# Research of trusted real-time electrical data transmission mechanism based on parallel proof of work algorithm

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**Abstract**

Secure and reliable electricity supply is a prerequisite for the development of smart cities, and the trustworthy and efficient transmission of electrical data is the foundation for the safe and stable operation of the power grid. This paper introduces a real-time data transmission blockchain technique based on parallel proof of work algorithm. The new block generation progress of proposed blockchain is divided into five subroutines: hash pointer computation, real-time data pudding, signature value iteration, interruption, block header assembly. The real-time data pudding and signature value iteration are parallel processed, which brings the effect of decreasing energy loss of blockchain system, and upgrades the speed of new block generation and the bandwidth of data storing on blockchain. Computer simulation shows the proposed strategy can be effectively applied in real-time electrical data transmission application, raising the data transmission reliability with no harm to real-time data transfer function. This strategy provides a solution to guarantee data transmission safety in the digital conversion of power grid.

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**Keywords:** blockchain; electric power data; consensus algorithm; proof of work

## 1. Introduction

Since 2008, when Satoshi Nakamoto invented Bitcoin, initiating the study of blockchain, blockchain technology has been leading a new global wave of technological and industrial transformation, becoming the "prime mover" of innovative social development. Blockchain technology with open and fault-tolerant characteristics, is highly compatible with shared economic model based on distributed systems. Meantime, blockchain techniques can also solve the essential requirements of electric power and energy industry. In the construction of electric power and energy industry, blockchain as the infrastructure of digital economy combined with industry applications, can form an immutable distributed ledger, potentially solving management, financing, regulation, and privacy issues caused by numerous transaction entities and opaque data information. Extensive research and attempts have been made by industrial experts and scholars on the application of blockchain technology in electric power field, including distributed energy trading[1], electric vehicle charging pile sharing[2], enterprise energy consumption monitoring[3], carbon emission trading[4], emerging energy business applications[5], etc. Such researches mainly based upon Bitcoin blockchain system, establishing a trustworthy energy trading platform through blockchain technology, thereby reducing trust cost in traditional power trading. On the other hand, blockchain can also be seen as a decentralized, tamper-resistant, and open autonomous distributed database, suitable for the trustworthy storage and transmission of enterprise data.

However, in the context of electric power production, various sampling data need to be transmitted to dispatch control center in a timely manner, and the real-time data transmission requirements in such applications have limited the direct application of blockchain technology. This paper proposes a parallel proof-of-work algorithm for blockchain, effectively applying blockchain technology to real-time electric power data transmission scenarios, thereby significantly enhancing the reliability and anti-tampering ability of electric power data transmission.

## 2. Blockchain Consensus Mechanism Principles

Nowadays, blockchain is commonly used for distributed storage of transaction data. According to transactions chronological order, different transaction data are stored in different blocks, and adjacent blocks are linked through hash pointers. Figure 1 illustrates the schematic diagram of blockchain data structure.

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**Figure 1.** Data structure diagram of blockchain

As can be seen from Figure 1, each block is divided into a block header and a block data section. The block data section is primarily used to store data information, such as transaction records in Bitcoin system[6], smart contracts in Ethereum system[7], etc. The block header records summary information of current block, including the Merkle tree root hash value of block data, and stores the block header hash value of previous block. Due to the one-way irreversibility of hash function, any tampering on block data requires simultaneous forgery of data's Merkle tree root hash value and of the block header hash value of previous block, which increases data tampering difficulty. Blockchain applies a consensus algorithm mechanism, which would be briefly explained in this section, making tampering with block data almost impossible.

### 2.1. Brief Description of the Proof of Work Principle

In blockchain system, to maintain data consistency across all network nodes, it is necessary to synchronize storage data of all nodes according to certain rules after a new block is generated. This rule is known as consensus mechanism. Various implementation schemes for consensus mechanisms based on different principles have been proposed[8], and Proof of Work (PoW) is one of the most representative, having been applied to Bitcoin system and undergone extensive practical testing[9]. The research approach of this paper is also based on PoW algorithm, and its principle is briefly introduced below.

Figure 2 shows a simplified flowchart of PoW algorithm. From the flowchart, it can be seen that PoW algorithm is mainly divided into three steps:

(1) Generate Merkle root hash value;

(2) Assemble block header;

(3) Iteratively calculate current block header hash value.

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**Figure 2.** Flowchart of Proof of Work algorithm

To generate a new block, data must first be placed within block, a process achieved by calculating Merkle root hash value. Block data is usually organized through a Merkle tree, the structural schematic is shown in Figure 3. In Merkle tree, the hash values of the block data are arranged in a binary tree structure, with the value of each parent node equal to the hash value of the sum of its two child nodes. Merkle tree root node is located at the top of entire binary tree, and its value is equivalent to the hash attestation of all data in current block. By storing Merkle root hash value in block header, a close association between block header information and block data is established, eliminating the possibility of an attacker tampering with the block data only.

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**Figure 3.** Merkle tree structure in blockchain

After determining Merkle root hash value, PoW algorithm proceeds to assemble block header, filling in corresponding fields with the hash value of previous block header, current timestamp, target value for generating new block, etc. The target value for generating new block is defined by blockchain network protocol and is updated at specified intervals. The value of random number (*nonce* ) in block header is determined through iterative calculation process of PoW algorithm.

During iterative calculation process, except for the random number (*nonce* ) field shown in Figure 1, all information of new block has been determined. At this point, PoW algorithm fills in a random value in*nonce* field and calculates current block header hash value. If this hash value is less than target value, the new block is considered as a "valid" block and will be broadcast to blockchain network. If the hash value does not meet target value requirement, PoW algorithm will regenerate a new random value to fill in *nonce* field and perform hash value verification.

During the execution of PoW algorithm, if a host receives a "valid" block generated by other nodes from blockchain network, it adds such block as the latest block to blockchain and executes PoW algorithm again on the updated blockchain[6].

## 2.2. Challenges of Proof of Work Algorithm

Blockchain system has solved the problem of constructing a trustworthy distributed database in a network environment where communication conditions are unreliable, and member information remains anonymous. Based on blockchain technology, decentralized digital currencies, smart contracts, distributed data storage, and other applications have been realized, with consensus algorithms playing a vital role.

As one of the most successful consensus mechanisms to date, PoW algorithm has been proven in practice to maintain long-term secure and stable operation of blockchain system. Its core concept is to select nodes to generate new blocks in proportion to the computing resources possessed by each node. Due to the adjustable difficulty and easily verifiable results of hash operation used by PoW algorithm, blockchain network can dynamically adjust the target value parameter in PoW algorithm according to the overall computing power of blockchain network, and quickly propagate a "valid" new block to every node once it is generated by a particular node.

However, while PoW algorithm effectively achieves decentralized data storage, traceable data operations, and immutable on-chain information, it also faces challenges such as high electric power consumption, long time of new block generation, and low bandwidth of data upload.

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**Figure 4.** Transmission progress of new block

Figure 4 illustrates the schematic diagram of the propagation process of a new block in blockchain network. After running PoW consensus algorithm for some time, Server A first finds a "valid" new block and attempts to propagate new block information to all nodes through blockchain network. Server A first needs to send the new block information to adjacent node B, and then Server B sends such information to other adjacent nodes. Such process would be repeated until all nodes in blockchain network receive the new block information. By analyzing this process, it can be seen that the generation and propagation of new block have following characteristics:

(1) Low Efficiency in Generating New Blocks. During block generation process, all computing resources in blockchain network are used to find a "valid" new block. As of June 2023, the total computational power of Bitcoin network has exceeded 370EH/s. It is evident that to achieve decentralization, PoW algorithm has sacrificed computing efficiency to some extent[10].

(2) Long Time to Generate New Blocks. During block generation process, if no node in blockchain network finds a "valid" new block, all nodes must continue running PoW algorithm. The average time to generate a new block is regulated by block generation target value, and to ensure system stability, this time cannot be set too small. For Bitcoin system, the average time to generate a new block is about 10 minutes[11]. Block generation speed limitation restricts the promotion and application of blockchain in some fields.

(3) Size Limitation for Individual Blocks. To ensure efficient propagation of the new block in blockchain network, the size of an individual block cannot be too large; otherwise, it would significantly prolong the time for entire network to reach consensus. In Bitcoin system, each block must not exceed 1MB[11]. Thus, the upload bandwidth of blockchain data is also limited.

In response to above problems, many new consensus algorithms have been proposed in recent years, such as Proof of Stake (PoS)[12], Delegated Proof-of-Stake (DPoS)[13], Proof of Space [14], Proof of Elapsed Time [15], etc. These algorithms replace the computing power competition in PoW with different competition methods to address resource consumption and security issues. However, these algorithms have not yet been experienced large-scale, long-term practical testing and have reduced the decentralization capability and usability of blockchain.

3. Characteristics of electric power data transmission

Power grid, as a vast electromechanical hybrid system, suffers from the risk of failure spreading throughout network, threatening the stability of entire system. To ensure the safe and stable operation of power grid, the timely transmission of grid status information to dispatch control center through electric power data network is of great significance. However, with the trend of power grid digitization development, electric power data transmission faces risks such as network attacks and malicious tampering. How to enhance the reliability of electric power data transmission and verify data credibility has become a key focus of academia and industry[16-19]. Blockchain as a cutting-edge technology can effectively build a trustworthy data transmission environment, becoming one of the alternative solutions to above problems.

Currently, electric power data is mainly carried in dedicated data networks. Unlike traditional Internet, the architecture of electric power data network is clear and fixed, and its business characteristics are explicit, allowing further optimization and enhancement of data transmission by applying blockchain techniques.

### 3.1. Power Dispatch Network Architecture and Transmission Services

Electric power dispatch data network is a dedicated data network for electric power dispatching and production services. Figure 5 shows the schematic diagram of electric power dispatch data network architecture. As can be seen from the figure, the architecture of electric power data network is a tree structure. Substations and power plants, as the terminal nodes in network, transmit operating data to dispatch and control center through dispatch data network via plant and station network equipment. To ensure the reliability of data transmission, each plant and station equipment is configured in a dualized manner, separately connected to two different levels of access networks[20]. Compared to traditional Internet, the main characteristics of electric power dispatch data network architecture are focused on two aspects: first, dispatch data network only carries electric power dispatching services, and its business nature and performance requirements are relatively fixed; second, once dispatch data network is established, there are very few large-scale changes in grid topology structure, and data transmission paths would rarely change.

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**Figure 5.** Framework of power dispatching data network

Figure 6 illustrates the classification and data flow direction of electric power dispatching services. Among them, the services carried on dispatch data network are mainly divided into control area services and non-control area services. Typical control area services include electric power monitoring system and management of safety device, five-protection device, relay protection device, phasor measurement unit (PMU), etc. The data transmission time delay requirement for such control area services is at millisecond or second level, using real-time subnets or dedicated channels of data transmission. Typical non-control area services include online status monitoring, auxiliary monitoring system, the management of electricity metering terminal and fault waveform recorder, etc. The time delay requirement of such services is at minute or hour level, using non-real-time subnets of data transmission.

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**Figure 6.** Business category and data flow of power dispatching

In addition to control area and non-control area services, there is management information zone for organization and management of production and personnel. More services such as administrative telephone network management, electric power enterprise data transmission are also involved in such zone. These services of management information zone are carried on enterprise data network.

### 3.2. Challenges of Electric Power Data Transmission

During the operation of power grid, the operating information of power plant/station such as voltage, current, active power, reactive power, circuit breaker opening/closing status is collected through various sensors installed on primary equipment like lines, buses, circuit breakers, transformers, generators, etc. Such information is used for emergency control by local control devices such as relay protection and safety automatic devices, and is also sent to dispatch master station through dispatch data network channel.

The transmission of electric power data from a plant/station to dispatch master station occurs in three ways: (1)some measurement data are regularly sent to master station in real-time; (2) alarm information and fault analysis results are sent directly after generation; (3)when the master station summons monitoring signals and/or graphical model information, the plant/station send data immediately. These data transmission methods can be summarized as follows: when there is no special data demand, data from plant/station are send to dispatch master station periodically; when any plant/station or dispatch master station triggers a data transmission event, such as the emergence of alarm information in plant/station or data summon request from dispatch master station, the plant/station would immediately send corresponding data to the master station.

These data transmission methods are adopted because power grid has high requirements on data transmission time delay performance. As a bridge connecting power plants and load demands, any change in load side may cause fluctuations in entire power grid's operating status. Various protection devices and automatic control equipment are used to enhance the local stability of power grid. And in order to maintain the safe and stable operation of power network, real-time monitoring of whole network status by dispatch control center is necessary. Currently, power grid lacks technical methods to judge the credibility of electric power data and mainly relies on traditional hardware such as firewalls and encryption isolation devices to guard against malicious attacks and data tampering. As energy infrastructure, power grid security defense level urgently needs to be further improved.

Applying blockchain technology to the field of electric power data transmission will bring three advantages: first, it effectively enhances the credibility of electric power data, laying foundation for the future intelligent and digital development of power grid; second, it can establish a reliable data traceability mechanism, providing a basis for the analysis and judgment of various events; third, it would optimize current power data organization, supporting data governance and management for power enterprises.

## 4. Electric Power Data Transmission Based on Parallel Proof of Work Algorithm

Although blockchain technology can effectively enhance data credibility and traceability, the drawbacks of current consensus algorithms restrict their applications in electric power data transmission.

This paper proposes a Parallel Proof of Work algorithm (P-PoW) based on early blockchain consensus mechanism, for the sake of enhancing the credibility and traceability of electric power data transmission.

### 4.1. Principle of Parallel Proof of Work Algorithm

The core idea of Parallel Proof of Work algorithm is to separate Proof of Work calculation process from new block generation process. Figure 7 shows the schematic diagram of Parallel Proof of Work algorithm principle. The blockchain structure shown is similar to Figure 1, where each block is divided into a block header and block data area. For P-PoW algorithm, block header contains $P$ , which is a hash pointer to previous block header. $M$ stands for the Merkle root hash of current block data. $TS$ represents the timestamp at which moment current block is generated. And $S$ is the signature of P-PoW algorithm. The subscript indices in Fig. 7 representing current block order. In block data area, $D$ is the electric power data written into block, with two subscripts representing the position of data item in block data area and the current block order, respectively.

Unlike PoW algorithm, P-PoW algorithm no longer iteratively calculates block header to find a suitable random number *nonce* to generate a new block. Instead, P-PoW algorithm extracts the hash pointer $P$from block header and generates a signature $S$ by iteratively executing P-PoW algorithm. At the same time, to achieve real-time transmission of electric power data, P-PoW algorithm has eliminated the block generation target field in block header.

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**Figure 7.** Diagram of Parallel PoW algorithm

Figure 8 is the flowchart of P-PoW algorithm. The process consists of five steps: hash pointer computing, real-time data filling, iterative calculation of current block signature, interruption triggering, and block header assembly. Such steps in the flowchart are executed from top to bottom, and the real-time data filling and block signature iterative calculation steps are carried out simultaneously.

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**Figure 8.** Flow diagram of P-PoW algorithm

By analyzing above flowchart, it can be seen that P-PoW algorithm proposed in this paper only needs to know the hash value $P$ of previous block to start running, and this hash value is also referred to as hash pointer. To generate a new block signature, P-PoW algorithm combines hash pointer with a random number, and calculates the hash value of combination string. During new block generation process, the random number that minimizes the aforementioned hash value would be used as the signature of that block. The above process can be represented by following formula:

(1)

Where $S_{\mathrm{n}}$ is the signature of $n$ -th block, $P_{\mathrm{n}}$ is the block header hash value of ($n$-$1$ )-th block, $H(\cdot)$ is hash function, and $r_{\mathrm{d}}$ is the random number generated in the $d$ -th round computation in block generation process. In the generation process of $n$ -th block, this random number $r_{\mathrm{d}}$ minimizes the result of hash function $H(\cdot)$ in equation (1).

During the iterative calculation of block signature, block data area is simultaneously being filled with real-time data. Unlike Bitcoin blockchain, the application scenario discussed uses blockchain to store electric power data, where each data item $D$ can include fields such as sampling time, data type, sampling value, station name, equipment identity, etc. A possible implementation method will be discussed in Chapter 4 of this paper.

In new block generation process, signature iterative calculation and real-time data filling proceed parallelly, and these two processes continue to run until timer reaches a predetermined moment or other interrupting events occur. Subsequently, when interruption events happen, hash pointer, Merkle root hash value, timestamp, block signature of new block are determined. And the new block is added to blockchain.

4.2. Trusted Transmission Scheme for Electric Power Real-Time Data

Applying P-PoW algorithm to the transmission of electric power real-time data requires further consideration of dispatch data network structure. Figure 9 shows the structure of electric power dispatch data network, where the core layer consists of provincial dispatch, backup dispatch, and two important 500kV substations, forming a partial mesh network between nodes; the backbone layer consists of 8 local dispatches and 14 hub substations, and the nodes in backbone layer connected each other in a mesh or ring manner, forming a ring with the core layer nodes; the access layer includes remaining 220kV and 110kV substations and 15 power plants, with substation nodes connected to the backbone layer nodes in a ring structure. It can be seen that electric power dispatch data network presents a tree organization structure: from access layer to core layer, the number of network nodes decreases, while the importance of nodes increases. Consequently, the communication bandwidth and hardware configuration of higher-level nodes are much higher than those of lower-level nodes.

Considering electric power dispatch data network characteristics, P-PoW algorithm can be applied to data transmission application scenario between substations, power plants, and dispatch control centers. Figure 10 shows real-time electric power data transmission method based on P-PoW algorithm, where Substation A, Substation B, and the power plant are all equipped with local computing and storage devices. And each node maintains a blockchain to store electric power real-time data locally. In substations and power plants, the dedicated servers collect real-time data generated by various data acquisition devices, encapsulating real-time data in block structures through P-PoW algorithm, and store such data in local blockchain. Meanwhile, the substations and power plants send new blocks to local dispatch nodes incessantly.

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**Figure 9.** Structure of power dispatching data network

In above application scenarios, there are two strategies for uploading new block information: one is that the plant/substation regularly upload new block information to dispatch center, and this strategy can be realized by utilizing the automated timing devices installed in plants/substations. When the counter of timing device reaches a specified value, it triggers an interruption to upload block information. Another strategy is that local dispatch sends data summon request to plants/substations, and the corresponding plants/substations upload new block information immediately after receiving such summoning message. Under either strategy, once the event to upload new block information is triggered, P-PoW algorithm would instantly stop the real-time data filling and signature iterative calculation progress, and assembles the block header. Then, new block information is sent to local dispatch center as soon as possible.

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**Figure 10.** Real-time transmission of electric power data based on P-PoW algorithm

After receiving new block information from plants/substations, regional dispatch center can verify the signature validation in new block. New block can be considered trustworthy if its signature satisfies the following inequality:

(2)

In inequality (2), $P$ represents new block hash pointer value,and$Sig$ is the block signature, $Addr$ is the address space of hash function outcome $Hash$ (*), $CP$ is computational power (TH/s) configured in the corresponding plant/substation, $\Delta T_{\mathrm{b}}$ is the time duration from receiving moment of previous block to the receiving moment of current block, and $\Delta T_{\mathrm{t}}$ is the time consumption in communication transmission process. Considering many factors such as computing power fluctuation, environment influence and uncertainty of transmission time can affect the computational result of left side of inequality (2), a coefficient $K$ is added to the right side of the equality to relax the verification condition. The specific value of $K$ can be determined based on the actual experimental test.

If new block signature does not satisfy (2), the dispatch center would reject the block. At this point, dispatch center may request corresponding plant/station to resend the latest block or send alarm message to dedicated personnel. For any attacker who wishes to tamper with electric power data via the communication channel, there are two challenges: In order to make dispatch center accept tampered data, the attacker must own sufficient computing power to produce a "good enough" signature satisfying inequality (2); The attacker must possess the historical information of the blockchain to make the header hash pointer $P$ conform to the rules of blockchain generation. By using a dedicated hash algorithm and deploying specialized hardware, while dispatching data network is used as communicational infrastructure to transmit data, the data tampering cost would become tremendous high that seldom individuals or organizations can afford. Therefore, the trustworthy transmission of real-time electric power data is guaranteed.



## 5. Simulation Verification

To validate the feasibility of P-PoW algorithm, this paper implements a simplified blockchain system for real-time electric power data transmission using C++ programming language and Qt library. Simulation experiment verifies the effectiveness of P-PoW algorithm for real-time data transmission application.

### 5.1. Blockchain Program Architecture Based on P-PoW Consensus Algorithm

The main application scenario of P-PoW algorithm in this paper is point-to-point data transmission. Considering the convenience of program implementation and debugging, a multi-thread architecture is used to build experimental program. Figure 11 shows the architecture of the experimental program, which is divided into four threads: real-time data generation thread, block data maintenance thread, P-PoW computation thread, and human-machine UI interaction thread.

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**Figure 11.** Structure diagram of experiment progress

As shown in the figure, Thread 1 simulates data collection function of plant/station, implementing real-time data generation through the program. Thread 2 creates a blockchain data structure called*BlockChain* , and fills real-time data generated by Thread 1 into the structure. Thread 3 implements P-PoW algorithm, and Thread 2 calls Thread 3 to realize proof of work of *BlockChain* . Thread 4 is responsible for implementing human-machine UI interaction, and it also communicates with Thread 2 to achieve timely reading and real-time summoning of block data. Thread 1 to 3 together realize the data collection, local blockchain generation, and storage functions of plant/station, while Thread 4 plays the role of local dispatch center in Figure 9.

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**Figure 12.** User interface of experiment progress

By implementing multi-thread program architecture, P-PoW algorithm runs in a individual thread, and the consensus algorithm of Thread 3 is independent of blockchain data filling process which is implanted in Thread 2. Therefore, the simulation program runs in exactly the same manner as P-PoW algorithm should practically do. Furthermore, through the communication interaction between Thread 4 and Thread 2, users can choose Thread 2 to generate new blocks periodically and display related information on UI interface, or to trigger an interruption event to achieve real-time data summoning.

Figure 12 shows the user interface of the experimental program, where the display area is mainly divided into two regions: block header information display region block data information display region. It also allows for the adjustment of new block generation speed, searching block information by index, real-time data summon, and other functions. The fields in the block header and block data regions are explained in Table 1.

Tab.1 Names and explanations of experiment program fields

| **Block Header Field** | **Explanations** | **Unit** |
|---|---|---|
| Index | Height of Block | — |
| PreHash | Previous Block hash | — |
| Timestamp | Block Timestamp | second |
| MerkleRoot | Merkle Root hash | — |
| Sig | Block Signature | — |
| Hash(PreHash+Sig) | Hash value of (PrHash+Sig) | — |
| **Block Data Field** | **Explanation** | **Unit** |
| Station | Sation Name | — |
| Rating | Station Ranking | kV |
| Device | Measurement Device | — |
| Value | Measurement Value | kV、A |
| Angle | Phasor Angle | degree |
| Moment | Measurement Moment | second |

5.2. Simulation Experiment Results

To further validate P-PoW algorithm, this paper uses a boosting station of a photovoltaic power plant as assumed data collection object for program verification. Figure 13 provides the main connection schematic diagram of boosting station. Typically, the boosting station of photovoltaic power plant adopts line-transformer group connection, with the high-voltage side connected to the upper-level substation and the low-voltage side lines leading to the photovoltaic plant. To monitor the operation of photovoltaic power plant in real time, dispatch control center needs to collect real-time data on the voltage and current of boosting station. In this case, the main consideration is the data collection of high-voltage side PT and high-voltage side No.1 interval outgoing line CT of the main transformer, represented in the figure as $U_{\mathrm{TH}}$ and $I_{\mathrm{LH}}$, respectively. By default, voltage and current sampling data are saved locally, and incremental sample data are sent to the local control terminal for synchronization every 15 minutes.

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**Figure 13.** Electrical connection diagram of boosting station for photovoltaic power plant

Figure 14 shows screenshots of the simulation program in operation. In Fig. 14(a), the detailed information of current block index, previous block hash, Merkle root hash, signature value is presented in block header information region. The signature is essentially a big random integer in the program implementation, and P-PoW algorithm would select the specific signature value to minimize the expression value of $Hash\ (PreHash + Sig\ )$. For the convenience of validating P-PoW algorithm, the validation result $Hash\ (PreHash + Sig\ )$ of current block is calculated and shown below the region. However, it should be mentioned that the validation result is not an entry existing in block header, it is only a program calculation result to prove P-PoW algorithm works right in such simulation.

In Fig. 14(b), the voltage and current sampling data are presented in chronological order. In the simulation program, every entry of sampling data includes information of station name, station ranking, measurement device, measurement value, measurement time. In blockchain data structure, all such information is organized by the form of byte strings, so users can design their own data entry in the simulation program as well.

The simulation screenshots in Fig. 14 show that the way the program works is the same as in previous theoretical analysis, which proves the validity of proposed P-PoW algorithm. The simulation program produces a voltage sampling value and a current one every second, and such sampling data are filled in block data region immediately. While data filling process is autonomously executed, simulation program iteratively searches the specific signature value which minimizes $Hash\ (PreHash + Sig\ )$ value simultaneously. The longer the program execution time is, the more optimized signature would be found.

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(a) Screenshot of Block Header Information Region

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(b) Screenshot of Block Data Information Region**Figure 14.** Screenshots of execution results of simulation program

By analyzing simulation results, Fig. 15 shows the generation time of different block in simulation program. It can be noted that most blocks take exactly 15 minutes for generation process. This is because many sampling data in station/plant are required to transmitted to dispatch center for every 15 minutes according to electricity industry regulations. For the program implementation, a timer is used to trigger an interruption for generating new block. However, if users need to acquire data immediately, they can summon data through simulation program interface. Such occasions, which are called data summon events, happen on block 7, block 15, block 25 and block 35, and it can be seen the generation time of those blocks is less than 15 minutes. Moreover, due to the existence of program timer, the subsequent block after any of these blocks also possesses generation time less than 15 minutes.

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**Figure 15.** Generation time of blocks for simulation program

A data visualization of further study on the number of data entries is illustrated in Fig. 16, and for the explicit, the data in first 300 minutes are only presented. Since the simulation program produces a current measurement data entry and a voltage one, the number of data entries stored in boosting station increases linearly. Meanwhile, when a new block is generated, the data produced in such new block generation process are stored in blockchain at once, hence a data synchronization between boosting station and blockchain happens. And that is the reason why the number of data entries in blockchain grows in a stepwise way. Furthermore, when a data summon event happens, the synchronization time would be advanced, so some "narrower" steps can be seen in the diagram of Fig. 16.

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**Figure 16.** Number of data entries in simulation program

In blockchain, each block generation process consumes a certain amount of hash computing power, therefore it can be regarded as every block has its own hash computing power inherently. Furthermore, since new blocks are generated based on former blocks, the hash computing power in one block would be accumulated. Any attacker trying to tamper with the data in one block should owns higher hash computing power than the one possessed by that block. Fig. 17 shows the hash computing power of block 1-7. From the diagram, it can be seen a former block always has higher hash computing power than that of newer ones. And as time goes by, the hash computing power of all blocks would increase. Such phenomenon can be treated as an evidence for proving the safety of blockchain with proposed P-PoW algorithm: the longer time the system runs, the harder an attack could be made.

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**Figure 17.** Blocks hash computing power in simulation program

Tab.2 Comaprison of P-PoW and PoW algorithms

| | **PoW** | **P-PoW** |
|---|---|---|
| **Credibility** | high | Medium |
| **Energy Consumption** | high | low |
| **Data Transmission Bandwidth** | low | high |
| **Minimum Hash Computation** | Global Computation | Local Computation |
| **Verification Method** | Difficulty-Based | Short-Term Hash Rate-Based |

Table 2 lists the characteristics comparison between the proposed P-PoW algorithm and the traditional PoW algorithm. In the PoW algorithm, the trust level of block data is based on the total computational power across all network nodes as it searches for the minimal hash value, making its credibility strictly higher than that of the P-PoW algorithm. On the other hand, the PoW algorithm leads to high energy consumption, slow new block generation, and low data upload bandwidth due to utilizing the total network computational power. The P-PoW algorithm, conducting the minimal hash value search through local computational power, has lower energy consumption, larger data upload bandwidth, and the data receiver can verify the sender's computational power through the hash value, increasing the difficulty for data tampering. Furthermore, P-PoW parallelizes the proof of work with new block data filling, enabling real-time new block generation, suitable for real-time electric power data transmission and other applications.

6. Conclusion

Based on the principles of the blockchain proof of work algorithm, this paper proposes a parallel proof of work method. By parallelizing the proof of work process with the new block data filling, the blockchain system can real-time generate and transmit new blocks, overcoming issues such as high energy consumption, slow new block creation, and low data upload bandwidth.

The results of computer program simulation demonstrate that the proposed parallel proof of work algorithm can be effectively applied to real-time data transmission scenarios like electric power data transmission. While enhancing data transmission trustworthiness, it retains functions such as timed data uploading and real-time data retrieval. This offers a feasible solution to the data security transmission problem in the digitization and intelligent development of the power grid.

References

[1]. Okoye M O, Kim H M. Optimized User-Friendly Transaction Time Management in the Blockchain Distributed Energy Market. IEEE Access, 2022. 10: p. 34731-34742.

[2]. Li Z, Chen S, Zhou B. Electric vehicle peer-to-peer energy trading model based on smes and blockchain. IEEE Transactions on Applied Superconductivity, 2021. 31(8): p. 1-4.

[3]. Afzal M, Huang Q, Amin W, et al. Blockchain enabled distributed demand side management in community energy system with smart homes. IEEE Access, 2020. 8: p. 37428-37439.

[4]. Hu Z, Du Y, Rao C, et al. Delegated proof of reputation consensus mechanism for blockchain-enabled distributed carbon emission trading system. IEEE Access, 2020. 8: p. 214932-214944.

[5]. Augello A, Gallo P, Sanseverino E R, et al. A Coexistence Analysis of Blockchain, SCADA Systems, and OpenADR for Energy Services Provision. IEEE Access, 2022. 10: p. 99088-99101.

[6]. Narayanan A, Bonneau J, Felten E, et al. Bitcoin and cryptocurrency technologies: a comprehensive introduction. Princeton University Press, 2016.

[7]. Antonopoulos A M, Wood G. Mastering ethereum: building smart contracts and dapps. O'reilly Media, 2018.

[8]. Mingxiao D, Xiaofeng M, Zhe Z, et al. A review on consensus algorithm of blockchain. 2017 IEEE international conference on systems, man, and cybernetics (SMC). IEEE, 2017: p. 2567-2572.

[9]. Chaudhry N, Yousaf M M. Consensus algorithms in blockchain: Comparative analysis, challenges and opportunities. 2018 12th International Conference on Open Source Systems and Technologies (ICOSST). IEEE, 2018: p. 54-63.

[10]. Prat J, Walter B. An equilibrium model of the market for bitcoin mining. Journal of Political Economy, 2021. 129(8): p. 2415-2452.

[11]. Nakamoto S. Bitcoin: A peer-to-peer electronic cash system. Decentralized business review, 2008: p. 21260.

[12]. Saleh F. Blockchain without waste: Proof-of-stake. The Review of financial studies, 2021. 34(3): p. 1156-1190.

[13]. Saad S M S, Radzi R Z R M. Comparative review of the blockchain consensus algorithm between proof of stake (PoS) and delegated proof of stake (DPoS). International Journal of Innovative Computing, 2020, 10(2).

[14]. Bentov I, Lee C, Mizrahi A, et al. Proof of activity: Extending bitcoin's proof of work via proof of stake. ACM SIGMETRICS Performance Evaluation Review, 2014. 42(3): p. 34-37.

[15]. Chen L, Xu L, Shah N, et al. On security analysis of proof-of-elapsed-time. Stabilization, Safety, and Security of Distributed Systems: 19th International Symposium, SSS 2017. Springer International Publishing, 2017: p. 282-297.

[16]. Li J, Wang L, Qin X. Distributed energy management study based on blockchain technology. International Journal of Computational Science and Engineering, 2022. 25(2): p. 222-233.

[17]. Rauniyar K, Wu X, Gupta S, et al. Risk management of supply chains in the digital transformation era: contribution and challenges of blockchain technology. Industrial Management & Data Systems, 2022. 123(1): p. 253-277.

[18]. Hasan M K, Alkhalifah A, Islam S, et al. Blockchain technology on smart grid, energy trading, and big data: security issues, challenges, and recommendations. Wireless Communications and Mobile Computing, 2022. 2022: p. 1-26.

[19]. Chen S, Mi H, Ping J, et al. A blockchain consensus mechanism that uses Proof of Solution to optimize energy dispatch and trading. Nature Energy, 2022. 7(6): p. 495-502.

[20]. Wang P, Ye H, Wang Z, et al. Research on the Overall Transformation Scheme of the First Access Network of Dispatching Data Network of State Grid Weifang Power Supply Company. 2022 IEEE 10th Joint International Information Technology and Artificial Intelligence Conference (ITAIC). IEEE, 2022. 10: p. 66-70.