Extraction of Ultraviolet Spectrum Discharge Parameters of Power Equipment Based on OpenCV

Hong-wei MA, Hao-yang CUI*, Wen-cheng GUO, Si-jia HUO, Chen-hang GE and Lun-ming QIN

College of Electronic and Information Engineering, Shanghai University of Electric Power, Shanghai 2000190, China
*Corresponding author

Keywords: OpenCV, Feature extraction, UV image, Fault diagnosis.

Abstract. Ultraviolet imaging technology is an effective method to detect the discharge of high-voltage electrical equipment. At present, the photon number is the main method to characterize the discharge severity of UV imaging. However, there is a complex nonlinear relationship between the parameter size and the gain and observation distance of the UV imager. The discharge was quantified. In order to quantify the analysis of discharge, based on the OpenCV image processing technology, the UV image was segmented by a combined threshold method, and the effective discharge region was extracted by the multi-region contour algorithm; Using the statistical information of foreground information pixel points, parameters such as area of discharge spot, perimeter, major axis minor axis, and spot profile are obtained. The method can quickly and efficiently judge the severity of UV fault images, save manpower and material resources, and have higher practical value.

Introduction

In recent years, with the rapid development of the electric power industry, the demand for stable operation of electric power equipment has continuously increased. However, when high-voltage electrical equipment is operated for a long time, partial discharge may occur. If equipment failure or failure detection is not detected in time, it will seriously endanger the electrical equipment, cause power failure, and even threaten personal safety. Therefore, it is necessary to detect the high voltage discharge to ensure the stable operation of the power system. Fault detection technology is currently the focus of research, and UV imaging technology[1,2] detects the discharge information of electrical equipment through non-contact methods, which has become an important detection method in the field of state assessment. For this reason, it is of great significance to use OpenCV image processing technology[3,4] for contour extraction and detection.

In the UV fault diagnosis and detection technology, the area of the discharge spot, the perimeter, the major axis and the short axis, and the number of discharge profiles are the key data to characterize the severe discharge intensity of the power equipment. Literature[5] proposed a UV image fusion algorithm based on wavelet transform method, which accurately judges the discharge degree and discharge position of the power equipment through the fusion of ultraviolet light spot and visible light; Literature[6] using the extracted light spot area of faulty high-voltage electrical equipment, a method of state recognition based on artificial neural network was proposed to classify faults in power equipment. The literature [7] mainly proposed the corona tracking algorithm based fault diagnosis of power equipment. The KMS fast corona tracking algorithm was used to effectively track and monitor the corona. However, the above parameters such as spot area are extracted by software such as Matlab to achieve related image processing. This method is slow in calculation speed, and the programming volume is not only large but also complicated, which is not conducive to the subsequent discharge of the device to serious fault strength.

In order to solve the above problems, based on OpenCV image processing technology, this paper extracts the feature parameters such as spot area, perimeter, long axis and short axis, etc. to quantify
ultraviolet faults in high-voltage power equipment. The calculation speed is fast, the man-machine interface is friendly and the operation is simple. It is convenient to use and provides a new method for the quantitative analysis discharge in the ultraviolet imaging detection of high voltage equipment in the future power system.

Introduction to OpenCV

OpenCV is an open source computer vision library developed for specific applications of frame extraction and image processing of video images in various formats. It has powerful image processing functions and is written in C/C++ language and can run on multiple operating systems. At the same time provide other interfaces for other software. The OpenCV main body is divided into 5 modules, and four of these modules are shown in Fig. 1.

![Figure 1. The basic structure of OpenCV](image)

UV Imaging Detection

The principle of ultraviolet imaging detection is shown in Fig. 2, the light entering the UV imager is divided into visible light signal and ultraviolet light signal by a spectroscope. After the UV signal is filtered by the UV cut filter, the remaining UV part is processed by the amplifier and input to the UV CCD camera. The visible light signal is input into a visible light CCD camera after being processed by an amplifier, and finally processed by an imaging software system to superimpose ultraviolet light and visible light to form a final output discharge image, thereby achieving the purpose of determining a fault position and a failure intensity.

![Figure 2. UV imaging detection principle](image)

Image Preprocessing

The composite image produced by the UV imager needs to be preprocessed before feature extraction. First, the image is grayed, binarized, image segmented, small area cleared, contour extraction and other preprocessing, and finally the desired image is obtained. Selecting the template as a 3×3 median filter for image enhancement can effectively remove noise. The whole threshold method[8] and the joint threshold method were used to segment the image after detouring. The results show that the effect of segmenting the image using the joint threshold method is better than the overall threshold segmentation method, which can improve the accuracy of the extraction of ultraviolet image feature parameters. And using a joint threshold algorithm for segmentation, the operation rate is faster than the overall threshold algorithm.
Discharge Area Contour Extraction

When a discharge failure occurs in a power device, one or more discharge regions may appear on the power device due to discharge intensity and other reasons. The multi-region contour extraction algorithm solves the problem that only one discharge region can be extracted at a time. For the effective discharge area, the spot area is an important parameter for evaluating the discharge intensity of electrical equipment. Because the UV imager is greatly affected by the environment, the detected device discharge spot has an irregular shape. If only the discharge area area parameter is extracted, it is not rigorous to judge the discharge intensity of the high-voltage device, which may cause misjudgment or missed judgment. Therefore, this paper adopts the multi-parameter parallel method to extract the state features such as spot area, perimeter, number of contours, perimeter, long axis and short axis. And use this as a diagnostic basis to classify and identify faulty equipment. The discharge area contour extraction flow chart adopted in this paper is shown in Fig. 3.

![Figure 3. UV discharge outline extraction flow chart](image)

Feature Extraction

When the power equipment fails to discharge, the area of the light spot, the number of contours, the perimeter, and the long axis and short axis are all important indicators that reflect the severity of electrical equipment discharge faults.

1. Spot area: The number of pixel points in the discharge outline area, that is, the number of pixel grayscale values is 1. The calculation formula is as follows:

\[ S = \sum_{(x,y) \in P} 1 \]  

(1)

2. Number of contours: The number of discharge contour areas resulting from noise and equipment parameters.

3. The perimeter of the spot: The number of consecutive pixels at the boundary of the discharge profile.

4. The long axis and short axis of the spot. The long axis of the spot means the longest distance between the two points on the boundary of the discharge area through the centroid of the discharge profile; The minor axis refers to the shortest distance between two points on the boundary of the discharge region through the centroid of the discharge profile.

Experimental Results and Analysis
Fig. 4 shows the UV discharge image captured by a 500kV substation. The image has pixels of 640, 480. The ambient temperature is 30°C, the humidity is 40%, the wind speed is 1m/s, and the UV imager model is CoroCAM 6D.

A multi-region contour extraction algorithm is used to extract the segmented gray image discharge region, as shown in Fig. 5(a). The extracted effective discharge region not only has a clear outline, but also does not lose the main characteristic parameters, that is, multiple discharge regions are extracted at one time. Using the effective discharge area as a template, the original UV spectrum is matched and fused, as shown in Fig. 5(b). It can be seen that the shape and size of the extracted discharge region are in good agreement with the actual contour of the image, and the size and shape of the original discharge region image can be maintained as much as possible while effectively eliminating noise.

In order to detect the accuracy and reliability of the electrical equipment discharge severity, a continuous 10 frames of image was used to detect the severity of discharge at the point of failure.

As shown in Fig. 6, processing 10 successively processed images as a group. Through analysis and statistics of 10 images, the maximum discharge spot area MaxS_1, the minimum discharge spot area MinS_2, the average discharge spot area AvgS_3, the maximum perimeter MaxL_1, the minimum perimeter MinL_2, and the average perimeter AvgL_3 are analyzed. Max major axis Maxa_1, minor major axis Mina_2, average major axis Avga_3, maximum minor axis Maxb_1, minimum minor axis Minb_2, average minor axis Avgb_3, number of contours, and other characteristic parameters.

| parameter | MaxS_1 | MinS_2 | AvgS_3 | MaxL_1 | MaxL_2 | AvgL_1 | Maxa_1 | Mina_2 | Avga_3 | Maxb_1 | Minb_2 | Avgb_3 | p |
|-----------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|--------|---|
| 1         | 1170.5 | 488.5  | 743.9  | 157.7  | 202.7  | 60     | 37     | 44.3   | 37     | 29     | 33.7   | 1      |   |
| 2         | 465.5  | 208.1  | 357.7  | 127.1  | 82.4   | 110.4  | 36     | 21     | 29.7   | 30     | 19     | 25.4   | 3  |
| 3         | 621.5  | 258.1  | 419.9  | 256.3  | 128.8  | 174.6  | 69     | 39     | 49.3   | 53     | 30     | 38.2   | 2  |
As can be seen from Table 1, using the OpenCV image processing function can effectively extract the image parameters of the above two spot areas, thereby achieving a quantitative analysis of the discharge intensity of high-voltage equipment.

Summary
There are certain deficiencies in the actual detection based on the photon number parameter. For the ultraviolet image feature of the surface discharge of the high voltage equipment, the digital image processing algorithm is used in this paper to grayscale the image, divide the threshold value, eliminate the small area area and extract the contour. VC++ wrote a related program and realized the above image processing algorithm by calling OpenCV function. The software has a friendly man-machine interface and is easy to use. The actual test results show that the above algorithm is effective.

Acknowledgement
This research was financially supported by the National Natural Science Foundation of China (61107081), Local Colleges and Universities Capacity Building Program (15110500900).

References
[1] Yang Ning, Wu Xu-tao, Bi Jian-gang, et al, Experimental research of influence factors in detecting corona discharge by UV imaging method, J. High Voltage Apparatus, 48(2012) 59-64.
[2] Li Yanpeng, Jin Tao, Zhang Jian, Application of ultraviolet imagery technology in partial discharge measurement test of UHV transformer, J. High Voltage Apparatus, 49,(2013) 123-126+132.
[3] Lei Jianfeng, Wang Wei, Research and implementation of image threshold segmentation based on OpenCV, J. Modern Electronics Technique, 36 (2013) 73-76.
[4] Qin Xiaowen, Wen Zhifang, Qiao Weiwei, Image processing based on OpenCV, J. Electronic Test, (2011) 39-41.
[5] Jin Lijun, Chen Junyou, Yan Shujia, et al, Partial discharge detection of power equipment by ultraviolet imaging based on image processing technology, J. Power System Protection and Control, 41(2013) 43-48.
[6] Tao Bohao, Ma Lixin, Zhang Liping, et al, Development of high-voltage discharge fault detection system, C. Unifying Electrical Engineering and Electronics Engineering, (2013) 449-456.
[7] Li Na, Chen Ziqi, Zhao Caihong, et al, Fault diagnosis of electric devices based on corona tracking algorithmv, J. Electronics Quality. (2016) 17-22.
[8] Liu Shengli, Jia Chuanying, Ma Kun, Instrumental image whole threshold segmentation method, J. Measurement Technique, (2003)5-7+15.