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Application Analysis of Ultrasonic Technology in Insulator Contamination Discharge Detection

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Abstract. Line insulator detection is a very important part of the power system. At present, the commonly used detection methods at home and abroad have certain defects. By referring to the application of ultrasonic technology in the United States and South Korea, this paper proposes a method of applying ultrasonic technology to line insulator detection. Through the acquisition, processing, analysis and amplification of ultrasonic signals, the fault detection of insulators is realized.

Keywords: Insulator detection, power system, ultrasonic technology, discharge detection.

1. Introduction

The existing transmission line insulators mainly include two types of contact measurement and non-contact measurement. Contact measurement mainly uses a contact instrument to measure physical quantities such as voltage, current, and insulation resistance. The most widely used non-contact measurement is temperature measurement, such as infrared sub-imager. Due to cracks in the insulator, tree damage, insulation damage, and other faults, there is almost no heat, and the way of determining the fault point by temperature measurement cannot be realized [1]. Ultrasonic testing is a good method. The fault point is positioned accurately, the personnel safety is high, and the live detection is realized, which is remote, fast, and requires no personnel to climb the tower [2].

2. Application Level and Development Trend of Ultrasonic Technology at Home and Abroad

Ultrasonic testing is a type of non-destructive testing, that is, the use of ultrasonic waves to detect the current state of a workpiece or device. From the end of the 19th century to the beginning of the 20th century, after the piezoelectric effect and the anti-piezoelectric effect were discovered in physics, the method of generating ultrasonic waves by using electronic technology was solved. Ultrasound has been widely used in flaw detection, medical treatment, ultrasonic inspection, and measurement. In recent years, it has also been applied in power detection.

The United States and South Korea first applied ultrasonic detection technology to the detection of defects in power equipment, and achieved significant gains in the ultrasonic field, and determined that power equipment generates ultrasonic waves when discharge, flashover, and breakdown occur [3]. The frequency range of the ultrasonic wave is 35 kHz - 40 kHz. Due to the different equipment, the frequency of the transmission is slightly different, but it is basically within this range. Therefore, after research and experiment, the corresponding ultrasonic sensor has been developed to solve the problem of signal acquisition. . After several years of continuous improvement and development, it has achieved good results in the United States and South Korea, especially in Korea, which has been applied extensively and played a major role [4].

3. Pros and Cons of Commonly Used Detection Methods for Line Insulators

(1)Spark Fork Method

According to the spark fork and the insulator contact, whether a discharge is generated to judge whether the insulator is good or bad.

(2)Small Ball Discharge Method

The insulator voltage distribution is analyzed by measuring the distance at which the small balls at both ends of the insulator are generated to determine whether the insulator to be tested is normal. This method requires frequent adjustment of the distance of the ball, and the false positive rate is large.

(3) Pulse Voltage Current Method

Detection principle: Apply a power frequency voltage higher than the line voltage to the running insulator, and measure the insulation resistance value of the insulator. However, this test only knows that a fault has occurred and requires personnel to board the tower[5].

4. Ultrasonic Testing Method for Line Insulator

4.1 Analysis of the Application Principle of Ultrasonic Technology.

A large amount of ultrasonic waves will occur when the line insulators flashover occurs. Such ultrasonic waves are inaudible to the human ear, the human ear audible frequency is below 20 kHz, and the ultrasonic frequency is between 20 kHz and 200 kHz.

4.2 Ultrasonic Technology Method for Detecting Line Insulators.

4.2.1 Acquisition of Ultrasonic Signals.

The acquisition of the ultrasonic signal can be realized by the wave concentrator, so that more ultrasonic waves are concentrated and reflected by the interface, and are received by the ultrasonic sensor, so that more ultrasonic high-frequency signals can be obtained.

The partial discharge phenomenon of insulator failure is accompanied by the occurrence and emission of ultrasonic waves, and the frequency of the ultrasonic signals emitted is concentrated between 20~40KHz and 80~140KHz. In technical applications, two different types of ultrasonic sensors can be used to receive ultrasonic signals in two frequency bands[6].

4.2.2 Selection and Filtering of Ultrasonic Signal Bands.

Experiments have shown that insulators produce a very broad continuous spectrum at the time of discharge, with frequencies ranging from a few hertz to hundreds of thousands of hertz. As the sound wave propagates through the medium, the energy gradually decreases as the propagation distance increases. As shown in Figure 1.The attenuation law of sound pressure and sound intensity is:

$$P_x = P_0 e^{-\alpha x} \tag{1}$$

$$I_x = I_0 e^{-2\alpha x} \tag{2}$$

P_x, I_x ——Sound pressure and sound intensity from the sound source x;

x ——Distance between sound waves and sound sources;

α ——Attenuation coefficient, in units of Np/m.

The fault insulator test in the laboratory shows that the sound wave in the 25-60KHz band is the strongest when the insulator has the same intensity current leakage; the same is true when the insulator current leakage changes.

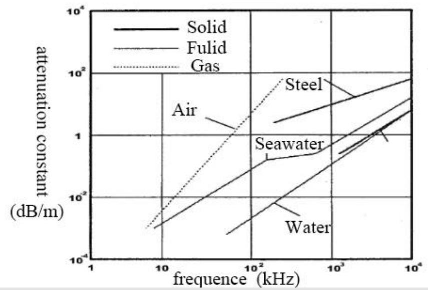


Fig. 1 Ultrasonic attenuation in various media

Through many experiments at the engineering site, it was finally confirmed that it is best to select the ultrasonic signal of 40 kHz for analysis, which can be used as the center frequency of ultrasonic signal acquisition.

4.2.3 Amplification of Ultrasonic Signals.

The acquired signal needs to be amplified, but it is found that the amplified signal is easily distorted. Finally, through the multi-stage precision amplification of the front, middle and rear, and AD conversion is placed in the second-stage amplification, the audio output is placed in the three-stage amplification, which not only ensures the signal amplification without distortion, but also ensures the reliability of the output.

The collected ultrasonic signal is first amplified by the host built-in amplifier circuit, and then the signal of the useful frequency segment is selected by the band pass filter circuit to be analyzed and judged by the host circuit. The host circuit is a single chip microcomputer composed of a signal analysis judgment and an overall control circuit. Its workflow is shown in Fig. 2.

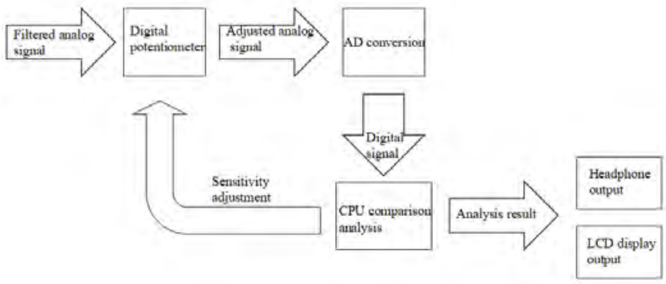


Fig. 2 Framework diagram of device structure principle

4.2.4 Host Hardware and Software Design.

The ultrasonic online diagnostic system software realizes real-time analysis and intelligent diagnosis of data in the field data collection. After the main device completes the detection work, it can import its front-end data into the ultrasonic online diagnostic analysis system. The system will read and transfer the data, and automatically and intelligently analyze the data. Then the system reads the data into the analysis software. Perform reprocessing to facilitate analysis of the map.

4.2.5 Ultrasonic Probe Design.

Ultrasonic probes can be divided into piezoelectric type, magnetostrictive type, electromagnetic type according to their working principle, and piezoelectric type is most commonly used. Piezoelectric ultrasonic waves are piezoelectric crystal that generates a free-running signal after voltage is applied.

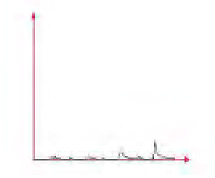
Using the design of the dual-probe collector, the acquisition of ultrasonic signals in different frequency bands can enhance the intensity and sensitivity of the detection. The ultrasonic sensor is integrated with the preamplifier. It is necessary to pay attention to the factors of signal interference: one is the interference of the electric field on the piezoelectric ceramic; the other is the influence on the amplifying element. The frequency of the power frequency electric field is low, the effect of the magnetic field can be neglected, and the method of electrostatic shielding is used to prevent.

5. Improvement and Application of Ultrasonic Testing Technology

The ultrasonic detection technology that has emerged in recent years can analyze and test substation equipment and transmission equipment. This technology is enabled in the power grid maintenance process to quickly detect defects existing in the power equipment without power failure, and then determine the defect level and specific location based on the spectrum. The new technology makes defect detection more flexible, and the maintenance efficiency and personnel safety are greatly improved. Specific application cases are shown in Table 1.

Table 1 On-site inspection example

Date of inspection	2016-8-31 8:45:20			**Enter date**	2016-9-26 16:37:36
Line name	Tuobei Line	**Line number**	10KVTuo#4 #11 Rod	**Management number**	1
Equipment type	lightning arrester	**equipment status**	good	**Degree of defect**	abnormal
Diagnostic advice	Shorten the inspection cycle and check regularly			**Inspector**	Zhen
frequency	40 KHZ	**temperatu re**	31 ℃	**humidity**	49 %
Detection distance	12 m	**longitude**	116.45909	**latitude**	33.92351
Maximum dB value	19 dB			**Average dB value**	1.32 dB

Recording image	**Power line number photo**	**Overall photo**	**Bad device photo**
			

State Grid Henan Shangqiu Yongcheng Yubei Line, received an abnormal ultrasound map, diagnosed as near faulty equipment, it is recommended to shorten the detection cycle or replace.

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