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Lifecycle Data Management of Nuclear Power Plant: Framework System and Development Suggestions

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Abstract: The amount of nuclear power plant data has grown exponentially and has become an important asset as a result of the digital and intelligent transformation of the nuclear industry. However, there is a lack of lifecycle data management systems for nuclear power plants. This paper summarizes the status of research on nuclear power plant lifecycle data management in China; analyzes the demands and challenges of nuclear power plant lifecycle data management; and constructs a data management framework around the lifecycle nodes and business flows of nuclear power plants. The major tasks in establishing a nuclear power plant lifecycle data management system include (1) promoting the comprehensive digitization of the nuclear power industry and unifying the nuclear power plant lifecycle data standards; (2) classifying lifecycle data according to data types and designing data models; and (3) formulating scientific data quality control policies and data quality measurement standards to ensure the security of the lifecycle data of nuclear power plants. Furthermore, the following recommendations are made. (1) A data integration platform should be established to catalog the items, business data, and three-dimensional simulation data of nuclear power plants to promote the interconnection of data across business systems. (2) Blockchain technology should be applied to nuclear power plant lifecycle data management to ensure the authenticity and traceability of the data. (3) Digital twins and model-based system engineering should be applied in nuclear power plant lifecycle data management to improve the level of intelligent development. (4) A green policy should be established for nuclear power plant data management to realize the low-carbon, efficient, and sustainable development of data centers.

Keywords: digital transformation; nuclear power plant; lifecycle; data management; framework system

1 Introduction

Nuclear power is a key part of a clean, low-carbon, safe, efficient, and modern energy system. The digital and intelligent transformation of nuclear power plants will not only ensure the high-quality development of the nuclear industry but is also an indispensable part of building a powerful nuclear industry. For nuclear power enterprises, actively promoting the digitization of nuclear power plants is the preferred path to reduce costs, improve efficiency, and gain a competitive advantage.

Industrial digital transformation is integral to the development of a digital economy. Countries with developed industries have actively laid out industrial digital transformation strategies [1]. The lifecycle of nuclear power plants spans several decades and generates massive amounts of data. Because of the lack of unified planning and management for huge and complex data, it is difficult to increase the data utilization rate and fully exploit the value of data [2].

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Therefore, a top priority in the digital transformation of nuclear power plants is the establishment of a data management system. As big data has become an important asset of nuclear power plants, it is important to develop a data management system to perform data collection, processing, transmission, and application during the lifecycle of nuclear power plants, strengthen data circulation, enhance data management and sharing mechanisms, and fully exploit the core values of data elements.

2 Research status of nuclear power plant lifecycle data management (NPPLDM)

Nuclear power plant lifecycle data management (NPPLDM) refers to the definition, collection, evaluation, sharing, collaborative application, maintenance, archiving, destruction, and other types of processing of various kinds of data from the main stages of the lifecycle of nuclear power plants. It also involves the scientific and comprehensive management of the data lifecycle. Data supports the development of digital twins and the digital handover of nuclear power plants. With the digital development of nuclear power plants, the amount of nuclear power data have grown exponentially. Data management that focus on storage management can no longer satisfy the in-depth data analysis and sharing requirements of related businesses. In the new era, NPPLDM should include data storage integration, shared application, safety, and reliability; the in-depth study of nodes, business flow, information flow, and data flow of the lifecycle of nuclear power plants; refined data management covering the entire operation of nuclear power plants, including planning, procurement, construction, commissioning, handover, operation, and decommissioning; realizing the value of big data generated by nuclear power plants, eliminating the “data island”, promoting business collaboration, and improving the safety, reliability, and economy of nuclear power plants.

Research on NPPLDM systems can be divided into two types: research on data management at a certain stage in the nuclear power plant lifecycle, and research on master data management of nuclear power plants. The former focuses on the three stages of nuclear power plant projects: (i) planning and design, (ii) engineering construction (including equipment procurement, civil engineering, and installation), and (iii) operation and maintenance. Because most nuclear power plant data are generated during the planning and design stage, the digitization of nuclear power plant design not only simplifies data transmission and sharing but also contributes to the “digital handover” of nuclear power plants [3]. In the construction stage, strengthening and standardizing equipment procurement data management [4], project management [5], and document management [6] will help shorten the construction period, reduce costs, and improve efficiency. Considering that the reactor oversight process is at the center of the nuclear power operation and maintenance management stage, the scientific management of such data is crucial for the safe and efficient operation of nuclear power plants [7].

Master data is the core data generated in nuclear power plant processes (e.g., planning and design, construction, installation, commissioning, operation, maintenance, and production) and meets the requirements of cross-departmental business coordination after it is collected, shared, and applied. Master data management ensures the consistency, integrity, sharing, and reliability of master data in the nuclear power plant lifecycle. Master data also plays an important role in nuclear power plant informatization and business activities. Domestic nuclear power enterprises have actively applied master data management practices. For example, Jiangsu Nuclear Power Co., Ltd. proposed a conceptual model for the Jiangsu nuclear power master data lifecycle. Daya Bay Nuclear Power Operation and Management Co., Ltd. designed the master data classification management [8] and a knowledge management framework of the nuclear power plant lifecycle [9]. Although these studies provide insights on the management of design, procurement, and engineering data during the digital transformation of nuclear power plants, there is still a lack of overall planning and control for NPPLDM systems.

Nuclear power generation is a complex engineering system with a lifecycle of 50–70 years from the planning and design to the decommissioning stage. The various types of data generated during the entire lifecycle of nuclear power plants are important to ensure their normal operation and safety; they also have a significant reference value. In the context of the digital and intelligent development of nuclear power plants, it is essential to effectively manage complex nuclear power engineering data as well as operation and maintenance data. As a holistic and framework study on NPPLDM, this paper first considers the needs and challenges of nuclear power plant data management, focusing on the integrated application of data management and nuclear power business collaboration. An NPPLDM framework system is proposed to achieve a more efficient data management strategy; industrial development strategies are also proposed to promote the development of digital nuclear power plants.

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3 Demand analysis and challenges of NPPLDM

3.1 Demand analysis of NPPLDM

3.1.1 Demand for nuclear power plant business collaboration

A nuclear power plant is a long-term project involving multiparty, multidisciplinary, and multi-equipment collaborations. Nuclear power plant data can be divided into engineering data and operation and maintenance data according to the business flow. Engineering data includes planning and design documents, procurement data, construction data, and commissioning data generated in the engineering and construction stage of nuclear power plants. Operation and maintenance data refers to the data generated in nuclear power plant operations, such as maintenance, life extension, and retirement data. The massive amounts of data are usually stored in different systems with nonuniform data standards, complex and diverse data types, and relatively independent operating systems that result in the duplication and fragmentation of business data and hinder data sharing and application, which affects the efficiency of collaborations in the nuclear power business. Therefore, the opening and sharing of the NPPLDM system is an innovative method to improve the efficiency of the nuclear power business and modernize the data governance capability for the nuclear power plant lifecycle.

3.1.2 Demand for digital handover of nuclear power plants

The digital handover of nuclear power plants is an important embodiment of the "integration of informatization and industrialization." In China, nuclear power plant construction projects mainly adopt an engineering, procurement, and construction general contracting mode [10]. Under the traditional nuclear power plant handover, relevant data is delivered to the owner in the form of paper and electronic documents. The emerging digital handover of nuclear power plants will deliver relevant information to the owner at the engineering stage in the form of structured data, intelligent models, and electronic drawings, while a digital nuclear power plant will be developed to support the intelligent operation of smart nuclear power plants. Data management throughout the lifecycle of nuclear power plants can support the interconnection and efficient analysis of data between business systems by standardizing data, associating data attributes, improving data quality, etc. Intelligent models and electronic drawings have good practicability and are more reliable in guiding the operation of nuclear power plants.

3.1.3 Demand for improving nuclear power safety

The safety of nuclear power plants has attracted considerable attention for many years. Nuclear power plant design usually adopts the "defense in depth" philosophy and uses technical means to minimize the damage caused by nuclear accidents. The operation and maintenance management of nuclear power plants mainly involve early warnings and fault quantification by monitoring the reactor operating status, equipment attributes, nuclear radiation dose, and other data [11]. The traditional analysis and processing of nuclear safety data is dependent on human experience. On the other hand, the digital and intelligent transformation of nuclear power plants has reduced the role of human operators in favor of data and algorithms that provide intelligent early warnings. At present, the nuclear power industry has yet to establish a standardized and comprehensive data management process. Problems such as the low degree of data correlation and multisource heterogeneous data hinder the digital and intelligent operation and management of nuclear power plants.

3.2 Challenges faced by NPPLDM

3.2.1 Complex business and serious "data island" in nuclear power engineering

A nuclear power plant is a complex engineering system that involves multiple participants, which results in the phenomenon of data closure. There is information asymmetry and untimely data utilization throughout the lifecycle of nuclear power plants. Nuclear power business systems are mostly self-contained and independent from each other. Although vertical businesses have achieved comprehensive coverage, the optimization of horizontal businesses remains insufficient. It is difficult to integrate and coordinate data across business fields or sectors owing to the serious "data island" in the nuclear power business caused by different data standards.

3.2.2 Numerous data types and low data availability

The multisource data of a nuclear power plant has resulted in data diversity [12]. However, the diversity of data carriers and format types has increased the complexity of data types. In view of the different functions of data and data structures in business as well as the obvious differences in data types, improper data classification and management will reduce data availability. Taking the nuclear power plant design stage as an example, most of the core data are saved and exchanged in the form of paper documents, which has disadvantages such as low transmission efficiency, difficult sharing, different versions, and difficult retrieval. In addition, with the diversification of data collection methods, unstructured data accounts for an increasing proportion of the total data, and is growing exponentially. This has resulted in problems such as increased data storage costs, difficulties in application analysis, more complex information integration and connection, and increased requirements for the real-time unification of information and integration of the virtual and real worlds.

3.2.3 Lack of effective data quality management mechanism

Improving data quality is one of the goals of NPPLDM. In the process of nuclear power plant construction and operation, data quality is affected by inaccurate data entry, missing data, and abnormal data. When a large amount of abnormal data provides invalid input values to automatic equipment, the normal operation of the reactor is affected and could even threaten the safety of the nuclear power plant. To date, nuclear power enterprises have yet to establish a strict and standardized data quality management system for the entire lifecycle of nuclear power plants. The corresponding oversight mechanism is also imperfect. The inconsistent quality of nuclear power plant data reduces the effectiveness of data analysis, integration, and prediction, which undermines the comprehensive digitization process of nuclear power plants.

3.2.4 More data security and privacy issues

As one of the core assets of enterprises, and because of its importance to the country, nuclear power plant data will face additional security problems after being fully digitized. Currently, enterprises pay insufficient attention to the security nuclear power plant data. The data security management mechanism covering the entire lifecycle of nuclear power plants has yet to take shape. Moreover, there is a lack of a long-term planning for data security problems after the data is uploaded to the cloud, such as the long-term remote storage security of massive data, stricter identity authentication measures, fine-grained access control; sensitive data analysis, sharing, and collaborative application; external network attack prevention, and ensuring data transmission security.

4 NPPLDM and collaborative application framework system

NPPLDM essentially establishes a fine data management method covering all the stages of a nuclear power plant project, including planning and design, procurement and construction, commissioning and handover, operation and maintenance, and decommissioning. This is achieved via the in-depth study of the nodes, business flow, information flow, and data flow of the nuclear power plant life cycle to realize the open sharing and collaborative application of data. The framework of NPPLDM and its collaborative application are shown in Fig.1. The overall framework takes the real plant as the object, the massive data generated by the entire lifecycle of the plant as the core, and the enterprise data management policy guidance and organization management as the auxiliary oversight. It presents the main objectives of NPPLDM: solving the problems of the data island, low data availability, inconsistent data quality, and data security; and promoting the high-quality and efficient data management in nuclear power plants.

4.1 Enterprise system standards management

The data management system is the cornerstone of managing the lifecycle data of nuclear power plants. The data management system of nuclear power enterprises is included in the business requirements of the nuclear power plant lifecycle and the development requirements of smart nuclear power plants. These include standardizing the key elements of data standards and data quality assessment, clarifying data security requirements, and establishing guidelines and standards for the delicacy management of nuclear power plant data. The key points are to clarify the importance of data management and help the relevant departments in the nuclear power plant lifecycle to reach a consensus; set data security norms to ensure data confidentiality, data availability, and data integrity of nuclear power plants; clarify the principles of data generation, application, and management to ensure the security of horizontal and vertical data sharing; establish an accountability system using reward and punishment to improve the efficiency of data management; and set standards for data quality management to improve data availability.

4.2 Organization management

Organization management provides the organizational structure and personnel for the NPPLDM system. The nuclear

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power plant lifecycle generates a large amount of data that requires efficient and systematic management and cooperation between members of the organization. The key points of organization management include designing the structure according to the characteristics of the nuclear power plant and clarifying the respective responsibilities, and establishing committees responsible for data quality control and optimization, data quality management, and data security management.

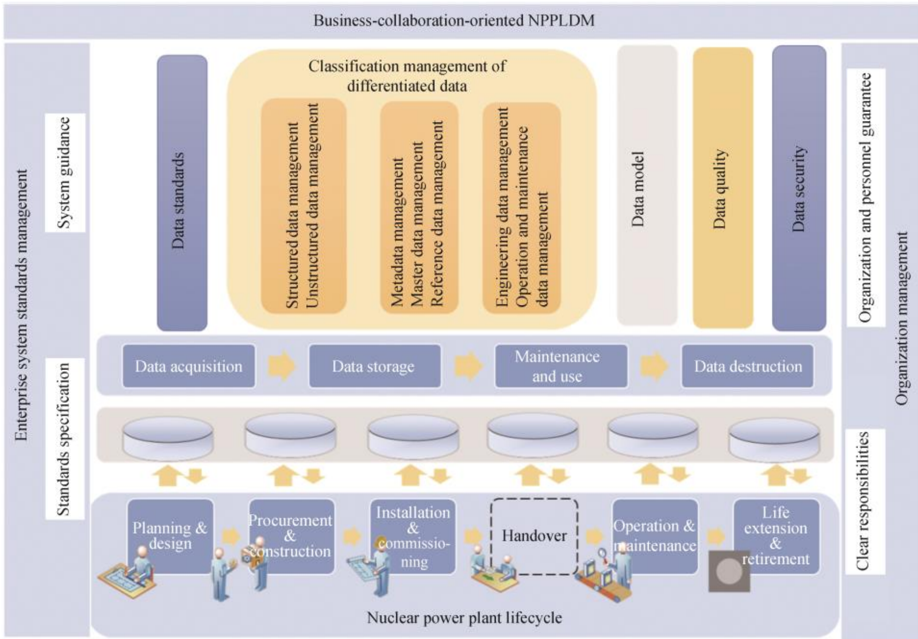

Fig. 1. NPPLDM and collaborative application framework system.

4.3 Business-collaboration-oriented NPPLDM

Based on the development requirements of nuclear power plants, a business-collaboration-oriented NPPLDM is designed to realize the following: breaking the barriers between different business data; realizing data sharing and query; increasing the efficiency of business processes through unified data standards, classification management of differentiated data, and reasonable construction of data models; improving the data quality of nuclear power plants; meeting business requirements and realizing a data-driven business; and optimizing the data security and network security protection mechanisms.

4.3.1 Unified data standards

Unified data standards are the normative constraints set to ensure the consistency and accuracy of data for internal and external utilization and exchange. The construction of a nuclear power plant involves several independent systems. Owing to different functions and standards, the same data will have different forms of expression in different systems, which hinders data sharing and utilization across systems. NPPLDM facilitates business flow in the nuclear power plant lifecycle. The formulation and management of data standards should be based on the business, while the definition and application of business objects in various information systems should be standardized to achieve business collaboration, data sharing, and the flexible use of data and data analysis applications in the nuclear power plant lifecycle to finally realize a data-driven business. A data standards system should also specify the attributes and attribute descriptions of data elements. These attributes include (but are not limited to) Chinese names, English names, identifiers, descriptions, data types, values, and associations. The attribute description covers the attribute notes and relevant standards rules. Data elements that do not conform to the standards system should be standardized through data mapping.

4.3.2 Classification management of differentiated data

NPPLDM can classify data from multiple perspectives according to data characteristics and data governance policies. Diverse data classifications will require different management methods. According to the definition of the data structure, data management includes both structured and unstructured data management. On the basis of different data types, data management can also be divided into metadata management, master data management, and reference data management. In line with the business processes of nuclear power plants, data management covers engineering data management as well as operation and maintenance data management.

(1) Structured data is the data with a standardized format that is recorded in a two-dimensional table. Relevant management technologies are quite mature, such as relational data management systems (MySQL). Unstructured data is data in various formats that cannot be represented by two-dimensional tables in the database. These include e-mail, documents, pictures, videos, and datasets generated by Internet of Things devices. Unstructured data accounts for a large proportion of the total amount of nuclear power data. It can serve as direct references for the operation, life extension, and retirement of nuclear power plant equipment; however, it is difficult to manage. To manage the unstructured data of nuclear power plants, one can establish an unstructured data management platform; innovate the underlying data structure to collect and manage object data, metadata, and index data; apply artificial intelligence technology; provide a new data architecture base; and use data lakes and other structures to realize intelligent data search and content automation.

(2) Throughout the digital transformation of nuclear power plants, metadata acts on the entire value stream, supports the unified management and operation of data services, and supports the effective implementation of business management rules. Nuclear power plant design and process documents are being converted into electronic documents [13]. The metadata management of nuclear power plants should focus on three areas: 1) building metadata standards, specifications, platforms, and management mechanisms, and establishing a metadata management system for the entire lifecycle of nuclear power plants; 2) formulating metadata registration methods and completing the metadata registration of the base according to the business requirements of nuclear power plants; 3) establishing a metadata center to manage the metadata in the nuclear power plant lifecycle, and connecting different types of metadata to carry out metadata association query, retrieval, and blood relationship analysis [14]. Master data is the core data of business activities in the nuclear power plant lifecycle that can be shared among business systems. To manage master data, a nuclear power plant master data management system should be built around the business requirements of the nuclear power plant lifecycle and data lifecycle. This system helps nuclear power enterprises collect data based on unified data standards; analyze, identify, and filter master data; improve the quality of master data; and optimize the operation and management of master data. Reference data refers to predefined static data that plays a key role in automating business processes, improving analysis quality, and improving external collaboration. The reference data management of nuclear power plants includes clarifying the management responsibilities of all parties; formulating relevant processes and specifications; and establishing a reference data management platform. Reference data management has three main parts: building a perfect information architecture to identify and manage reference data; managing the association and mapping relationship of reference data; unifying the reference data standards to integrate and manage the reference data of the nodes throughout the nuclear power plant lifecycle.

(3) Engineering data includes business data generated during the process of nuclear power plant planning and design, procurement and construction, installation, and commissioning. Operation and maintenance data includes data generated in the process of nuclear power plant operation and maintenance, life extension, and decommissioning. For an actual nuclear power plant, according to the decomposition results of the process system, certain business rules, classification principles, and coding systems, a hierarchical structure that reflects the physical elements of the entire plant is created, and a data management model is established with the plant breakdown structure as the organizational level. The nuclear power business can be decomposed according to the business work object. Guided by deliverables, the engineering elements can be grouped and refined according to the work breakdown structure. The total cost of a nuclear power plant project and the cost of each node in the engineering stage of the nuclear power project should be efficiently managed according to the cost breakdown structure. The operation and maintenance of the business activities of nuclear power plants include production planning, operation monitoring, daily inspection, overhaul and refueling, spare parts management, chemical analysis, and radiation protection. The development of digital twin technology for nuclear power plants has made traditional operation and maintenance management less effective. Therefore, this system should deal with the invoking relationship of operation/maintenance data and master/reference data, and the correlation between operation and maintenance data to ensure the smooth transmission of upstream and downstream information.

4.3.3 Data model management

The design and management of data models is of great value to improve the data processing efficiency and data

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value. The construction of data models should be based on different data classifications and describe the relationship between the data and operation method at the corresponding data structure level. Taking metadata as an example, the corresponding data model can provide data management standards and serve as an index reference for quality scoring. It can also standardize the data structure, reduce the occurrence of abnormal data storage or operation, enable the mapping from the business to data warehouse, and provide more accurate data for data science and manual algorithm analysis. The selection of a nuclear power plant data model also requires multiparty evaluation and careful implementation.

4.3.4 Data quality management

Data quality management is an essential tool to improve the value of data [15]. The data quality problems of nuclear power plants are mainly technical in nature. Data quality problems may occur in data sources, such as those caused by the improper configuration of data cleaning rules and data conversion rules; quality problems caused by data loss and repeated records; and data inconsistencies caused by mutually independent business systems. Changes in business requirements have a significant impact on data collection, transmission, storage, and other processes that are prone to data quality problems. Owing to the lack of data planning and effective data quality control mechanisms, data conflict may be caused by nonstandard data inputs by different business departments and life nodes. Therefore, data quality management should be a closed-loop process in each node and enable business flow in the nuclear power plant lifecycle. The data quality management system must be able to analyze, evaluate, and identify the data in a timely manner; clean and process the corresponding data; and optimize the data quality management process. The relevant rules should be perfected to monitor key data in real time and provide a warning on data quality problems.

4.3.5 Data security management

The development of nuclear power plants is conducive to the establishment of a clean, low-carbon, efficient, and safe energy system [16]. It is important to protect the data security of nuclear power plants. A data security system for conventional operations is not suitable for complex nuclear power plants with big data. The data security of nuclear power plants can be divided into data security and network security. (1) For data security supervision, based on the development background of nuclear power digital assets and nuclear power plant digitization, and focusing on the business needs of each node in the entire lifecycle of nuclear power plants, it important to reassess the confidentiality and significance of key data, establish a hierarchical data confidentiality mechanism, and strictly manage the access to confidential data and identity authentication. In the development and mining of nuclear power plant big data, strict data desensitization standards and technical specifications must be formulated, and homomorphic encryption technology must be adopted to carry out the analysis and mining of confidential data [17]. (2) For network security management, almost all systems and equipment in the nuclear power plant rely on the network to transmit information to maintain normal operations and the risk prediction ability. Network security management should include clarifying the emergency specifications after network attacks, planning network security strategies, improving the network security prevention system, and evaluating the quality of network security personnel on the basis of the *Nuclear Power Network Security Technology Policy* and the heightened network security supervision of nuclear power plants. At the physical level, through the widespread application of firewall and encryption technology, the security of data transmissions can be significantly improved. For all systems of the nuclear power business, the safe operation of information systems must be ensured and the system security status must be evaluated regularly. Overall, the data security management of nuclear power plants should be combined with network security, layered protection strategies should be formulated, and security guarantee systems should be improved [18].

5 Suggestions on the development of NPPLDM

5.1 Building a data integration platform for nuclear power plants

China has become one of the top nuclear energy-producing countries in the world. The comprehensive digitization and intellectualization of nuclear power plants is an important strategy that has accelerated its transition into one of the largest nuclear power producers in the world. The nuclear power plant data integration platform is an objective requirement to realize the informatization and intelligence of data-driven businesses in all sectors. It also provides strong support for the centralized management, efficient sharing, deep mining, and intelligent operation of data in the nuclear power plant lifecycle. The nuclear power plant data integration platform is a comprehensive platform that integrates data management, data visualization, data code hosting, intelligent analysis, and decision-making platforms.

In the construction stage, it takes each business system and the entire nuclear power plant lifecycle as data sources; sorts the information resource directory (e.g., items, simulation data, etc.) of relevant departments; and collects the data generated during the design, procurement, construction, installation, operation, maintenance, and decommissioning of nuclear power plants. The second function of this platform is to realize information exchange and sharing across departments; and promote resource sharing, openness, and collaborative business innovation among systems. Furthermore, personalized recommendations and intelligent services can be developed through emerging technologies, such as artificial intelligence, to support multidimensional intelligent monitoring, data analysis, and early warning.

5.2 Promoting the deep integration of blockchain technology and NPPLDM

Accelerating the integration and application of blockchain technology and NPPLDM can solve the bottlenecks encountered by nuclear power plants during the digitization process, such as data integration, cross-departmental business collaboration, open sharing of information resources, and network security. Smart contracts based on consensus networks can be used to record the responsibilities and authority, design drawings, design changes, equipment and materials, and other data of all participants in the construction of nuclear power plants. The tamper-resistance and traceability of blockchains ensures the authenticity, reliability, and integrity of the on-chain data. Setting the calculation complexity of the block ensures the short lag time and high security of data in the uplink process, and improves file transmission. In addition, the equipment procurement data recorded on the chain not only improves the utilization rate of materials and equipment in the construction stage but also decreases the workload of procurement information backtracking in the later operation and maintenance stage, which reduces the difficulty of early document retrieval caused by the long time span of the nuclear power plant lifecycle. Through the data in the blockchain, the nuclear power plant owner can monitor the progress of materials procurement and construction in real time, and carry out backtracking and investigation of suspicious data.

5.3 Accelerating the application of digital twin technology in nuclear power plant big data

In addition to relying on technological progress to avoid risks, nuclear power plants should make full use of operation monitoring and maintenance data to predict risk events and adopt risk mitigation measures. Digital twinning technology was first applied in the simulation analysis of aviation and aerospace equipment [19]. In recent years, international nuclear power equipment enterprises have begun implementing digital twin technology in nuclear power plants. Physical nuclear power plants are digitized using big data analysis technology and digital models, and mapped into digital twins in virtual space [20]. Applying digital twin technology to nuclear power plant big data supports the digital handover of nuclear power plants; overcomes the isolation, dispersion, and other structural difficulties in the traditional handover process; and improves data reusability and utilization efficiency. Predictive maintenance driven by machine learning can effectively reduce the trial-and-error costs of new nuclear power plants and accurately predict failure events during plant operation and maintenance. It is suggested that China's nuclear power industry should speed up the implementation of digital twin technology; realize the in-depth mining and flexible applications of the complex data accumulated in the entire lifecycle of nuclear power plants; maximize the data value; and ensure the safe production and operation of nuclear power plants.

5.4 Strengthening the integration of model-based systems engineering (MBSE) and nuclear power plant design

In the design stage of nuclear power plants, the MBSE method is applied to transform nuclear power plants from document-centered to model-centered, and to improve their lifecycle data management ability [21]. Strengthening the integration and application of MBSE and nuclear power plant design has many advantages. MBSE adopts standardized digital modeling instead of document recording, and the data file is more structured to reduce the need for unstructured data management and improve the efficiency of data sharing and analysis. The "model island" of the system model caused by discipline differences can be eliminated by a unified modeling language. System modeling throughout the lifecycle supports the traceability, verifiability, and dynamic correlation of multidomain models in the entire lifecycle; improves the efficiency of design analysis; and enhances the reusability of data.

5.5 Establishing and improving the green management policy system of nuclear power plant data

The green management policies for nuclear power plant data must be improved to realize green and highly effective NPPLDM. The digital development of nuclear power plants is dependent on the strength and reliable operation of data

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centers, while the storage and maintenance of massive amounts of data will consume a large amount of energy. In the context of carbon peaking and carbon neutralization, building a green data center is a natural choice for nuclear power plants to reduce energy consumption, reduce costs, and improve efficiency. The green data management of nuclear power plants is a key component in realizing a green data center. Green data management systems for the lifecycle data of nuclear power plants should be established and improved; preferential subsidies and policy support can be provided to enterprises to realize the green management of nuclear power plant data; and policy guidance and pilot demonstrations should be strengthened to explore a practical model of green data management in nuclear power plants.

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