Analysis of the Research and Development Status and Future Development of Porcelain Insulator Fault Detection Equipment Based on a Portable Insulator Detection Device

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Abstract. Fault detection of porcelain post insulators has always been the research direction of power industry. At present, the insulator testing equipment still has some defects, such as high cost, complex operation and poor effect. For the design and development of fault detection equipment for porcelain insulators, this paper will introduce the design principle and basic structure of an insulator detection equipment based on a portable insulator fault detection equipment. In this paper, combined with modern science and technology, artificial intelligence and UAV technology are combined with insulator detection work to make innovation and prospect for the future development of insulator detection equipment.

Keywords: Electrical equipment, post insulator, fault detection, vibration acoustics, artificial intelligence, UAV.

1. The problem and research significance
Porcelain post insulator, as the basic pillar equipment of power grid system, plays an important role in realizing electrical insulation and mechanical fixation in power grid system, and it needs to adapt to work in various complex extreme environments. This puts high demands on its mechanical structure performance and strict use standards. Porcelain insulators are subjected to electrical, thermal and mechanical stress and harsh working environment in operation, and their performance will gradually decline and deteriorate, which is mainly manifested by the original micro-cracks expanding into macro-cracks [1]. The internal cracks of insulators will directly lead to the performance decline and deterioration, and eventually lose their functions. Cracks are the most important and dangerous defects that lead to the deterioration of the working performance of porcelain insulators.

Strict use standards and vulnerable product characteristics of insulators put forward high requirements for their production, transportation and use detection. Insulator detection technology plays an important role in the use of insulator equipment. On the one hand, it is necessary to carry out fault detection before the equipment is installed and used, so as to eliminate the equipment damage caused by production errors and transportation damage, and ensure that the equipment with the best performance is installed and used. On the other hand, in long-term use, insulators will be damaged for various reasons and need to be replaced. This requires the relevant management enterprises to detect the
faults of relevant equipment in time, screen and replace the damaged equipment in time, so as to avoid the power grid system paralysis caused by insulator damage and bring greater economic losses. It can be said that early detection and fault detection are of great significance to the safe use of insulators and even the steady development of power grid industry.

2. Research and development status at home and abroad

At present, the fault detection of post insulator at home and abroad is mainly divided into two categories live on-line detection and power off detection [2]. The main difference is whether it is necessary to cut off the power of the line where the insulator is located. It can be said that live detection is the basic functional requirement of the current most mainstream porcelain post insulator fault detection equipment, and also the necessary function of the future porcelain post insulator fault detection equipment.

For insulator related detection technology, in the long-term development of power industry, there have been many detection methods. Conventional detection methods of porcelain insulator, such as ultrasonic detection, Doppler vibration method, infrared temperature measurement method and ultraviolet corona imaging method [3]. However, the detection methods and equipment based on these methods have some shortcomings, such as poor detection effect of microcrack defects, many interference factors, unable to detect on-line and so on. Therefore, the research and development of on-line nondestructive testing equipment with high reliability and strong field adaptability will become an urgent requirement for the performance diagnosis of porcelain insulators, which has great safety and economic benefits.

3. Problem solution

For the porcelain post insulator fault detection equipment, the porcelain post insulator fault detection equipment based on vibration acoustics and spectrum analysis technology [4] has the advantages of cost-effectiveness and easy operation, and has a good development prospect. Related technologies are constantly improving and maturing, and the research and development of related equipment has always been the focus of the power industry. This paper is based on a portable porcelain post insulator testing equipment based on vibration acoustics.

![Fig.1 This paper is based on a portable porcelain post insulator testing equipment based on vibration acoustics.](image)

The vibroacoustic detection method was first used by Russian scientists in the detection of industrial equipment, and now it has been widely used in the detection of medical equipment, high-precision equipment, flaw detection and many other industries. Its simplicity and economic characteristics also make it popular. As for vibration acoustics, its essence is to judge whether the mechanical structure of workpiece has changed through the change of sound, which is the same as the essence of ancient percussion detection. Only in the development of modern science and technology, it adopts a more
scientific and accurate method to obtain the frequency of sound waves, and then analyzes the frequency to judge whether the workpiece to be measured is damaged.

The research team of this thesis uses a portable insulator fault detection equipment based on vibration acoustics and spectrum analysis. The convenience of use is fully considered in the R&D and manufacturing stage of the equipment. Miniaturized components are adopted in each modular equipment, which greatly reduces the overall volume of the equipment and improves the convenience of the equipment.

The main technical requirements of vibroacoustic insulator detection equipment are to generate excitation to the workpiece and receive the mechanical vibration wave fed back by it, and then analyze the collected data by spectrum to obtain the spectrum diagram. Compare and analyze the spectrogram of the measured workpiece with the spectrogram of undamaged equipment, and then judge the structural state of the workpiece to be measured.

In the basic equipment studied in this paper, two independent vibration exciters are installed at the front end, and a signal receiver is installed inside the vibration exciter. The central control module is in the middle, and the control MCU and Wi-Fi communication module are installed inside, which is mainly used for controlling the equipment and feeding back the data. At the same time, the equipment is also equipped with a central display screen, which is mainly used for displaying relevant parameters of the equipment and prompting the working state. The lower part is a detachable support bar, which is made of steel. In order to facilitate the storage and carrying of the equipment, a detachable screw fastener is designed to improve the convenience of the equipment in use.

![Fig.2](image-url) The lower part is a detachable support bar, which is made of steel.

When in use, it is only necessary to press the front vibration exciter against the flange of the post insulator, and press down the equipment to cause the front spring to compress, thereby triggering the internal dip switch and starting the equipment. Under the control of MCU, the equipment starts to collect data. After data collection, the data can be transmitted to the data analysis equipment through Wi-Fi interaction or USB. Use data analysis equipment to obtain the spectrum analysis diagram of the data, and finally compare and analyze the obtained spectrum analysis diagram to judge the mechanical structure quality of the workpiece to be tested, and replace and repair the unqualified equipment in time.
Fig. 3 The front spring to compress, thereby triggering the internal dip switch and starting the equipment.

The equipment used by this research team has many advantages, such as live detection, simplicity, portability, high efficiency and accuracy, which will be the basic performance requirements of insulator fault detection equipment in the future. For the future research and development of equipment, it is necessary to fully combine the future development of science and technology with the needs of the industry for improvement in order to obtain equipment with better performance.

4. New design ideas and future development ideas
As for the future development and design concept of porcelain post insulator fault detection equipment, this paper thinks that the development trend of insulator detection equipment in the future will develop in three main directions: "portable, efficient and intelligent". "Portable" is the performance goal pursued by any product or device, which is directly related to the use effect of the device and the user's experience. "High efficiency" is an important embodiment of the performance advantages of testing equipment in terms of testing speed and accuracy, which will bring great help to the front-line testing work. "Intelligentization" is an important performance index pursued by various electronic devices in the era of rapid development of science and technology. With the development of modern science and technology, more mature technologies will be developed and applied to insulator fault detection equipment.

In the short term, as far as the basic equipment studied in this paper is concerned, it will try to develop in the direction of "more efficient and integrated" in the future.

At present, the main work of the equipment is divided into two modules, one is fault detection and data collection, the other is data processing and comparative analysis of the collected data. In the future, the central control screen with higher screen refresh rate can be adopted, and relevant data processing programs can be built into the internal single chip microcomputer. In this way, the detected data can be directly and automatically processed, and then the detected spectrogram of the detected equipment can be automatically displayed through the installed high refresh rate screen. Detectors can quickly judge whether the internal mechanical structure of insulator equipment is damaged, which will greatly improve the working efficiency of related work.

In the long run, with the development of modern science and technology, there will be more high-tech used in insulator fault detection equipment. UAV and artificial intelligence are the important technologies for the combination of all kinds of detection equipment [5].

In the future, from the working principle of the equipment studied in this paper, we can consider the combination of mature UAV technology and detection equipment [6-7]. The UAV with special mechanical design can carry the miniaturized detection equipment to detect the fault of the equipment.
under the operation of the operator and return the data. The main difficulty of this assumption is how to design a reasonable mechanical arm or UAV fuselage structure to ensure the stability of the detection equipment. If the equipment is successfully combined with UAV, the amount of live working at height of front-line workers will be greatly reduced, which will greatly reduce the difficulty and risk factor of related work.

Because the fault detection of insulator is mainly the operation of electronic equipment, artificial operation can be replaced by artificial intelligence technology [8]. On the one hand, the control of UAV can be controlled and deployed by the artificial intelligence management system, which can liberate a lot of human and material resources and realize the integrated management of related work. On the other hand, the maintenance and replacement of related damaged equipment can also be combined with AI intelligent robot. With the rapid development of artificial intelligence technology, the relevant artificial maintenance and replacement work can be replaced by intelligent robot [9].

For the idea of combining with artificial intelligence, we need to establish a cloud database, which can save the data and analysis results of each work as reference samples, and serve the detection system to determine whether the insulator needs to be replaced and issue work instructions to the robot. Combined with artificial intelligence, insulator fault detection will become an integrated autonomous intelligent management system [10], which will realize all-weather cruise detection of regional power grid and provide effective guarantee for stable operation of power grid system.

5. Conclusion and Prospect

Conclusion:
The paper studies and analyzes the following contents:

(1) Firstly, starting from the problems and research status, this paper discusses the related technologies and development status, and compares and analyzes various methods.
(2) Starting from a portable detection device, this paper introduces the principle and technology of vibration acoustic detection, and puts forward reasonable solutions to the problems studied.
(3) Combining advanced technologies such as artificial intelligence and unmanned aerial vehicle, this paper puts forward long-term and short-term assumptions for the future development of insulator fault detection equipment, and provides improvement ideas for the update iteration of related equipment.

The research contents have the following characteristics:

(1) The detection technology studied is live online detection, which is economical and easy to operate, and reduces the loss of manpower and material resources in the process of porcelain insulator detection.
(2) Combining advanced technologies such as artificial intelligence and unmanned aerial vehicles, it provides reasonable suggestions for the future development of related industries and makes reasonable ideas and designs.

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 embodied in the aspects of "portability, high efficiency and intelligence", which will meet the current industry demands related to insulator detection in many aspects and provide guarantee for the safe operation of power equipment.

In the future development, not only the fault detection of post insulators, but also all links of power industry will be combined with artificial intelligence. Many dangerous manual work will be replaced by robots, which will greatly improve the overall intelligent operation of the power grid system, and the power grid system will continue to transform into smart grid.

References
[1] Guo Lei, Fu Haijin, Zhang Ke, Dong Manling, Ding Guojun. Cause analysis and countermeasures for fracture of pillar porcelain insulators[J]. Henan Electric Power, 2019(S1): 87-91.
[2] Gao Jian, Miao Xing, Wang Bin. Discussion on the detection method of pillar porcelain insulators[J]. Electric Power Safety Technology, 2014, 16(08): 60-62.
[3] Zhang Haijie, Chen Rengang, Jian Youwei, Liu Kuang. Ultrasonic detection analysis and application of pillar porcelain insulators[J]. Shandong Electric Power Technology, 2014, 41(06): 47-48+59.

[4] Guo Chen, Jiang Xin, Zhang Renqi. Application research on vibro-acoustic testing of porcelain pillar insulators[J]. Guizhou Electric Power Technology, 2015, 18(03): 42-44.

[5] Yan Xiaobin. Artificial intelligence and its application in power systems [J]. Electronic Production, 2021(02): 98-99+97.

[6] Tang Junjie. Research on the Application of UAV Technology in Power Line Inspection[J]. Smart City, 2020, 6(24):59-60.

[7] Liu Zhiyong, Zhao Xiaodan, Qi Hongchang, Li Yanfei. Prospect of UAV power inspection technology in the new era[J]. Southern Energy Construction, 2019, 6(04): 1-5.

[8] Li Shu. Zhongfei Saiwei: Intelligent inspection, promoting new changes in the operation and maintenance model[J]. Industry and City, 2020(12): 66-69.

[9] Cao Jie, Chen Rui, Wu Yingshuang. Application of artificial intelligence technology in the intelligent maintenance of power grids[J]. Electrical Engineering Technology, 2020(24): 62-64.

[10] Bao Yong. Application analysis of robot technology for on-line maintenance of substation equipment[J]. Low Carbon World, 2020, 10(10): 58-59.