Study on Performance Evaluation of TEV Partial Discharge Detector

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Abstract. Transient Earth Voltage (TEV) detection technology has become one of the important detection methods for high voltage electrical equipment. However, due to the lack of uniform standards within the industry, the equipment manufactured by the manufacturers is not of good quality, resulting in the performance evaluation problems of the TEV partial discharge instrument during the purchase and acceptance process. Therefore, this paper proposes a signal simulation evaluation method, and analyzes in detail the advanced function evaluation of TEV partial discharge instrument including frequency characteristics, signal linearity, sensitivity, pulse count, and discharge source positioning performance. It is possible to have a more complete understanding of the performance of the TEV partial discharge meter.

1. Introduction
Insulation degradation of power equipment poses hidden dangers to the safe and reliable operation of the power system. The use of partial discharge detectors to detect partial discharges can timely and effectively detect the inherent defects of the power equipment insulation and the hidden dangers caused by long-term operation aging. The degree of insulation degradation can be judged, and sudden insulation faults can be avoided. It is of great significance to the safe and reliable operation of power equipment [1]. TEV detection technology has been widely used in partial discharge detection of power equipment. The advantages of TEV partial discharge detection devices such as portable carrying and simple operation have also been promoted. However, due to the lack of uniform production standards, the quality of TEV PD instruments varies greatly. Purchase and acceptance require a set of evaluation proposals to select equipment with better performance.

2. Working principle of TEV partial discharge detector
If there is a high local electric field (uneven field intensity distribution) in the insulation structure, or defects due to imperfect manufacturing processes and organic decomposition of the insulation during operation, and the solid insulation damaged by mechanical forces, etc., these defects are likely to cause insulation breakdown and partial discharge in the operation. For internal discharge of electrical equipment, the discharge power is accumulated on the inner surface of the ground shield. Therefore, if the shield is continuous, the discharge signal cannot be detected externally. However, in practice, shields often appear broken and discontinuous at the insulation, gasket connection, and cable insulation terminations. This causes high-frequency signals to be transmitted to the outer layer of the...
device, forming a transient earth voltage, abbreviated as TEV [2]. The TEV detection diagram is shown in Figure 1:

![TEV detection schematic](image)

**Figure 1. TEV detection schematic**

3. **TEV partial discharge detector performance and evaluation parameters**

   For the TEV partial discharge instrument produced by different manufacturers, a unified evaluation standard is required and evaluation is performed by setting the analog signal defect. The basic function test of the TEV partial discharge detector is as follows:
   ① The device is turned on and self-tested;
   ② The TEV partial discharge measurement shows the result, and the unit is dB or dB mV;
   ③ The calibrator can accurately measure;
   ④ The alarm function is normal and can be modified according to the alarm threshold;
   ⑤ The battery is charging normally. After the basic detection of the partial discharge detector is fully qualified, the static characteristics are evaluated. The evaluation parameters are as follows [3-4]:

   ① Frequency characteristics: It can measure the working frequency range that this partial discharge detector can measure;
   ② Linearity of the signal: When the input signal changes linearly, the output response characteristic of the partial discharge detector can be obtained;
   ③ Sensitivity: Partial discharge detectors can measure the sensitive performance of a signal;
   ④ Pulse counting: Can it be determined whether the partial discharge detector pulse count is accurate and effective;
   ⑤ Positioning performance of the discharge power source: The positioning capability of the partial discharge detector with positioning function is evaluated.

   This paper mainly evaluates and compares the TEV partial discharge detectors produced by two different manufacturers that have the positioning performance of the power source, and concludes that this set of evaluation methods has high feasibility and effectiveness.

4. **Signal Simulation Test and Evaluation**

   4.1. **Overall evaluation plan**

   The main items of TEV test performance evaluation are: frequency characteristic measurement, linearity measurement, sensitivity measurement, pulse number measurement and evaluation of discharge source positioning performance. The evaluation device system mainly includes a high-performance oscilloscope, a partial discharge detector waiting to be evaluated, a controllable pulse signal generator, a metal plate, an insulating plate, and a worktable [5]. As shown in picture 2:
4.2. Frequency characteristics assessment

Firstly, the sensor of the detection device is placed directly on the metal plate, and the signal generator outputs a sine wave signal and is loaded on the metal plate[8]. Secondly, the amplitude of the sine signal output by the signal generator is fixed at 10V, and its initial value of the frequency is set to 1 MHz. Thirdly, the amplitude of the detection device is measured by observing each adjustment process from 1 MHz to 80 MHz with a step size of 1 MHz, and the reading of the detection device is recorded as the frequency of the output sine wave signal changes. Finally, an amplitude-frequency characteristic with an amplitude of 10V is plotted. As shown in Figure 3:
Figure 3. Frequency characteristic curve of TEV partial discharge detector

It can be seen from Figure 3 that when the amplitude of the signal generated by the signal generator is 10V, the starting frequency of the TEV partial discharge detector I and the partial discharge detector II is at 1 MHz, and the cutoff frequency of the partial discharge detector I is 83 MHz. The cut-off frequency of the Partial Discharge Detector II is 120 MHz. The operating frequency bands of the Partial Discharge Detector I and the Partial Discharge Detector II device specifications are 1 to 80 MHz and 1 to 100 MHz respectively. The cut-off frequency of the Partial Discharge Detector II is greater than the specification, and that of the partial discharge detector I comply with the specification. The over-consumption of the working frequency band leads to a reduction in the ability of anti-interference. At the same time, it can be clearly seen from Figure 3 that the curve of I is relatively smooth with respect to II, further illustrating the partial discharge detector I performs better than the partial discharge detector II.

4.3. Linearity Measurement of Signals

The signal generator is used to output a sine wave signal of the main resonant frequency and is loaded onto a metal plate [9]. Place the sensor of the testing equipment directly on the central position of the metal plate to measure the reading of the testing equipment under different discharge amount, and through the detection capability (whether it can detect the amplitude of transient earth voltage under different discharge capacity) and the increasing trend (Whether the transient ground voltage amplitude increases synchronously with the discharge amount), to measure the linearity of transient to ground voltage detection. In this evaluation, the fixed frequency is set as the main resonant frequency. From the evaluation of the frequency characteristics, the fixed frequencies of the partial discharge detector I and the partial discharge detector II are 55 MHz and 56 MHz respectively. The initial amplitude of the sine wave signal is 0.1V, which is sequentially superimposed to 10.0V in steps of 0.1V. The TEV value corresponding to the partial discharge instrument is recorded, and the measurement is repeated twice. Then the measured TEV value curve is plotted. The evaluation results are shown in Figure 4:
From the measurement results of the linearity of the signals of the two partial discharge detectors, when the fixed frequency is the main resonant frequency, the evaluation curve of the partial discharge detector I is significantly smoother than that of the partial discharge meter II, thus indicating that the linearity performance of the partial discharge detector I is stronger than partial discharge detector II.

4.4. Sensitivity assessment

The signal generator is used to output the minimum amplitude, and based on the frequency characteristics, the fixed-frequency sine wave signal of the high-sensitivity frequency point given by the amplitude-frequency characteristic is measured and loaded on the metal plate. Based on the fixed amplitude test data, the variation of the output signal amplitude test data is adjusted to determine the data of the partial discharge detector sensitivity (V/dB) [10]. This test evaluates the fixed frequency of the sinusoidal signal as the main resonant frequency, and detects the sensitivity of the amplitude at 2.0V, 5.0V, and 8.0V. According to the amplitude of the partial discharge tester's reading increasing by 1dB, it is continuously measured twice, sensitivity is the subtraction of two amplitudes. As shown in Table 1:

Table 1. Test results of sensitivity

| Frequency     | Input Voltage (V) | Device Reading (dB) | Sensitivity (V/dB) |
|---------------|------------------|---------------------|--------------------|
| First time    | 2.0              | 46.2                | 0.2                |
|               | 2.2              | 47.2                |                    |
| Second time   | 5.0              | 55.8                | 0.5                |
|               | 5.5              | 56.8                |                    |
| Third time    | 8.0              | 60.3                | 0.8                |
|               | 8.8              | 61.3                |                    |

| Frequency     | Input Voltage (V) | Device Reading (dB) | Sensitivity (V/dB) |
|---------------|------------------|---------------------|--------------------|
| First time    | 2.0              | 45.6                | 0.3                |
|               | 2.3              | 46.6                |                    |
| Second time   | 5.0              | 55.3                | 0.7                |
|               | 5.7              | 56.3                |                    |
| Third time    | 8.0              | 61.8                | 1.1                |
|               | 9.1              | 62.8                |                    |
It can be clearly seen from the above table that the sensitivity of the partial discharge detectors I and II is reduced by the increase of the input signal value, in particular, the decrease in the sensitivity of the partial discharge detector II is more pronounced.

4.5. Pulse count assessment

Use the signal generator to output an exponentially rising edge pulse signal and load it onto the metal plate. In 1kHz–80kHz, increase the frequency of the adjustment output signal in accordance with the step length of 1KHz, record the pulse number reading of the detection device. When the pulse number of the output signal changes, observe whether the pulse number trend and accuracy of each device are correct. The pulse number is measured and evaluated. The pulse count is shown in Figure 5:

From Figure 5, it can be seen that the partial discharge detector I is close to the theoretical value before 40 KHz, and increases linearly. After 40 KHz, the partial discharge detector I tends to be stable near the pulse number 35,000, and the sensor does not receive any more pulse signals. The Partial Discharge Detector II was close to the theoretical value before 11 KHz, and gradually deviated from the theoretical value after 11 KHz, and slightly decreased after 47 KHz.

4.6. Power source positioning evaluation

The positioning capability of the partial discharge detector with positioning function is evaluated. First, set the signal generator output pulse signal, and then load it into the center of a 200cm long, 15cm wide, 0.2cm thick metal plate. Secondly, the two sensors of the device under test are all attached to the surface of the metal plate. Third, tests are performed at 30 cm and 60 cm distances from the distance signal, and it is observed whether or not the near channel of the distance inspection device arrives first. Realize the evaluation of the positioning function of the testing equipment [10-11]. As shown in Figure 6:
The standard pulse signal generator is used to output the pulse signal with the amplitude of 10V to the metal plate, and the partial discharge detector I and the partial discharge detector II are placed on the left and right sides of the metal plate respectively (60cm and 30cm from the center of the metal plate respectively). Record the position accuracy rate of the position distribution of the sensors in different positions for many times, and measure the accuracy of the detection and positioning. After two sensors perform one measurement, then the exchange position is used to perform a measurement. Positioning test results are shown in Table 2:

**Table 2. Discharge source positioning accuracy evaluation**

(a) Partial discharge detector I accuracy

| Location situation | Positioning judgment | Location situation | Positioning judgment |
|--------------------|----------------------|--------------------|----------------------|
| 1 ×                 | 11 √                 |
| 2 ×                 | 12 ×                 |
| 3 √                 | 13 √                 |
| 4 ×                 | 14 √                 |
| 5 ×                 | 15 ×                 |
| 6 √                 | 16 ×                 |
| 7 √                 | 17 √                 |
| 8 ×                 | 18 √                 |
| 9 √                 | 19 √                 |
| 10 √                | 20 ×                 |

(b) Partial discharge detector II accuracy

| Location situation | Positioning judgment | Location situation | Positioning judgment |
|--------------------|----------------------|--------------------|----------------------|
| 1 ×                 | 11 ×                 |
| 2 √                 | 12 √                 |
| 3 √                 | 13 √                 |
| 4 ×                 | 14 ×                 |
| 5 ×                 | 15 ×                 |
| 6 √                 | 16 ×                 |
| 7 ×                 | 17 √                 |
| 8 ×                 | 18 ×                 |
| 9 ×                 | 19 ×                 |
| 10 ×                | 20 ×                 |

It can be seen from Table 2 that the positioning accuracy rate of the partial discharge detector I and the partial discharge detector II can be calculated after 20 times of different positioning measurements, the accuracy of the partial discharge detector I is 55% and the partial discharge detector II is 30%. In comparison, the partial discharge detector I positioning accuracy is better than that of the partial discharge detector II.
5. Conclusion

By analyzing the working principle of TEV partial discharge detector in field application, a test method for evaluating the performance of TEV partial discharge detector by signal simulation evaluation method is proposed:

(1) It is highly effective and practical to evaluate the basic and static characteristics of TEV partial discharge detectors, and there is a great deal of high use value for procurement and acceptance of the partial discharge detectors.

(2) Using the signal simulation test method can accurately measure the frequency characteristics, signal linearity, sensitivity, pulse count, and discharge power source positioning of the TEV partial discharge detector. It is recommended that the partial discharge detector should be evaluated periodically to avoid detection errors and alarm errors during the use of the partial discharge detector.

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