Application of Acoustic Spectrum Analysis in Detection of Porcelain Post Insulators Based on a portable insulator detection equipment

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Abstract. Fault detection of porcelain post insulators has always been the research direction of power industry. At present, the related equipment for flaw detection of porcelain insulators still has some defects, such as high equipment cost, complex operation and poor detection effect. For the fault detection of porcelain post insulators, this paper will put forward a complete set of fault detection methods based on the application of acoustic spectrum analysis in the fault detection of porcelain post insulators. The equipment used is a portable insulator testing equipment independently designed by the research team based on the basic principle. Based on this method, a large number of comparative experiments and testing applications have been carried out, which verifies the effectiveness and reliability of the vibroacoustic testing method in the detection of porcelain post insulators.

Keywords: Electrical equipment, post insulator, fault detection, vibration acoustics, spectrum analysis, flaw detection.

1. Background and significance of the thesis
At present, with the rapid development and all-round transformation and upgrading of the domestic power and energy industry, the voltage level of the power grid system is constantly improving, and the number of large-capacity and high-parameter generator sets is also increasing [1]. The form and operation characteristics of power system are becoming more and more complex, especially the non-traditional hidden dangers brought by the application of many new technologies are increasing, which puts forward higher requirements for the capabilities of all aspects of the system, and brings a severe test for ensuring the safe and stable operation of the power system. This not only puts forward higher requirements for the sophisticated technology in China's power industry, but also puts forward higher requirements for many basic equipment and basic services in the power industry.

Among them, as the basic pillar equipment in power industry, the main function of insulator is to realize electrical insulation and mechanical fixation, and it has various electrical and mechanical performance requirements, so its fault detection is very important in practical work. Insulators are subjected to electrical, thermal and mechanical stresses and various harsh working environments when running in the power grid, and their performance will gradually decline and deteriorate. The main form
of damage is that the original microcracks expand into macroscopic cracks [2-3]. Cracks are the most important and dangerous defects that lead to the failure of porcelain insulators due to the decline of mechanical properties. In order to ensure the safe and stable operation of the power grid, it is necessary to detect all kinds of external and internal cracks and defects such as low mechanical strength of insulators in advance, and then take corresponding remedial measures according to specific conditions to avoid accidents.

Therefore, it is an urgent requirement to study the online nondestructive testing method with high reliability and strong field adaptability for the performance diagnosis of porcelain insulators, which has great safety and economic benefits.

Conventional methods for detecting porcelain insulators [4-5], such as ultrasonic detection [6], have some shortcomings, such as poor detection of microcrack defects, many interference factors, and inability to detect on-line, which are difficult to meet the needs of effective detection and diagnosis of porcelain insulators. Among them, the vibration acoustic detection and diagnosis technology[7] can directly determine the overall strength and stiffness of the component, so it has the advantage of evaluating the safety performance of the component in the bearing state.

Based on the above background, this paper will introduce the application of vibration acoustic detection method in the fault detection of porcelain post insulator. The vibration exciter will send the excitation to porcelain post insulator and receive the feedback acoustic signal. The spectrum analysis of the acoustic signal will get the corresponding spectrum. Through the comparative analysis of the spectrum, the damage of the insulator to be tested is evaluated and analyzed.

The research of this paper is a practice of insulator fault detection based on the principle of vibration acoustics. It will comprehensively consider the key problems existing in the current insulator fault detection and the corresponding industry needs, carry out targeted research and design, and form a complete insulator detection theoretical system and scheme. This will provide some reference for the development of the front-line work of the power industry, and promote the development of China's power industry to a certain extent.

2. Introduction and application of technical principle
Vibration acoustic detection [8], its principle is similar to the traditional percussion detection. Since ancient times, there are many objects detected by tapping detection. Such as striking porcelain bowls and beating watermelons, which are similar to this, are some cases of traditional vibration acoustic detection methods. Its essence is to judge the structural state of the object to be tested by using the change of sound caused by defects. In the modern sense, vibration acoustic detection uses more scientific methods and accurate detection instruments instead of traditional empirical judgment, and in essence, it still uses the change of sound caused by defects to judge whether the workpiece has defects.

The technical basis of vibroacoustic detection method is to artificially excite the workpiece to generate mechanical vibration sound waves inside it. It is economical and easy to realize to judge the state of its structure by measuring its vibration characteristics.

At present, there is a certain theoretical basis for vibroacoustic detection technology at home and abroad, and the detection method based on vibroacoustic has been applied in the quality control of refractory materials, railway locomotive parts and so on. Vibration acoustic nondestructive testing method based on the natural frequency of the component to be tested is a new nondestructive testing method. Its principle is through the correlation between the elastic constant of the component material and some mechanical properties (such as hardness, strength, etc.). The change of elastic parameters of component material will lead to the change of resonance frequency when the component vibrates freely, so the change of mechanical characteristics of workpiece can be determined by measuring the resonance frequency of the component vibrates freely.

The principle of detection method introduced in this paper is based on vibration acoustic detection method [9-10]. In the testing process, the vibration exciter installed at the front end of the equipment is used to excite the device to be tested so as to generate mechanical vibration sound waves inside it, and then the obtained sound wave data are collected by feedback. The data processing after feedback
collection is more integrated with modern advanced technology, and the equipment directly visualizes the obtained data to obtain the spectrum analysis chart. The data spectrogram corresponding to normal equipment is analyzed and compared, so as to judge whether there are defects (cracks) in the equipment and obtain the working condition of the tested equipment.

3. Technical scheme design and improvement

Based on the research background and technical principles introduced above, the team that published this paper designed a set of reasonable and effective technical scheme based on the basic principles of vibroacoustics when conducting experiments in the laboratory, and further improved and perfected the experimental scheme and specific testing equipment through continuous experiments and improvements.

![Technical design module introduction](image)

**Figure 1. Technical design module introduction**

According to the basic principle of vibroacoustic detection, to realize the detection of porcelain post insulators, there are several main links, such as excitation generation, signal reception, signal conversion and data analysis. The equipment uses STM32F4 single chip microcomputer as the central control system to control the operation of each module of the equipment. Among them, the excitation generation is to directly use the vibration exciter to generate excitation for the insulator to be tested, at the same time, the signal receiver collects and stores the feedback acoustic signals, and realizes the conversion between ADC and DAC signals under the processing of single chip microcomputer. After collecting the signals, the data is retained by storage devices such as USB flash drive, and then transmitted to the data processing terminal through "WiFi interaction" and other ways, and the data is further analyzed by the
data processing software to obtain the spectrum analysis diagram as the basis for judging the basic performance of the insulator under test.

In the process of data processing, the experimental team uses a program software developed and designed by itself. When the data is directly imported into the software system, the software will perform spectrum analysis on the data according to the predetermined function, obtain the spectrum analysis diagram of the measured data and generate the number of main peaks independently, which provides a good data basis for the subsequent evaluation work.

4. Test data analysis and results
After the basic data collection is completed, the corresponding spectrum analysis diagram is obtained by using data analysis software. The analysis of spectrogram is mainly based on the number of peaks in the corresponding range of spectrogram. Among them, there is only one main peak in the frequency range of 3k-5k in the spectrum analysis diagram obtained after the good insulator is detected by the vibroacoustic principle detection equipment. There are two or three or more main peaks in the range of 3k-5k for damaged insulators to be eliminated, and there may be a main peak near 8k.

Therefore, in order to judge whether the insulator is damaged or not, it is necessary to obtain the number and distribution of peaks under vibration acoustic detection technology. In order to verify and improve the technical scheme more accurately, the experimental team started the experiment from three directions and recorded the data.

On the one hand, a batch of good and undamaged insulators and a batch of damaged insulators are respectively subjected to vibration acoustic detection, and the measured data are recorded and then subjected to spectrum analysis, and the obtained peak distribution is recorded in a table. On the other hand, a comparative experiment is carried out. After measuring the spectrogram of a good insulator, it is damaged by manual knocking, and the equipment damaged by knocking is detected again, and the corresponding data is recorded in the table.

In this way, the experimental team obtained the frequency spectrum of damaged insulators, good and undamaged insulators, the corresponding peak number and peak distribution, and also obtained several groups of comparative experimental data, which provided a good foundation for the analysis of subsequent problems and data collation and analysis.

![Experimental spectrum analysis diagram](image)

Figure 2. Experimental spectrum analysis diagram

Experimental data table:
Table 1. The number of experimental peaks of undamaged insulators

| Frequency range | Insulator number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|-----------------|------------------|---|---|---|---|---|---|---|---|---|----|
| 3k-5k frequency range | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |    |
| Near 8k frequency       | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |    |

Table 2. The number of peaks of the damaged insulator experiment

| Frequency range | Insulator number | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|-----------------|------------------|---|---|---|---|---|---|---|---|---|----|
| 3k-5k frequency range | 2 | 2 | 3 | 2 | 2 | 2 | 3 | 2 | 3 | 2 |    |
| Near 8k frequency       | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 0 |    |
| Frequency range | Insulator number | 11| 12| 13| 14| 15| 16| 17| 18| 19| 20 |
| 3k-5k frequency range | 2 | 3 | 2 | 2 | 2 | 3 | 2 | 3 | 2 | 2 |    |
| Near 8k frequency       | 0 | 0 | 1 | 1 | 0 | 1 | 2 | 1 | 0 | 0 |    |

Table 3. Comparison of experimental peak numbers before and after insulator damage

| Frequency Insulator number | Intact insulator 1 | Damaged insulator 1 | Intact insulator 2 | Damaged insulator 2 | Intact insulator 3 | Damaged insulator 3 | Intact insulator 4 | Damaged insulator 4 |
|-----------------------------|--------------------|---------------------|--------------------|--------------------|--------------------|--------------------|--------------------|--------------------|
| 3k-5k frequency range       | 1                  | 2                   | 1                  | 2                  | 1                  | 2                  | 1                  | 2                  |
| Near 8k frequency           | 0                  | 1                   | 0                  | 1                  | 0                  | 0                  | 0                  | 1                  |

5. Conclusion and prospect

Conclusion:
The paper studies and analyzes the following contents:
1. The research begins with theoretical research and analysis. The fault detection technology of porcelain post insulator based on vibroacoustic principle is analyzed and demonstrated, and the direction to solve the problem is put forward.
2. The paper analyzes the strategy and technical scheme based on theoretical analysis, and analyzes the experimental data obtained by the research team and the corresponding test results.

The research content has the following characteristics:
1. The adopted porcelain insulator detection scheme is reasonable, effective, simple and economical, which reduces the loss of manpower and material resources in the process of porcelain insulator detection.
2. The adopted detection means can realize the detection of porcelain post insulators without power failure, and can reduce the impact on regional economic development caused by the need of power failure detection in other detection schemes.

Prospect
Safe operation of power equipment is closely related to the development of post insulator flaw detection technology, which is one of the key research directions for deepening reform and continuous transformation of power grid system. Its development trend will be reflected in the aspects of speed,
accuracy, portability and economy, which will meet the current industry demand related to insulator
detection in many aspects and provide guarantee for the safe operation of power equipment.

In addition to the fault detection of porcelain post insulators, many working equipments need fault
detection. Vibration acoustic detection technology is also expected to be applied in medical devices,
high-precision equipment, material processing and other fields, and the related technologies introduced
in this work will be widely used with its comprehensive advantages in many aspects.

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