Overview of One-Key Sequence Control Technology Based on Isolation Switch Equipment Detection

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Abstract. This article introduces the one-button sequence control operation of the isolating switch in the intelligent substation, as well as the sequence control system architecture and different kinds of identification technology operation applications. Combined with actual engineering, different recognition technologies have been proven practical and innovative.

1. Introduction
With the vigorous development of the “Ubiquitous Power Internet of Things”, many key production equipments are needed to complete ubiquitous monitoring and networking. Disconnector is one of the most used equipment in substations and its failure rate is very high. The main reason is that the outdoor isolating switch is directly exposed to the atmosphere, and the metal parts are prone to oxidation and corrosion [1]. There are basically no sealing measures for shaft pins, bearings, and connecting rods. The direct contact with air is prone to deterioration and loss of grease. In addition, oxides and dust are easy to accumulate in the joints, and problems such as jamming and insufficient clamping force may occur after a certain period of time [2-3]. There is a lack of effective technical monitoring methods for transmission mechanism failures, and more methods are used to enhance product quality and rust prevention performance, and to improve equipment installation and maintenance processes.

When the movable contact finger of the isolating switch cannot effectively contact the static contact rod, causing defects such as heating and overheating at the contact part of the movable contact finger and the static contact rod, it causes the switch to be damaged. Furthermore, a large-scale blackout occurred in the power grid. Therefore, the damage of the isolating switch causes huge economic losses to the power system and damages the personal safety of power station operators. Accurately judging whether the isolating switch is in place is a key issue to solve the normal operation of high-voltage electrical equipment in the substation [4-5]. In actual production, there is an urgent need to detect the status of the isolation switch drive system in order to take preventive measures to avoid power outage accidents.

At present, judging whether the isolating switch is in place mostly adopts the method of manual field observation and subjective judgment using telescopes. This method is susceptible to the subjective influence of the observer. Its shortcomings are low accuracy and low efficiency. At present, power departments in various places are piloting applications of high-definition cameras or mobile robots to obtain second-dimensional operating status information of isolation switchgear, and intelligently process image data through the background intelligent analysis host to support remote control of substations [6]. The intelligent image analysis mode generally meets the requirements of remote operation and maintenance of substations, but the following problems still exist at this stage: (1) The
number of cameras is large, the cost is high, the maintenance workload is large, and the location is greatly restricted by the site. (2) Extra measures need to be taken at night to ensure image quality. (3) The robot has high cost and high requirements on the running track, and the running area is greatly restricted by the site.

When the operating state of the isolating switch is detected, the control technology is also randomly born. One-key sequence control, as a new intelligent substation inspection technology, is gradually being promoted and applied in substations. In order to realize the switch of equipment status, switch is used.

Operation switches the equipment to four states: overhaul, hot standby, cold standby and running. However, there are usually higher voltages in substations [7]. Misoperation in the switching operation will not only endanger the safety of people and equipment, but also cause the breakdown of the power system. One-key sequence control means that the operator assigns tasks on the integrated information platform, which can realize the instructions of operating project software prefabrication, task module construction, equipment status recognition and operation steps one-click start and execution in sequence at one time. The traditional one-key sequence control system uses the signal collected by the remote signal to judge the running status of the equipment, and uses the intelligent protection system to judge whether the programmed operation is in place.

Therefore, a state detection technology is proposed in this article.

2. One-key sequential control system based on isolation switch detection

The one-key sequence control system is shown in Figure 1. A set of online monitoring system for the opening and closing status of combined electrical appliances based on multi-parameter attitude sensors is designed. It can accurately determine the position of the knife switch by directly measuring the position of the knife switch lever. Without affecting the performance of the equipment, it is consistent with the original. Some knife switch auxiliary contacts determine the knife switch position. The method of setting together forms a non-homologous “double confirmation” judgment system for the position of the switch. The monitoring system is safe, reliable and stable, and has played a positive role in promoting the construction of the energy Internet of Things. At present, the switching operation of smart substations mostly adopts “one-key sequential control” technology, in which the disconnection and closing state of the isolating switch is an important criterion of “one-button sequential control”.

When the isolating switch is operated remotely, there are at least two non-same-origin instructions at the same time. The corresponding change can confirm that the isolating switch has been operated in place. The first criterion of “dual confirmation” for disconnecting and closing of an isolating switch generally uses auxiliary switch contacts to determine the position state. The other non-homogenous monitoring methods include stroke, video, pressure, grating, attitude sensor method and other monitoring methods. According to the characteristics of the transmission structure of the isolating switch, the operation characteristics of the transmission mechanism of the operating mechanism when the position of different switches are changed. Different, but the main operating mechanism will show posture changes, so the main purpose of the second criterion is to measure the posture position of the knife gate.

The detection signal sends the opening and closing status information of the knife switch to the knife switch status receiving device through the serial port. After analysis and judgment, the knife switch status receiving device outputs the passive contact indicating the opening and closing status of the knife switch to the measurement and control device (conventional station) or on-site device (smart station), according to different application scenarios, wired transmission and wireless transmission can be designed to realize the knife switch monitoring under a variety of motion conditions. The knife switch status receiving device uploads the sensor's angle, opening and closing time, knife switch status and other information to the background system, the knife switch status receiving device and the host computer information system through the RS485 interface or the network port. The sensor transmits the information to the signal receiving device by measuring the change of the knife switch operating lever, so as to calculate and analyze the knife switch position information. Through the software algorithm,
the corresponding real-time monitoring judges “opening in place”, “closing in place”, There are four states: abnormal opening and abnormal closing. For the opening and closing status of each knife switch equipment, 3 pairs of contact signals are output, 2 channels are used for the opening and closing status of the knife switch, and 1 channel represents the sensor fault contact signal. The sensor fault contact is closed and separated when normal. In addition, the receiving device transmits the monitored signal to the background system through the IEC61850 protocol, and then forms a non-homologous “double confirmation” determination system for the position of the knife and switch together with the traditional auxiliary switch contact to determine the position of the knife.

3. Deep learning state detection technology based on one-key sequence control technology

To effectively detect and identify different disconnector states, a multi-task learning network is proposed. The network not only needs to detect the state of the isolating switch, but also needs to identify the state of the isolating switch according to the unique text description below the state of the isolating switch. Figure 2(a) is the overall framework of the method in this article. For a given input picture, the network first uses one the shared convolutional layer extracts the shared features; then a text detection network is used to detect and recognize the text, a recognition frame is used to detect the area of the hard platen, and its switching status is classified and recognized.
Feature sharing network uses ResNet-50 as the basic network. Feature Pyramid Structure (FPN) is used to fuse high-resolution and low-resolution features to integrate global and local information. The feature fusion process is satisfied.

$$g_t = \begin{cases} \text{unpool} \left( h_t \right) & (i = 3) \\ \text{conv}_{3 \times 3} \left( h_t \right) & (i = 4) \end{cases} \quad (1)$$

$$h_i = \begin{cases} f_i & (i = 1) \\ \text{conv}_{3 \times 3} \left( \text{conv}_{3 \times 3} \left[ g_{i-1} ; f_i \right] \right) & (i \neq 1) \end{cases} \quad (2)$$

where $g_t$ and $h_t$ are the feature map to be fused and the feature map after fusion, respectively; unpool is the up-sampling operation; conv is the convolutional layer operation. In order to ensure that the size of the feature map is consistent during feature fusion, the last stage of the feature map is up-sampled, and the size is doubled;

This paper uses the data set collected above to evaluate the performance of the proposed algorithm. Table 1 shows the accuracy comparison results of different algorithms for the detection and positioning of the hard plate. CTPN stands for CNN and long and short-term memory deep network, which can effectively detect horizontally distributed text in complex scenes. SSTD is a binary image digital watermarking algorithm. It can be seen from Table 1 that the proposed algorithm has higher accuracy than other independent detection algorithms.

| Algorithm       | Detection accuracy | Recognition accuracy |
|-----------------|--------------------|----------------------|
| CTPN            | 72.63              | 80.36                |
| SSTD            | 85.36              | 85.68                |
| The proposed algorithm | 88.23              | 96.35                |

After performing the above-mentioned feature extraction and feature fusion operations, the extracted shared features are sent to the isolation switch detection network and the text detection network for detection and recognition. The proposed method can improve the accuracy of isolating switch state recognition, and at the same time ensure the safety of one-key sequential control operation.

4. **Image recognition unit network based on one-key sequence control**

Through this series of processes (Figure 3), the binarized isolating switch image is processed for shape contour, and the measurement difference is used as the basis for analyzing the shape feature of the isolating switch, and these shape features are used as the input feature vector for the image recognition and analysis of the isolating switch. Satisfactory results can be obtained in the identification analysis.
To verify the effectiveness of the image recognition program for the identification of the disconnector during the switching operation of the smart substation, the actual measurement of the transformed substation was carried out.

Table 2 Isolation switch recognition success rate

| Identification type                  | Identification item | Identification number | Recognition success number | Identification accuracy |
|--------------------------------------|---------------------|-----------------------|---------------------------|------------------------|
| Electric signal + position signal    | Isolation switch    | 25                    | 18                        | 72%                    |
| Electric signal + position signal +  | Isolation switch    | 25                    | 20                        | 80%                    |
| image signal                         |                      |                       |                           |                        |

It can be seen from the test results that the addition of image recognition can effectively improve the recognition success rate, and it also improves the success rate of sequential control switching. Image recognition technology and image analysis and recognition algorithms process real-time images collected from electrical equipment to obtain images and signals that reflect the status of the equipment, as a standard logical switching operation to monitor and track the synchronous display of equipment pictures to avoid electrical mis-operation. When the error caused by a single electrical signal is recognized, the power device of the electrical equipment switch is not in place correctly, and the remote inspection and monitoring equipment is realized through sound, video and pictures.

The result of image recognition processing is regarded as a standard logical switching operation to monitor and track the equipment pictures displayed simultaneously to avoid errors caused by electrical mis-operation. When a single electrical signal is recognized, the power unit of the electrical equipment switch is incorrectly in place and realized Remote inspection and monitoring equipment through sound, video and pictures. This method can not only improve the safety and efficiency of the switch operation, but also improve the reliability of the one-key sequence control switching operation. Through remote inspection, the workload of operators can be reduced, and strong technical support can be provided to improve the integration level of dispatching and control, and to ensure the stability and safety of the power grid.

5. Conclusion

Because the traditional sequence control only uses electrical signals and position signals to confirm, it is caused by the low success rate of identifying the status of the target device. To solve this problem, this paper uses different identification technologies to assist in the discrimination method to solve this problem in the sequence control of the intelligent substation, so as to achieve one-button sequence control. In this paper, the research of image recognition technology and deep learning technology in the recognition of substation switch is carried out. Finally, the proposed method is run and tested, and the test results prove that the addition of auxiliary discrimination technology to the original recognition method can significantly improve the recognition of the switch position the success rate.

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