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Research and application of power equipment monitoring and fault diagnosis

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Abstract. Power equipment monitoring and fault diagnosis are important parts of power system operation and maintenance. By monitoring the status and performance parameters of power equipment in real time, and timely discovering and diagnosing potential fault problems, the reliability, safety and economy of the power system can be improved. At present, this research has made significant progress, but there are still some research gaps that need to be further explored and resolved. Through the research and application of power equipment monitoring and fault diagnosis, this paper aims to improve the reliability, safety and economy of power grid, reduce the risk of failure, optimize equipment operation and maintenance strategies, and improve power supply quality and user satisfaction. Condition monitoring and fault diagnosis are very important for the normal operation of the power system equipment, which can not only strengthen the fault diagnosis of the power system equipment, but also avoid the problem of large-scale paralysis caused by the failure of the power system equipment.

Keywords: Power Equipment, Monitoring, Fault Diagnosis, Power System, Reliability.

1. Introduction

This paper aims to discuss and analyze the importance and application of power equipment monitoring and fault diagnosis in power system. Firstly, the significance of operation status monitoring and fault diagnosis of power equipment for the safe and reliable operation of power system is introduced. Then, the theoretical basis and related concepts of power equipment monitoring and fault diagnosis are expounded, including sensor technology, data acquisition and processing methods, etc. Then, through examples and case studies, the application of power equipment monitoring and fault diagnosis in different equipment and scenarios, such as generators, transformers and transmission lines, is discussed. Further, the advantages and challenges of this technology are analyzed, and future development directions and research suggestions are proposed.

Through effective equipment monitoring and fault diagnosis, potential equipment problems and faults can be found in time, preventive maintenance measures can be taken, the impact of equipment failures on power system operation can be reduced, and the reliability and safety of the power system can be improved. Timely diagnosis and maintenance of equipment failures reduces equipment downtime and maintenance cycles, reduces maintenance costs, and optimizes O&M resource utilization. This helps to improve the economic efficiency and overall operational efficiency of the power system. Through research and practice, the continuous exploration and improvement of power equipment monitoring and

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fault diagnosis methods and technologies can promote the development of this field and provide advanced monitoring and diagnostic technical support for the field of power engineering.

2. Generator monitoring and fault diagnosis

2.1. Generator condition monitoring and fault warning

Generator condition monitoring is typically achieved through a variety of sensors that can monitor critical parameters such as temperature, vibration, current, voltage, etc. Monitoring data is collected, analyzed, and processed for fault diagnosis and prediction through data models and algorithms.

The fault warning system compares the difference between the current monitoring data and the normal operation state based on historical data and models, and determines whether there are potential faults. When the system detects an anomaly, it generates alerts or notifies the relevant personnel so that they can take timely action [1].

2.2. Methods and models of generator fault diagnosis

The traditional methods of generator fault diagnosis are: vibration analysis: by monitoring and analyzing the generator vibration signal, faults such as bearing wear, imbalance and looseness can be detected; Temperature monitoring: monitor the temperature changes of each component of the generator in order to detect overheating problems in time; Oil quality analysis: Through chemical analysis of generator oil, abnormal conditions such as metal particles, moisture and pollutants can be detected; Current and voltage monitoring: Monitor waveforms and parameters of generator current and voltage to determine if there is an electrical fault.

In the fault diagnosis of power system equipment, the staff should choose the appropriate diagnosis method according to the specific condition of the equipment fault, so as to improve the work efficiency. The specific methods are: (1) fault diagnosis through sensing and information technology. It is to use a variety of sensors in the process of fault diagnosis of power system equipment and then carry out a comprehensive and detailed diagnosis of the fault, and at the same time, it is necessary to comprehensively consider various diagnostic characteristics to determine the fault type and better improve the accuracy of fault diagnosis. (2) Fault diagnosis is carried out through space vector and equipment fault characteristics, so as to better reduce possible errors in fault diagnosis. (3) Pay attention to the uncertain factors contained in the characteristics of the equipment and its data information, and then use fuzzy mathematics to calculate the fault characteristics so as to provide a very important reference basis for fault diagnosis [2].

3. Transformer monitoring and fault diagnosis

3.1. Transformer operation monitoring and insulation condition assessment

Transformer operation monitoring mainly includes the following aspects: Temperature monitoring: Through the installation of temperature sensors, real-time monitoring of temperature changes inside and outside the transformer. High temperatures may indicate problems such as overload, poor winding contact, or cooling system failure and require further analysis and treatment. Oil quality monitoring: The gas, moisture and pollutant content in transformer oil are important indicators to reflect the insulation status and internal faults of transformers. By regularly sampling and monitoring the transformer oil, it is possible to determine whether there are abnormal components in the oil and determine whether the oil needs to be treated or replaced based on the results of the analysis. Vibration monitoring: The mechanical parts inside the transformer, such as cooling fans, moving parts, etc., will generate vibration during operation. By installing vibration sensors and monitoring the vibration of transformers, it is possible to determine whether there are problems, such as loose mechanical parts and wear, and take timely measures for maintenance. Winding ground current monitoring: The ground current of the transformer winding is an important indicator to evaluate the insulation status and insulation performance. Through the monitoring and analysis of the winding grounding current, it can

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be judged whether there are problems with the insulation, such as insulation aging, winding short circuit, etc., and take corresponding maintenance measures.

Insulation condition assessment mainly includes the following aspects: insulation resistance test: through the resistance of the insulation material, the quality and state of insulation are evaluated. Commonly used methods include insulation resistance measurement and dielectric loss factor test, which can determine whether the insulation is normal and whether there are problems such as leakage and electricity. AC withstand voltage test: The winding and insulation structure are tested by high-voltage AC power to evaluate the strength and resistance of the insulation. This test can find hidden faults in the insulation structure, such as small hole perforation, local breakdown, etc. On-site partial discharge detection: Evaluate the reliability of insulation by detecting the partial discharge signal of the transformer insulation structure. Partial discharge is the discharge phenomenon caused by defects in insulation materials, and by detecting and analyzing partial discharge signals, it is possible to determine whether there are defects or aging problems in the insulation. Thermal infrared detection: Infrared thermal imaging of transformers with a thermal imaging camera to assess the thermal distribution of insulation structures. Abnormal hot spots and temperature distributions may indicate insulation failures, poor contacts, etc., and require further service. In short, transformer operation monitoring and insulation condition assessment are important means to ensure the safe operation of transformers. Monitoring of temperature, transformer operation and insulation condition is one of the important means to ensure the safe and reliable operation of transformers. By monitoring and evaluating the operating status and insulation status of transformers, potential faults can be detected in time, risks can be warned in advance, and corresponding measures can be taken for maintenance and repair.

3.2. Methods and techniques of transformer fault diagnosis

Fault diagnosis analysis is the analysis of the physical process, chemical process, and causal relationship of failure that cause power equipment to fail. The steps are: first, summarize and simplify a large number of intricate equipment state feature quantities; reduce dimensionality; etc.; then, use recognition technology (such as fuzzy recognition, neural networks, mathematical methods, expert systems, etc.) to identify the fault characteristic parameters; and finally, determine the nature, category, degree, location, and cause of the fault [6]. The relationship between various faults of electrical equipment, whether electrical, mechanical, insulating materials, etc., and their symptoms is inextricably intertwined and complex, and generally has nonlinearity and uncertainty. This requires summarizing the experience of experts in various fields, integrating fuzzy mathematics, artificial neural networks and other technical judgment relationships, establishing a practical intelligent diagnosis system based on neural networks, and determining the state of equipment through reasoning methods. At present, some online monitoring background fault diagnosis system analysis software is relatively single and cannot comprehensively analyze the collected data parameters. In this regard, we need to carry out more in-depth work [3].

4. Transmission line monitoring and fault diagnosis

Before the 1980s, due to the low voltage level of the power grid, the small capacity, and the loss and impact of faults, people generally adopted the preventive maintenance system. In the 1980s, especially in the past decade, with the rapid development of ultra-high voltage and UHV transmission and transformation technology, the power grid capacity was large, the coverage was wide, and the consequences of accidents were becoming more and more serious. Monitoring and risk assessment of the operating status of transmission lines [4].

The monitoring and risk assessment of the operating status of transmission lines is an important part of ensuring the safe and stable operation of the power grid. Through real-time monitoring and risk assessment of transmission lines, potential problems can be identified and solved in a timely manner, and the reliability and stability of transmission lines can be improved.

Operating status monitoring includes real-time monitoring of various parameters of transmission lines, such as current, voltage, temperature, etc. Sensors and monitoring devices are installed in key locations, collecting relevant data and transmitting it to monitoring centers. The monitoring center uses

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professional software to analyze and process data, find abnormal situations in time, and take corresponding measures to deal with them. Monitoring data can help O&M personnel understand the real-time status of transmission lines and prevent potential failures.

Risk assessment is a comprehensive assessment of possible risks in transmission lines. The assessment includes the aging of transmission lines, the health of equipment, environmental factors, etc. By comprehensively assessing these factors, the degree of risk present in the transmission line can be determined and corresponding control measures can be developed. Risk assessment can also predict future risk trends based on historical data and experience, and provide decision-making basis for O&M personnel. Based on the results of operation status monitoring and risk assessment, corresponding operation and maintenance plans can be formulated. For example, for transmission lines with abnormal conditions, timely repairs or replacement of critical equipment can be carried out to ensure the safe operation of the line. For transmission lines with higher risk, the frequency of inspections can be increased, preventive maintenance can be strengthened, and potential failures can be reduced. It is extremely important to supervise relevant personnel to implement transformer fault diagnosis in place, which is of great significance to ensure the safe operation of the entire power system equipment and people's lives and property are not threatened [5].

4.1. Methods and tools for fault diagnosis of transmission lines

The fault diagnosis of transmission lines is an important part of ensuring the safe and stable operation of the power grid. Commonly used methods and tools include thermal imaging cameras. You can detect hot spots on the line to determine whether there is an abnormality. When the line has problems such as local overload or poor contact, heat is generated, showing obvious hot spots in infrared images. By using infrared thermal imaging cameras for inspection, potential failure points can be found in time. An ultrasonic detector can be used to detect the discharge phenomenon on the line. When the line insulation is damaged or degraded, a discharge signal is generated. Ultrasonic detectors can receive and analyze these signals to determine the location and type of fault; The power wireless temperature measurement system can monitor the temperature of various parts of the transmission line in real time and transmit the data to the monitoring center for analysis. Through the monitoring of temperature changes, it can be judged whether there are problems such as overload and poor contact of the line; High-frequency impedance measuring instrument can be used to diagnose poor contact problems in transmission lines. By measuring the impedance change of the line, the location and degree of poor contact can be determined; The line parameter measuring instrument can measure the current, voltage, power factor and other parameters of the transmission line and compare it with the theoretical value. Through the measurement and analysis of parameters, it can be judged whether there is a fault or abnormal situation in the line; The data analysis software can process and analyze the collected monitoring data, determine whether the line is faulty through algorithms and models, and give corresponding diagnostic results and suggestions.

4.2. Case studies of transmission line failures

On a 500kV high-voltage transmission line in a certain city, a serious failure occurred. The failure led to outages of transmission lines and large-scale blackouts, with serious impacts on local residents and businesses. The transmission line is an important long-distance transmission channel that connects the two cities and supplies electricity to the surrounding area. One night, multiple users suddenly reported a power outage in their area. The dispatching center immediately sent maintenance personnel to the site for troubleshooting. When maintenance personnel arrived at the scene, they found that one of the conductors of the transmission line had broken significantly, resulting in the inability to transmit electricity. After a preliminary inspection, a damaged insulator was found on the wire. Further investigation revealed that the insulator may have been damaged due to external causes (such as wind, rain, birds, etc.), which in turn caused the conductor to break, thus causing the failure of the entire transmission line. In response to the fault case, the dispatch center took the following measures to deal with it: emergency power outage and isolation: In order to ensure the safety of personnel, the dispatching

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center immediately issued an emergency power outage order, and isolated the fault area to prevent the fault from expanding, and notified the user to limit the use of electricity.

Troubleshooting and repair: Maintenance personnel replace damaged insulators and repair broken wires to ensure that transmission lines can operate normally. At the same time, a thorough inspection of the entire transmission line is carried out to confirm whether there are other potential problems.

Fault analysis and improvement: Through the in-depth analysis of the fault case, the dispatching center can summarize the lessons learned and take corresponding measures to improve the reliability and anti-interference ability of the transmission line, such as strengthening the protection measures of insulators, regular inspection and maintenance.

This transmission line failure case illustrates a common failure scenario that can occur in transmission systems. Timely troubleshooting and repair measures, as well as fault analysis and improvement measures, are of great significance to ensure the stable power supply of transmission lines and improve the reliability of the power grid. Through similar case studies, valuable experience can be gained to improve the safety and reliability of power systems.

5. Advantages and challenges of power equipment monitoring and fault diagnosis technology

5.1. Technical advantages and application prospects

Power equipment monitoring and fault diagnosis technology has obvious advantages in improving reliability, reducing maintenance costs, enhancing predictive maintenance, and improving operational efficiency. With the continuous development of technology and the expansion of application scenarios, this technology has broad prospects in smart grid, renewable energy integration, big data analysis and cross-border applications.

5.2. Challenges and Problems

Power equipment monitoring and fault diagnosis technology faces challenges and issues in data management and processing, complexity and diversity, reliability and accuracy, resources and cost, data security and privacy protection, and legal and regulatory requirements. However, with the continuous development and innovation of technology, these challenges can be gradually solved and promote the widespread application of monitoring and fault diagnosis technology in the power industry.

5.3. Future research direction and development trend

In the future, power equipment monitoring and fault diagnosis technology will become more and more intelligent, automated, and combined with other advanced technologies to achieve comprehensive monitoring and accurate diagnosis of the operation status of the power system, and provide strong support for the safe and stable operation of the power system.

6. Conclusion

This paper introduces the advantages of power equipment monitoring and fault diagnosis technology in improving reliability, reducing maintenance costs, enhancing predictive maintenance, and improving operational efficiency. With the continuous development of the technology and the expansion of application scenarios, the technology has broad prospects in smart grid, renewable energy integration, big data analysis, and cross-border applications. Future research directions for power equipment monitoring and fault diagnosis technology will mainly include data-driven fault prediction and diagnosis, cross-field fusion applications, adaptive and self-healing capabilities, open data sharing and standardization, intelligent operation and maintenance management, new materials and sensor technology, and security and privacy protection. These directions will further promote the development of monitoring and diagnostic technologies to improve the reliability, efficiency, and safety of power systems.

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