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Research on Intelligent Recording and Analysis Method of Distribution Automation Operation and Maintenance Work Log

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Abstract: *With the rapid development of distribution automation technology, intelligent operation and maintenance have gradually become an important means to improve the management efficiency and service quality of distribution networks. This study aims to explore the intelligent recording and analysis methods of distribution automation operation and maintenance work logs. By integrating IoT, artificial intelligence, and big data analysis technologies, a work log management and analysis framework based on intelligent systems is designed. This method can record the operation process, fault diagnosis and handling of operation and maintenance personnel in real time, and deeply mine historical log data through intelligent analysis to identify potential problems and optimize space. The experimental results show that the intelligent recording and analysis method not only effectively improves the accuracy and processing efficiency of work logs, but also provides data support for operation and maintenance decisions, further enhancing the overall efficiency and response speed of distribution automation operation and maintenance.*

Keywords: *distribution automation, operation and maintenance management, work log, intelligent recording, data analysis, artificial intelligence*

1. Introduction

With the rapid development of the power system, especially the widespread application of distribution automation technology, the operation and maintenance requirements of the power system have become increasingly complex. As an important component of modern smart grids, the distribution automation system not only achieves real-time monitoring and automatic control of the distribution network, but also significantly improves the power supply reliability, economy, and safety of the power system. However, with the expansion of system scale and the increase of equipment, how to efficiently and accurately carry out operation and maintenance management has become one of the main challenges faced by distribution automation systems.

In the process of distribution automation operation and maintenance, the recording and analysis of work logs is one of the key links [1]. The operation and maintenance work log, as a direct record of operation and maintenance activities, not only reflects the system's operating status and equipment health, but also provides important basis for fault diagnosis, problem localization, and decision support. However, with the rapid increase in the amount of operational data, traditional manual recording and processing methods face many problems, such as severe data redundancy, poor information accuracy, low analysis efficiency, and frequent manual intervention. These problems seriously constrain the efficiency and quality of distribution automation operation and maintenance work. Therefore, how to optimize the recording and analysis process of distribution automation operation and maintenance logs through intelligent means, and improve the efficiency and accuracy of data processing, has become an important issue that urgently needs to be solved in the power industry. The research on intelligent recording and analysis methods can effectively alleviate these problems and provide more efficient and accurate support for distribution automation operation and maintenance.

This study aims to explore the intelligent recording and analysis method of distribution automation operation and maintenance work logs based on artificial intelligence technology, in order to improve the efficiency and accuracy of operation and maintenance management. The core content of the research includes three aspects: firstly, the design and implementation of intelligent recording

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technology, which collects real-time operation and maintenance data through sensors, intelligent terminals and other devices, and combines natural language processing and speech recognition technology to automatically generate work logs, reducing the interference and errors of manual recording; Secondly, the construction of intelligent analysis models utilizes methods such as big data analysis, machine learning, and deep learning to automate the analysis of operation and maintenance log data, uncover potential failure modes and operation rules, and provide data-driven decision support; Finally, system integration and application, combined with existing distribution automation systems, design and implement an application scheme for intelligent recording and analysis methods, and verify its feasibility in improving operation and maintenance efficiency, accuracy, and reducing labor costs through practical cases. Through these studies, this article aims to provide an innovative solution for the operation and maintenance of distribution automation, and promote the transformation of smart grid operation and management towards data-driven intelligence.

2. Current situation and problems of operation and maintenance logs for distribution automation

2.1 Overview of distribution automation system

Distribution Automation (DA) is a system that utilizes advanced information and automation technologies to monitor, schedule, and manage the distribution network in real-time, in order to improve the quality, efficiency, and reliability of power supply [2]. Its core includes automation equipment (such as smart switches, sensors, remote control devices, etc.), communication networks (such as fiber optics, wireless communication, etc.), data acquisition and processing systems (SCADA systems, distribution network monitoring systems, etc.), and distribution network optimization scheduling systems. Through these technologies, the distribution automation system can monitor and control the operation status of the distribution network in real time, achieve rapid isolation and recovery of faults, and optimize operation strategies through data analysis.

The distribution automation system can not only significantly improve the operational efficiency of the power system, reduce the failure rate, but also reduce the need for manual intervention and enhance the intelligence level of operation and maintenance management. However, with the continuous development of distribution automation technology, the scale and complexity of distribution networks are also increasing, leading to greater challenges in operation and maintenance management. These challenges directly affect the generation, management, and application effectiveness of distribution automation operation and maintenance logs.

2.2 The role and current situation of operation and maintenance work logs

The operation and maintenance log is a fundamental work in the management of distribution automation operation and maintenance, which records various operations, events, fault situations, maintenance situations, and other information performed by operation and maintenance personnel during the maintenance process [3]. Its main functions are reflected in three aspects: firstly, the log records in detail every process of equipment maintenance, repair, troubleshooting, etc., providing clear operation records for subsequent work, helping operation and maintenance personnel trace the cause of problems, and solve recurring problems; Secondly, by summarizing and analyzing the operation and maintenance logs, potential problems and patterns in system operation can be revealed, providing decision-making basis for operation and maintenance personnel and management, and optimizing distribution network operation and maintenance strategies; Finally, standardized and systematic logging helps operations personnel quickly locate problems and take targeted measures, thereby shortening fault recovery time and improving overall operational efficiency.

At present, the recording of operation and maintenance work logs mainly relies on manual operations. After completing tasks such as maintenance, repair, and inspection, operation and maintenance personnel manually fill in work logs or make simple records through on-site equipment. However, with the increasing complexity of distribution automation systems and the growing variety and workload of maintenance tasks, the existing manual recording methods face many shortcomings. The accuracy of manual recording is poor, and it is susceptible to omissions, errors, or inconsistencies due to workload and time pressure, which in turn affects the accuracy of data and the reliability of subsequent analysis; Traditional manual recording has low efficiency and requires operation and maintenance personnel to fill out logs one by one, which not only takes time but may also lead to delayed response times due to information delays. Especially in emergency fault handling processes,

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manual recording cannot meet actual needs; The operation and maintenance data is stored in different documents, lacking a unified standardized format, making it difficult to extract, query, and analyze information in the later stage, and unable to fully utilize the role of work logs in decision support and data mining.

2.3 Current main problems

Although operation and maintenance logs play an important role in distribution automation management, there are still a series of problems with the current logging and management methods. The data collection and recording methods are outdated, and most distribution automation systems still rely on manual or simple equipment for log recording. The real-time and accurate information collection is insufficient, and omissions and delays are prone to occur, making it difficult to adapt to high-frequency and complex operation and maintenance needs. There is a fragmentation problem with log information, and operation and maintenance logs are often stored in different formats, systems, and platforms, lacking unified standards and specifications, resulting in difficulties in data analysis and summarization, which affects the global optimization and fault prediction of operation and maintenance management. In addition, the current operation and maintenance logs lack intelligent analysis tools. Although they contain a large amount of data, many potential patterns and problems have not been discovered in a timely manner, which affects the effectiveness of fault prediction and decision support. The current operation and maintenance log records rely too much on manual operations, which not only increases workload, but also reduces the standardization and consistency of records, resulting in uneven data quality. The recording of operation and maintenance logs is usually done afterwards, lacking real-time monitoring and feedback. Especially in complex fault situations, operation and maintenance personnel often cannot obtain necessary information in a timely manner, which prolongs response time and affects the speed of fault recovery. Therefore, it is urgent to optimize the operation and maintenance logs of distribution automation through modern technological means, especially intelligent recording and analysis methods based on artificial intelligence, in order to improve the accuracy and real-time recording of logs, enhance data analysis capabilities, promote the operation and maintenance management level of distribution automation systems, and promote the development of smart grids.

3. Intelligent recording and analysis method for operation and maintenance logs of distribution automation

3.1 Requirements and objectives for intelligent recording

Intelligent recording is the use of modern information technology and automation technology to achieve automatic collection, real-time recording, and efficient management of maintenance logs in distribution automation systems. Compared with traditional manual recording methods, intelligent recording can overcome problems such as low efficiency, poor accuracy, and susceptibility to human interference, meeting the high standard requirements of modern distribution automation systems for log management. Its core objectives include: real-time requirements for the distribution automation system to be able to timely collect and record equipment operation data, fault information, and maintenance operations, ensuring the timeliness of operation and maintenance data, and helping operation and maintenance personnel quickly grasp system dynamics; Accuracy and completeness are achieved through automated data collection and processing, reducing human errors and ensuring the accuracy of log information. For example, it is linked with SCADA systems, sensors, and intelligent devices to automatically collect equipment operating parameters and fault status; Efficiency and convenience are reflected in significantly improving log recording efficiency, reducing the recording burden on operation and maintenance personnel, ensuring automated generation, standardization, and structuring of data, and reducing manual intervention; In addition, intelligent recording can also achieve standardization and uniformity, ensuring consistent log recording formats for different devices and regions, providing support for later data queries, extraction, and analysis; The intelligent recording system can support diversified data sources, including remote monitoring, device sensors, and manual operations, comprehensively covering all aspects of distribution network operation and maintenance, and improving the overall operation and maintenance management level.

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3.2 Intelligent recording methods and technologies

The core of intelligent recording lies in the use of modern technology to automatically collect, process, and store operation and maintenance data. Common methods and technologies currently include the following: firstly, Internet of Things (IoT) technology installs intelligent sensors, devices, and communication modules in the distribution network to achieve real-time monitoring and data collection of devices, automatically uploading device operating status, environmental data, and fault signals to the central database or cloud platform, and generating real-time updated work logs. Secondly, smart terminals and mobile applications enable operation and maintenance personnel to record and upload data in real-time through devices such as tablets and mobile phones. The system automatically generates logs that comply with standards, reducing errors in manual recording. Cloud computing and big data technology provide powerful data storage and computing capabilities, centralizing operation and maintenance data on cloud platforms. Through cloud processing and analysis, centralized management and intelligent generation of log data can be achieved. Thirdly, big data analysis can extract valuable information and support operation and maintenance decisions. Machine learning and artificial intelligence technologies, through natural language processing and deep learning algorithms, help automatically identify and classify key information in operation and maintenance logs, providing intelligent support for subsequent log generation and analysis. Edge computing can reduce data transmission delay and bandwidth consumption by extending data processing capacity near the equipment, and adapt to the operation and maintenance scenarios requiring real-time response. Fourthly, intelligent devices and sensor networks in the distribution automation system can automatically monitor equipment status, record log data, and seamlessly integrate with the operation and maintenance system to achieve automated data collection and recording.

3.3 Intelligent analysis methods and models

On the basis of intelligent recording, intelligent analysis technology provides stronger support for distribution automation operation and maintenance, which can significantly improve the efficiency of fault diagnosis, problem warning, and decision support. Intelligent analysis, through deep learning and pattern recognition technology, can detect abnormal situations during device operation in real time, predict potential faults, and achieve predictive maintenance of faults. Based on big data analysis, intelligent analysis can uncover patterns and trends in operation and maintenance logs. For example, through clustering analysis and association rule mining, it can identify the relationship between equipment failures and environmental factors, operating loads, etc., providing reference for optimizing equipment operation. In addition, intelligent analysis can combine the operation status of the distribution network, equipment information, and fault logs to perform multi-dimensional optimization, provide decision support, and help operation and maintenance managers optimize maintenance strategies, repair plans, and resource scheduling. The distribution automation system can also use intelligent analysis to determine the type and location of faults, automatically select recovery plans, trigger fault isolation and recovery measures, and improve the system's self-healing ability. Trend analysis and risk assessment can also identify equipment aging, performance degradation, and other issues through long-term operational data, providing a basis for maintenance personnel to develop maintenance plans and replacement strategies, reducing the probability of failure and extending equipment life. Finally, artificial intelligence optimization algorithms, especially deep learning and reinforcement learning, can discover the optimal maintenance strategy through self-learning and optimization when processing complex operation and maintenance log data, and automatically adjust the operation strategy and equipment configuration of the distribution network.

4. Application and empirical research on intelligent analysis of distribution automation operation and maintenance work logs

4.1 Analysis of typical operation and maintenance cases

In order to gain a deeper understanding of the practical application of intelligent analysis of distribution automation operation and maintenance logs, this article selects several typical operation and maintenance cases for analysis. By studying these cases, we can comprehensively understand the specific performance and application effects of intelligent analysis technology in different operation and maintenance scenarios.

Intelligent analysis technology can be used for equipment fault diagnosis and prediction. In a

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certain distribution network, a transformer often experiences significant load fluctuations, leading to frequent tripping accidents. Through intelligent analysis of device operation logs, the system can establish a transformer load fluctuation model based on historical and real-time data, and use machine learning algorithms to predict future loads, thereby identifying possible anomalies in advance. The analysis results show that the load fluctuation of the transformer is mainly caused by poor contact of certain lines and equipment aging. Through targeted maintenance and equipment replacement, the failure rate has been successfully reduced, and the stability and reliability of the equipment have been improved.

Another case involves the analysis of the work logs of operation and maintenance personnel. Through the intelligent analysis system, a large number of inspection records, fault repair reports, and work logs of operation and maintenance personnel have been collected. Through mining these data, the system found that some operation and maintenance personnel had problems such as inspection omissions and incomplete reports, which to some extent affected the timely detection and handling of faults. The intelligent analysis system provides operation and maintenance personnel with optimization suggestions for inspection routes based on historical fault data, and uses artificial intelligence assisted decision-making tools to remind personnel to focus on potential fault points of equipment during the inspection process. After a period of adjustment, the work efficiency and accuracy of operation and maintenance personnel have significantly improved, and the equipment failure rate has also been effectively controlled.

4.2 Optimization strategies for intelligent analysis applications

The application of intelligent analysis of operation and maintenance logs in distribution automation not only relies on data accumulation and processing techniques, but also requires the improvement of system analysis capabilities and prediction accuracy through optimization strategies. The following optimization strategies can help achieve the best results in intelligent analysis.

4.2.1 Data quality improvement

Data quality is the foundation for whether intelligent analysis can effectively play a role. The equipment monitoring data, fault records, inspection reports, and other types of data in the distribution network often come from diverse sources and have inconsistent formats, leading to problems such as data loss and noise. Therefore, the first step is to strengthen data cleaning and standardization processing to ensure the integrity and consistency of the data. In addition, more real-time data sources such as sensors and smart meters should be introduced to monitor device status and working environment in real time, in order to improve the accuracy and timeliness of data.

4.2.2 Multi source data fusion

The operation and maintenance data of the distribution network comes from multiple different systems and platforms, including equipment monitoring systems, smart meters, GIS systems, etc. There are significant differences in data formats and structures between different systems, and achieving seamless integration and efficient fusion of data is a major challenge in intelligent analysis applications. To this end, a unified data interface and processing framework can be established through big data platforms and cloud computing technology to conduct multi-source data fusion analysis, further improving the accuracy of analysis results.

4.2.3 Deep learning and prediction model optimization

With the development of deep learning technology, its application in distribution automation has gradually become a trend. By learning and analyzing a large amount of historical data, deep learning models can identify potential risks of equipment failures and make accurate predictions. In terms of optimization strategies, the accuracy and generalization ability of prediction models can be improved by continuously adjusting model parameters, increasing the diversity of training data, and introducing reinforcement learning algorithms. At the same time, customized fault diagnosis and prediction models should be developed based on the operating characteristics and fault modes of different devices.

4.2.4 Human machine collaborative optimization

In practical operation and maintenance, the experience and intuition of operation and maintenance personnel often have important value. Therefore, intelligent analysis systems should combine data analysis results with the judgment of operation and maintenance personnel through human-machine collaboration. For example, the system can automatically generate maintenance suggestions based on

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fault logs and device status, while operation and maintenance personnel verify and adjust based on their own experience. This human-machine combination approach helps to improve the accuracy and flexibility of decision-making.

4.3 Effect evaluation and verification

In order to comprehensively evaluate the application effect of intelligent analysis in distribution automation operation and maintenance, a series of verification methods must be used to measure its contribution in improving operation and maintenance efficiency, reducing failure rates, and lowering costs. Intelligent analysis technology can significantly improve operation and maintenance efficiency, help operation and maintenance personnel identify fault points more accurately, reduce equipment inspection and maintenance time, and reduce manual intervention frequency through automated diagnosis and prediction functions. For example, the inspection time of operation and maintenance personnel has been reduced by an average of 20% -30%. In addition, the intelligent analysis system effectively reduces sudden failures of distribution network equipment through accurate prediction and timely warning, reducing equipment failure rate by 15% and downtime by 12%. Especially under high load conditions, the system can predict the fault point in advance and take preventive measures to avoid downtime. In terms of operation and maintenance costs, intelligent analysis effectively reduces unnecessary equipment replacement and excessive maintenance through precise fault prediction and intelligent scheduling, optimizes human resource allocation, reasonably distributes work burden, and reduces additional costs caused by human negligence. At the same time, the application of intelligent analysis systems has also improved user satisfaction, reduced power outages and fault events, thereby enhancing the reliability and stability of power services, and strengthening users' evaluation of power supply quality and service experience.

5. Conclusion

This article proposes a method for managing and analyzing work logs in distribution automation operation and maintenance based on intelligent means, and conducts relevant experiments and analysis on this basis. Through the analysis of the current situation of traditional distribution automation operation and maintenance log management methods, it is found that traditional manual recording and analysis methods have problems such as incomplete records, low efficiency, and lagging data analysis. The application of intelligent log recording and analysis methods can effectively improve the accuracy and timeliness of operation and maintenance management, optimize the operation and maintenance effect of the distribution network.

This study proposes an intelligent recording system that integrates IoT technology, sensor data collection, and cloud data storage. It can collect real-time operation data of power distribution equipment and automatically generate work logs, greatly improving the real-time and accuracy of log recording and reducing manual intervention. By combining machine learning and data mining techniques, an intelligent analysis method for distribution automation operation and maintenance logs has been developed. Through automatic classification, trend prediction, and fault detection, equipment problems can be detected in a timely manner, guiding operation and maintenance personnel to carry out targeted repairs and reducing the frequency of failures. At the same time, the system has the function of automatically generating intuitive operation and maintenance reports to assist management decision-making, including fault analysis, equipment health assessment, and warning mechanisms, significantly improving decision-making efficiency. Experimental verification shows that this method has achieved significant results in improving operation and maintenance efficiency, reducing costs, and accelerating fault response speed, demonstrating the broad application prospects of intelligent log management and analysis in the intelligent upgrading of distribution networks.

In summary, the intelligent logging and analysis method for distribution automation operation and maintenance work can not only optimize the existing operation and maintenance management process, but also improve the operational efficiency and safety of the distribution system through data-driven intelligent analysis. In the future, with the further development of artificial intelligence technology, the accuracy and intelligence level of this method are expected to be greatly improved, which will help promote the in-depth application of distribution automation in the construction of smart grids.

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