Fault Diagnosis of Photovoltaic Array Crack Based on Infrared Image

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Abstract

Hot spot is the most common fault in the operation and maintenance of photovoltaic power plants, which seriously affects the normal operation of photovoltaic power plants, and crack is one of the important reasons for the formation of hot spots. The infrared image characterizes the surface temperature of the object, which can represent different hot spot failure modes to a certain extent. It is an important work to apply infrared image to the fault diagnosis of PV array crack. Based on the diagnosis method of PV array crack fault, the infrared image processing mechanism is used to perform grayscale transform enhancement and filter denoising on the PV array image. By extracting the feature quantity, the gradient method is used to determine the high temperature region, and finally the experiment is carried out. Verification, the results show that it is feasible to effectively determine the fault area of cracks and cracks.

Keywords

Infrared image, photovoltaic array, fault diagnosis, feature extraction, gradient method.

1. Introduction

In recent years, with the rise of the photovoltaic industry, it has played an increasingly important role in the development of the national economy and is the focus of the national economic development strategy. In the long-term operation of photovoltaic power plants, due to the harsh natural environment and some human factors, some problems will inevitably occur. For example, due to human factors such as packaging process, the photovoltaic module may be cracked and invisible cracks invisible to the naked eye to form hot spots; or due to the presence of the obstruction, the temperature of the region may increase to form hot spots and the like[1]. These faults have greatly affected the operational safety of photovoltaic power plants.

At present, there are many methods for hot spot detection of photovoltaic arrays, but the research on hot spot defects caused by cracks is not deep. For example, in the literature [1], image processing and pulse neural network are used to detect hot spot of photovoltaic array, and a method for detecting hot spot phenomenon during operation is adopted. [2] According to the thermal distribution map of photovoltaic module, fault diagnosis Environmental factors such as temperature and light intensity are considered in the algorithm. The SVM algorithm used in the literature [3] classifies the features and uses the temperature difference for fault diagnosis. However, the method focuses on the image segmentation and is not fully applicable in terms of cracks. The literature [6] uses image processing first. Establish diagnostic algorithms for fault diagnosis; the three main methods of image statistical information, single point monitoring, and infrared image diagnosis in literature [7] are fault diagnosis for power equipment. The fuzzy theory of this method can realize automatic identification, but for equipment failure reasons. The judgment is not very accurate and has certain limitations; these methods have many advantages in application, but have great limitations in troubleshooting the hot spots caused by cracks.

With the development of image processing technology, it is practically feasible to apply it to the fault diagnosis of PV array cracks and to determine the fault area of cracks[2]. In this paper, by analyzing the characteristics of PV array image features and crack faults, a diagnostic method for PV array crack faults using image processing and gradient method is proposed. Specifically, it includes:

establishing infrared image processing mechanism of photovoltaic array, setting image processing related parameters, extracting feature vector, performing grayscale transformation on PV array image to enhance contrast, image filtering denoising, and using OTSU (Maximum Inter-Class Variance) algorithm for threshold segmentation Finally, the gradient method is used to identify the high temperature region of the image, and then the fault region of the PV array crack is determined. In this paper, an experimental photovoltaic panel of the photovoltaic array branch of Qinghai Yellow River upstream limited liability company is used as an object to test the crack of the photovoltaic array, which proves the feasibility of the method.

2. Infrared Image High Temperature Region Extraction Principle

The principle of infrared thermal imaging, in simple terms, is that the infrared camera converts the invisible infrared energy emitted by the object into a visible thermal image. The different colors on the infrared image represent different temperatures of the object[3]. With the development of infrared thermal imaging technology, its application in the field of fault detection has become very common. Infrared thermal imaging technology can detect the temperature change of the PV array, and can predict the faults that will occur. It can be applied to the diagnosis of cracks in the PV array, and the fault can be accurately identified.

In the process of infrared image acquisition, various noises will appear, which often cause edge blur of the infrared image of the PV array and target background contrast.

Low, noise pollution and other phenomena, so the image must be denoised and grayscale enhanced, etc., the gradient method can reflect the map more intuitively.Like the color changes. In this paper, by establishing an infrared image processing model, the PV array image is processed to extract the high temperature region of the image, which provides a basis for crack diagnosis of the PV array. The specific operation steps of the fault diagnosis model established in this study are as follows:

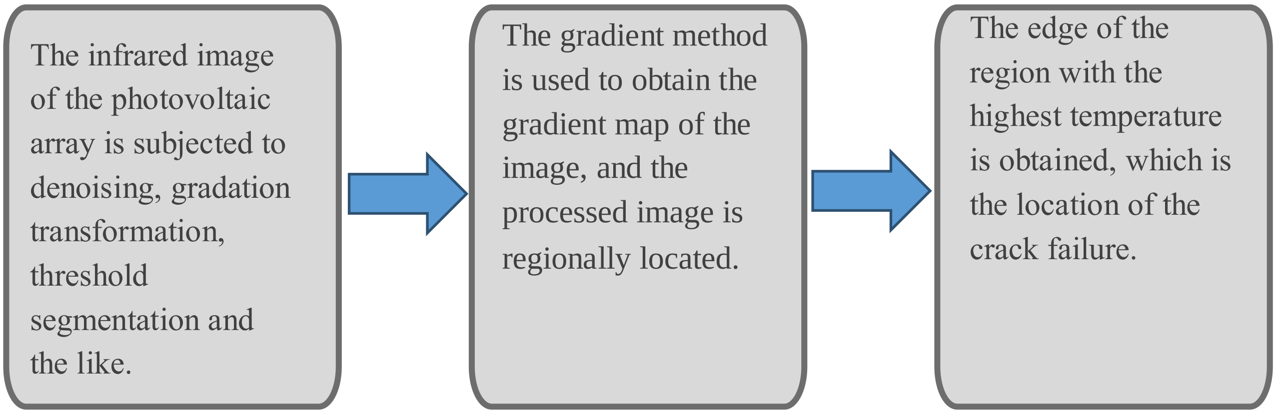

Figure 1. Fault model diagnosis flow chart

3. Photovoltaic Array Image Processing Model

According to the characteristics of the infrared image of the PV array, this study establishes the image processing model and performs a series of processing on the PV array image to make the image target area feature prominent, which provides a basis for the application of the gradient method to judge the crack fault diagnosis.

3.1 Median Filtering Denoising

Due to the low contrast of the infrared image of the PV array, the median filtering is used to denoise this study.

The median filter is a nonlinear smoothing technique that contains noise, especially salt and pepper noise and pulsed noise in the image. The median filter is used to eliminate noise in the noise, but it also retains more Image detail, in order to prevent edge blur, will be centered on the neighboring pixel, minimum, intermediate value and other meta output values.

Image processing using a spatial domain template, called spatial filtering enhancement of the image. Median filtering is a nonlinear signal processing technique based on the theory of sorting statistics that can effectively suppress noise. The basic principle is to use the value of a point in a digital image or a sequence of numbers to the median value of each point in a neighborhood of the point. Instead, the surrounding pixel values are close to the true value, eliminating isolated noise points. When denoising the image, pay attention to the edge part of the image target, and then remove the influence of background noise on the target [4].

The median filtering method is to use a two-dimensional sliding template of a certain structure to sort the pixels in the board according to the size of the pixel value, and to generate a two-bit data sequence in which the car monotonously rises (or falls). This time, the medfilt2 function is used to implement median filtering. The calling format is as follows: B=medfilt2 (A)

B=medfilt2 (A,[m,n]);

In the actual operation, m and n are selected, and each output is the median value of the m*n field. According to the characteristics of the photovoltaic array image, this study takes m and n as 3 to obtain a 3*3 template. Median filtering to denoise the image.

3.2 Grayscale Conversion Enhances Contrast

Since the contrast between the target and the background in the infrared image of the photovoltaic array is low and the edges are blurred, it is difficult to determine the boundary, so it is necessary to perform grayscale transformation enhancement to enhance contrast. The gradation transformation can increase the dynamic range of the image, and the contrast is expanded to make the image clear and the features clear.

In order to enhance the contrast of the photovoltaic panel image, the image is processed by the maximum entropy method to highlight the characteristics of the target image. The myhisteq function is used to enhance the image. The calling format is as follows:

[wnew, h1]=myhisteq (w);

Where w is the input grayscale image, wnew1 is the output enhanced image, and h1 is the transformed histogram. The results show that the myhisteq function can effectively enhance the target contrast [5].

3.3 Image Threshold Segmentation

The OTSU (Maximum Inter-Class Variance Method) algorithm is a dynamic threshold segmentation method. The basic idea is: based on the gray-scale information of the image, by traversing the optimal threshold for finding the image, the image gray value t is divided into the target and the background. Class, two categories are calculated separately, and when it is the maximum variance, the image is segmented based on the gray value threshold. T is the segmentation threshold, and the image is divided into two categories, C0 and C1. C0, C1 pixel image is W0, W1 and the average gray level U0, the percentage of U1, the total average gray level image U is U = W0 * U0 + W1 * U1 across the gray value range across t, when t When the variance between two categories g= W0*(U0-U)2+W1*(U1-U)2 is the maximum value, t is the threshold segmentation[6].

In this study, the OTSU algorithm is used to realize the threshold segmentation of the PV array image, which provides the basis for the crack region of the PV array image.

4. PV Array Crack Fault Diagnosis Method

In this paper, the gradient method is used to determine the fault area of the PV array crack. The gradient high temperature region determination process is as follows: Gradient is an effective high temperature region detection method. The change of the gray image in different regions, especially the edge region, is obvious, and this change can be expressed by the gray gradient. The positive and negative edge gradients reflect their movement, which is equivalent to one direction. Since the above background image is likely to have many weak interferences, it has no effect on image target recognition, but due to the influence and aesthetics of the gradient map, this paper uses a simple histogram enhancement to enhance the background image after the pre-image enhancement of the simple image. Degree, which is conducive to the extraction of targets [7]. For processed grayscale gradients, the grayscale value of the image can be obtained, showing the edge where the target is changed. The image gradient can take the image as a two-dimensional discrete function. The gradient is actually the derivative of the two-dimensional discrete function. There is a vector G somewhere, and the direction of the vector is the direction in which the rate of change f is the largest at that point. Also equal to the value of this maximum rate of change, the vector G is called the gradient of the scalar field f [8].

$$\nabla f = \begin{bmatrix} G_x \\ G_y \end{bmatrix} = \begin{bmatrix} \frac{\partial f}{\partial x} \\ \frac{\partial f}{\partial y} \end{bmatrix} \tag{1}$$

For discrete image information,

$$\begin{cases} \frac{\partial f}{\partial x} = f(x+1) - f(x) \\ \frac{\partial f}{\partial y} = f(y+1) - f(y) \end{cases} \tag{2}$$

Since the crack region will cause hot spot failure and form a high temperature, this method is used for the determination in this study, and the high temperature region is the fault region to realize the fault diagnosis of the photovoltaic array crack.

5. Experimental Data Settings

5.1 Experimental Objects

In this paper, an experimental photovoltaic panel of the photovoltaic array branch of Qinghai Yellow River upstream limited liability company is taken as the experimental object, and the infrared image of the PV array crack fault is taken and the experimental data is obtained.

5.2 Experimental Parameters

Combined with this experiment, the main parameters of the infrared camera used to capture the infrared image of the PV array are determined. The detailed parameters are shown in Table 1.

Table 1. Parameter setting of infrared thermal imager

parameter	Numerical value	parameter	Numerical value
Emissivity	0.86	Atmospheric temperature	20 ℃
Atmospheric transmittance	0.99	Emission temperature	22 ℃
Atmospheric relative humidity	0.6	Thermal range	Automatic device control
Image frame rate	30 Hz	Shooting distance	Automatic device control

5.3 Experimental Group Settings

The acquisition of data is obtained in consideration of the interference of various external factors, and fully considers external factors such as equipment parameters, lighting conditions, ambient temperature, etc., thereby ensuring the reliability and authenticity of the data. The experiment photographed two sets of related images for the PV array crack failure and its standard conditions. The specific experimental group settings and thermal image numbers are shown in Table 2. One of them is shown in Figure 2 and Figure 3:

Table 2. Experimental group Settings

Group No	content	Number of images
1	Photovoltaic array standard infrared thermography	10
2	Photovoltaic array crack fault infrared thermography	10

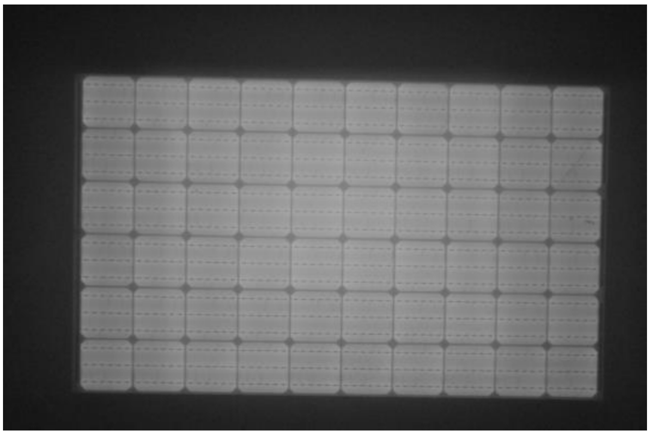

Fig. 2 original pv array diagram

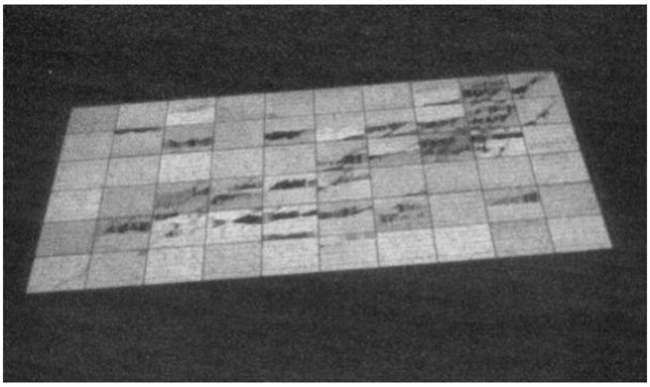

Fig. 3 crack failure diagram of pv array

It can be seen from Fig. 1 and Fig. 2 that there is a significant difference between the PV array crack and the standard image surface, but the specific crack position and the invisible crack position need to be determined by the image processing and gradient method proposed in this paper.

6. Experimental Analysis and Results

According to the method proposed in this study, the aerial image of the photovoltaic power station was selected in Figure 3. The hot spots caused by PV array cracks and other causes of hot spot diagnosis are not the same. Therefore, using the method introduced in the second section, first use the median filter to denoise, remove some noise that is not related to the target, reduce the interference, and then use the grayscale transform to enhance the target contrast. The OTSU algorithm performs threshold segmentation. The process analysis is as follows:

As shown in FIG. 4, according to the captured PV array image, the selected area is analyzed, as shown in FIG. 5, the first, second, and third rows of the eighth, ninth, and tenth columns are selected for analysis; Dimensionalization, the results are shown in Figure 6. Immediately after the image denoising and grayscale transformation enhancement is performed on the selected area, the extraneous noise is removed and the contrast is enhanced. The results are shown in Figure 7 and Figure 8. Finally, the threshold segmentation is performed. As shown in Figure 9, the edges of the image have been processed more clearly.

After the image processing is completed, the high temperature region is discriminated by the gradient method, and the cracked region can be determined by comparing the positioned high temperature region with the standard image. As shown in FIG. 10, the gray scale change image of the image is obtained by using the gradient method to obtain a line graph of the gray value change before and after image filtering, and the high temperature region can be determined. In the line graph, the solid line represents the gray value before the image processing, and the dotted line represents the gray value after the image processing. It can be seen that the processed image has a significantly enhanced gray value, and the image gray value changes significantly. The edge of the area for the target. Therefore, it can be judged that the region is a high temperature region, and finally the position of the crack can be determined by comparison of the standard infrared thermal image of the photovoltaic array. Through this test, the feasibility of this method for PV array crack fault identification is verified.

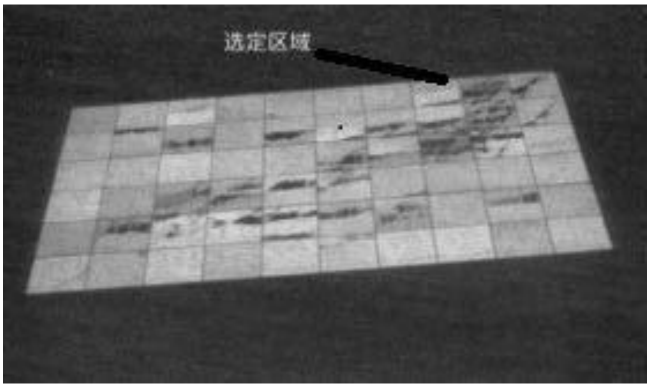

Fig. 4 experimental photovoltaic panel

Figure 5. Target area

Fig. 6 image 2d

Figure 7. Image de-noising

Figure 8. Image grayscale transformation

Figure 9. Image threshold segmentation

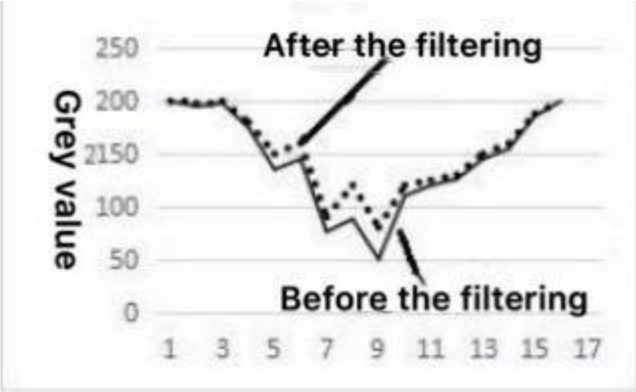

Figure 10. Gray scale variation before and after a region filtering

7. Conclusion

This paper studies a method for crack fault diagnosis of photovoltaic arrays based on infrared image and gradient method. The main steps are as follows: 1. Denoising by median filtering to reduce the unrelated noise in the image. 2. Enhance the target contrast by using grayscale transformation, which is convenient for observation and analysis. 3. Using the OTSU algorithm to perform threshold segmentation, more accurately determine the target background boundary and reduce the workload. 4. The gradient method is used to discriminate the high temperature region to determine the crack fault region.

Experiments were carried out on an experimental photovoltaic panel of the Photovoltaic Array Branch of Qinghai Yellow River Upstream Co., Ltd., which verified the feasibility of the research method. The results show that the proposed method can effectively extract the infrared image of the hot spot caused by crack or crack, and then use the gradient method to determine the exact region of the PV array crack fault, which has certain versatility and feasibility. This method is the application of infrared thermal imaging technology in the field of fault diagnosis, and provides a new method and approach for the common crack and crack fault diagnosis in photovoltaic arrays.

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