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Transformer fault detection based on infrared power image

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Abstract. The purpose of this study is to study the transformer fault detection based on infrared power image. Based on the infrared detection method of transformer, a scheme of on-line fault detection for power transformer is proposed. The transformer fault on-line detection and diagnosis system is designed. The effect of on-line detection of transformer faults is tested. The system focuses on a particular area. Through the fault temperature threshold and the rate of temperature change, it can predict the operation of the equipment. Combining the information in the infrared image database, it can determine the type of transformer failure. The results show that the application of infrared diagnosis technology in transformer fault diagnosis ensures the normal operation of transformer, improves the utilization ratio of transformer, and reduces the economic loss of power system. Therefore, it can be concluded that the system realizes on-line fault detection of infrared image of transformer.

Key words. Infrared detection, power transformer, image processing, fault diagnosis.

1. Introduction

In the process of power transmission and distribution, power transformers are one of the most critical devices in the grid [1]. It is responsible for power transmission and voltage and current conversion and other functions [2]. Its operating state directly affects the integrity of the entire power system operating chain. Therefore, it is very important to reduce and prevent transformer failure [3]. The safe operation of the transformer is not only an economic problem, but also a matter of social public interest [4]. With the expansion of power production scale, the security of power generation is becoming higher and higher [5]. In the live state, the maintenance technique determines the operation of the equipment [6]. The on-line detection technology of transformer can improve the reliability of equipment, reduce the cost of equipment maintenance and improve the economic benefits [7]. The infrared thermal imaging or the infrared thermography is based on the principle of infrared radiation [8]. By measuring the infrared radiation energy of the object surface, the

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temperature distribution on the surface of the object is converted into an image of an intuitive thermal image (greyscale or color chart) for subsequent analysis [9]. Because of its fast detection speed, large area and wide range, infrared thermography is more and more widely used in thermal diagnosis of power equipment [10].

Infrared inspection technology is a new state maintenance technology which has been developed in recent years [11]. Through non-contact infrared thermal imaging technology, it can detect the running state of the equipment, so as to keep abreast of the operation of the equipment, find out the cause of the accident and predict the future status of the equipment [12]. At present, infrared detection technology has been widely used. It has become an important means of on-line detection of power equipment [13]. In the detection of power equipment failure, infrared diagnostic technology has the advantages of safe operation, high sensitivity, accurate judgment, visual image, high detection and diagnostic efficiency, and free from electromagnetic interference [14]. It can be calculated and analyzed. It can detect and diagnose a large number of internal and external defects in power transformers, and quickly perform infrared imaging on the device's thermal state. Through the analysis of the infrared image distribution of the transformer, the hidden faults and defects of the transformer in operation are diagnosed. The infrared detecting technology can find the hidden trouble of transformer in time and accurately. It reduces energy losses caused by equipment failures, thereby avoiding certain electrical equipment accidents. In the safe operation of power equipment, fault detection technology has played a significant role [15].

2. State of the art

As far as the international scope is concerned, in the middle of 1960s, the Swedish national electric power company firstly applied infrared thermal imaging technology to the fault diagnosis of power equipment. In 1980s, under the auspices of the American Electric Power Research Institute, American road research and development company developed a new on-line monitoring instrument for internal temperature of high-pressure equipment, that is, fluorescent fiber thermometer. The British and Swiss state power bureau and the former Soviet Union electricity management department have set up standards and procedures for using infrared inspection technology to detect power equipment. In 1993, Detroit Edison and Illinois State Electric Company introduced the latest developments in the detection of electrical equipment in overhead transmission lines, substations and power stations by infrared detection technology. It shows that the infrared detection and diagnosis technology has become an important technical means for monitoring the power equipment, discovering the hidden dangers and preventing the sudden and sudden malignancy. The American Electric Power Research Institute published the RP1289-1 report in June 1994. It points out that optical fiber point thermometer plays an important role in ensuring the operation life of transformer and reducing the fault of power transformer. In China, in 1960s, the Northeast power technology improvement bureau, Shenyang Electric Power Bureau and Changchun Institute of Optics and optics jointly developed the first generation of power equipment detection and diagnosis infrared thermometer.

In 1988, the North China electric power test research institute undertakes the main research on infrared diagnosis technology of power generation and transformation equipment. In 2008, the national development and Reform Commission promulgated the code for application of infrared diagnostics of live equipment (DL1T664-2008). In October 2009, in the "national Power Grid Corp high voltage skills competition" held in Xi'an, the infrared diagnosis was listed as one of the important events. Dai Wenyuan proposed a theoretical model for establishing the relationship between the size of the defect to be measured and the brightness level in the infrared thermal image. Wang Yanwu proposed a method to simulate the two-dimensional temperature field according to the temperature distribution curve. The defect types within the material are determined by simulating the temperature field. However, according to the surface temperature measurement results, the theoretical model for accurate identification of defect size needs further study. Based on the infrared radiation theory, the infrared radiation model of the inner parts of the shell was established when the internal components were overheated. Based on the infrared imaging temperature measurement of shell surface, the inverse problem of heat conduction is studied by using conjugate gradient method, and the heating temperature and orientation of internal components are identified. According to the characteristics of electrical equipment failure and the characteristics of infrared diagnosis of electric power, Jiang Dingyou studied a method of automatic fault recognition of red heat image of high pressure equipment. Yang Zhengbo, who use infrared imager to obtain the transmission line temperature change image. Based on the analysis of the characteristics of the infrared image of the transmission line, the edge information of the image is obtained by comparing the advantages and disadvantages of each color space and applying HSI color space conversion. With the advantage of preserving the edge information by median filtering, the improved median filter is used to eliminate the interference. The highest temperature region is extracted by the gradient method, which can quickly and accurately diagnose the fault of the transmission line. In China's power industry equipment fault diagnosis, infrared diagnosis has made some progress. However, from the equipment diagnostic engineering, it is still in the initial stage. Therefore, standardization and intelligentization are the future directions of infrared diagnostic technology.

3. Methodology

In fact, through the analysis of the temperature field of the running equipment and the study of the thermal image, the nature of the equipment fault is determined. That is, by revealing the local overheating or abnormality of the surface by means of the transformer, the source of the fault is found. This requires a large number of on-site operation of the transformer for infrared scanning detection. The transformer fault can be distinguished only by mastering the law of thermal image of transformer faults. The infrared image fault detection and diagnosis system mainly uses the infrared image. It converts the image information into the temperature information of the equipment. According to the temperature value and change of parts, the operation of the equipment is predicted.

The design idea of fault diagnosis system is as follows: the infrared image is enhanced by linear transformation and histogram equalization algorithm. Wavelet packet threshold algorithm is used to denoise infrared image. The Canny operator edge detection method is used to segment the image. The improved H-u invariant moments are used to extract infrared image features, and the nearest neighbor classifier is used for image recognition. With Visual Basic 6.0 as the developing tool, the on-line fault detection and diagnosis system of power transformer is designed. The key of fault diagnosis is to establish the database corresponding to the fault and temperature information. Database-saved data and infrared image data can also provide analytical data for archival analysis. Infrared image database includes the following: Transformer parts of the normal operation of the infrared image and the corresponding fault infrared images, the average temperature of each part of the equipment is running, the operating voltage / current, the maximum temperature of the current part of the transformer, the operating voltage / current and ambient temperature, the type of image (faulty, faulty description, cause of failure) and so on. The processing of infrared images is shown in Fig. 1.

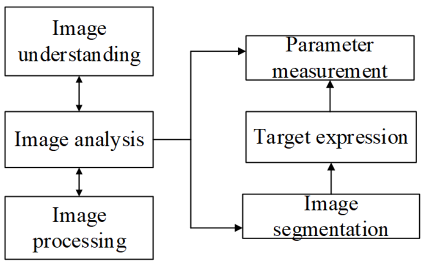

Fig. 1. Activity period of the sensor node and the wireless communication base station

After the normal operation for a period of time, the surface temperature distribution of the transformer will tend to be stable or the rate of change tends to be stable, that is to say, it will enter a relatively stable state. However, from the beginning of the work to the steady state, the surface temperature changes follow certain rules. According to this rule, the temperature variation curve can be plotted. When the monitoring site fails, the surface temperature change curve will change, and the temperature will rise at a certain rate.

Transformer infrared diagnostic steps: According to the image displayed at the abnormal temperature of the device, the infrared image of the abnormal part is acquired. The infrared thermal image is processed and segmented to facilitate the diagnosis of equipment faults. According to the operation principle of the equipment and the operation data of voltage and current, the fault types are judged. According to DL/T664-2008 standard, equipment defects are classified. According to the characteristics of temperature difference and image, the qualitative conclusions of defects are made. Depending on the nature of the defect, the cause of the site fever is found.

4. Result analysis and discussion

As shown in Fig. 2, the maximum temperature of the transformer monitoring site changes with time. It can be seen from the figure that the initial temperature rise rate is the largest and decreases with time. Finally, the state tends to be stable. In the figure, curve 3 represents the temperature change during normal operation of the transformer. It can be observed that the transformer operating temperature finally rises to a steady state. When the temperature is stable, the operating temperature of curve 2 is greater than the threshold value T. It can be seen from the figure that the temperature change rate k of curve 2 after stabilization is almost zero. It proves that the transformer can continue to run, but it is also in general alert. The curve 1 is mutated when the transformer temperature is about to enter a steady state. Temperature change rate $k > 0$ will indicate a serious failure. It will prompt the dialog box, warning the device failure. Therefore, in the transformer fault incubation period, the potential failure can be diagnosed by measuring its temperature change rate.

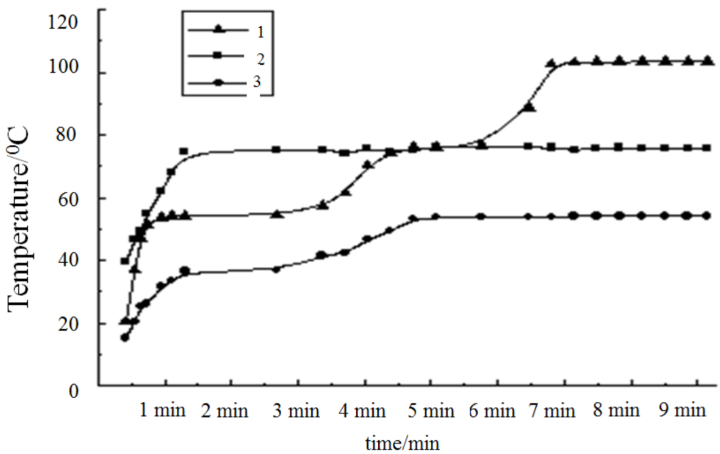

Fig. 2. Change of the maximum temperature of transformer with time

The infrared thermal image of the collected transformer casing was tested. The fault diagnosis of the transformer is tested by the fuzzy temperature difference method. The general failure of the equipment is obtained, and possible causes of such failure are listed. Field inspection showed that the connection of transformer bushing was bad.

5. Conclusion

In this paper, based on infrared image recognition and diagnosis technology, the on-line detection of power transformer is carried out. Through the theoretical analysis and experimental simulation test, the application of infrared diagnosis technology in transformer fault diagnosis is realized. The utility model ensures the normal operation of the transformer, improves the utilization rate of the transformer and reduces the economic loss of the power system. In the future work, on the basis of a large number of detection experiments, the nature of transformer faults needs to be further studied. Through the infrared thermal image, the equipment failure is described in detail. It reveals the root causes of various failures and improves the ability to diagnose faults.

The following aspects need to be improved and perfected. The improvements in the algorithm are limited. By using classical image processing and segmentation algorithm, the infrared image is processed and segmented. Although a certain effect has been achieved, it is necessary to do more improvements, in order to achieve better display results. Because of the faults of the transformer, the source of the infrared image is limited, and the number of the contrast samples in the database is not enough, which makes the experimental results convincing. In future tests, the fault information in the database should be filled at any time. The problems such as the infrared thermal image characteristics, the internal relationship between the infrared thermal image and the fault type are still needed to be studied deeply and systematically.

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