Research on the Application of Artificial Intelligence in Operation and Maintenance for Power Equipment

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Abstract. With the continuous deepening of the construction of the State Grid, more and more power grid equipment such as substations need to be repaired and maintained in a timely manner, which makes the workload and difficulty of the power grid equipment operation and maintenance personnel more and more difficult. Electricity is a necessity for our daily life and enterprise production. In order to ensure the rapid and stable economic development, reliable power supply must be provided, and the normal operation of power equipment is the key to safe and stable power supply. Due to the rapid development of cities, various problems have begun to appear in some power grid plans, coupled with the upgrading of power grid equipment and the implementation of new power grid plans, making the operation and maintenance of power grid equipment more and more difficult, and more and more challenges high. Therefore, this article first analyzes the process of intelligent state maintenance of power grids, analyzes the key technologies of artificial intelligence in the operation and maintenance of power equipment, and analyzes the application of artificial intelligence technology in the operation and maintenance of power equipment.

1. Introduction

The State Grid selected 5 typical environmental areas nationwide to build 5 composite insulation material aging stations, and finally selected Tibet Yangbajing (high altitude and strong ultraviolet), Inner Mongolia Genhe (extreme cold), Xinjiang Turpan (high temperature), Henan There are five construction sites in Zhengzhou (Central Plains climate) and Fujian Meizhou Island (Marine Salt Fog), which together form a composite material aging test research platform covering various typical climate and environmental characteristics. State Grid Mengdong Electric Power Research Institute is responsible for the construction, operation and maintenance of the Genhe Aging Test Station.

Comply with the requirements of the relevant technical specifications for the construction of smart laboratories and substations, and respond to the requirements for the construction of the smart IoT system, deploy and implement it in the Genhe Extreme Cold Aging Test Station of the State Grid Inner Mongolia, and deploy a remote monitoring platform in Hohhot based on the existing monitoring methods. On-site and remote intelligent interaction, carry out on-site implementation of various sensors in internal and external environments, development and debugging of various sensor APPs, deployment and configuration of micro-meteorological collection systems, cable collection systems, etc., to achieve remote monitoring of the status of test products Implement mastery. In order to accurately analyze the aging process and trend of the test product, carry out the on-site implementation of various sensors of
the main equipment monitoring system, and the development and debugging of various sensor APPs to realize remote intelligent control and monitoring of the test station, so that the operation and maintenance personnel can always grasp the test Accurate handling of emergencies in the situation of the station. In this context, to promote the innovative application of artificial intelligence technology in the business of transmission and transformation equipment status assessment, fault diagnosis, health management, etc., is to enhance the intelligent and intensive level of power grid operation and maintenance, and promote the comprehensive operation and maintenance of equipment status. An important technical means to advance in a precise and efficient direction.

2. The basic process of smart grid maintenance
At present, in the domestic intelligent substation maintenance mode, the substation maintenance team is basically responsible for completing the substation maintenance and elimination. Due to the requirements of intelligent substations for maintenance work and the differences between intelligent substation and conventional substation maintenance modes, intelligent substation maintenance management is mainly realized through six major processes, as follows:

- Information collection of substation equipment. Information collection of substation equipment is the primary link of equipment condition maintenance and the basis of equipment condition evaluation and risk assessment.
- State evaluation of substation equipment. The state evaluation and risk assessment of substation equipment are the maintenance management links of intelligent substation. Accurate evaluation of the status of power equipment is directly related to the risk assessment and maintenance of substation equipment. It is the key point for the state maintenance of intelligent substations. Scientific methods must be used to accurately evaluate the status of substation equipment and provide a scientific basis for the formulation of maintenance strategies.
- Risk assessment of substation equipment. According to the risk assessment classification of substation equipment, develop maintenance strategies.
- Formulate maintenance strategies and plans for substation equipment. Maintenance strategies include power failure maintenance, non-power failure maintenance, partial parts maintenance and replacement, and overall equipment replacement.
- Implement the maintenance plan for substation equipment. The implementation of the maintenance plan for substation equipment is the most critical link in the state maintenance. The overhaul of substation equipment should be implemented on time in accordance with the overhaul plan discussed and decided by the relevant departments of the company. The implementation of the maintenance plan includes the preparation phase, the implementation phase and the summary phase.
- Evaluate the effectiveness of substation equipment maintenance. The evaluation of the effectiveness of the overhaul of substation equipment is a test of the implementation effect of the overhaul plan. After the implementation of the overhaul plan is completed, the operating personnel should check the condition and status of the equipment together with the person in charge of overhaul work, whether there are any leftovers, whether the site is clean, etc., and then end the work ticket. The operating personnel evaluate the results of the overhaul, determine whether the equipment is waiting for normal operation after the overhaul, and report to the control center.

Figure 1 shows the basic process of substation equipment maintenance management, these six processes form a closed-loop management system.
3. Key technologies of artificial intelligence in power equipment operation, maintenance and repair

Artificial intelligence is a frontier technology science that studies and develops theories, methods, technologies and application systems for simulating, extending, and expanding human intelligence. Its goal is to use machines to realize part of human intelligence and replace humans to realize recognition, cognition, and Various functions such as classification and decision making. Artificial intelligence technologies for data analysis mainly include expert systems, uncertainty reasoning, machine learning, intelligent optimized calculations, natural language processing, and computer vision. In this paper, aiming at the intelligent demand of power transformer condition maintenance, this paper mainly analyzes the multi-modal machine learning.

The data sources related to the operation, maintenance and repair of power transmission and transformation equipment are wide and varied, including physical signals, images, videos, texts, audios and other heterogeneous data. Each source and form of information can be called a model. Comprehensive analysis of various modalities constitutes multi-modal machine learning. Multi-modal learning aims to improve the ability to process and understand multi-source modal information through machine learning methods. Multi-modal machine learning integrates multi-modal information for better feature representation, extraction and recognition. It should be noted that the multi-modal learning model does not simply splice different models and turn on their respective "switches" in different scenes, but truly integrates and learns multi-source features from the model mechanism.

Compared with single-modal learning, multi-modal learning eliminates the redundancy between modalities through the complementarity between multiple modalities, thereby achieving a better learning effect. Transfer learning is a typical multi-modal learning method. This method uses a resource-rich modal information to assist the learning of another modal with relatively poor resources. It has a good development prospect in small-sample learning. Figure 2 shows a typical deep adaptation network migration learning principle. In the equipment operation and maintenance service, due to various factors such as equipment, technology, resources, and procedures, some of the collected state variable data resources are relatively abundant, while other information is relatively scarce. If modal complementation can be carried out, comprehensive analysis of equipment status or faults from different
sides will further improve the accuracy of judgment. At present, some scholars have explored equipment operation and maintenance information fusion technology at the levels of multi-period, multi-information, and multi-criteria, and have achieved good results, but the true multi-modal machine learning is still in its infancy.

![Deep adaptation network migration learning](image)

**Figure 2. The basic principles of deep adaptation network migration learning**

4. **Application of artificial intelligence in power equipment operation and maintenance inspection**

With the in-depth advancement of State Grid's "Three Collections and Five Majors", smart substations have all been unattended. There are more and more contradictions caused by the independent operation mode of operation and maintenance. Considering the utilization efficiency of human resources, the amount of time cost, transportation cost, and the continuous reduction of operating personnel under the pattern of large-scale operation and large-scale maintenance, the integration of operation and inspection of smart substations can improve the efficiency of operation and maintenance of substations.

In the process of long-term operation, the power transformer will be affected by the combined action and influence of various internal and external factors such as electrical stress, thermal stress, mechanical stress, operating conditions, and meteorological environment, which will damage the insulation performance and cause defects or even failures. The changes in equipment operating status and the evolution of faults during this process are contained in numerous status information such as inspection tests, live detection, online monitoring, operating conditions, environmental climate, and grid operation. With the gradual improvement and application of power information platforms such as power transmission and transformation equipment status monitoring and management systems, production management systems, energy management systems, geographic information systems, and meteorological information systems, information related to the operating status of power transformers has shown multiple sources and differences. Data characteristics of the structure, multi-dimensional, refined state assessment and prediction results can provide a more reliable reference basis for equipment maintenance decision-making optimization, thereby further improving the level of transformer state management. Figure 3 shows the application framework of artificial intelligence technology in the operation and maintenance of power equipment.

![Artificial intelligence-driven data analysis technology application framework](image)

**Figure 3. Artificial intelligence-driven data analysis technology application framework**
4.1. Equipment health assessment
In order to effectively ensure the power supply reliability of the power grid and reduce the waste of manpower and material resources caused by regular maintenance, the domestic and foreign power industry has extensively carried out the health assessment and maintenance of power transformers, reactors, transformers, circuit breakers and other AC and DC transmission and transformation equipment. Work and formulate relevant work guidelines, forming a lot of expert experience. However, the equipment represented by power transformers has complex structure, high cost, and key role, and its distribution area and working characteristics are different, and there are more quantities to characterize its state, which has a high degree of uncertainty and ambiguity. In the development process, there is a lack of universal, objective and comprehensive evaluation standards.

In order to solve the drawbacks of traditional business evaluation work based on guidelines and expert experience, academia has carried out research work on equipment state evaluation models based on multi-source equipment state data, applying mathematical analysis methods and machine learning algorithms, hoping to fully and accurately reflect power the true state of the transformer. These models are mainly divided into two categories: One is to use mathematical models to objectively calculate evaluation weights, and to determine the closely related key feature indicators, relative importance, and evaluation weights by analyzing the relationship between various state quantity indicators and transformer status. Then evaluate the status of the transformer; The second is to use machine learning algorithms to directly construct a predictive model between state quantities and transformer state evaluation based on training samples. Currently commonly used machine learning algorithms include artificial neural networks and cluster analysis.

4.2. Equipment operating status prediction
Equipment status prediction is further developed from equipment status monitoring and status evaluation. It can start from the historical and real-time status data of the equipment, and combine the grid operation data and external environment information associated with the equipment to discover equipment operation indicators or the changing law of key parameters can predict the future operation of the equipment. Considering the complex operating conditions and numerous index parameters of power transmission and transformation equipment, the current equipment state prediction is usually based on certain key indicators as the prediction target. With the help of the technical advantages of artificial intelligence in dealing with highly non-linear and multiple correlation problems, it can be established Time series or association prediction models, common methods include support vector machines, deep belief networks, recurrent neural networks, long and short-term memory networks, etc. According to different prediction targets, the current research objects of power transmission and transformation equipment state prediction based on artificial intelligence include winding state, insulating oil chromatogram, oil temperature, load level, etc.

4.3. Power equipment fault diagnosis
The text information of power transformers mainly includes a large number of test/patrol inspection records, defect/fault reports and maintenance/elimination documents accumulated during the long-term operation. The equipment health information contained therein has important guiding significance for the state maintenance work. At present, foreign countries have conducted related research on the risk prediction of power equipment failures through trouble tickets, but there are obvious differences between Chinese text and English text in terms of part of speech and grammatical structure, so it is necessary to develop key information for the characteristics of power Chinese text Mining research.

The processing process of the Chinese text classification problem mainly includes 3 stages:
- Text preprocessing, including segmentation, sentence, word segmentation, stop word filtering, etc.;
- Text representation, that is, converting text into a form that can be recognized and processed by a computer;
• Selection, construction, training and testing of classifiers. In view of the insufficient data processing and feature extraction capabilities of traditional machine learning classifiers, the introduction of deep learning models such as long and short-term memory neural networks and convolutional neural networks as text classifiers for training and testing has realized the cause and effect of faults in fault texts Automatic extraction of relationships and automatic determination of the severity of defects in defect records, and the classification accuracy is significantly improved compared to traditional machine learning models.

5. Conclusion
With the increase in the types of power grid equipment of power supply companies, as well as the actual demand for the transformation of power grid equipment operation and maintenance management information. In the context of the era of big data in electric power, through the comprehensive development of artificial intelligence technology represented by expert systems, uncertainty reasoning, machine learning, intelligent optimization calculations, etc., in the comprehensive mining and analysis of power transformer state data, it can provide Operation and maintenance management of equipment provides important decision support. Due to the limitations of objective factors such as data quality, data barriers, and lack of abnormal samples, the application of artificial intelligence technology in related scenarios is still in its infancy. In the future, we should focus on strengthening the management and maintenance of status data, and explore effective new monitoring methods, so as to further promote the intelligent development of power equipment status maintenance.

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