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ASSET MANAGEMENT OF SMART GRID USING DIGITAL TWIN TECHNOLOGY AND MACHINE LEARNING ALGORITHMS

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Abstract. In order to solve the problem of data insecurity in the current smart grid asset monitoring and management platform, the author proposes a research on smart grid asset management using digital twin technology and machine learning algorithms. This study achieves data security performance verification and monitoring through the application of data consensus mechanism. When verifying data in data nodes, data regulation verification information can be published in the form of a set of data packets to the data chain. The best node in the node is used as the data packet in the blockchain to build a platform structure. Management is achieved through data encryption, data monitoring, and device status classification. The experimental results show that the data theft rate simulated using this method has been reduced by 25.48%, and the security performance of the scheme is higher. The use of digital twin technology and machine learning algorithms for smart grid asset management has improved the security issues existing in traditional solutions and has enormous potential for application.

Key words: Smart grid, Asset monitoring, Management platform, Blockchain, Equipment status classification

1. Introduction. With the strengthening of power regulation in various countries around the world, the aging of power equipment, and fierce competition in the market environment, power companies are forced to optimize investment and reduce costs. At the same time, the development of the social economy continuously increases the reliability requirements of the power system. The market and business models of power companies are gradually changing, and there is an urgent need to further optimize management processes and improve asset management levels. Therefore, as an advanced management concept, asset lifecycle management has developed rapidly in foreign power companies. The goal of asset lifecycle management in foreign power grids is mostly to pursue overall economic optimization while meeting certain constraints (such as reliability constraints, environment, user needs, etc.) [1].

With the continuous deepening of smart grid construction, the deployment and application of power grid dispatch automation systems, intelligent operation and inspection systems, distribution automation systems, and electricity consumption information collection systems, etc [2]. On the one hand, it has improved the ability to operate, control, and maintain equipment, and on the other hand, it has greatly improved the ability to collect data, and the system has accumulated more and more data. How to manage and make good use of the increasingly large amount of data is an urgent problem that power grid enterprises need to solve. Smart grid big data processing requires the adoption of new technologies and means to solve data processing problems [3]. Data asset management is a management model that combines traditional asset management methods with the characteristics of data [4]. It is a variety of management activities adopted by enterprises or organizations, which is a function of planning, controlling, and supplying relevant data and information to ensure the security and integrity of data assets, improve the economic benefits brought by data assets through the discovery of big data value, and ensure and promote the development of various businesses of enterprises [5]. Through effective data management and big data analysis and mining, power grid data assets will play an increasingly important role in areas such as power grid scheduling, intelligent operation and maintenance, and intelligent power distribution. This will reduce labor costs, improve equipment utilization, and ensure the safe and stable operation of the power grid [6].

2. Literature Review. In recent years, in the production and operation of the power grid, data analysis can effectively improve work efficiency and effectiveness. For example, by integrating power grid operation data and external environmental data, big data analysis can predict weak points in the power grid in advance,

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identify problems in a timely manner, and handle them, which can greatly improve the reliability of the power grid and reduce economic losses for enterprises. The traditional smart grid asset monitoring and management platform is mainly realized by the distributed business model of the Internet, so it is necessary to establish a centralized structural system [7]. Completing data exchange, equipment maintenance, and user information resource processing in the operating system of the smart grid, the centralized structural system, due to the existence of a large number of transaction management systems, will cause interference and security risks to the numerous data of the smart grid. Tiwari, S. et al. used various machine learning based algorithms to estimate power grid stability to avoid fault situations. Using the Bagging classifier algorithm to accurately predict electricity demand will help avoid power grid failures, thereby improving the stability and robustness of the power grid [8]. Hudani, D. et al. proposed a data-centric approach (DaC) to generate such invariants. The entire study was conducted using operational data from a functional smart grid, which is also a live laboratory [9]. Wang, R. et al. proposed an anti electricity theft prediction method based on power big data. This method constructs electricity theft data samples based on anomaly rules and introduces constraints on the growth rate of line loss rate [10].

In order to solve the problems in traditional solutions, the author conducted research on the asset monitoring and management platform of smart grids based on the use of digital twin technology and machine learning algorithms.

3. Method.

3.1. Smart Grid with Digital Twin Technology. The smart grid under the digital twin technology includes both the physical level physical grid and the virtual grid in the digital world. The two contents that exist in different dimensions are essentially coexisting and intertwined. The virtual grid will fully restore the various conditions and related parameters of the physical grid, thereby obtaining data and case support for the control of the physical grid through observation and adjustment of the virtual grid [11]. In this process, other digital information technologies can be applied to assist, enabling the smart grid to form deep learning capabilities in the process of continuous autonomous optimization, thereby enabling the smart grid to derive development models that can self detect, improve, and optimize, gradually establishing the ability to operate and manage itself [12].

3.2. Structure Construction of Smart Grid Asset Monitoring and Management Platform. The author applies decentralized technology to monitor and manage electrical equipment assets in the smart grid, and sets corresponding monitoring and management system structures based on different data and equipment characteristics for block management [13-14]. Firstly, a decentralized ledger management structure for electrical equipment should be established, which includes statistics on the model, operating status, installation date, purchase date, and coverage range of electrical equipment. It is also necessary to backup complete information records on the maintenance and inspection frequency of electrical equipment, and scientifically build a safety database that can be extracted and retrieved in a timely manner. Electrical equipment inevitably incurs certain self losses during operation, and it is necessary to manage potential vulnerabilities in the equipment. The loss and vulnerability information of electrical equipment should be recorded in different regions and promptly reported to relevant power grid departments. The main task is to promptly investigate and manage vulnerabilities in electrical equipment. The monitoring of the status of electrical equipment is one of the very important tasks in the operation of the smart grid [15]. A complete decentralized database needs to be established for the daily maintenance data of equipment, equipment failure status, equipment operation time, and corresponding maintenance plans, ensuring the normal operation of the smart grid and the monitoring and management of electrical equipment assets in the smart grid [16].

In order to prevent the occurrence of information leakage caused by exhausted data verification of nodes, the author constructed a decentralized data chain structure. The optimal nodes are divided according to time periods, and the data is selected for data security verification according to different time periods [17]. When parsing data packets in nodes, it is necessary to obtain the data content in the packets through the data key, ensuring the one-way data security of the smart grid. The author's structural framework is shown in Figure 3.1.

The smart meter in the structure is mainly installed in the customer's electrical equipment, facilitating the collection of multidimensional data by the smart meter [18]. Smart meters are customized based on the

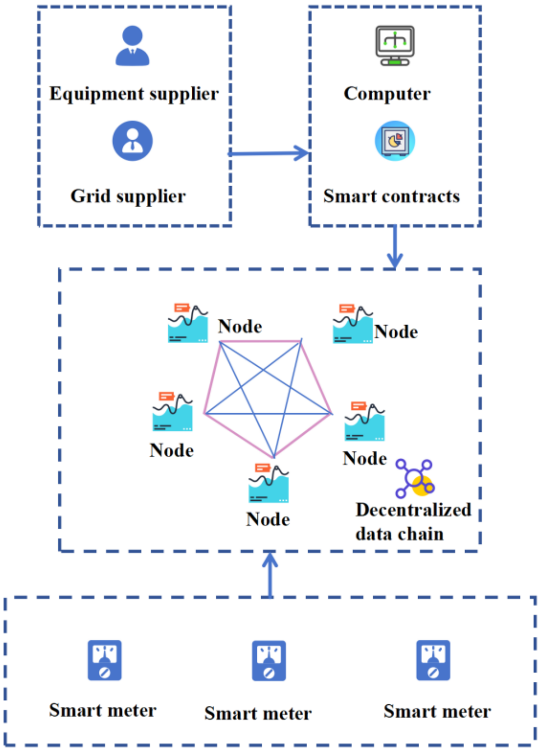

Fig. 3.1: Architecture diagram of intelligent grid asset monitoring and management platform

user's electricity consumption characteristics and the characteristics of the electrical equipment, and require the user's real name login to connect with the data chain in the block [19]. Smart meters will directly send users' multidimensional data to the data nodes of the smart grid, achieving flexibility and accuracy in data application, while also reducing communication load in the smart grid [20]. After receiving data, the operating unit of the smart grid formulates different electricity feedback policies based on different types of customers, and monitors and manages the set electricity equipment in real-time in the form of contracts. When the contract in the smart grid meets the set conditions, the content of the contract will be automatically implemented, and users will cooperate with the conditions in the contract to provide feedback on electricity consumption information and adjust the electricity equipment. This not only improves the power supply efficiency of the smart grid, but also reduces the power supply burden of the smart grid. The efficiency calculation function for smart grid power supply in the contract is:

$$\partial = x \times J(N) \tag{3.1}$$

In the formula: ∂ represents the working efficiency of the smart grid; x is the channel pressure coefficient in the contract; J(N) is the time parameter for multi-dimensional data feedback.

The smart grid contains a control center for asset monitoring and management platforms, which utilizes the blockization and decentralization of data communication links to achieve the independence and permanence of data storage, management, and detection. The implementation of this function does not require human involvement and is achieved through the automatic data allocation technology of the intelligent system, avoiding data account theft caused by personnel participation. In addition, the data management structure of the control center is also equipped with power grid operation chips, which monitor the data information of power grid assets for faults and violations, and issue timely warnings to management personnel.

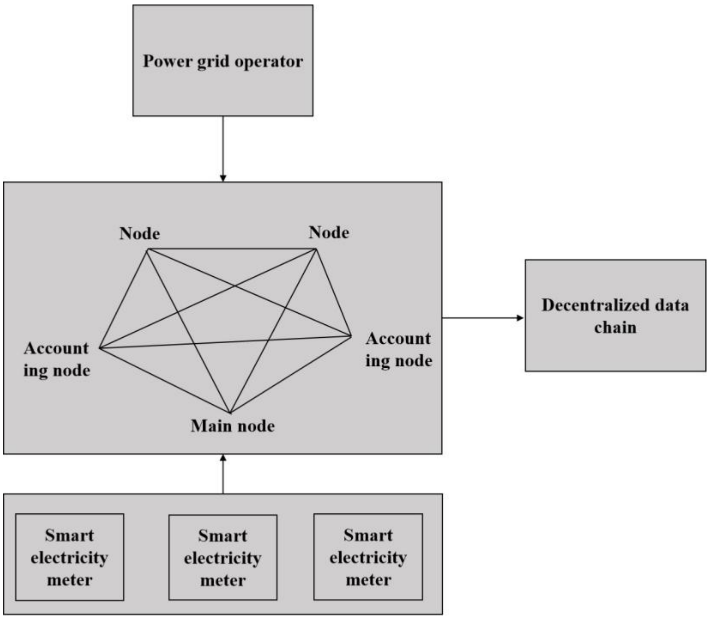

Fig. 3.2: Implementation flowchart of aggregate encryption

3.3. Workflow Analysis of Smart Grid Asset Monitoring and Management Platform. The workflow of the smart grid asset monitoring and management platform is mainly reflected in the analysis of multidimensional data. From obtaining multidimensional data to managing multidimensional data, it needs to be coordinated and allocated through a decentralized data chain structure. The smart meter first collects user's smart grid asset data and publishes it to decentralized grid nodes, which then further transmit the data to the corresponding management platform through blockchain technology. In order to ensure the security of data, the transmission of multidimensional data is mainly carried out in the form of encrypted files. The encryption mechanism of multidimensional data is implemented through aggregation encryption. The encryption mechanism function of multidimensional data is:

$$U = \frac{K-1}{N} \tag{3.2}$$

The encryption public key N is defined as:

$$N = g^N \times modN^2 \tag{3.3}$$

In the formula: U represents the aggregated encryption result; K is the encryption security factor for multidimensional data; N is the public key code. Figure 3.2 shows the implementation flowchart of aggregate encryption.

After the successful data acquisition of the smart grid, it is necessary to monitor the key data, check whether the anti theft function of the data is complete, and prevent illegal users from tampering with the data in the high-voltage grid and stealing high-voltage electricity. By monitoring the data, three-phase voltage data, current preprocessing data, and data dimension can be obtained. The monitoring data needs to be sent to the data chain, and the data from the main node should be transmitted to the blockchain for permanent storage to ensure the stable operation of the smart grid. Data monitoring can be achieved through diagnostic networks in power equipment. Figure 3.3 shows the data monitoring structure diagram.

Smart grid operators also need to effectively control and manage real-time data to ensure stable electricity supply within the coverage area of the smart grid and avoid insufficient power supply during peak periods, based on the situation where users obtain electricity. The implementation of this technology is mainly achieved

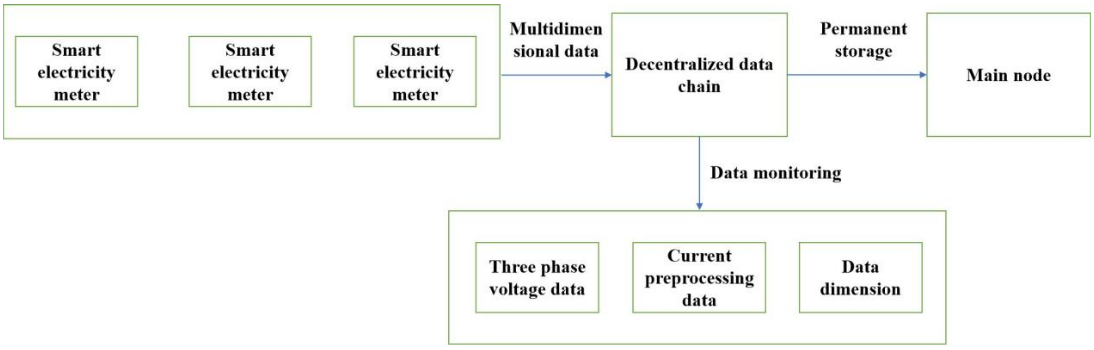

Fig. 3.3: Data monitoring structure diagram

through the contract mechanism between operators and users, and the smart contract contains two operation functions: user electricity consumption and grid electricity supply. When the data in the contract changes, an alert will be issued, and a decoding threshold value needs to be set to limit the continuous power supply of the smart grid. The threshold limit function in the contract is shown in equation 3.4.

$$e(c,1) = e[k, H(N)] \tag{3.4}$$

In the formula: (c,l) represents the threshold value result; K is the multidimensional data electricity consumption coefficient; H(N) is the user's electricity consumption. When the user's electricity consumption exceeds the power supply cost, the smart contract will also reduce the continuous power supply to the user. In severe cases of user arrears, the power supply will be stopped. The data related to equipment assets in the smart grid also needs to be monitored and managed. Equipment suppliers first provide certain factory data and process the safe operation status of the equipment in a decentralized data chain structure. This structure divides the operation status of power grid equipment into normal operation status, alert status, emergency status, and shutdown status. When a device malfunctions, it is necessary to immediately transmit the fault information to the management personnel. The management personnel should make corresponding adjustment plans based on the factory information. The equipment supplier should also transmit the relevant data of the device, Figure 3.4, and the schematic diagram of the device status classification to the blockchain, forming a decentralized permanent database. Figure 3.4 is a schematic diagram of the device's state classification.

3.4. Experimental preparation. The implementation of this scheme first requires the installation of smart meters within the conventional coverage range of the smart grid, the collection of asset data of the smart grid, the introduction of communication contracts in the smart meters, and the removal of centralization in the content data of the contracts, so that the data communication of the smart terminal is connected in real-time with the bus of the smart grid. In order to ensure stability during the test process, the model of the smart meters used in the test is DB2750 three-phase smart meters. The contract in smart meters mainly transmits data to the outside in duplex communication mode, and the working mode of the communication contract is determined based on different data types. The most common communication frame rate in the contract is 48H, and 8 bytes are a separate communication area. During data transmission, the bytes are transferred to form a barcode, which has encryption function and requires a key from the management personnel to parse the data content, enhancing the security and stability of the experiment.

In order to ensure that there is no interference from other power grid data in the experimental environment, a data signing process is established in the smart grid data environment. A key system is required for the transmission and exchange of user related data and smart grid related data, and the data receiving port can have an independent key. When attackers of smart grid assets install stolen files in the data channel, the eavesdropping files cannot be effective until users publish data information to a decentralized data chain structure, and the data content needs to be decrypted through a signed password. The ciphertext in channel transmission is in a sealed state, and even if the attack file obtains the data information in the channel, it cannot

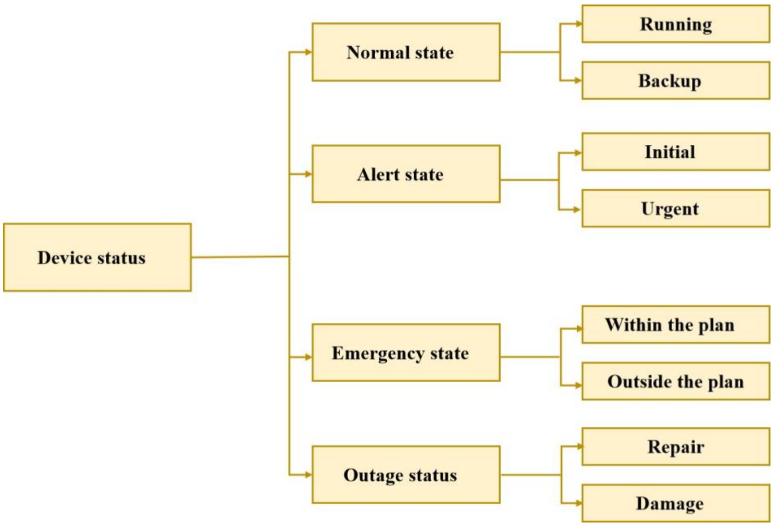

Fig. 3.4: Schematic diagram of device status classification

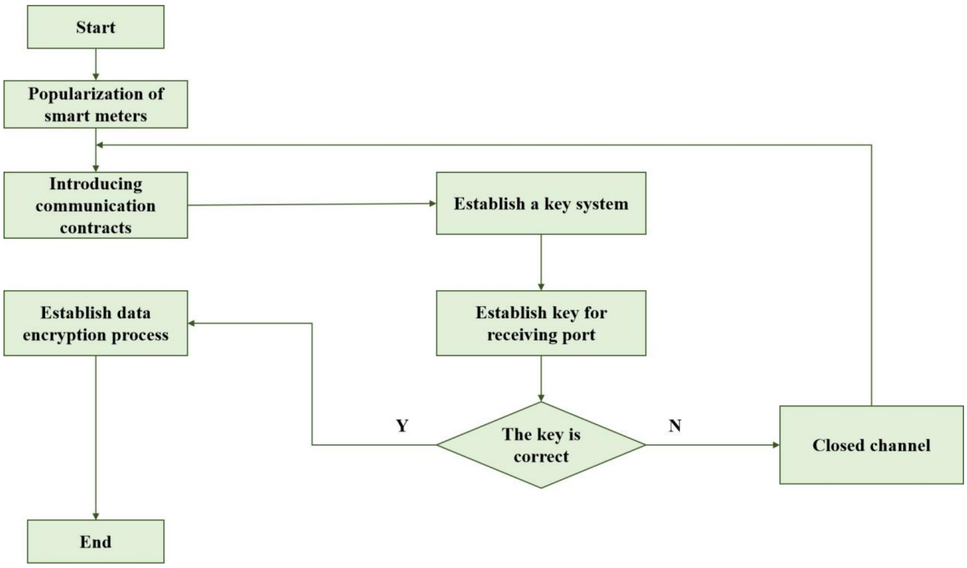

Fig. 3.5: Experimental Environment Construction Flow Chart

crack the encrypted file. The permanent and decentralized nature of multi-dimensional data in electricity can adapt to the confidential characteristics of blockchain data blocks. Figure 3.5 shows the flowchart for constructing the experimental environment.

4. Results and Discussion. The asset information and management platform of the smart grid in the experiment require multidimensional data content. The reception and processing of the management platform should cooperate with the regulation of the smart grid, and the decentralized data chain structure has permanence. The data stored by the management platform cannot be corrected again. The comparison results of the operational effectiveness and performance of the asset monitoring and management platform in the face of data attacks in the same smart grid by three schemes based on the content of the smart treaty are shown in

Table 4.1: Performance Comparison of Three Schemes

Performance	Internet distributed business model	Multidimensional data aggregation feedback mechanism	Author's proposal
Confidentiality	good	good	excellent
Data integrity	excellent	good	excellent
Dimension collection	good	good	excellent
data management	good	excellent	excellent
Permanent	excellent	good	excellent

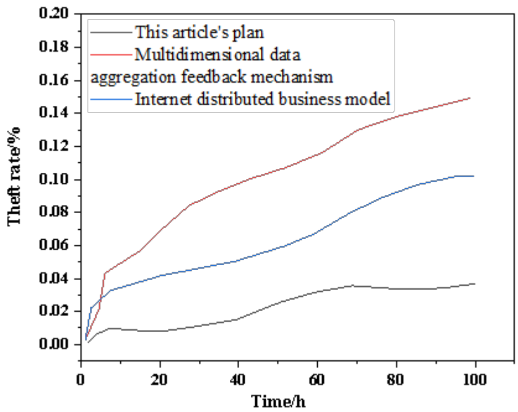

Fig. 4.1: Comparison of Security Processing Capabilities of Three Schemes for the Same Stolen Files

Table 4.1.

The author's plan has a wide coverage of the implementation of the intelligent grid asset monitoring and management platform, including the monitoring and management of intelligent grid electrification equipment assets and user data information assets. For the asset management of electrification equipment, this article establishes a decentralized ledger management structure to achieve monitoring and management of electrification equipment resources in multiple states such as operation, maintenance, and repair. In the experiment, the safety performance of electrical equipment asset monitoring and management in the smart grid was first compared. The same electrical equipment data information was monitored in the same experimental environment, and the same data theft files were installed in three different schemes. Figure 4.1 compares the security processing capabilities of three schemes for the same stolen files.

It can be seen from Figure 4.1 that the security performance of the author's scheme is the highest. After 100h, the data theft rate reaches the highest (about 0.04%), followed by the Internet distribution business model, which reaches about 0.08%, and the data multi-dimensional aggregation feedback mechanism is the worst, which reaches about 0.15%. In addition, the security processing capacity of the author's scheme is growing steadily within 100h, while the traditional method rises to 0.03% to 0.04% within 10h. The security stability is poor. The multidimensional data source for asset electrification data in the smart grid in this plan was initially from equipment suppliers. This plan is based on the data provided by suppliers as the foundation of a multi-dimensional data chain structure, and monitors whether there will be data failures and leaks during the operation of electrical equipment based on relevant safety performance data. It scientifically manages vulnerabilities in the electrical equipment channel, establishes real-time contact with the regulatory authorities of the smart grid, and enhances the stability of security performance. The author has also completed decen-

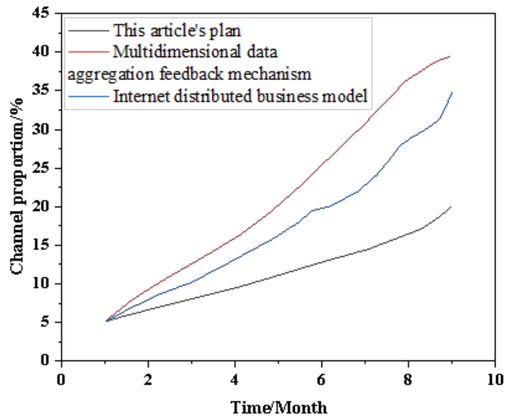

Fig. 4.2: Comparison of Communication Channel Pressure

tralization in the overall structure, making the monitoring and management of intelligent grid electrification equipment assets an independent operating system, and ensuring higher safety performance. Asset monitoring and management in smart grids require communication to be completed through data nodes, and the accuracy of data transmission between nodes is also one of the comparison objects of this experiment. The same type of data is obtained separately and transmitted between nodes, and the accuracy of data transmission is monitored in the channel.

The intelligent grid asset monitoring and management of this scheme has a higher degree of accuracy, achieving 100% accurate data transmission, while the other two traditional schemes have a minimum accuracy of nearly 30%. In the same area, this scheme applies smart meters to collect power supply data from users. The collected data has real name characteristics, and the transmission of nodes requires security verification to be transmitted in real time, thereby ensuring the accuracy of the data transmission process. The application of smart contracts as communication protocols in the asset monitoring and management communication channel of this scheme can timely feedback inappropriate data, reducing the overall channel pressure of the structure. The decentralized node blockchain adopts a phased working form, which also reduces the communication pressure of the channel. Figure 4.2 shows a comparison of communication channel pressures for intelligent grid asset monitoring and management under three different schemes in one year.

From Figure 4.2, it can be seen that the channel pressure under this scheme is the smallest, and the channel proportion of the author's scheme is controlled within 20%, while the channel proportion of the traditional scheme has reached 30%. The author has mainly improved the data transmission source and transmission medium of the channel, enhancing the smoothness of data transmission in asset monitoring and management, and thereby enhancing the overall efficiency of the structure.

5. Conclusion. The author proposes the study of using digital twin technology and machine learning algorithms for smart grid asset management. The smart grid asset monitoring and management platform is the basic guarantee for efficient and stable power supply in the smart grid. The traditional implementation scheme of the smart grid asset monitoring and management platform mainly operates in a centralized mode, which is easily affected by interference from other power grid data. In response to the security, accuracy, and efficiency of the intelligent grid asset monitoring and management platform, the author establishes a decentralized structure for the intelligent grid asset monitoring and management platform, and applies technologies such as channel smart contracts, node data transmission, and key processing to improve the problems existing in traditional solutions.

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