Research on Key Technology Development and Application of Grid Asset Management

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Abstract. With the improvement of grid reliability requirements in social development, grid asset management must develop in the direction of digitization and informatization. Based on the latest research results of asset management and risk assessment, the article first discusses the current development status of grid asset management technology, then introduces the theoretical methods of three key technologies and their application status in asset management, i.e. state assessment, reliability and risk assessment, and Life Cycle Cost (LCC) analysis. Secondly, this paper summarizes the application of information technology in power grid asset management, and analyzes the supporting role of digital technology in asset management and its key technologies. On this basis, it puts forward suggestions for China's power grid asset management, in order to provide a useful reference for the improvement of China's power grid asset management from the technical level.

1. Introduction
With the strengthening of power regulation in the world, power companies are forced to optimize investment and reduce costs. At the same time, the development of social economy has improved the reliability requirements. As the power market and business model change, it is vital to improve asset management. As an advanced management method, asset life cycle management has developed rapidly. The goal of lifecycle management is to pursue economic optimization while meeting certain constraints (such as reliability constraints, environment, user needs, etc.). In order to achieve the goal, on the one hand, the power grid improves the asset management system and management processes. On the other hand, it uses a variety of key technologies.

On the management level, some power grids formulate corresponding asset management guidelines and procedures based on the current status of their own grid assets, and build a rational asset life cycle management system to improve management efficiency. In terms of management system, countries such as the United States and Singapore have set up power control institutions independent of power grid enterprises, and adopt a cost-plus-management mode to supervise the operating expenses, reasonable expenditures and reliability of grid assets[1]; National Grid plc(NGG) adopts a flat
organizational structure, and the division of responsibilities between the decision-making and executive levels is clear, which improves the efficiency and accuracy of asset management[2].

On the technical level, some power grids use key technologies such as LCC analysis, state assessment, risk assessment and life assessment to optimize the decision-making of all processes to achieve the goal of asset management. In the planning and design phase, NGG uses LCC analysis and risk assessment to determine the investment plans for each link from a global perspective, and to determine the priority of investment through a quantitative risk level [2]. In the operation and maintenance phase, NGG implements risk management and condition maintenance, comprehensively analyses the current and future health status of the equipment to make maintenance decisions.

Based on the latest research results of asset management and risk assessment at the International Power Supply Conference, this paper summarizes the key technologies of domestic and international grid asset management, and analyses the supporting role of digital technology in asset management process and its key technologies, hoping to provide reference for China's power grid to deepen the application of energy management technology methods.

2. Key technologies in power grid asset management
The asset life cycle management puts forward new requirements for equipment management, which promotes the transformation of equipment management from empirical qualitative analysis to quantitative management. The key technologies widely used include state assessment, reliability and risk assessment and LCC analysis theory. Figure 1 is a schematic diagram of the application of key technologies based on digital technology in grid asset management. A variety of key technologies are integrated in all aspects of asset life cycle management to provide technical support for effective decision-making in asset management.

2.1. State assessment technology
State assessment of asset equipment includes state detection, diagnosis and evaluation. Accurate and timely detection of equipment status is the basis of asset management. Only under the premise of mastering the status of equipment, can the equipment maintenance work be carried out in a targeted manner, and the operation and maintenance cost of assets can be optimized from the perspective of the whole life cycle.

2.1.1. Theoretical approach to state assessment.
State detection technology is mainly divided into off-line test technology, live detection technology and online monitoring technology [3]. Live detection technology and online monitoring technology represent the direction of equipment detection technology, through basic sensing technology such as smart sensing, mode Identification, real-time acquisition of grid equipment status, intelligent monitoring and fault warning, improve the availability of power equipment, ensure reliable operation of the power grid is realized.

After detecting the status information of the asset equipment, the diagnostic analysis and extraction of the state characteristics of the device is the key to achieving state evaluation. Traditional diagnosis relies mainly on conventional electrical equipment insulation diagnostic methods and expert experience. However traditional diagnostic methods have obvious subjectivity, with the improvement of computer technology and artificial intelligence technology. Intelligent diagnostic techniques based on fuzzy logic, support vector machines and extreme learning machines have been widely recognized and developed in the power industry.

At present, the equipment state evaluation methods that are widely used include equipment status scoring system, expert system method, and multi-dimensional equipment status evaluation method based on traditional machine learning [4]. Among them, the traditional state evaluation method based on expert system is the most mature, and the key is to determine the weight of different feature quantities of equipment operation, as shown in Figure 2, establishing models that can calculate device defects and probability of failure based on different state detections of the device.

\[ N = F(M) \]

\( M \) the device status parameter

\( N \) defect/fault probability

Figure 2. Traditional state evaluation method diagram.

2.1.2. Application of state assessment in asset management.
1) Maintenance and repair of asset equipment
Equipment maintenance and fault are a pair of contradictions, and equipment state maintenance still has the difficulty of coordination between maintenance and operation. For this reason, some scholars have proposed the concept of grid state maintenance, that is, from the perspective of grid operation, considering the individual performance of the equipment, the correlation between the equipment and the operation mode of the power grid, the maintenance strategy is formulated according to the loss and minimum corresponding to the risk of the power grid maintenance and the fault risk under the operating conditions. Among them, the grid fault risk refers to the risk of equipment individual and grid loss caused by equipment failure; the grid maintenance risk refers to the equipment maintenance
cost and fault risk during equipment maintenance. At the practical application level, China Light and Power Corporation (CLP) has good practical experience in power grid condition maintenance [5], relying on the information management system to monitor the health of key transmission and distribution equipment through real-time condition monitoring. The failure risk value is evaluated and the maintenance plan is continuously updated to achieve coordination and efficiency of power grid maintenance and operation.

2) Asset life assessment and decommissioning
State assessments predict the remaining life of the equipment and then make decisions of decommissioning or maintenance. In Ref.[3], based on the load condition and operating environment of the cable, the electric aging model of the cable asset was established. Based on the state and importance of the cable, based on the state detection information and the aging model, statistical methods are used to formulate the operation and decommissioning strategies of different cables. Ref.[6] applies intelligent asset management, based on historical and real-time data analysis of equipment status, improves equipment performance and predictability of health status, and extends residual life of medium voltage circuit breakers through preventive maintenance and other risk aversion measures.

2.2. Reliability and Risk Assessment in Grid Asset Management
Stateful inspection, failure, maintenance, and system operational data for equipment can be used to perform reliability and risk assessments to support asset management strategy development. Reliability and risk assessment in asset management involves both equipment and systems. At the equipment level, reliability assessment is to assess the possibility of equipment failure through historical fault statistics and real-time status data; risk assessment is to quantify the impact of failure on the system, society, economy and other aspects on the basis of the possibility of equipment failure to form the risk of equipment failure. The risk assessment at the system level refers to the comprehensive reflection of the probability of outage accidents caused by component failures and the losses caused by accidents. Equipment reliability and risk assessment are mostly used for condition maintenance and decommissioning of equipment, while system risk assessment is often used for planning and designing the grid assets.

2.3. Application of LCC Theory in Power Grid Asset Management
LCC refers to the total cost incurred from the planning, design, acquisition, installation, operation, maintenance, update, and scrapping of the equipment or system based on its long-term economic benefits. The grid assets LCC can be divided into equipment-level LCC and system-level LCC. The former pays attention to the life cycle cost of the single equipment, while the latter pays more attention to the impact of the asset collection on the system. The relationship between system level LCC and equipment-level LCC is shown in Figure 3.

![Data Management System](Image)

**Figure 3.** Relationship between system-level LCC and equipment-level LCC.

Based on this, the Ref.[7]a three-dimensional LCC model for the whole power system from the perspective of components, cost and time, and studied the cost decomposition structure of equipment-level, system-level and external environmental costs in the cost dimension, and further improved the LCC calculation model.

LCC theory is the basis for asset life cycle management. At present, LCC theory is widely used in power grid asset management for power grid planning and optimization, power equipment investment transformation strategy, maintenance and repair strategy. Ref. [8] proves that long-term investment in
the transformation of distribution transformers should be selected according to the LCC minimum principle. The time and method of maintenance will affect the reliability of equipment operation, thus affecting the cost of power outage loss and equipment replacement cost. Therefore, the maintenance plan should also consider the cost of LCC, taking into account the economics and reliability of maintenance equipment.

3. Application of Digital Technology in Grid Asset Management

The formulation of asset management strategies requires the integration of multiple key technologies, and the application of key technologies is inseparable from the support of digital technologies. The digital technologies commonly used in power systems are communication technology, information technology (including computer technology, Internet technology and Internet of Things technology) and big data technology. These digital technologies have played an important role in the data transmission, storage, analysis and decision-making process of asset management.

3.1. Communication Technology
With the development of smart grids, the requirements for reliability, flexibility, security and real-time performance of communication technologies are continuously improved to ensure efficient and orderly management of grid asset management. At present, communication technologies commonly used in power grids include Power Line Communication (PLC), optical fiber communication, and wireless communication. Various communication methods coexist and complement each other. The application and innovation of communication technology greatly improve the state awareness, operation and maintenance quality and efficiency of the equipment, and the economics of management. In the current grid enterprise asset management, communication technology is mainly applied in two aspects: equipment status detection and status maintenance. Among them, the state detection is the monitoring of the equipment assets, and the state maintenance is based on the state detection, focusing on the scheduling of the maintenance personnel. Figure 4 is a schematic diagram of application of communication technology in equipment state detection and state maintenance, and the wireless communication technology exhibits flexibility in personnel scheduling.

The power equipment condition monitoring data is collected and transmitted by means of communication technology, and the operation and maintenance and replacement decision of asset management is assisted. Ref.[9] points out that the remote asset monitoring and control system obtains the device status data detected by the sensing device through the wireless sensor network, evaluates the device status according to the detection data, predicts possible faults, and helps the operation and maintenance personnel optimize the equipment maintenance and replacement plan.

In the future, 5G technology will be used in power systems, which will enable the rapid transmission of massive monitoring data, realize panoramic holographic sensing, information interconnection and intelligent control of power systems, improve the efficiency and accuracy of online monitoring. With the use of the Internet of Things and 5G, it can realize remote state evaluation while detecting equipment, and feedback equipment status evaluation information to on-site maintenance personnel, greatly improving maintenance efficiency. In addition, drone inspection has the advantage of not being affected by geographical factors. The 5G application allows the drone to capture and transmit more pictures and videos with higher definition. This can improve the reliability of inspection, reduce the labour cost of power grid operation and maintenance, and provide a new type of inspection mode for power transmission and transformation equipment.
3.2. Information Technology

The development of computer and Internet technologies has made the storage and processing of increasingly complex and large grid asset data a reality, providing an information software platform for analysis of state assessment and risk assessment. Enterprises in many countries have their own software information platform for asset management. For example, CLP records the geographic information of different types of equipment through the Automated Mapping/Facilities Management system and establishes a Performance Management Data Repository (PMDR) integrates data from different systems to obtain an effective asset performance assessment analysis [5]; The IBM Watson platform [10] in the United States integrates information analysis, natural language processing and machine learning technologies to provide enterprise asset management and preventive maintenance solutions through data mining. On the basis of the Production Management System (PMS), State Grid Corporation of China has developed the Asset Operation and Maintenance Lean Management System (PMS 2.0), which is based on the asset life cycle management, with state maintenance as the core and deeply integrate the dispatching system, Enterprise Resource Planning(ERP), relying on the grid Geographic Information System (GIS), constructing the integrated graph of the number of graphs, building an enterprise-level grid resource center, and realizing equipment (asset) inspection cost collection and optimal allocation of resources.

With various software platforms, data sharing and collaborative management for each business and full cycle can be realized. Ref.[11] introduces the concept and basic framework of Smart Asset Management (SAM), which is to achieve efficient data management through IT technology, such as the visualization software platform of asset health data, and the processing of "bad data", so as to provide support for intelligent decision-making of power grid asset management. Ref.[12] describes the system management framework of grid assets based on IEC-61850, including system configuration, monitoring and maintenance, software management and asset management, to achieve unified management of information and data generated by a large number of intelligent automation equipment.
Through the Internet and the communication system to achieve data sharing interaction between various departments, data analysis can identify the key asset equipment that affects the health status, reliability and risk of the grid as a whole, so as to develop an optimal asset investment and maintenance strategy.

Internet of Things technology is the extension and expansion of the Internet, and is an effective means to realize the intelligent and automated monitoring and management of power grid equipment. Through information sensing devices, the Internet of Things connects any assets with the Internet to form a real-time state detection system interconnection, and realizes the panoramic information perception, intelligent monitoring and management, status assessment, etc. of power transmission and transformation equipment, and supports the asset life cycle management functions such as depreciation, statistics, query, tracking, inventory, etc., and realizes unified management, analysis and data sharing, greatly improving the efficiency and accuracy of asset management. The application of electronic tags and smart meters can monitor the charging information of electric vehicles, the power consumption of smart homes and the output of distributed power sources, etc., to improve the economics of grid asset planning and management.

3.3. Big Data Technology

Big data technology covers the whole life cycle management process of data from information generation, collection, storage, transformation, integration, mining, analysis, calculation, display, application and maintenance [13], which is mainly used for the collection, storage, analysis, mining and data display of massive data. Cloud computing provides a platform for storage and analysis of heterogeneous and diverse data generated during the operation and management of smart grids. Ref.[14] introduces the advantages and disadvantages of current mainstream big data processing technology, and discusses the opportunities and challenges faced by big data technology in smart grid from four aspects: big data visualization, big data storage, real-time data processing, heterogeneity data source fusion. Among them, big data visualization analysis technology draws data into high-precision, high-resolution images through a series of complex algorithms, and provides interactive tools to effectively use human visual systems to observe and qualitatively and quantitatively analyze data [14]. It can provide an intuitive basis for grid planning and asset management decisions.

With the rapid growth of power grid scale and the increasingly complex power grid structure, the data of asset state monitoring and grid operation has grown exponentially. In addition to the large-scale, multi-source, heterogeneous and complex features [13], it has the characteristics of dispersion and sparsity, which creates space for the application of big data technology. The priority of the maintenance is determined from the perspective of the network operating state and the importance of the device, thereby achieving the grid state maintenance mode that takes into account the system's comprehensive risk is improved to improve the efficiency and economy of the power grid maintenance. Traditional reliability and risk assessment are based on historical equipment failure data, and it is impossible to analyse the factors affecting reliability and risk. Big data can mine these key influencing factors to realize the prediction and evaluation of grid operation reliability and risk in the future.

4. Conclusion

The arrival of the era of big data and the advancement of information and communication technology can provide a reliable data basis for the planning investment of power grid assets and the scientific decision-making of operation and maintenance, and further improve the asset management level. This paper reviews the current state of development of key technologies in grid asset management, including state assessment, reliability and risk assessment, as well as LCC theory. Secondly, it introduces the application status of digital technology represented by information communication technology and big data technology, analyses the supporting role of digital technology in asset management process and its key technologies, and expounds the development trends and challenges of the application of digital technology in grid asset management in the future. On this basis, we propose targeted recommendations for China's power grid asset management, hoping that the work of this paper can provide a useful reference for the in-depth development of China's power grid asset management.
5. References

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