Vacuum Switch Contact Position Detection Based on Labview

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Abstract. Arc shape of vacuum switch is one of the main influencing factors of the breaking performance of vacuum switch. The contact opening distance directly affects the development of arc shape. How to accurately detect the real-time position of the contact and calculate the contact distance is of great significance. Therefore, based on Labview virtual instrument technology, a software and hardware system for real-time position detection of contacts for vacuum interrupter is designed. The system collects the arc image during the vacuum switch opening process by high-speed camera, and then uses the virtual instrument development platform Labview as the programming software to process the arc image and analyze the edge features. Finally, the edge information detected is used for fitting, to realize pinpoint of the moving and static contacts. The experimental results show that the detection system can accurately detect the real-time position of the contact. It has the characteristics of high detection efficiency, stable operation and easy operation. The detection results provide technical support for analyzing the vacuum switch arc shape.

1. Introduction

With the increasing scale of China's power network, higher requirements have been placed on the protection and control equipment of power systems. The vacuum switch is used as one of the power system protection and control devices. The extension of its service life, the optimization of structural design, and the reliability of breaking current are the key research objectives of scholars in related fields. [1] At present, the research focus on the service life is how to make the agglomerated arc rapid transformation into the diffused arc and reduce the ablation of the contact surface. Therefore, the study of the vacuum switch arc shape is a key issue. In the current research stage, most scholars use high-speed camera CCD (Charge Coupled Devices) or CMOS (Complementary Metal Oxide Semiconductor) to capture the arc image during arc combustion process, and then apply image processing technology to extract key information from the image to obtain Research program for arc morphology. [2-3]

The vacuum switch arc combustion is a process of coupling multiple physical fields, the electrical, magnetic and mechanical parameters of the vacuum switch have influence on it. Scholars have made in-depth research on the electrical and magnetic parameters of vacuum switches, such as voltage, current, transverse magnetic field of contact, longitudinal magnetic field, etc., However, the influence of mechanical parameters on the arc shape needs further study. Wu Jianwen [4] and other scholars obtained the relationship between the diffusion region of arc, the arc voltage and the contact opening distance by changing the contact opening distance and controlling the arc current. Jiang Sheng [5] and other scholars use the sensor to analyze the static and dynamic opening travel of the contact and other mechanical parameters. Lang Fucheng [6] et al proposed the application of a transformer sensor to measure the displacement signal of the moving contact to realize the diagnosis of the mechanical parameters of the vacuum switch. However, the above methods have some limitations. In the process
of using the sensor for motion signal acquisition, the acquisition signal will be affected by mechanical vibration, sensor accuracy, data transmission and other conditions, resulting in large errors in the positioning accuracy of the contacts. Therefore, how to accurately position the moving contact and calculate the contact opening distance is of great significance to realize the quantitative analysis on the change of the arc shape of the contact opening distance.

Based on the image sequences for arc combustion of the vacuum switch opening process, the edge information of the arc image is detected, and the position of the moving and static contacts is obtained by calculation and fitting, which lays a foundation for analyzing the influence of the contact opening distance on the arc shape.

2. Hardware Design
The system uses virtual instrument development platform Labview as the processing center, which consists of current source, high-speed camera, data acquisition card, capacitor charge and discharge circuit, operating mechanism, vacuum interrupter and other structures. The structure flow chart is shown in Figure 1.

![Figure 1. System hardware flow chart](image)

The main structure of the vacuum interrupter is consists of contact, shielding case, moving and static conductive pole, bellows and an insulating shell, as shown in Figure. 2. The type of arc extinguishing chamber used in this experiment is BD-20B type, the contact diameter is 75mm, and the material is oxygen-free copper. The insulating housing is made of glass, making it easy for high-speed cameras to capture arc shapes [7].

Figure 3 shows the equivalent circuit diagram of the physical connection diagram of the control loop. Where, C is the storage capacitor, R is the resistor, V is the diode, L is the inductance coil, and T is the transformer. The experiment uses two electrolytic capacitors in parallel mode with a capacitance parameter of 30mF/450V. First, the storage capacitor C is charged by a transformer (output is 360V/0.3A), and then discharged through the diode V for the opening or closing coil of the operating mechanism [8].

![Figure 2. Vacuum interrupter](image)

1-static conductive pole;2- moving contact;3- bellows;4-insulating shell;5- static contact;6- moving conductive pole.
Figure 3. Equivalent circuit

The operating mechanism of the system is a permanent magnetic actuator. The main structure of the permanent magnetic actuator includes a moving and static iron core, a permanent magnet, a split and a closing coil, and the like. When the operating mechanism receives the opening command, the opening coil is energized and the current generates a magnetic field. Under the action of the current magnetic field and the magnetic field of the permanent magnet itself, the opening and closing operation of the vacuum circuit breaker is realized[9].

In order to meet the requirements of high-precision acquisition of contact opening images, this paper selects the CMOS high-speed camera developed by Optronis of Germany, the maximum resolution is 1280×1024, and the internal capacity of caching is 4G. The maximum frame rate of the camera is 3×10^5fps, which can meet the experimental requirements. The camera lens is M5081-MP type with a focal length of 50mm and an aperture of F1.8-F16C[3].

3. Software Design

The software design of the experimental device is based on virtual instrument Labview. The main functions of the software include experimental initialization, parameters setting, image preprocessing, edge detection, and generation of experimental reports.

3.1. Initialization and Parameter Setting

The initialization module mainly includes measurement parameter initialization, control component reset, interface data initialization, and so on. Before the experiment begins, Labview automatically creates a file and data storage path with time. Assign all parameters to the experiment with initial settings. The parameter settings mainly include acquisition parameters, experiment types, laboratory technician and unit information[10]. This scheme selects an image processing module among the experimental types.

3.2. Image Preprocessing and Edge Detection

The vacuum arc image collected by the experiment is shown in Figure. 4. It can be seen that the gray image has an uneven gray scale distribution, the arc portion has high brightness, the gray value is high, and the background portion has low brightness and low gray value. With the extension of the arcing time, the gray level of the arc part changes rapidly. After 10 ms, the gray value at the same pixel point has a large jump, and the arc shape does not have regularity. Therefore, it is necessary to preprocess the arc image before edge detection, namely image filtering, grayscale and binarization. The pre-processed arc image is shown in Figure 5.

NI Vision Builder is the image processing module of the Labview development platform, which provides image processing functions such as smoothing filtering and edge detection operators. The experiment results indicate that when the filter function is firstly used to denoise the arc image, and then the edge of the arc image is extracted, the experimental result is more ideal. In the process of acquisition and transmission of arc image, due to scanning current, light, atmospheric motion and other reasons, composite noise pollution dominated by Gaussian noise is generated [11]. The quality of the arc image is degraded. Therefore, the method uses Gaussian transform based on Fourier transform to denoise the arc image.

Edge detection technology is very mature in the field of image processing. The commonly used edge detection operators include Laplacian edge detection operator, Sobel edge detection operator and Prewitt edge detection operator. [12] But the above operator is applied to the edge extraction of
Labview, and there are many false edges, and the detection results are greatly deviated from the actual ones. By studying the arc image, the upper edge of the image is the first pixel value of 255 from top to bottom in each column of pixels, and the lower edge is the bottom pixel value of 255 in each column of pixels.

The arc image pixels have a total of N rows and M columns. When searching for the upper edge: search the Xth column (1≤X<M) first to the first Y (1≤Y<N) pixels until all the qualified ones are found. The line fitted by these points is the upper edge of the image. When searching for the lower edge, the Nth column to the Xth (1≤X<N) pixel points of the Yth column (1≤Y<N) are searched until the pixel whose pixel is 255 is found, that is, the lower edge point. According to this algorithm, Labview is used for programming.

The detection of the upper and lower edges of the arc is not an ideal experimental result, as shown in Figure 6. The reason is mainly because the metal vapor is ejection during the burning process, so that part of the contact image will also appear arc brightness, and the detection result is not completely matched to the actual edge of the contact. To make the experimental results more accurate, use Labview's straight line fitting function to fit the position of the contacts. The upper and lower edge fitting results are shown in Figure 7.

3.3. Generate an Experiment Report
After the experiment, the Labview system will automatically generate an experimental report of the experiment and store it in the default path. The contents of the experiment report mainly include: experimenter, experiment start and stop time, test parameter setting, opening time statistics, collecting picture frame number statistics, image processing results and other information. Through the experimental report, the entire experimental process and results can be summarized.

4. Experimental Results
In order to verify the accuracy of the algorithm, the single-frame arc image is processed first. In the collected arc image, one frame is selected from the 120th frame arc image at intervals of 10 frames, and a total of 6 frames of arc image are obtained from the 170th frame. The image processing is performed by Labview. The detection results are as follows: Y120=105.31, Y130=110.28, Y140=116.90, Y150=123.07, Y160=129.62, Y170=136.54. The experimental data can accurately locate the displacement of the moving contact, and the algorithm is reliable.

During the experiment, the switch opening process lasted 10ms, and a total of 430 frames of arc images were acquired. A frame is selected every 10 frames to process the arc image, and a total of 43 lower edge fitting results are obtained. Origin's fitting function was used for curve fitting on logarithmic data points. When fitting, the smoothing adjacent average algorithm is selected, and the
number of windows is 7. The data error after fitting is between 3% and 7%, the error range is reasonable, and the judgment fitting method can be applied.

Figure 8. Moving contact displacement curve

Figure 8 is a displacement curve of the moving contact after fitting. It can be seen from the figure that the contact displacement is gradually increasing during the braking process. After 9.5363ms, the contact displacement is stable at 15mm, reaching the rated opening distance of the contact. The contact displacement fluctuates within an arcing time of 1.6279 ms to 2.5583 ms. The five data in this time period are 2.66mm, 2.50mm, 2.74mm, 3.61mm and 3.57mm respectively. This arcing time is the vacuum arc arcing stage, and the vacuum switch has a large opening speed, so that the contacts are in bounce occurs during the movement, and the displacement of the contacts fluctuates within a small range. The discovery of this phenomenon provides important support for studying the shape of the arc.

5. Conclusion
Aiming at the problem that the position recognition accuracy is not high, this paper proposes a contact position detection software and hardware system based on virtual instrument development platform Labview. The method first collects the arc image during the vacuum switch opening process through the hardware system. According to the characteristics of the arc image of the vacuum switch arc image, the upper and lower edges are consistent with the moving and static contacts, and the arc image is processed by the software system to realize the contact displacement detection. After processing the single-frame image, it is verified that the algorithm is reliable, and the arc sequence image is processed, and the following conclusions are drawn:

(1) There is a big error in the edge of arc image extracted by this algorithm, so it is necessary to use the linear fitting function of Labview to achieve the experimental purpose. The main reasons are as follows: First, during the arc combustion process, the contact gap temperature rises rapidly due to the instantaneous rise of voltage and current. At the same time as the arc image is formed, a large amount of metal vapor is ejected to the contact image position. The contact pixel point with the lower pixel value is covered by the metal vapor with a very high pixel value, and a false edge is formed during the edge detection process. Secondly, the instantaneous high temperature of the arc clearance has ablation on the surface of the contact, which is also the reason for the error in edge extraction.

(2) The displacement curve of the contact is generally rising, and the contact opening distance is 15mm. During the arcing phase of arc burning, the displacement of the contacts fluctuates. The reason of the fluctuation is mainly due to the bounce of the contact. During the arc starting phase, the operating mechanism provides tremendous power for the opening action, and the moving contact has a sufficiently large speed to achieve the opening operation. Therefore, the displacement of the contact increases rapidly in a short time, the contact vibrates, and the collected arc image also affects the area change. It provides a basis for future scholars to study the arc shape change in the arcing stage.
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7. References
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