Research on Failure Detection Method of High Voltage Cable Terminals

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ABSTRACT

The failure rate of XLPE cable terminations is much higher than that of the cable body. In order to solve the operational failure problem of the high voltage cable terminals, the conjunction of ultrasonic method and pulse current method are tested on the polyethylene material and the cable terminal in the lab. When the voltage of 6kV is applied on the cable, the partial discharge will occur at the cable terminal. The amplitude of the voltage detected by the pulse current method is about 20mV and the result detected by ultrasonic method is about 80mV. The test data show that the comprehensive application of the ultrasonic and pulse current method can improve the measuring accuracy of the partial discharge results. It can suppress interference effectively and achieve an accurate diagnosis of the partial discharge sources.

INTRODUCTION

The terminals of the high voltage power cable play a very important role and function in the whole process of power supply and distribution. Most of the insulation faults of power cables come from the failures of the cable terminals. The operation faults caused by the cable accessories account for more than 70% of the total faults according to the relevant statistical information. Therefore, it is necessary to detect the insulation state of the cable terminals. At present, the detection technologies of partial discharge are various. The ultrasonic testing method for the partial discharge of the cable terminal can overcome the electromagnetic interference effectively and it is convenient to operate without the need of power failure. The HFCT is used to extract the partial discharge signal in the pulse current method and it is very convenient and widely used. In this paper, the combination of ultrasonic and pulse current method are used to test the partial discharge of cable terminal, which can effectively detect the development trend of PD and eliminate potential hazards.

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DETECTION PRINCIPLE OF PARTIAL DISCHARGE BASED ON ULTRASONIC METHOD AND PULSE CURRENT METHOD

The principle of the ultrasonic detection is that the defects can be diagnosed according to the ultrasonic signals. The ultrasonic sensors are used to receive the ultrasonic waves which transmit from the internal discharge layer through the insulating layer to the outside surface. Because there is a certain amplitude proportion relation on the ultrasonic signal and the electrical signal, so the degree of cable terminal discharge can be judged according to the amplitude of the ultrasonic wave. When a partial discharge occurs at the cable joint, a high frequency pulse current will be generated. The pulse current travels along the cable body in the form of the traveling wave and then enters the ground through the grounding wire of the intermediate joint or terminal. The partial discharge pulse current can be coupled by the pulse current sensor, so the conditions of the cable terminal can be judged by observing the amplitude of the pulse current. This is the detection principle of pulse current method.

THE SIMULATED DISCHARGE TEST

The polyethylene material with a needle can simulate the cable terminal partial discharge, which can be used to observe the detection effect of this combined method clearly. The test chart is Figure 1.

![Figure 1. The discharge test of the polyethylene material with a needle.](image)

Experimental Materials and Devices

Polyethylene material (2cm×2cm×1.5cm), the distance from the tip to the metal piece is 1.5mm) beaker, silicone oil, electrode, ultrasonic sensor, pulse current sensor, oscilloscope and test transformer.

Experimental Procedures

Place the electrode on the bottom of the beaker and the lead wire of the electrode is connected to the ground. The pulse current sensor passes through the lead of the electrode in order to capture the discharge current pulse signal. The lower part of the polyethylene material should be bonded with the electrode tightly. Pour the silicone oil inside the beaker until the polyethylene material with a needle is completely immersed in the silicone oil. Then connect the needle to the high voltage terminal of the test transformer. The ultrasonic sensor is pasted on the wall of the beaker, and the position of the ultrasonic
sensor is kept at the same height as the discharge location. Then the two-channel oscilloscope is connected to the ultrasonic sensor and the pulse current sensor respectively. After all the external connections are finished, the voltage of the test transformer is raised to 6.5kV. Under the different time interval, the oscilloscope test results are shown in Figure 2 and Figure 3.

![Figure 2. Discharge data after 0h and 1h.](image)

![Figure 3. Discharge data after 2h and 3h.](image)

**Experimental Results and Discussion**

From the oscilloscope detection waveforms we can see that the combination of the pulse current method and ultrasonic method are more sensitive to capture the signal of the partial discharge in the silicone oil. The two signals fit well and coincide in phase. As the time goes by, the number of pulses which are captured by the ultrasonic method and the pulse current method increases gradually. The amplitude of the pulse signals increase with time indicating that the partial discharge is more and more serious, and the field intensity at the local changes seriously. It also shows that the main insulation of the cable terminal will be carbonized and thinned under the partial discharge for a long time, which will lead to the grounding fault. The experiment also obtained the qualitative relationship between the ultrasonic signal and the partial discharge. As the time goes by, the intension of the partial discharge of the material increases, and the amplitude of the ultrasonic signal increases gradually. The discharge measured by the pulse current sensor also shows a tendency to increase, which indicate that the magnitude of the ultrasonic signal is positively correlated with the magnitude of the partial discharge.

**MEASUREMENT DATA ANALYSIS OF THE CABLE TERMINAL PARTIAL DISCHARGE**

The test data need to be collected and analyzed in many ways and then the conclusions can be summarized to determine whether the signal is a partial discharge signal or not.
Ensuring the authenticity of the test results, the ultrasonic method and the pulse current method are adopted to detect the partial discharge of the cable terminal in the lab, and a lot of experimental data are obtained. The test charts are shown in Figure 4 and Figure 5.

![Diagram of measurement of partial discharge based on the ultrasonic method.](image)

Figure 4. Measurement of partial discharge based on the ultrasonic method.

![Diagram of measurement of partial discharge based on the pulse current method.](image)

Figure 5. Measurement of partial discharge based on the pulse current method.

**Eliminate Interruptions**

During the experiment, the ground wire of the transformer and cable need to be connected with the ground electrode at the same time. There are some errors on the signals because of the mutual interference. So the connection modes of the two ground wires and the same ground wire are adopted in the experiment respectively. According to the oscilloscope spectrum, there is no difference on the oscilloscope waveforms in both cases. So the two ground wire of the transformer and cable are connected to the same ground electrode, which have no effect on the experimental results.

**Experiment Procedures**

One end of the cable is connect to the high voltage terminal of the transformer and the other end of the cable is hanged in the air. The pulse current sensor passes through the ground wire of the cable and the ultrasonic sensor is attached to the insulation near the cable termination. Then the voltage of 6kV is applied on the cable. This time we use the Tektronix DPO7054 oscilloscope to collect the experimental data. The experimental data measured by the oscilloscope can be derived after finishing several groups of the experiments. Processing the experimental data with the origin software, Figure 6 and Figure 7 are obtained.
Experimental Results and Discussion

The partial discharge time is extremely short, so the waveform of the partial discharge is a single pulse waveform. When the discharge is over, the waveform will oscillate again and then flatten after a short period of time. From the figures we can see that the pulse current method and the ultrasonic method can calibrate each other when the partial discharge happens, and the voltage amplitude measured by the ultrasonic method is higher. The combination of the two methods can detect the partial discharge of the cable terminal more accurately. The pulse current method and ultrasonic method can also be combined to locate the position of the cables and accessories with partial discharges preliminarily. Therefore, the combination of the two detection methods is of great significance to the development of the partial discharge test of cables.

CONCLUSION

Based on a series of experiments about the detection problems of the high-voltage cable terminal failure in the lab, the combination of the ultrasonic method and pulse current method can judge the PD situation of the cable terminal more accurately. The field tests
show that this test method is great, which can detect the hidden dangers and prevent failure faults by monitoring the PD characteristics of the cable terminal better.

REFERENCES