Research and Application of Intelligent Maintenance of Relay Protection Equipment Based on Internet of Things Technology

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Abstract. Relay protection equipment is an important guarantee for safe and reliable operation of power grids. Relay protection technology is also developing towards computerization and networking. The integration of information technology and communication technology is bringing tremendous changes to the operation and maintenance management of relay protection equipment. Through high-capacity mobile communication networks, high-speed wireless networks and various types of mobile terminals, the operation and maintenance mode will be transformed, not only to achieve paperless, portable, high-efficiency transformation, but more importantly, this kind of Internet The five generations + ubiquitous new ideas, new experiences, and new solutions brought about by the power Internet of Things will reconstruct the relay protection operation and maintenance system and the mobile interconnection maintenance framework.

1. Status introduction

At present, the collection and verification of the operation information of the field equipment of the substation still relies mainly on the transcription of the operators, which may lead to clerical errors. Although a few manufacturers use barcodes to realize equipment identification and management, they have not yet established associations with the current operation and maintenance management systems of the State Grid. Identification management increases the difficulty of asset management, resulting in problems such as untimely data updates and difficulty in ensuring accuracy.

During the operation of the equipment, the operator is required to patrol the operation of the equipment at regular intervals and at a fixed point, and manually record the inspection results. Because the paper materials are inconvenient to save and inquire, it is impossible to statistically analyze the inspection results through scientific methods, effectively helping management. Personnel make auxiliary decisions [1] to predict hidden faults in advance.

In the management of relay protection equipment, the management process lacks effective connection, business information cannot be shared, work performance lacks regular evaluation feedback, and closed-loop management mechanism of continuous optimization has not been established [2].

With the development of identity recognition, mobile internet and the fifth generation wireless communication private network technology [3], in response to these problems, the relay protection
equipment operation and maintenance must introduce advanced intelligent technology and scientific management mode to realize real-time intelligent identification. A series of functions such as acquisition, tracking, analysis, diagnosis and early warning, through the process of multi-dimensional information flow, comprehensive analysis and centralized management, greatly improve the operation and maintenance level and management level of relay protection equipment.

2. Technical framework

![Figure 1. Technical framework](image)

As can be seen from the technical architecture diagram, it consists of the following parts:

1. Data source management, providing data standardization access and loading strategies through wireless communication technologies such as sensors (identification) and mobile terminals.

2. The data center platform adopts a variety of data analysis algorithms combined with a graphical modeling system to provide data query calculation, cross-database correlation calculation and other capabilities to achieve rapid transformation of business applications.

3. Business application management, combined with the relay protection operation and maintenance operation scenario, integrates and shares the relevant system data to realize the data access service of the terminal service.

2.1. Identification technology

The core technology of relay protection equipment account management is to generate QR-CODE (Quick Response Code) matrix two-dimensional coding technology [4] combined with mobile terminal GPSUUUID (Universally Unique Identifier) algorithm (Global Positioning System) global positioning system Substation relay protection equipment for unique identification.

The unique identity code is generated by a certain algorithm based on the Ethernet card MAC address, namespace, chip ID code, timestamp, random number, timing, etc. defined by the standard specification
developed by the Open Software Foundation (OSF). A universal unique identification code (UUID) consisting of 32-bit hexadecimal numbers. The QR-CODE fast response matrix code of the H-level error correction level is automatically generated by black and white, and the square pattern of the "back" word pattern is automatically generated. The dimension code is generated by the generated two-dimensional code into a relay protection device, and the GPS global positioning technology is used to uniquely identify the protection device through the two-dimensional code label.

![Figure 2. Schematic diagram of device identity uniqueness identification](image)

The mobile terminal scans the two-dimensional code label on the surface of the protection device, parses the identification code in the two-dimensional code, and combines the geographic location of the substation located by the GPS module, and retrieves the corresponding device information in the substation equipment database according to the location information.

Since the UUID is mainly generated based on timestamp, random number, MAC address and other information through the degradation algorithm, there is still a possibility of repetition in the world, so a space coordinate is added to the UUID code by the GPS global positioning system. The uniqueness of the device identification code is further ensured, and the QR-CODE encoding method matched with it has the advantages of fast reading speed, large data density, small occupied space, and the like, and further enhances the applicability of the identification technology.

2.2. Mobile terminal technology

With the miniaturization of components such as central processing unit, memory, input and output, and the rapid development of integrated circuit technology, the processing capabilities of mobile terminal devices are becoming stronger and stronger, and they are gradually becoming portable and lightweight, and have been widely used in many fields. Application, relay protection equipment intelligent operation and maintenance to fully explore the mobile terminal technology [5], get rid of the time and space constraints of the operators in the traditional operation and maintenance work, using advanced work concepts and methods to carry out relay protection operation and maintenance work, The advantages of mobile terminal technology are mainly reflected in the following aspects:

1. In the hardware system, the mobile terminal not only has a variety of input modes such as a touch screen, a microphone, a camera, but also has various output modes such as a display screen and an earpiece, and can be connected to various wireless transmission technologies such as Bluetooth, WIFI, and GPS. NFC, RFID, infrared and other Internet of Things sensing devices communicate to enhance the input and output capabilities of mobile terminal devices.

2. In the software system, mobile terminals have many operating systems to choose from, such as: Windows Mobile, Symbian, Palm, Android, IOS, etc. However, the current mainstream and open system is still android. Most software applications are developed based on the operating system platform, such
as: SCD file analysis software, recorded file analysis software, CAD drawing tool software, etc. Meet the individual needs of users.

(3) In terms of communication capabilities, mobile terminals have flexible access modes and support multiple wireless data services. They can choose not to use the carrier's network standard (e.g., GSM, WCDMA, TD-LTE, etc.) according to user needs. The development of customized communication modules can be carried out according to user needs and business environment, so as to meet the needs of users and facilitate user use.

(4) In terms of functional applications, mobile terminals pay more attention to the development of human-computer interaction functions that are humanized, personalized, and functionally diverse. With the rapid development of a large number of new technologies such as embedded computing, control technology, image recognition technology, biometric authentication technology [6], mobile terminals integrate many software and hardware, combined with professional applications, fully embody the principle of "people-oriented" and develop a large number of Industry software that can be used, used, and practical.

2.3. Data center platform

Figure 2 shows the composition of the patrol robot control system. The robot system mainly includes the control system, the tracking system, the navigation system, and the moving parts.

The intelligent operation and maintenance of relay protection equipment has completed the collection of various source data through various technical means. These structured and unstructured massive data are scattered and have no meaning. Big data analysis technology is the collected data. Equipment account data, professional inspection records, equipment inspection records, operational defect data, and other data written into the data warehouse are integrated for comprehensive analysis.

The data center platform [7] combines big data analysis and graphical modeling system to form a big data modeling and analysis system. The modeling and analysis system has built-in multiple data analysis algorithms to support graphical model design functions, which can be directly graphical. Components implement data analysis models in a variety of ways, making data analysis more efficient. When the business model changes or needs to be expanded, the extended algorithm database can be added to increase the corresponding data analysis to quickly realize the transformation of the business system, greatly improving the efficiency and simplifying the transformation of data analysis.

After the data flat center platform aggregates, analyzes and processes the data, it provides an accessible and cross-platform data sharing method through the data bus mechanism, and provides an efficient channel for task access data and system automatic extraction of data.

2.4. Fifth generation wireless communication technology

With the continuous improvement of the remote operation requirements of power automation equipment by State Grid Corporation, the wireless transmission technology of communication network is the carrier of intelligent operation and maintenance of relay protection equipment. The transmission rate, bandwidth, delay, security and other factors are particularly important. Electrical protection intelligent operation and maintenance combined with the current mainstream fifth-generation wireless communication private network technology, optimized from user experience, information security, network quality, etc., a subversive upgrade of the fourth generation wireless communication network technology, will The communication between people turns to the Internet of Everything, and proposes a more flexible and efficient new mode for the intelligent operation and maintenance of relay protection equipment, which can transform more operation and maintenance services to mobile terminals.

The fifth generation wireless communication private network technology has the following advantages:

(1) Fast data rate

The total data rate that the communication system can support at the same time is 1000 times higher than that of the previous generation communication system; when the user is at the edge of the system (i.e., the transmission rate is the worst), the transmission rate of the fifth generation wireless
communication private network is 100 Mbps to 1 Gbps. It is at least 100 times higher than the previous generation; the peak system transmission rate will reach 10Gbps.

(2) Shorter delay

Now the fourth-generation wireless communication system has a round-trip delay of 15ms, of which 1ms is used by the base station to allocate the necessary cost to the user to allocate channels and access methods. With the application of big data, cloud computing and wearable devices, the fifth Generation of wireless communication networks can provide lower latency.

(3) Lower energy costs

With the development of the fifth generation of wireless communication technology, the energy consumption of communication will be lower and lower, because the user gets the data rate increased by at least 100 times, which requires the energy consumption per bit to be reduced by at least 100. Double, so the energy utilization rate will be greatly improved.

(4) More device access

The fifth-generation wireless communication network has stronger service capabilities and can access more users at the same time. With the development of device communication technology, a single macro cell should be able to support more than 1000 low transmission rate devices while continuing to support common high transmission rate devices.

The fifth-generation wireless communication technology is not only a new generation of mobile technology, but also a brand-new network. It will redefine the relay protection operation and maintenance mode, provide a unified connection architecture for different operation and maintenance services, and realize the interconnection of all devices. With the help of big data automatic analysis, the operation and maintenance work is more convenient, more efficient and smarter.

2.5. Business Applications

The application mode of intelligent operation and maintenance technology of relay protection equipment based on mobile internet is very convenient for multi-dimensional collection and process delivery of on-site operation and maintenance data, assisting analysis and optimization management; and establishing a complete information library to realize relay protection device Fine management, accurately track the detailed life cycle of the equipment [8], realize traceability of operation and maintenance, realize remote operation of operation and maintenance work and collect data, and improve the operation and maintenance management level of relay protection equipment.

(1) Equipment basic data management

A two-dimensional code label with a unique identification code is established for each relay protection device, and the correspondence between the protection device, the identification code, and the two-dimensional code label can be established by scanning the two-dimensional code, and the device is fixed and configured. The basic data such as documents, drawings, manuals, etc. are electronically managed for database management, and the automatic association with the equipment is realized. The operator can scan the device QR code in real time by hand-held mobile terminal to scan the device image information in real time, which is quick and avoids the tradition. Paper documents are inconvenient to access, inconvenient to carry, and poorly shared.

(2) Control of operation and maintenance process

The division of personnel duties is clearly divided, decentralized and sub-domain management, and the mobile terminal is used to realize the on-site operation control of the core operation and maintenance of relay protection equipment, forming a closed-loop management. During the execution of the task, the mobile terminal automatically records the traces of each link. Easy to trace. Ensure on-site safety and improve work efficiency.

Before carrying out the inspection and inspection work on the spot, the operator needs to scan the QR code label of the equipment to confirm the work place and the operation equipment, and use voice prompts to effectively prevent the accidental entry interval and avoid the occurrence of safety accidents.

During the operation, the terminal can use the terminal to query the operation content of each node in the operation and maintenance operation, the technical standard of the key nodes, and the safety
precautions of the dangerous nodes, etc., to supervise and remind them in a clear way, to clarify the key points of work and ensure that the preparation work is targeted.

(3) Substation equipment display
Record the status of the pressure plate, air opening, handles and indicator lights of the substation field equipment during normal operation, as well as the multi-angle photo information of the device, the front, and side and back of the panel. The operator does not need to reach the substation site to operate and maintain. The team initially completed the site survey before the operation, completed the filling of the safety measures ticket, combined with the 3D modeling technology to construct a three-dimensional model of the whole station equipment through these picture information, and visualized the panoramic view of the substation and its equipment.

(4) Intelligent diagnosis of power grid faults
According to the requirements of massive data processing performance and timeliness of relay protection business applications, the offline computing, real-time computing and memory computing components suitable for relay protection big data are constructed; the data analysis and mining algorithms are required according to the relay protection various business applications. Build an analysis and mining component suitable for the relay protection business support platform, extract data, pre-processing and integration strategies through the data communication specification and scheduling instruction specification between the platform components, and realize the seamless link between the components of the platform. Pre-defined strategies for intelligent diagnosis and early warning of grid faults.

3. Technical characteristics
(1) Data mining technology
Data mining technology [9] is a technology that sorts, organizes, and extracts hidden, unknown, and useful information through clustering, searching, disassembly, and other algorithms in a data warehouse. Usually, data cleaning is required. Transformation, implementation and other steps.

(2) Predictive analysis techniques
Predictive analysis technology [10] refers to the data mining technology to extract the data implied by the operation and maintenance data of the device, predict the operation trend of the device, and provide early warning of the failure, so as to prepare adequately before the failure occurs. To avoid the occurrence of grid faults.

(3) Data quality and management technology
Big data analysis is inseparable from data quality and data management. It requires scientific processing of data through standardized processes and specialized tools to ensure the authenticity and effectiveness of the final analysis results and to obtain a high-quality analysis result.

(4) Data storage and warehouse technology
The data warehouse [11] is a relational database established to facilitate multidimensional analysis and multi-angle display of data stored in a specific mode. Data warehouse is the basis of intelligent operation and maintenance of relay protection equipment. It undertakes the integration task of all business data of relay protection equipment, and provides retrieval and calling to intelligent operation and maintenance advanced applications to provide basic data support for data mining.

4. Application effectiveness
The intelligent operation and maintenance technology of relay protection equipment based on mobile internet will bring about revolutionary changes in equipment operation and maintenance, not only paperless, portable, high efficiency, but more importantly, this kind of Internet five generation + grid relay protection operation and maintenance belt The new ideas, new experiences and new solutions have broken the traditional relay protection operation and maintenance system based on management procedures and technical regulations, and built a new mobile interconnection maintenance framework.
(1) Strengthen the safety of relay protection equipment operation

Using the data protection and processing technology of relay protection modeling based on big data analysis technology, integrating massive data such as equipment basic data, operation data and fault information, and researching key quantitative indicators reflecting the level, action behavior and health level of relay protection equipment. Fully master the equipment operation status and enhance the reliability and safety of equipment operation.

(2) Improve the ability of operation and maintenance personnel to diagnose and dispose of faults

Using multi-dimensional information, the method of evaluating the hardware and secondary loop state of the device is studied to realize fault location of the hardware and secondary loop abnormalities of the device, and can realize hidden fault identification and early warning, secondary system abnormal state deduction, fault and abnormal information. Push to improve the ability of operational maintenance personnel to quickly diagnose and handle equipment defects.

(3) Improve the reliability of maintenance decision-making

Combined with big data analysis and mining technology, the paper analyzes and evaluates the health status of equipment, further improves the existing state evaluation system, builds a power grid maintenance assistant decision-making system, scientifically predicts its development trend, and provides auxiliary decision-making and improvement for existing relay protection state maintenance work.

(4) Enhance the perception in operation and maintenance operations

To study the application of multi-dimensional sensing and detection technology in substation inspection, and use artificial intelligence technology to establish an integrated intelligent inspection mode combining the intelligent inspection of relay protection equipment, remote inspection and a relay protection equipment linkage inspection to effectively improve the inspection efficiency. Reduce the pressure on the site staff.

5. Summary

The integration of information technology and communication technology is bringing tremendous changes to the operation and maintenance management of relay protection equipment. With the advancement of the construction of the three-network and two networks of the State Grid Corporation, mobile communication technology and Internet of Things technology have become the main driving force for the development of information and communication technologies, through high-capacity mobile communication networks, high-speed wireless networks and various types of mobile The information terminal will transform the management of relay protection equipment to a highly intensive, change the management mechanism to a closed-loop process, change the management method to quantitative lean, change the management means to informationization, and finally realize the traditional operation and maintenance mode to intelligent operation and maintenance. The transformation of the model fundamentally solves the problem of human resource waste in the management of relay protection equipment, avoids waste of system resources, saves economic costs, greatly improves the management level and work efficiency of relay protection, and improves the performance of power grid operation.

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