Research on thermal imaging fault detection system based on weibull distributed electrical system

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Abstract. A fault prediction analysis is performed in order to use infrared thermal imaging technology to detect electrical system faults, based on Weibull distribution technology. First, the principle is explained, the key technologies and factors of infrared thermal imaging and the electrical fault monitoring system are analyzed, and the available technologies are summarized. The detection process and analysis research are established with the help of on-site inspection and analysis results for power system fault analysis and research. The research shows that the method is effective for fault detection and trend analysis, and provides a reference for power fault detection and prediction analysis.

1. Introduction

This paper is based on the thermal imaging principle of the Weibull distribution electrical system to analyze and study part of its fault detection system. In this study, Weiber distribution analysis method is used to analyze and predict the failure of relatively accurate small data samples. According to the obtained probability values, the distribution parameters are predicted and deduced, which provides a basis for preventive maintenance and maintenance, and the data are processed to predict the life and reliability of electrical components [1-3]. To Study the weak link of the electrical system, implement "condition-based maintenance", and put forward the solution of the problem At the “International Conference on Large Power Grids (CIGIE)” held at the end of the 20th century abroad, infrared diagnostic technology was recognized by most countries, and pointed out that the application of this technology makes the maintenance of electrical equipment transition from passive maintenance to proactive prevention, which is of great significance for improving the reliability of system operation [4]. Now infrared thermal imaging detection technology has become the most widely used detection technology after the five conventional non-destructive testing of ultrasonic (UT), radiography (RT), ET (ET), magnetic particle (MT) and penetrant testing. Currently, epidemic prevention and control and the power industry are the most important application areas of infrared thermal imaging detection technology.

Infrared imaging is used in China to diagnose internal defects of high-voltage switch insulation rods and ultra-high-voltage insulation tools [5]. After a large number of field tests and experiments, the researchers have mastered the basic characteristics of the external infrared thermal image of various electrical equipment internal and external failures, as well as a large number of typical infrared spectra of various equipment failures and the temperature change law of the equipment.

Aiming at the current status of insufficient mastery of electrical system status information by existing enterprises, backward maintenance methods, and sufficient quantitative analysis of the status of most
electrical systems and sufficient predictive capabilities for failure trends, combined with condition monitoring and diagnosis technology, using the idea of condition maintenance, and infrared technology, image analysis and processing technologies, establish a "real-time dynamic" condition-based maintenance mode, and use computer and database technology to develop an electrical fusion state monitoring and diagnosis system [6-7]. It provides a new path for the modernization of enterprise electrical management for how to prevent electrical failures, eliminate accidents, extend the operating cycle of electrical equipment, and reduce maintenance costs.

The safe and reliable operation of the electrical system is an important guarantee for the safe production of enterprises. In the actual operation and management of the electrical system, about 70% of the power system failures are caused by electrical equipment failures, and more than 50% of the electrical equipment failures are caused by leakage, magnetic leakage, weak connection, poor contact, etc. When the electrical equipment of the enterprise is operated for a long time in a harsh environment with a small space and poor heat dissipation, the electrical equipment is prone to abnormal heating conditions, metal parts being "creep", and the insulating parts being easy to age and lose their insulation. These will cause serious damage to the equipment. A power grid accident occurred. For example, when the transformer tap has a bad contact, the temperature rise will occur, and the weakening of the elasticity of the compression spring will lead to the worse contact of the joint, which in return increases the temperature rise and eventually causes the equipment to malfunction.

2. Weibull distribution

Weibull distribution is the theoretical basis for reliability analysis and life testing of electrical systems. This theory is widely used to study the distribution of cumulative failures of electromechanical products. Based on the probability value to predict and infer its distribution parameters, the basis for preventive maintenance and maintenance, and data processing to predict the life and reliability of electrical components. The study adopts the Weibull distribution study, which is based on its relatively accurate failure analysis and failure prediction of small data samples, and formulates solutions to problems as soon as possible. By studying the shape of the distribution state, maintenance measures can be selected well. The slope of the Boolean probability graph is a clue to the physical failure, and further study the weak links of the electrical system and carry out "condition-based maintenance".

The life distribution function of the three-parameter Weibull distribution is shown in formula (1).

\[ F(N) = 1 - \exp \left( - \left( \frac{N - \gamma}{\eta} \right)^m \right) \]  

(1)

\( N \) is the life of the part, \( m \) is the shape parameter, \( \eta \) is the scale parameter, and \( \gamma \) is the position parameter.

Most electrical system failures are functions of time, and a lot of practice and research have shown that it is a "bathtub curve". When the position parameter \( \gamma = 0 \), the three-parameter Weibull distribution is simplified to the two-parameter Weibull distribution probability density function, as shown.

\[ g(t) = \frac{m}{\eta} \left( \frac{t}{\eta} \right)^{m-1} \exp \left( - \left( \frac{t}{\eta} \right)^m \right) \]  

(2)

t is the time from normal to complete failure of the electrical system.

The cumulative distribution function of failure rate is shown in formula (3).

\[ G(t) = 1 - \exp \left( - \left( \frac{t}{\eta} \right)^m \right) \]  

(3)

The reliability function of the electrical system is shown in formula (4).

\[ R(t) = 1 - G(t) = \exp \left( - \left( \frac{t}{\eta} \right)^m \right) \]  

(4)

In order to calculate the Weibull cumulative distribution function, the two-parameter Weibull distribution probability density function (2) is derived from both sides and the logarithm is obtained, as shown in (5).

\[ \ln \left( \ln \left( \frac{1}{1-G(t)} \right) \right) = m \ln t - m \ln \eta \]  

(5)

In order that the Weibull distribution function can be converted into a solving function, let \( \ln[\ln(1/(2-G(t)))]=y; \ln t=x; \) then
y = mx - mlnn

Carry out linear regression analysis according to the least square method, find the slope m value and intercept mlnn value in the linear equation.

The median rank method is used in the selection of the Weibull distribution function value. The failure rank is the order of the electrical components obtained in the infrared electrical fault detection from normal operation to failure, and the sequence number is marked, and the failure time is ranked from small to large. Serial number. As shown in formula (6).

\[ G(t_i) = \frac{i^{0.3}}{k^{1.4}} \]  \( (6) \)

i is the failure rank; k is the total number of electrical fault detection samples, and G(ti) is the Weibull distribution function value of the electrical fault electrical components under the i rank. In order to fully grasp the status of electrical fault detection, the infrared thermal imager must always be in a real-time monitoring state. Through the secondary development of the thermal imager, the camera is controlled to capture the thermal image regularly to shorten the experiment time of electrical faulty electrical components. An optical calculator can be used to accurately determine the size of the surface of an object. Use your optical data and the distance of the measurement target to measure the field size, pixel size (IFOV) and determined 3 x 3 pixels (MFOV), so that you can avoid measurement errors and fix Optris in an appropriate manner as much as possible. The location of the thermal imager.

3. The electromagnetic radiation spectrum

In a literal and physical sense, a spectrum is understood as the intensity of a mixture of electromagnetic waves that function as wavelength or frequency. The electromagnetic radiation spectrum covers a wavelength area of about 23 decimal powers and varies from sector to sector in origin, creation and application of the radiation. All types of electromagnetic radiation follow similar principles of diffraction, refraction, reflection and polarization. Their expansion speed corresponds to the light speed under normal conditions, the construction of a black body is simple. A thermal hollow body has a small hole at one end. If the body is heated and reaches a certain temperature, and if temperature equilibrium is reached inside the hollow room, the hole ideally emits black radiation of the set temperature. For each temperature range and application purpose the construction of these black bodies depends on material and the geometric structure. If the hole is very small compared to the surface as a whole, the interference of the ideal state is very small. If you point the measuring device on this hole, you can declare the temperature emitting from inside as black radiation which you can use for calibrating your measuring device. In reality, simple systems use surfaces, which are covered with pigmented paint and show absorption and emissivity values of 99% within the required wavelength range. Usually, this is sufficient for calibrations of actual measurements. With rising temperature the maximum of the spectral specific radiation shifts to shorter wavelengths. As the formula is very abstract it cannot be used for many practical applications. But, you may derive various correlations from it. By integrating the spectral radiation intensity for all wavelengths from 0 to infinite you can obtain the emitted radiation value of the body as a whole. This correlation is called Stefan Boltzmann law. The illustration shows the basic construction of an infrared thermometer. Using input optics, the emitted infrared radiation is focused onto an infrared detector. The detector gene-rates an electrical signal that corresponds to the radiation, which is subsequently amplified and can be used for further processing. Digital signal processing transforms the signal into an output value proportional to the object temperature, which is then either shown on a display or provided as an analog signal. An infrared thermometer, As shown in figure 1.
The most important element in each infrared thermometer is the radiation receiver, also called detector. There are two main groups of infrared detectors. With these detectors, the temperature of the sensitive element changes due to the absorption of electromagnetic radiation. The temperature change causes a modification of the temperature-dependent property of the detector, which is electrically analyzed and serves as a measure for the absorbed energy. The decisive difference between quantum detectors and thermal detectors is their faster reaction on the absorbed radiation. The mode of operation of quantum detectors is based on the photo effect. The visible photons of the infrared radiation lead to an increase of the electrons into a higher energy level inside the semiconductor material. When the electrons fall back, an electric signal (voltage or power) is generated.

4. Research implementation
Through the investigation and analysis of the distribution of electrical equipment in the enterprise and the structure of the system, study the distribution of measurement points and the object segmentation of electrical equipment at the location of the measurement points. Reasonably arrange the measuring points to achieve full coverage of the monitoring of key electrical equipment such as power distribution cabinets and transformers of the enterprise electrical system. The wireless infrared temperature sensor is used to realize the temperature monitoring of the key parts of the key electrical equipment, and the visible light camera and the infrared camera are synchronously driven by the pan-tilt to realize the overall monitoring of the key electrical equipment. Realize multi-measurement point information tour collection through field bus. Aiming at the preset position of the wireless infrared temperature sensor, through field testing, to ensure that the preset position monitors the temperature of the key parts, for the PTZ system, through field experiments and manual adjustments, preset the rotation of the PTZ Stay (image acquisition) position, so that the infrared imaging of the electrical equipment at that position is the best in terms of location, content, and environmental adaptability. Through the first inspection, the visible light image and infrared imaging of each preset location are taken at the same time. Through image processing and two image comparison methods, the location device is registered with the characteristic temperature to construct the location device and its characteristic temperature database. Through the fusion and registration of the dual detection data of the infrared temperature sensor and the infrared camera, a full coverage, focused, more accurate and reliable temperature monitoring is realized. Analyze the composition of the electrical system at the preset location and its temperature characteristics.
when it fails, and design fault diagnosis methods for each device based on the temperature characteristics. In the process of equipment monitoring and inspection, online monitoring and fault diagnosis of key electrical equipment are realized based on the images taken by the monitoring inspection station, image analysis and processing methods, location equipment libraries, and equipment temperature characteristics fault diagnosis methods. The first inspection information, cruise inspection information, and fault diagnosis information are stored in the system in a unified format as a system file for reference. The key monitoring and diagnosis information is shared with each workstation in the mode of wireless transmission.

Study the distribution of electrical equipment, system composition, failure causes and files of the enterprise, and classify electrical equipment (general, severe, and dangerous) based on temperature rise and degree of hazard. Research the problem of object segmentation, reasonably plan infrared monitoring points, and realize the monitoring of key electrical equipment such as power distribution cabinets and transformers. Through the reasonable layout of measurement points, the full coverage of the monitoring of key electrical equipment such as enterprise power distribution cabinets and transformers can be realized. The temperature monitoring of key parts of key electrical equipment is realized through wireless infrared temperature sensors, the infrared camera is driven by the pan-tilt to realize the overall monitoring of key electrical equipment, and the information of multiple measuring points is patrolled through the field bus.

Integrate infrared sensing, infrared camera, field bus, computer, image analysis and processing and other related technologies to build a distributed monitoring and management system for enterprise electrical equipment as a whole to realize centralized online fault information of key electrical equipment such as power distribution cabinets and transformers Monitoring, transmission, intelligent analysis and early warning functions. Aiming at the preset position of the wireless infrared temperature sensor, through field testing, to ensure that the preset position monitors the temperature of the key parts, for the pan-tilt system, through field experiments and manual adjustment methods, preset each stop of the pan-tilt rotation (Image acquisition) location, so that the infrared imaging of the electrical equipment at that location is optimized in terms of location, content, and environmental adaptability.

Based on on-site inspection data, research on infrared thermal image enhancement, noise reduction, segmentation, compensation, matching, analysis and other issues based on the characteristics of enterprise electrical equipment failures, so as to achieve accurate extraction of electrical equipment characteristic temperature data. Through the first inspection, the infrared imaging of each preset location is taken at the same time, and the location device is registered with the characteristic temperature through image processing and two image comparison methods. Build a database of location equipment and its characteristic temperature. Through the fusion and registration of the dual detection data of the infrared temperature sensor and the infrared camera, a full coverage, focused, more accurate and reliable temperature monitoring is realized. According to the characteristics of enterprise electrical equipment failure, integrate absolute temperature judgment method, relative temperature judgment method, similar (in-phase) comparison method, thermogram analysis method, file analysis method, etc., to realize the diagnosis, prediction, and early warning functions of electrical equipment faults. By analyzing the composition of the enterprise's electrical equipment at the preset location and its temperature characteristics at the time of failure. Based on temperature characteristics, design fault diagnosis methods for each device. During the equipment monitoring and inspection process, based on the images taken by the monitoring inspection station, image analysis and processing methods, location equipment libraries, and equipment temperature characteristics fault diagnosis methods, online monitoring and fault diagnosis of key electrical equipment are realized.

5. Conclusions
Enterprise electrical system failure is a process of continuous increase in the local temperature of the equipment, gradual aging of the insulation, and gradual increase in leakage, and then a process of breakdown from quantitative to qualitative change. Therefore, temperature characteristics are the carrier of the enterprise's electrical system operating well, and electrical equipment based on infrared
monitoring. Fault diagnosis has the advantages of non-contact, real-time, online, large-area rapid scanning, reliable detection, easy calculation and analysis and management of data, and has achieved remarkable results in power generation, power distribution and other places. Real-time monitoring of equipment operating status, prediction, prediction, and early warning before enterprise electrical failures, and effective measures to eliminate hidden dangers, so as to ensure the safety of enterprise power grids and power systems, promote the development of intelligent, systematic and standardized enterprise electrical equipment management, promote the development of enterprise electrical equipment management in the direction of "conditional maintenance" and reduce maintenance costs. According to the infrared thermal imaging expert system Analysis, the thermal imaging map is divided, so it has accurate, real-time, dynamic, high-efficiency, non-contact monitoring Test capability, which can check the status of high-voltage electrical equipment. The body of equipment seems to be less affected by strong electromagnetic interference around it, and it is safe and stable, Reliable, and worthy of development and application in the future smart grid era. It has become the most important inspection method for the state maintenance of power equipment in the future transmission grid.

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