



Research on Equipment Management and Control System Under the Integrated Mode of Operation and Maintenance in Pumped Storage Enterprises in China

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Abstract. With the continuous development and growth of power enterprises, equipment management is also increasingly valued, especially in the hydropower industry, which mainly focuses on clean energy. Equipment management is even more important. Based on the current international concept and best practices of full process equipment management, this study provides a comprehensive overview of the successful experience of integrated equipment management, operation and maintenance, as well as routine maintenance and inspection in China, and delves into the practical and characteristic aspects of integrated equipment operation and maintenance management in the hydropower industry. Combining with the current situation of equipment control under the integrated operation and maintenance mode of pumped storage enterprises in China, and utilizing the advanced concept of equipment lifecycle management, a complete system is established for equipment control under the integrated operation and maintenance mode of pumped storage enterprises.

Keywords: equipment management · operation and maintenance · operation and maintenance · pumped storage enterprise

1 Introduction

The original intention of implementing the integration of operation and maintenance is to continuously improve the degree of automation of equipment, gradually weaken the role of operating personnel within the existing business scope, and ensure the stable operation of equipment by ensuring the quality of equipment maintenance. Therefore, pumped storage enterprises must transform the core of power plant production management from equipment operation to equipment management, and transform operation and

maintenance personnel from single business to complex talents. Through the training of personnel, create an excellent management team, and through standardized management of equipment, achieve the reliability of enterprise production, while achieving cost reduction and efficiency increase.

After years of integrated operation and maintenance, some pumped storage enterprises have currently established a relatively complete integrated production management system for operation and maintenance. However, compared to the equipment management and control system and the spot inspection and regular repair system, there are certain gaps in the management links such as regular equipment work, technical supervision, professional analysis, and optimization of maintenance strategies. This thesis aims to improve the reliability and management efficiency of operation and maintenance by studying the equipment management and control system under the integrated mode of operation and maintenance, and achieve the goals of improving the professional ability and technical level of personnel operation and maintenance management and optimizing equipment safety management under the integrated mode of operation and maintenance [1].

This paper studies the advanced concepts and best practices of international and domestic integrated equipment management and operation and maintenance management models throughout the process, and explores and constructs an integrated equipment operation and maintenance management model suitable for the characteristics of pumped storage enterprises in combination with the operational characteristics and equipment management practices of the hydropower industry. From the perspective of management structure, a top-down system design approach is adopted to ensure the scientificity and applicability of the overall framework of the system from the overall to the local level, while ensuring the flexibility of integrated management of operation and maintenance of local units. This study systematically designs all links of integrated operation and maintenance management from the entire process of managing objects (equipment) to ensure the comprehensiveness and effectiveness of control.

In addition, the applicability and effectiveness of the equipment management and control system under the integrated operation and maintenance mode are verified by selecting representative pilot units to test run. On the basis of pilot verification, it is necessary to continuously correct and optimize the equipment management and control system under the integrated operation and maintenance mode to ensure the scientific and practical nature of research results.

2 Research and Analysis on the Current Situation of Equipment Management

From the perspective of the development history of equipment management theory, equipment management has evolved from simple post maintenance management to preventive maintenance of equipment, to comprehensive equipment management, and then to condition based maintenance of equipment, TPM (Total Production Maintenance), and finally to the current equipment comprehensive management and equipment management system standards.

After systematic research on the concept and historical development of domestic equipment management, it is found that the development of equipment management theory in China has gone through the following stages, and the development process of equipment management is as follows:

2.1 Post Maintenance

Repair the equipment when it fails or has poor performance. It is suitable for situations where the structure of the equipment is simple, the maintenance and repair of the equipment do not require specialized technology, and the maintenance cost of the equipment is low, without considering or less considering cost effectiveness [2].

2.2 Preventive Maintenance

All activities are carried out to prevent functional failures and maintain equipment in a specified state through systematic inspection, testing, and replacement of equipment. It can include adjustment, lubrication, regular inspection, etc. It is mainly used for products whose failure consequences may endanger safety, affect task completion, or cause significant economic losses.

The purpose of preventive maintenance is to reduce the probability of product failure or prevent functional degradation. It carries out maintenance at predetermined intervals or according to specified criteria, usually including maintenance, operator monitoring, use inspection, functional testing, scheduled disassembly and scrapping, and other types of maintenance work. The effect is particularly evident in process industrial systems such as petroleum, chemical, and steel.

2.3 Routine Inspection and Repair Level

Routine inspection and scheduled repair is an equipment management system that “determines maintenance items” by performing a “routine inspection” on the equipment status. It is a set of scientific equipment management methods. It conducts fixed point and regular inspections of equipment through point inspectors, discovers abnormalities and hidden dangers of equipment against standards, grasps initial information about equipment failures, and takes timely measures to eliminate failures in their infancy. Currently, many enterprises in China still adopt this mode, and the following will focus on the study [3].

2.4 TPM (Total Productive Maintenance)

TPM is an equipment maintenance and repair management system that aims to improve the overall efficiency of equipment, takes preventive maintenance of the entire system as a process, and is based on the participation of all personnel. It was formally proposed in 1970 by the former Japanese Equipment Management Association (Nakajima et al., 1970) after the production and maintenance system in the United States was piloted by Nippon senso (engine, generator, and other electrical appliances) electrical companies in Japan [4].

2.5 Whole Process Management (Equipment Life Cycle Management)

The whole process management of equipment is a new equipment management method proposed by integrating equipment engineering and process management theory. The basic idea is to expand the scope of equipment management to include the entire process of equipment research, design, manufacturing, procurement, installation, commissioning, use, maintenance, and transformation, until scrapping. Every link in this process is essential, and each link issue will cause a chain reaction in the entire process. Its basic purpose is to ensure and improve the reliability, maintainability, and economy of equipment as a whole through the entire process management [5].

2.6 TnPM (Total Normalized Productive Maintenance)

The TnPM system was proposed by professor Baowen Li of Guangzhou University in 1998, and based on the essence of Japanese TPM, combined with the actual situation of Chinese enterprises, it has formed a complete set of equipment management standard systems with logic and operational guidance.

TnPM is a “comprehensive standardized production and maintenance” management system. A production and equipment maintenance, care, and repair system based on comprehensive efficiency and fully effective productivity of equipment, a system wide preventive maintenance system as the carrier, employee behavior standards as the process, and full staff participation.

3 The Concept of Equipment Whole Process Management and Implementation in China

The whole process management of equipment is generally considered as the management of the whole life cycle in the world, so it is also known as LCM (Life Circle Management).

Life cycle management has three meanings. The first is life cycle management in three-dimensional space. The second is to highlight the equipment life cycle failure rate curve (bathtub curve), with different management characteristics at different stages. The third is life-cycle cost management. The entire process management of equipment is a comprehensive process that focuses on the planning, selection, design, manufacturing, procurement, installation, operation, maintenance, transformation, update, and scrapping of equipment from the perspective of maximizing its long-term economic benefits. It focuses on integrating and seeking the optimal cost, performance, and risk of the entire process of equipment.

3.1 The Concept of Overall Process Management of Equipment

The purpose of the entire process management of equipment is to better serve the organization's business strategic objectives, adhere to the principle of efficiency as the center, rely on technological progress, improve the scientific management of equipment man-machine systems and the entire process management level of equipment, ensure safe production, improve product quality, implement management norms, and promote lean management and improve quality control costs and efficiency.

- 1) Through standardized management of the entire process of equipment, reduce equipment management errors and achieve lean management.
- 2) Through the provision and utilization of market-oriented equipment resources, and through the comprehensive collaboration of the organization's production, equipment, technology, research and development, and process information, we pursue the best use cost, performance, and risk control of equipment.
- 3) Through lean equipment planning, design, and manufacturing, continuous optimization and standardization of equipment procurement, use, maintenance, transformation, remanufacturing (including remanufacturing of in-service equipment), scrapping, and information feedback processes to equipment manufacturers, equipment reliability and maintainability are continuously improved.
- 4) Incorporate AM (Autonomous Maintenance), PM (Preventive Maintenance), and MP (Maintenance Prevention) work into integrated management to achieve source problem resolution and proactive maintenance of equipment failures.
- 5) Through the design of equipment inspection and maintenance system solutions, the maintenance strategy of equipment is made scientific, achieving the goal of improving maintenance efficiency and quality, and reducing maintenance risks and costs.
- 6) Through the establishment of a multi-dimensional training system for employees, improve their quality and ability, and achieve synchronous growth between employees and the enterprise.

3.2 Implementation of the Whole Process Management of Equipment in China

From the perspective of the development history of equipment management theory, equipment management has evolved from simple maintenance management to preventive maintenance of equipment, to comprehensive equipment management, and then to conditional maintenance of equipment, and finally to the current equipment management system. The concept of equipment whole process management in China is developed from the concept of equipment life cycle management.

The concept of whole-process management of equipment in China is mainly applied in some large equipment asset intensive enterprises, such as the State Grid, the petrochemical industry, and the tobacco industry. Among them, the operation and practice in the State Grid of China has been relatively long. Liu Zhenya's book "Enterprise Asset Lifecycle Management" is based on the development of equipment management theory as the main line, combing the development process of asset management from simple equipment maintenance management to the formation of asset lifecycle management concepts. This book summarizes the experience of the State Grid Corporation of China in the entire process management of equipment as assets, and the asset lifecycle management theory with Chinese characteristics is refined and formed.

3.3 Development Trend of Equipment Management in China

TnPM (Total Normalized Productive Maintenance), which was born in 1998, is an equipment management system suitable for China's national conditions, based on the concept of full personnel independent maintenance and summarized through nearly 20 years of

practice. The “China Equipment Management Standard - Equipment Management System” developed on the basis of TnPM has been recognized by the National Standards Committee and released by the China Equipment Management Association.

The equipment management system covers the entire life cycle of equipment, starting from maximizing long-term economic benefits of equipment, and comprehensively paying attention to the entire process of equipment planning, model selection, design, manufacturing, procurement, installation, operation, maintenance, transformation, update, and scrapping. It will promote more standardized, sound, systematic, and intelligent equipment lifecycle management, which is a supplement to, rather than a replacement for, the existing equipment management mechanisms and technical specifications of the organization.

Its core content is to analyze and calculate the life cycle cost (LCC) of equipment or systems, and evaluate equipment based on quantitative values. In equipment procurement, organizations should not only consider the purchase price of equipment, but also consider the support cost of equipment throughout its entire life cycle, including the entire process of equipment installation, operation, maintenance, transformation, update, and scrapping, in order to maximize the value of equipment throughout its life cycle.

4 Design Principles of Equipment Control System Framework

4.1 Composition of Equipment Control System

The management system is divided into three levels. The decision-making level, the management level, and the execution level. The responsibilities of each level are very clear. The decision-making level is responsible for formulating the development strategy and resource strategy of the head office, which highlights the company’s long-term development direction and strategy. The management level is responsible for managing the entire life cycle of the equipment. Each production unit at the executive level is responsible for the operation and maintenance of production, as well as the calculation and entry of production data into the information platform.

4.2 Building a Data Platform

It is necessary to build an advanced information platform to achieve real-time monitoring of equipment, and timely feed back the experience and status of equipment operation to the design center, providing support for subsequent equipment procurement and technical transformation. With the development of the company, the application of this data platform is very important for the company to control the situation of various production units.

4.3 Clarifying the Policies and Objectives

The firm shall clarify the policies and objectives of equipment management, and monitor the implementation of the objectives and objectives of each production unit through the performance evaluation of transportation inspection.

4.4 Establishing a Whole-Process Management Mechanism for Equipment

It is essential to introduce the concept of the entire life cycle of assets, establish a whole-process management mechanism for equipment, and achieve the whole-process management of planning and design, procurement and construction, operation and maintenance, and retirement disposal. The firm should implement the principle of unified management and segmented responsibility. Then the firm should focus on controlling two checkpoints, namely, the acceptance of new equipment and the scrapping of in-service equipment. The management technology center and project implementation department are responsible for the early stage, and the production units are responsible for the operation and maintenance. In the later stage, the operation and maintenance department will provide treatment opinions based on the status of the equipment, and report them to the company for treatment. The parameters and information of the entire process of the equipment are communicated through the information platform.

4.5 Lean Management of Equipment

The production unit implements lean management of the production process by implementing integration of operation and maintenance, standardization of operations, and specialization of condition monitoring. The equipment ownership system could help realize the integration of equipment operation and maintenance by the operation and maintenance personnel. The closed-loop preventive maintenance of equipment would be achieved through professional maintenance (or routine inspection and repair). The closed-loop maintenance and prevention can be achieved through professionalization of condition monitoring.

4.6 Human Resource Management

The firm need to establish excellent operation and maintenance teams through personnel training and growth to achieve lean management. The lean management of spare parts, could reduce the consumption of spare parts, and achieve optimal cost of integration of operation and maintenance.

4.7 Production Safety Management

It is necessary to ensure the safe operation of production through risk control and technical supervision of the entire process of equipment.

4.8 Continuously Improving the System

Through the improvement of the system and system, it is necessary to form a system suitable for the firm, form work and technical standards, achieve standardized operation and records, and ensure that each detail of the entire process of equipment is controlled.

5 Innovation of Equipment Management and Control System Under the Integrated Mode of Operation and Maintenance

5.1 Platformization of Equipment Management and Control System

This equipment management and control system reflects the management philosophy of the decision-making level and adds the company's equipment management policies and objectives. According to the operational characteristics of pumped storage enterprises, the firm has realized the idea of unified management, hierarchical management, and segmented responsibility, increased the decision-making level's control ability over production units, and clarified the context of the management system. Then it achieves refinement of management through segmentation of key indicators.

5.2 The Entire Process Management of Equipment and Interface Management

This system utilizes an information based platform and implements the concept of equipment entire process management, including equipment feasibility study and design, procurement and manufacturing, installation and commissioning, acceptance and handover, operation and maintenance, and retirement and scrapping. Operation and maintenance data can be analyzed and utilized in a timely manner. Under the integrated mode of operation and maintenance, two key passes (acceptance and evaluation) are focused, laying the foundation for safe, efficient, and comprehensive cost optimal operation of equipment.

5.3 Equipment Ownership is the Key to Operation and Maintenance Integration

After the integration of operation and maintenance, it is important to highlight the cultivation of versatile talents, optimize team management, and more importantly, simultaneously carry out talent cultivation and team building (team management) to allow employees to grow from actual operations. Operation and maintenance integration should be the integration of team operation and maintenance, not everyone's operation and maintenance. It's necessary to strengthen comprehensive management and assessment of the team, and achieve integrated management of operation and maintenance teams and equipment management. During the shift period of equipment owners, the control of equipment owners has been weakened, and it is necessary to strengthen the responsibility of equipment owners, clarify the equipment owners, and implement the same standards for both corners A and B, and be able to simultaneously master the status information of equipment.

6 Conclusions

Combining the current international concept and best practices of full process equipment management, this study provides a comprehensive overview of the successful experience of integrated equipment management, operation and maintenance, as well as routine maintenance and inspection in China, and delves into the practical and characteristic aspects of integrated equipment operation and maintenance management in

the hydropower industry. Based on the current situation of equipment control under the integrated operation and maintenance mode of pumped storage enterprises in China, and utilizing the advanced concept of equipment lifecycle management, this research designed a complete system for equipment control under the integrated operation and maintenance mode of pumped storage enterprises and summarized the innovation points of this equipment management system.

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