from the support of smart grids. This grid that can accept renewable energy power generation on a large scale is equivalent to the city’s energy master. The future smart grid is to make the power grid more 'smart' and the citizens' electricity use more 'smart'. With it, faults can be isolated and restored to power supply in the shortest time. This is a vivid description of the smart grid in future life applications, so we must continue to devote ourselves to the development of smart grids with new technologies. Among them, blockchain is the new technology involved in this article, which is introduced in detail in this article to pave the way for the application of blockchain technology in smart grids in the future. The microgrid in the smart grid is an important field for the development of the smart grid in the future. The smart contract technology of the blockchain solves the power transaction problem of the microgrid. However, many problems are exposed in the actual application process, such as: the maintenance of the microgrid requires a lot of the human and material resources, the low transaction rate of smart contracts and other issues. These problems are inevitable. It takes a lot of time from the birth of a new technology to its application to make it mature. Therefore, I believe that the application of smart contracts in the microgrid will become more and more mature in the future. glorious future.

References

[1] Zhongyue Liu. Planning and Application of Smart Distribution Network [J/OL]. Application of Integrated Circuits, 2019(12):88-89[2019-11-29].

[2] Yuchen Zhou. Summary of key technologies and development of smart grid [J]. Communication World, 2019, 26(01):161-162.

[3] Bi Jianxing, Ma Hongbin, Zhao Jiaying. Overview of Smart Grid [J]. Hebei Agricultural Machinery, 2018, (08):38.

[4] Ju Ping, Zhou Xiaoxin, Chen Weijiang, Yu Yiping, Qin Chuan, Li Ruomei, Wang Chengshan, Dong Xuzhu, Liu Jian, Wen Jinyu, Liu Yutian, Li Yang, Chen Qing, Lu Xiao, Sun Dayan, Xu Chunlei, Chen Xingying, Wu Feng,Ma Hongzhong.Summary of "Smart Grid+" Research [J]. Power Automation Equipment, 2018, 38(05):2-11.

[5] Zhu Ran, Sun Ji. Overview of foreign smart grid technology development practice [J]. Electronic quality, 2016(09):24-29.

[6] Dai Yan, Wang Liuwang, Li Yuan, Yan Yong, Han Jiajia, Wen Fushuan. A review of the application of new-generation artificial intelligence in smart grids [J]. Electric Power Construction, 2018,39(10):1-11.

[7] Cai Xingguo, Wang Juan. Application of Blockchain Technology in the Electricity Market[J]. Cyberspace Security, 2019, 10(05):82-87.

[8] Hu Jian, Xiao Peng, Yin Jun. Research on power grid security based on blockchain technology [J]. Yunnan Electric Power Technology, 2018, 46(06):7-11.

[9] Yang Baohua, Chen Chang. Principle, Design and Application of Blockchain. Machinery Industry Press. 2017-9-1

[10] Cai Xiaoqing, Deng Yao, Zhang Liang, Shi Jiuchen, Chen Quan, Zheng Wenli, Liu Zhiqiang, Long Yu, Wang Kun, Li Chao, Allergy Yi. Blockchain principle and core technology [J/OL]. Chinese Journal of Computers, 2019:1-51 [2019-12-17]

[11] Wu Yue, Li Junxiang. The evolution process of blockchain consensus algorithm [J/OL]. Computer application research:1-9 [2019-12-17].

[12] Zheng Zhanghua, Ai Qian. Research status of microgrid and its application prospects in my country [J]. Power grid technology, 2008(16):27-31+58.

[13] Wang Chengshan, Wu Zhen, Li Peng. Research on key technologies of microgrid[J]. Journal of Electrotechnical Technology, 2014,29(02):1-12.

[14] Yang Xinfa, Su Jian, Lu Zhipeng, Liu Haitao, Li Rui. Overview of Microgrid Technology[J]. Proceedings of the Chinese Society of Electrical Engineering, 2014, 34(01):57-70.

[15] Lu Zongxiang, Wang Caixia, Min Yong, Zhou Shuangxi, Lu Jinxiang, Wang Yunbo. Overview of Microgrid Research [J]. Automation of Electric Power Systems, 2007(19):100-107.

[16] Feng Feng. Design and Implementation of Smart Grid System Based on Blockchain Smart Contract Technology [D]. Shandong University,2018.

[17] Liu Mingchuan. Design of distributed electric energy trading system based on energy blockchain [D]. North China Electric Power University (Beijing), 2018.

[18] Song Xiqiang, Pan Yi, Wang Pingping, Yu Hongquan, Lin Fei, Li Keyu. Blockchain-based smart micro-grid settlement system [J]. China's new technology and new products, 2019(04):1-4.

[19] Zeng Yun, Zhang Li, Mei Wenming, Sun Qi. Smart grid system based on blockchain technology [J]. Electric Power Information and Communication Technology, 2019, 17(01):31-35.

[20] Han Dong, Zhang Chengzhenghao, Sun Weiqing, Zhang Wei, Yang Wenwei, Xiao Min. Architecture design of intelligent distribution and sale trading platform based on blockchain technology [J]. Automation of electric power systems, 2019, 43(07):89-99.