1 INTRODUCTION

In the world, the Swedish State Power Corporation was the first one to apply the infrared image recognition technology to detect the status of the electrical equipment in the mid-1960s. Since then, it opened up a new field of infrared image recognition technology in monitoring the operation status of the electrical equipment. In the 1970s and 1980s, American Luke Company developed a fluorescence optical fiber thermometer—a brand new instrument for online monitoring of internal temperature in electrical equipment. The fluorescence optical fiber thermometer has been widely applied by some electrical equipment manufacturers to electrical equipment transformation. Later, the United Kingdom, Switzerland, the Soviet Union and other countries have developed standards, rules and regulations related to the electrical equipment detection by using infrared technology. In 1993, the United States Illinois Power Corporation proposed a kind of new technology to detect the electrical equipment in the overhead transmission lines, transformer substations and power stations by using the infrared detection technology. The new technology indicates that the infrared detection technology can timely detect hidden dangers of the electrical equipment and put an end to sudden accidents, which is an important technical means to ensure the normal operation of electrical equipment.

Meanwhile, the infrared detection technology can ensure the service life of transformer, and reduce the fault of electrical equipment and save economic losses caused by accidents. According to the statistical data of the relevant departments in the United States, the input-output ratio for detection of electrical equipment by using infrared technology is up to 1:19 or above. Therefore, some foreign power sectors still monitor the operation status of the electrical equipment by using the infrared detection technology so far.

In the 1960s, the northeast China was one of the first districts to online monitor the electrical equipment by using the infrared detection technology. After application of the technology, the electrical equipment overheating phenomena were significantly improved. In the early 1980s, the electrical power department introduced three sets of imported infrared imager. After application, there was a great improvement for online monitoring technology of the electrical equipment, reduction in the accidents caused by overheating of the electrical equipment, improvement in the economic efficiency and avoidance of power-off maintenance during peak season. The infrared detection technology has a rapid technical detection speed, which can protect safe operation of the power industry, and this kind of achievement is at leading level in China. Nowadays, most of the power units are equipped with infrared
imagers, which are widely used in the electrical equipment detection and diagnosis.

With the development of computer science and technology, the image processing and recognition has entered into a new era of comprehensive application. It formed a comprehensive discipline, and it is widely used in various fields, increasingly affecting our production and life.

In the power system, the real-time monitoring of the electrical equipment can be gradually realized by using the digital image processing technology, and the fault diagnosis of the electrical equipment can be achieved by using the infrared thermal imaging technology. However, the complex image analysis and status recognition are still in an experimental research stage. The Robotics Research Centre of Shandong University acquires the target image through a high-resolution camera which is applied to the robot, and this kind of camera is connected with the ground base station so the staff can judge whether the equipment is damaged based on the information provided by the image. Through observation of the previous artificial image frame by frame, it is of high efficiency, safety and reliability.

Since the early 1970s, China began to research the infrared monitoring technology of the electrical equipment and detect the overheating of electrical equipment in operation through an infrared thermometer. In the mid-1980s, a fault detection test was carried out for the equipment in the transformer substation through introduction of the optical mechanical scanning thermal imager, and it achieved good results. In the late 1990s, the field tests had a further expansion. Through the study of simulated experiment on the diversion circuit fault and insulation fault of high-voltage electrical equipment and then combined with the infrared image features of various equipment faults mastered by the field detection experience, the differences in these features can be understood by the temperature variation curve patterns and a large number of typical atlases. Thus, this technology can not only make a qualitative diagnosis of internal and external fault types of the high-voltage electrical equipment, but also make judgment on the exact fault location and quantification of fault severity, and make a further in-depth research on other factors and measures that affect the accuracy of equipment fault diagnosis. This technology has reached an international advanced level in the aspect of internal fault diagnosis of the high-voltage electrical equipment. Meanwhile, our country has formulated relevant standards, namely, the standard of Heating of A.C. High-voltage Apparatus under Long Runs (GB763-90), and the standard of Application Rules of Infrared Diagnosis for Live Electrical Equipment (DL/T664-1999), this step furthers the application of the infrared image recognition technology in the power system.

2 ANALYSIS OF SPECIFIC APPLICATION OF INFRARED IMAGE RECOGNITION TECHNOLOGY IN THE ELECTRICAL EQUIPMENT

In recent years, some power plants and transformer substations have installed the video monitoring systems, which have realized equipment monitoring, remote-control camera shooting, digital video recording and other functions. However, these video monitoring systems can only achieve the video monitoring function for equipment rather than the recognition function of a certain image in the video. The image recognition technology has been widely used in the power system, such as unmanned substation and so on. So far the remote visual system still requires the staff to observe and analyze collected images, and judge the operation status of the equipment. This system is relatively lack of automatic identification and analysis of the electrical equipment in the transformer substation. Compared with other industries, the power industry is relatively backward. This paper is used to learn from the successful experience of application of the image processing and recognition technology in other fields, carry out comparative analysis of the algorithm of the image processing technology and pattern recognition technology and find out the most suitable algorithm to apply in the electrical equipment. The infrared image recognition technology is more widely used in the fault diagnosis of the power grid equipment. The infrared image data acquisition, target data detection and segmentation and recognition are indispensable parts of the infrared image recognition technology. And the process flow of the infrared image recognition system information is usually shown in the figure 1.

First, the infrared image recognition technology needs to transform the infrared radiation into electrical signals in the scene by the detector through the optical system. The size of signal directly reflects the strength of infrared radiation; through imaging and electronics processing, the video signal distributed by the target infrared radiation is displayed in the imaging system, thus achieving the visible image of the target thermal image. The image pre-processing refers to the gray-scale processing of the image acquired, so as to eliminate the lake image noise by using the smoothing filter.
The image is divided into a number of specific areas with unique nature, and interested target and process are proposed, such a technology is called the image segmentation technology. Its key step is from the image processing to the image analysis.

The first step is to acquire the image information, that is, to transform the electrical equipment image into an electrical signal which is transmitted to a computer through the infrared imaging equipment and transmission equipment, so as to prepare for subsequent processing. The second step is to extract information feature, that is, to arrange and analyze the data of electrical equipment image acquired, so as to eliminate the false and retain the true, and extract relevant information of the essential feature about electrical equipment.

2.2 Examples of texture feature recognition

In the computer vision and pattern recognition, the texture analysis plays a vital role. The texture analysis methods are divided into the statistical texture analysis method and the structural texture analysis method. The most commonly-used method is the statistical texture analysis method.

The texture is an important feature of the image, and the regular texture and the quasi-regular texture are two types of texture. The regular texture is regularly arranged by the basic elements of clear texture, which is generally referred to the artificial texture as well.

The basic elements of quasi-regular texture are distributed by a certain color or gray scale without clear shape rules. Generally, it is impossible to observe the local range of the quasi-regular texture. The quasi-regular texture can only be displayed as a whole, which is generally referred to the natural texture.

For the switching equipment in the transformer substation, it has a very strong texture feature in the local part. Therefore, we use the texture features to recognize the switching equipment. In the process of texture analysis about these equipment images, the statistical texture analysis method of the neighborhood feature is adopted to test the gray-scale statistical feature which will be calculated in a certain area as the image texture, and it is used to carry out analysis and judgment by determining the maximum and minimum value method, absolute difference method, variance method and other methods, of which the maximum and minimum value method and the absolute difference method are commonly used. According to the texture analysis of the electrical equipment, the maximum and minimum value of the window, \( \Delta(i, j) \) is obtained, which should satisfy 20 < \( \Delta(i, j) \) < 60; the absolute difference of the window, \( D(i, j) \) should satisfy 300 < \( D(i, j) \) < 800.

The maximum and minimum value method is to make the difference between maximum and minimum values of the gray scale in the center of the window \((2k+1) \times (2k+1)\) for the pixel \((i, j)\) as the statistical value of the texture feature in center of the window, that is:

\[
\Delta(i, j) = \max_{|x-i| \leq k} \min_{|y-j| \leq k} f(x, y) - f(x, y) \quad (1)
\]

The size of detected texture depends on the size of window, and the strength of texture can be reflected by \( \Delta(i, j) \).

The absolute difference method is to make a sum of gray value of each pixel in the center of the window \((2k+1) \times (2k+1)\) for the pixel \((i, j)\) and the absolute difference value of the mean value of the gray scale in the window as the statistical value of the texture feature in center of the window, that is:

\[
D(i, j) = \frac{\sum_{x=i-k}^{i+k} \sum_{y=j-k}^{j+k} |f(x, y) - u|}{(2k+1)^2} \quad (2)
\]

In the above formula, \( u \) represents the mean value of gray scale in the window; \( D(i, j) \) also reflects the information of texture strength.

The variance method is to make the gray-scale variance in the center of the window \((2k+1) \times (2k+1)\) for the pixel \((i, j)\) as the statistical value of the texture feature in center of the window, that is:

\[
\sigma^2(i, j) = \frac{\sum_{x=i-k}^{i+k} \sum_{y=j-k}^{j+k} |f(x, y) - u|}{(2k+1)^2} \quad (3)
\]

In the above formula, the mean value of gray scale in the window is \( U \); \( \sigma^2(i, j) \) reflects the information of texture strength.

In order to more conveniently calculate the texture
features, there is a need to first transform the image acquired into the gray-scale image, and then analyze the image of $5 \times 5$ from left to right, top to bottom, and calculate the texture test value parameter of the window according to $D(i, j)$. When the parameter is within the range of set value, it indicates that the window may be a part of an image to be recognized, thereby recognizing the images in the adjacent area. When four or more windows are connected with, it is judged as the image of the circuit breaker or disconnecting switch. In order to accurately judge the nature of the equipment, there is a need to conduct the second transformation toward these images. And then we need to conduct the target segmentation toward these images after transformation through the image segmentation method and find out the distance ($L$) and vertical chord length ($W$) between two farthest pixels of each target, as shown in the following diagram:

![Figure 2. Flowchart of isolator open-and-close judgment.](image)

2.3 Image recognition of the isolator status in the transformer substation

The isolator in the transformer substation is used to control connection and disconnection of the high current circuit. In case of power cutoff accident or routine inspection, the isolator needs to be in a closed state. Currently, whether the isolator is closed can be only judged on spot by staff. Under normal conditions, the location of transformer substation is far away from the work place of staff, so it is time-consuming, laborious and quite inconvenient for on-site observation. A number of transformer substations are widely distributed. In case of fault or routine inspection of several transformer substations, there is a need of vast human resources. Therefore, in order to change this traditional and unsafe working mode, there is a need to realize visual monitoring of the equipment in the transformer substation, so as to reduce the accidents and improve work efficiency.

Currently, the closed state of the isolator in the transformer substation is confirmed by the image comparison technology. This technology solves the difficulty in the lack of disconnection of the isolator in the transformer substation. The image analysis adopts the strategy which is to break up the whole into parts: With the area of the straight line features acquired in the still video image of the closed isolator as a contrasting area and each image in the contrast area as a contrast basis for the entire isolator, it indicates that the isolator status is closed when the difference in the image of the contrast area is within the prescribed range, but it also indicates that the isolator status is disconnecting when the difference in the image of the contrast area is not within the permissible range. The decentralized technology through the image segmentation can reduce the difficulty in determining the
isolator status and also solve the interference of some factors during judgment.

3 CONCLUSION

The application of the infrared image processing technology and recognition technology to the electrical equipment in the transformer substation is a new kind of technology to monitor the operation status of the electrical equipment. It reduces difficulty in monitoring the operation status of the electrical equipment in the transformer substation and proposes a monitoring and analysis program for the operation status of the electrical equipment; in addition, it removes the defects of electrical equipment images through the image pre-processing of the equipment in the transformer substation, so as to improve the quality of image and improve accuracy of the image recognition and analysis. Moreover, the image features extracted by different equipment are different. Through detection of the status of the electrical equipment, it analyzes and processes the key areas to find out the changes in the operation status of the electrical equipment, thereby determining whether there are faults or hidden faults, ensuring safe and reliable operation of the electrical equipment and guaranteeing high-speed and stable development of the power grid career.

The infrared image recognition technology is currently in the development stage, which is used to obtain a certain effect in monitoring the electrical equipment, but it needs to be further improved and perfected. First, the processing of the infrared image has a certain effect through the image processing and segmentation algorithm, but there is still a need to do more improvements in the algorithm so as to achieve a better effect; second, there is a need to have a further understanding of the features of various fault modes and inner links of fault types of the equipment in the transformer substation, and improve it by doing more systematic research. In future work, there is still a need to do a lot of detection experiments, so as to have a deeper understanding of the nature of various faults on the basis of the experiments, and more specifically and vividly reveal the source of fault through the infrared image recognition technology, and improve the fault diagnosis capabilities.

REFERENCES


