# Review on Application of Infrared Detection Technology in State Detection of Electrical Equipment

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**Abstract.** Electrical equipment will generate a lot of heat during operation, which greatly increases the frequency of electrical equipment failure. Accidents caused by thermal failure of electrical equipment occur frequently. Infrared detection technology can realize fast and real-time on-line monitoring and fault diagnosis and analysis of electrical equipment. This paper introduces the principle of infrared detection technology, analyzes the role of infrared image in the detection and treatment of thermal faults and gas leakage faults of electrical equipment, summarizes the applications of infrared detection technology in edge detection, image segmentation, image registration, gas leakage detection and infrared equipment carried by line patrol robot, and summarizes the advantages of various technical methods.

**Keywords:** Infrared detection technology · Thermal fault · Condition monitoring of electrical equipment · Fault diagnosis and analysis

## 1 Introduction

With the comprehensive application of electrical equipment and the accumulation of time, equipment aging, insulation deterioration and other phenomena are becoming more and more serious, which will lead to a variety of power faults and equipment defects. Among them, thermal fault is one of the most common faults, which directly affects the normal operation of the whole power system. Therefore, regular inspection and fault diagnosis must be carried out for the equipment. Conventional detection methods need to be based on equipment shutdown, but with the continuous increase of electrical equipment, the requirements for shutdown inspection are higher and higher, resulting in greater and greater economic losses.

With the continuous development of infrared image analysis technology, the advantages of infrared detection in analyzing thermal faults of electrical equipment gradually appear. Its biggest advantage different from conventional detection methods is to realize on-line state detection and thermal fault diagnosis and analysis without equipment shutdown. Therefore, in recent years, it has been more and more widely used in the field of electrical equipment monitoring at home and abroad.


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## 2 Overview of Infrared Detection Technology

All objects have the continuous movement of molecules, which will cause the object to continuously radiate the thermal radiation that can indicate the characteristic information of the object, and the thermal radiation corresponding to different temperatures is also different. So, the object information can be obtained through the infrared imaging map [1]. Usually, infrared detection technology is used to obtain the temperature distribution of the object surface, and then the infrared radiation signal is converted into an electrical signal, and then the electrical signal is amplified. Finally, the surface temperature field distribution of the object is displayed in the form of digital image [2]. Infrared thermal imaging method is a detection technology that scans the thermal radiation radiated by an object into an image. The thermal fault detection of power equipment using infrared image analysis improves the detection efficiency and operation safety [3].

### 2.1 Advantages of Infrared Detection Technology

(1) Safe operation. In infrared detection, non-contact operation is carried out, which is convenient and safe. It has obvious advantages in fault detection of live equipment, rotating equipment and high-altitude equipment.
(2) Dynamic on-line monitoring of electrical equipment can be carried out without shutdown, which improves the continuity and reliability of equipment operation, and avoids economic losses caused by equipment shutdown.
(3) It can realize large-scale and rapid scanning, and the results of status display are visual and intuitive. It can effectively improve the detection efficiency and reduce the labor intensity of maintenance personnel.
(4) The result of infrared detection is thermal image. The output result is convenient for computer analysis and promotes the development of power system in the direction of intelligence.

## 3 Common Methods of Infrared Detection

At present, there are five common infrared detection and analysis methods for electrical equipment [4]: ① surface temperature discrimination method: after measuring the temperature value of the equipment surface, observe whether the temperature rise exceeds the specified standard according to the corresponding standards, to judge whether the equipment is faulty. ② Relative temperature difference method: relative temperature difference refers to the ratio percentage of the temperature difference between two observation points of the same equipment and the temperature rise of the observation point with higher temperature under the same state. ③ Similar comparison method: when the equipment is abnormally hot, it is compared with the original data of temperature rise at the corresponding parts of the same type of equipment in the same circuit. Generally, when the temperature difference of the same kind exceeds 30%, it is determined as a major defect. It is mainly used for diagnosis of current type and voltage type equipment. ④ Thermogram analysis method: judge whether the equipment has defects according

to the difference between the thermogram of the same type of equipment under abnormal conditions and normal conditions. ⑤ Archival analysis method: the premise of this method is to establish temperature rise and heat map archives for the tested equipment, and compare the detected results with the data in the archives to obtain the diagnostic results. The accuracy of temperature measurement data shall be ensured in practical operation.

## 4 Application of Infrared Detection of Electrical

### 4.1 New Infrared Image Edge Detection Technology

In general, the thermal image of the equipment collected by the infrared instrument will be very fuzzy, and the details shown in the image are few, and it is also affected by noise interference, which is not enough to analyze the fault of the image, so effective methods are needed for edge detection of the infrared image.

Literature [5] combines nonlocal mean filtering algorithm and median filtering algorithm to filter the interference of noise, and then enhances the edge of infrared image through the advantages of 10 norm smoothing algorithm. Literature [6] focuses on solving the problems of low contrast and fuzziness of infrared images, and proposes a binary image edge detection method combined with cellular neural network (CNN). Literature [7] and [6] also use cellular neural network to detect the edge of infrared image, but this literature mainly uses FPGA technology to construct virtual neural network to realize real-time image processing. Reference [8] studies the application of particle swarm optimization algorithm to image edge detection, which can better improve the interference to noise and obtain complete edge information than traditional algorithms.

Among them, document [9] proposed a new infrared image edge detection method, which improved the traditional LOG operator by using mathematical morphology, and then combined with the improved Roberts operator data. Finally, the image edge information obtained by the two methods was fused to obtain the final edge image. This method makes full use of the advantages of the two operators and obtains an infrared image with strong anti-interference and accurate positioning.

### 4.2 Thermal Fault Detection System Based on Infrared Image Analysis

Before the infrared technology, the thermal fault monitoring of electrical equipment mainly relied on the active temperature sensor to monitor the temperature of the equipment, but this method has low accuracy, low efficiency and is greatly affected by the environment.

Document [10] proposed a portable infrared detection system under the advantages of the development of electronic circuit technology, which has the advantages of high efficiency, portability and low cost. Document [11] is an early infrared image analysis system in China, which first combines infrared image and computer analysis, making up for the gap in this technical field.

On this basis, document [12] proposed a new thermal fault detection system based on infrared image analysis. This system is mainly composed of image acquisition module

and image detection module. The image acquisition module is responsible for the acquisition of infrared images of the equipment, and the image detection module is responsible for fault analysis of the collected infrared images. The image acquisition module collects the infrared image of the device and sends it to the image detection module. The image detection module analyzes the image to obtain the temperature value. If the temperature value exceeds the normal temperature threshold of the device, an alarm will be sent automatically.

In addition, in order to improve the accuracy of diagnosis results, reference [13] modifies some parameters of the system, such as emissivity of temperature value and distance correction of temperature value.

(1) The emission correction rate of image acquisition instrument needs to jump to the appropriate position. Different emission rates have a great impact on the definition of infrared image.
(2) The distance correction of temperature value mainly includes two methods: coefficient correction and wind speed correction.

Coefficient correction: it refers to summarizing the law of temperature variation with distance according to the experimental data. The temperature error caused by different distances can be offset by coefficient correction at different distances.

Wind speed correction: if there is natural wind in the detection scene, the wind will affect the diffusion of heat in the standby, and have a great impact on the image acquisition of the detection equipment.

### 4.3 Infrared Image Registration Technology

The infrared detection system needs to have a certain image recognition ability, that is, image registration, which is to classify the collected infrared thermal images. It is based on extracting various unique information features from the thermal images and comparing them with the original knowledge base. The greater the matching degree of feature information, the image will be classified as the corresponding equipment. However, there is a big gap between infrared image and visible image.

Reference [14] proposes to generate simulated infrared image with countermeasure network, extract feature points from the simulated image, establish matching model combined with accelerated robustness, construct mapping function, and finally realize image matching with weighted double multiplication. Even in the same scene, two images are often difficult to match. Therefore, literature [15] filters the infrared image and visible image by segmentation method, and then draws the contour of the target again. The algorithm is used to filter the feature contour and approximate the external quadrilateral of the feature contour, replace it into the transformation model, and finally match.

#### 4.3.1 Template Matching Method

The template matching method refers to pre dividing the reference picture based on the threshold to make a reference template, and then comparing the collected thermal image with the template after preprocessing.

(1) Image segmentation algorithm

Image segmentation algorithm refers to the segmentation of key areas in the thermal image of electrical equipment. The key areas generally have unique attributes or feature forms. The above method adopts the segmentation method based on threshold. The segmented thermal image provides convenience for the subsequent image analysis, processing and matching process. According to Sobel operator, document [16] proposed a method to scale the gradient information of the image by using the scaling factor, and the accuracy of edge detection has been improved. Infrared images generally contain a lot of noise and have low contrast. In view of these shortcomings, literature [17] performs c-means clustering on infrared images in advance, and then transforms lazy snapping algorithm from global segmentation to regional segmentation, and constructs energy function. Through this segmentation algorithm, the segmentation efficiency is greatly improved and has strong robustness. Similarly, aiming at the shortcomings of infrared images, documents [18] and [19] use Fourier algorithm to filter the image to form gradient graphics, then select multiple adjacent points in the gradient graphics to calculate the slope change, and finally separate the target region and noise region to obtain the required segmented image. This method has high segmentation accuracy. In reference [20], Gaussian filtering is applied to the image to retain the overall characteristics of the image gray level, obtain the gradient amplitude map, carry out morphological processing on it, use Otsu threshold segmentation method to segment and mark the image, and finally carry out watershed transformation to obtain the final segmented image. This method solves the phenomenon of over segmentation.

(2) Feature point acquisition

The feature points can replace the relevant points of the peripheral contour curve attribute of the equipment, adopt the corner detection method of the peripheral chain code to collect the feature points, sequentially encode the peripheral points of the segmented thermal image to obtain the peripheral chain code, and obtain the corners of the collected thermal image through the peripheral chain code.

(3) Feature point matching

Calculate the distance between the obtained feature points and the reference template feature points. If the number of points with the same distance exceeds two-thirds, it can be determined as the correct matching point, and then obtain the corresponding variable parameters and mapping relationship to complete the infrared image registration.

### 4.4 Infrared Temperature Measurement and Line Inspection Robot System

In recent years, more and more line patrol robots have been put into the line patrol work of substation, which greatly reduces the workload of maintenance personnel, and is not affected by weather factors, so the line patrol work has higher stability and accuracy.

Documents [21] and [22] proposed the inspection system of line inspection robot equipped with infrared thermometer. The patrol inspection system mainly includes: base station layer, terminal layer and communication layer.

The infrared detection device carried by the robot will carry out real-time online temperature detection for the electrical equipment in the designated area. When the detected

temperature value exceeds the temperature threshold of the equipment, the machine will send an alarm to the terminal and send the fault information to the background for maintenance personnel to arrange repair.

However, the system is only applicable to the internal patrol inspection of the substation and cannot complete the patrol inspection of the UHV transmission system. Document [23] proposes that the UAV is equipped with measuring instruments to patrol the high-voltage transmission line and transmit the infrared image and visible image to the background for calibration. Document [24] also uses the UAV equipped with infrared instrument. When the high-voltage transmission line sends an alarm signal, the infrared UAV can be operated to detect the transmission line, to determine the location of the fault point. In reference [25], aiming at the hidden trouble points of urban cables, UAV is used to take infrared aerial photos of urban power, and the improved Bernsen algorithm is used to analyze the infrared images, which can quickly identify the fault points.

The detection of electrical switchgear is generally to install infrared sensors inside the switchgear, but this method has a temperature measurement blind area and low sensitivity [26]. Documents [27] and [28] use the inspection robot equipped with infrared temperature measurement unit to detect the temperature measurement window on the open light. With the flexible operation of the robot, the flexible inspection inside the switchgear can be completed, and then the state evaluation can be carried out, the system state evaluation system is mainly divided into application layer, middle layer and perception layer [29].

## 5 Summary and Prospect

Infrared detection technology breaks through the visual barrier of human beings, can effectively detect the fault defects that cannot be detected by the naked eye when the equipment is running, can realize the dynamic on-line monitoring of the equipment under the natural conditions that human beings cannot bear, can effectively reduce the probability of dangerous accidents and ensure the safety of inspectors, and has strong anti-interference Strong target recognition ability. It also plays an increasingly important role in other fields outside the field of power system Infrared image acquisition is not difficult, but image analysis and diagnosis has always been the focus of this technology.

The development direction of infrared detection technology in the future should be quantification, combination and intelligence.

(1) Quantification: at present, infrared imaging technology is widely used in the field of equipment fault detection, but most of the image diagnosis methods still stay in qualitative analysis, so the development of infrared technology in the future must be promoted to the quantitative level, with a complete theoretical analysis basis to form an authoritative infrared radiation diagnostic.
(2) Integration: infrared testing is quite different from nondestructive testing. Today, with the development of computer technology, we should constantly explore new methods and algorithms. Combining with other nondestructive testing technologies can solve more practical problems and expand the application field of infrared testing technology.

(3) Intelligence: the future development of infrared detection equipment should be intelligent, simple and flexible, to improve the detection accuracy and portability.

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