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Research on Vibro-Acoustic Detection Method of Porcelain Pillar Insulators

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Abstract: High-voltage pillar-type porcelain insulators are important components of power plants and substations, and are widely used in power grids. In recent years, various kinds of accidents caused by breakage of pillar insulators have occurred frequently during the operation of the power grid, posing a serious threat to the safe operation of the power grid. Aiming at the problem of the deterioration detection of porcelain strut insulators in transmission lines, this paper introduces the detection principle of vibro-acoustic method and the vibro-acoustic detection process of porcelain strut insulators. A set of vibro-acoustic-based porcelain strut insulator detection equipment is studied and designed, and its design principle is expounded. And hardware components, the effectiveness of the detection function is verified through the actual measurement analysis, which provides support for the follow-up research and promotion of this detection technology.

Key words: Porcelain Post Insulator; transmission line; vibroacoustics; Testing Equipment

1. Introduction

Porcelain post insulators are important components of electrical equipment in power grids and power plants[1]. Due to improper design, manufacture, installation, maintenance and overhaul, as well as the influence of the harsh environment during operation, it is easy to cause the failure and fracture of the porcelain pillar insulator, which endangers the safe operation of the power grid[2-3]. Therefore, strengthening the inspection and quality evaluation of in-service porcelain pillar insulators in the power grid is crucial to ensuring the safe, reliable and economical operation of the power grid. For a long time, the power system has used the traditional periodic test method (preventive test) to detect high-voltage equipment porcelain pillar insulators, but the test needs to be carried out during a power outage. operation; and regular power outages will cause losses to the national economy. The fracture of the post insulator is a sudden phenomenon. Its occurrence is caused by both the insulator itself and the influence of external factors during operation. Judging from the results of on-site detection, the main cause of defects and fractures is the injury of the strut insulator during operation and operation. From the results of the accident investigation, the backward manufacturing process and low product quality are the internal causes of the insulator fracture[3-5]. Therefore, it is necessary to carry out research on the mechanism and application of effective detection methods for cracks, void penetrations and other defects in pillar porcelain insulators.

At present, the defect detection of pillar insulators at home and abroad mainly adopts ultrasonic flaw detection technology[6]. Since porcelain parts are good carriers of ultrasonic waves, by emitting longitudinal waves, transverse waves, creeping waves and other waves at the flange, and receiving reflected signals to detect defects, it can effectively detect cracks, interlayers and other defects on the surface of the porcelain pillar insulator. But it belongs to the local damage detection method, which is greatly affected by the operator's proficiency and experience. Another researcher found that there is a misjudgment phenomenon in ultrasonic testing of pillar insulators[7]. This is mainly because the ultrasonic wave does not propagate in an absolute straight line after entering the porcelain body at a small angle, but propagates in a spindle shape[8]. Due to the proximity of the probe to the porcelain sand, part of the outer edge of the ultrasonic wave may encounter the porcelain sand on the porcelain body, or the gap between the porcelain sand and the porcelain sand, resulting in a reflection waveform similar to the defect wave that exceeds the distance-amplitude curve. The flaw detector mistakenly thought it was an internal defect of the insulator. Vibration detection methods have been widely used in machinery, ships, bridges and other fields[9]. In view of the advantages of the vibration method, such as simple loading equipment, fast test speed, easy extraction of vibration signals, sensors can be installed in places that people are not close to, and the process of damage detection does not affect the normal use of the structure. , which will greatly make up for the deficiencies of existing detection methods and

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improve the safe operation index of pillar insulators. In this paper, the feasibility and detection law of the vibration method applied to the defect detection of pillar insulators are mainly discussed from the perspective of experiments, and a comparative study is carried out with the ultrasonic detection method.

2. Method

2.1 Design Principles

The basic criterion for maintaining the mechanical strength of the porcelain strut insulator is its characteristics. The model of the porcelain strut insulator can be studied: the vibration of the insulator appears at the fundamental frequency in most cases, which is about 4kHz; When loaded with force, the vibration contains complete information on the dynamic characteristics of the insulator; when there is a crack in the bottom flange area of the insulator, it results in a frequency component below the fundamental frequency; and when there is a crack in the upper flange area, it results in a frequency component above the fundamental frequency frequency components. The mechanical state of the porcelain strut insulator can be judged according to its mechanical strength, that is, the bearing capacity, and the mechanical strength value of the porcelain strut insulator can be judged by exciting sound waves at a certain frequency on the insulator and evaluating the response power spectrum of the insulator with mechanical vibration. The bearing capacity or the ultimate failure load of the porcelain post insulator is calculated according to the following formula:

$$P_1 / P_2 = \left(\omega_1 / \omega_2\right)^2$$

where P_2 is the ultimate load of the undamaged insulator; P_1 is the ultimate load of the damaged insulator; ω_2 is the center frequency of the vibration response spectrum of the undamaged insulator; ω_1 is the center frequency of the vibration response spectrum of the damaged insulator. It can be seen from the above formula that when random vibration is applied to the porcelain pillar insulator, the cracked insulator will have frequency components different from the fundamental frequency. According to the center frequency of its spectrum, the mechanical state of the insulator can be evaluated, that is, by evaluating the excitation effect of the pillar insulator. The response spectrum of the sound wave to determine whether the strut insulator has been damaged.

2.2 System module

In this paper, the STM32F4 series microcontroller is used as the main control, and the high-performance DAC digital-to-analog chip is used to generate the arbitrary waveform vibration excitation signal, and the high-performance ADC analog-to-digital conversion module is used to collect the insulator vibration signal, and the sampling frequency is 50kHz.

This circuit adopts a modular design idea. According to the design requirements, the circuit is divided into five parts: power supply module, DAC digital-to-analog conversion module, ADC analog-to-digital conversion module, functional module, and microcontroller module. The specific composition block diagram is shown in the figure.

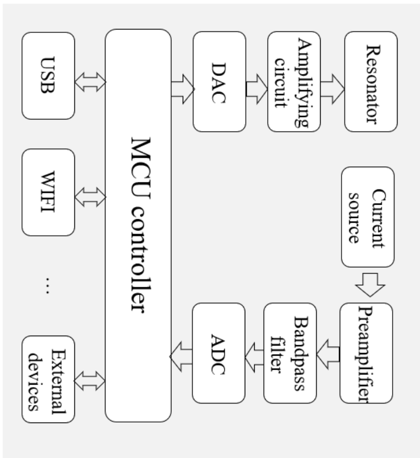

Figure 1 System circuit module composition

The hardware equipment mainly includes the data acquisition end and the data transmission end. A miniature vibration exciter is installed at the data acquisition end, which excites the insulator; a sensor is installed on the front-end mushroom-shaped shell as the acquisition end to collect the vibration signal of the insulator; at the same time, the front end is equipped with a sensor.A vibration wave collection device is also installed to transmit the collected data to the data transmission end at the back end. The data transmission end mainly includes a circuit board and a WiFi interactive signal transmitter, which is used to transmit the collected data and send it to a computer and other devices. The front and rear ends are connected by a connecting device with a built-in spring trigger; the spring is not only used to connect the front and rear devices, but also plays the role of controlling the trigger DIP switch. When in use, the trigger switch placed inside the spring follows the compression of the spring Will turn on to start working, spring back to length when not in use and finally disconnect the switch.

Figure 2 Device hardware model diagram

When the equipment is in use, press the upper end of the exciter at the front-end data acquisition place against the lower edge of the lower flange of the insulator, and push the front two probes directly (with a spring trigger switch inside). The internal DIP switch will be triggered and the circuit board will be powered on to start collecting data. When the data collection is completed, the device will automatically issue a "data collection complete" prompt signal to remind the staff that the collection work has been completed. After the data collection is completed, the data is sent to data analysis devices such as computers through the back-end data transmitter in a WiFi environment.

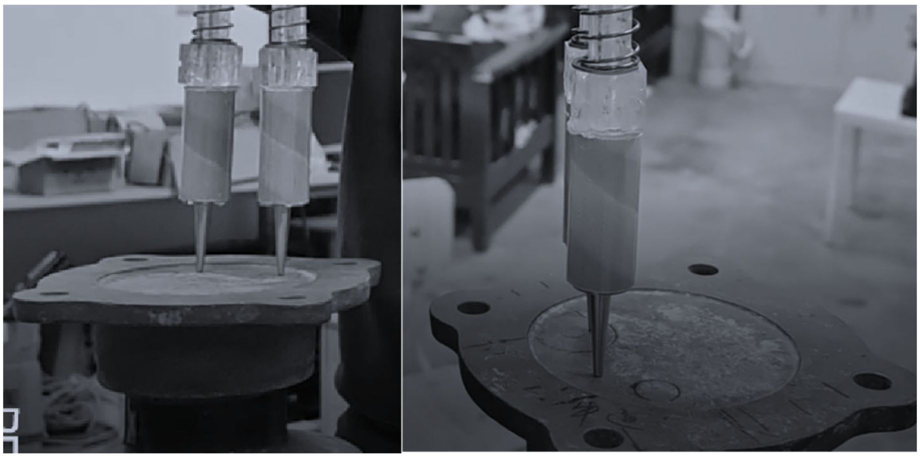

Figure 3 Actual use diagram of testing equipment

Finally, use the designed signal detection software or MATLAB software to analyze the collected data, obtain the spectrogram, and then analyze the offset of the peak frequency, and then analyze whether the equipment has cracks and other faults. There is a DIP switch installed inside the probe at the front end of the equipment. When using it, you only need to directly touch the exciter at the front of the product to the lower flange of the insulator to be tested. The probe with the DIP switch in the front section directly contacts the insulator. When the operator After pushing the device upwards, the DIP switch will be turned on, and the integrated circuit module will be powered on to start collecting data; after the data collection is completed, the device will emit a tone to remind the operator. With the opening of the switch, the exciter works to generate excitation to the insulator. After the excitation propagates in the insulator, the feedback forms a response and provides it to the front-end signal collector; The WIFI interaction is directly transmitted to the computer, and then the corresponding data in the form of ".txt" text is obtained. After analyzing the data corresponding to the equipment to be tested, the obtained spectrogram is analyzed and compared with the spectrogram corresponding to the standard undamaged insulator, and the damage of the equipment to be tested is analyzed and judged. The detection image of undamaged insulators has only one peak in the frequency range of 3k-5k, but damaged insulators will have two or more peaks, and even different peaks will appear in other spectral ranges, which is the main basis for judgment, to analyze the damage of the insulator. It can be seen from the figure 4 that there are multiple peaks in the spectrum on the right, so it is determined to be a faulty insulator.

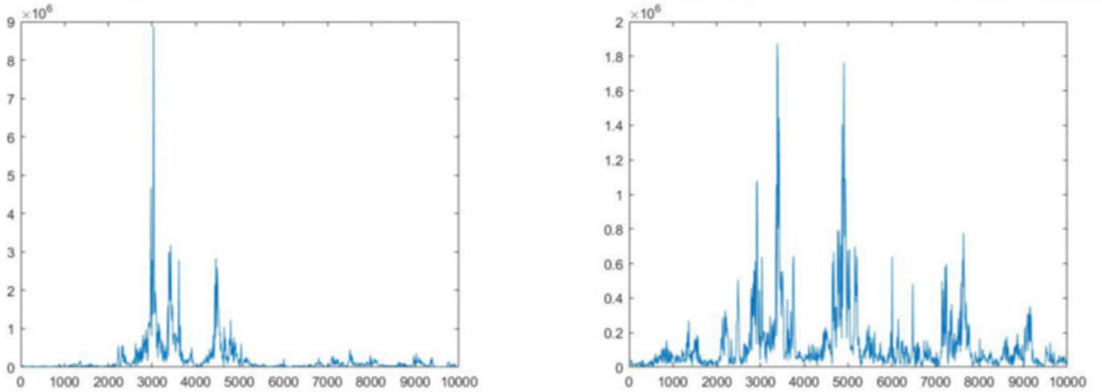

Figure 4 Insulator spectrograms in normal and faulty states

3. Conclusion

The insulator fault detection equipment developed and designed in this paper is based on the excitation acoustic detection method. The equipment uses a small vibration exciter to contact the lower flange of the insulator. After excitation, the small vibration signal collector at the front end of the equipment receives the vibration signal, and then Feedback into the device's integrated circuit transmits data to the computer via the installed Wi-Fi interactive device. Combined with the software used for data analysis in this project, the data is processed and analyzed, and the vibration spectrogram is obtained. Whether the mechanical performance of the insulator is damaged. Through experimental analysis, the spectrogram obtained by normal insulator equipment through feedback after detection is a projection image with only one peak, while the image obtained by feedback from an insulator with cracks will have a main peak and a secondary peak, and the generation of a secondary peak means that If the insulator equipment fails, it needs to be replaced and repaired in time.

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Development of a new type of post insulator live detection equipment based on vibration resonance technology (716002022030302SC00001)

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