Research on Measurement and Evaluation of Ultra High Frequency Partial Discharge Monitoring Device

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Abstract. In order to evaluate the partial discharge Ultra High Frequency (UHF) detection device, the author conducted a laboratory simulation experiment on UHF Partial Discharge (PD) online monitoring system. The UHF signal is simulated by the pulse signal generated by the ns steep pulse generator. By comparing the characteristics of the generated UHF signal with the spectral features detected by the UHF partial discharge on-line monitoring system, the detection capability, pattern recognition ability, and anti-jamming capability of the UHF partial discharge on-line monitoring system are measured and evaluated. Through the research on the testing and evaluation of power equipment, it can ensure the normal operation of the partial discharge online monitoring system.

1. Introduction
Gas insulated substation (GIS) has a very important position in power equipment, due to its small footprint, high efficiency, strong anti-interference, and long equipment life [1]. In order to ensure the reliable operation of GIS, the local discharge ultra-high frequency detection method is widely used to monitor the operation status of GIS in substations and other places where GIS equipment is installed. GIS equipment in the production, transportation, installation, operation and other aspects will appear some defects resulting in some burrs and metal particles inside the GIS, which will cause the internal metal tip partial discharge and partial discharge of the floating potential body. Failure to deal with these defects in a timely manner can lead to rapid aging of the internal insulation layer of the device due to partial discharge, which may cause a large power accident. It is necessary to check whether the function of the UHF partial discharge monitoring system online monitoring system is normal, and whether it is caused by aging, damage or other factors during the normal use process is very necessary [2]. The size of partial discharge itself does not indicate the degree of risk of equipment failure, but the cause of partial discharge must be clarified before assessing the extent of partial discharge impact on the equipment.

2. Measurement principle
Each partial discharge in the insulating medium in the GIS is accompanied by one or several steep current pulses, which radiate electromagnetic waves to the surroundings. Studies have shown that the spectral characteristics of electromagnetic waves radiated by partial discharges are related to the geometry of the partial discharge source and the dielectric strength of the discharge gap. When the
discharge gap is relatively small, the discharge time is relatively short, the steepness of the current pulse is relatively large, and the ability to radiate high-frequency electromagnetic waves is relatively strong; and when the dielectric strength of the discharge gap is relatively high, the breakdown process is relatively fast, the steepness of the current pulse is relatively large, and the ability to radiate high-frequency electromagnetic waves is relatively strong. Moreover, the electromagnetic waves radiated by the partial discharges in SF6 gas can reach the UHF range of several GHz. Due to the resonance effect of the GIS gas cell, a variety of modes of UHF resonant electromagnetic waves are formed [3]. Therefore, the detection of the partial discharge and the degree of insulation of the device can be achieved by detecting the UHF electromagnetic wave.

Since the GIS air chamber is like a low-loss microwave cavity, the time for the oscillation wave of the partial discharge signal in the air chamber is extended and can be as long as 1 millisecond, so that the built-in/external couplers installed in the GIS must have enough time to capture these signals [4]. The intensity of the partial discharge signal captured by the coupler is very low, only in the millivolt range.

However, after the ultra-high-frequency partial discharge monitoring device (detection prototype) was enlarged, he was analyzed using the partial discharge artificial intelligence analysis software to determine the possible deficiencies of GIS. After detecting that the GIS device has a partial discharge phenomenon and determining the type of defect by analyzing the Phase Resolved Peak Display (PRPD) waveform, it is necessary to locate and find out the location of the partial discharge for maintenance work [5]. In order to evaluate the GIS equipment online monitoring system, the UHF sensor should be evaluated first. After the end of the detection of UHF sensors, the UHF partial discharge monitoring device (detection prototype) is checked to ensure the accuracy during preparation. The UHF PD monitoring device (detection prototype) detection platform is shown in Figure 1.

![UHF partial discharge monitoring device (test prototype) detection platform](image)

**Figure 1. UHF partial discharge monitoring device (test prototype) detection platform**

3. Simulation test

In order to be able to accurately evaluate the on-site GIS equipment, calibration instruments need to be calibrated to ensure its accuracy.

3.1. **UHF monitoring device (test prototype)**

The UHF PD monitoring device (test prototype) is often used as a maintenance instrument for the GIS equipment in the substation. It can detect, record and analyze the partial discharge events in the GIS, analyze its causes, and develop the tracker for early processing to avoid the complete shutdown accident. The UHF PD monitoring device (test prototype) consists of two parts: a laptop computer that runs the partial discharge artificial intelligence analysis software Port SUB and a portable data acquisition unit (DAQ). One part is built into the portable data acquisition unit DAQ detector and the other is the partial discharge artificial intelligence analysis software Port SUB installed in a laptop computer. The computer is connected to the DAQ via a network cable and receives the UHF partial discharge signal acquired by the DAQ through the Coupler (up to 3) [6].
After the partial discharge event is detected by using the UHF partial discharge monitoring device (detection prototype), an appropriate oscilloscope can be used to accurately locate the partial discharge source by calculating the time difference of the detected signal. All partial discharge data detected by the DAQ is transmitted to the laptop via the network, allowing users to observe the results in real time. The connection diagram is shown in Fig. 2.

Figure 2. Connection diagram of UHF partial discharge monitoring device (detection sample)
The system detects the peak value and discharge rate of the partial discharge signal for each time period and displays them on a computer screen. In order to improve the reliability of the detection, the system adopts the interpolation average method to process the detection data, that is, to average the detection values of the adjacent three detection time periods. The Port SUB system software provides a variety of methods for processing signal peak data. Port SUB system software flow chart shown in Figure 3.

Figure 3. system software flow chart
The analysis of partial discharge in this system is performed automatically, and the results of analysis and judgment are automatically given and displayed on the screen in a graphical manner, which helps the user to perform in-depth fault diagnosis of GIS equipment.

3.2. Test Capability Evaluation
The UHF sensors were evaluated in the laboratory to ensure that the sensors used were standard, and the ns steep pulse generator was used to output a 3 V voltage UHF signal with a pulse train interval frequency of 50 Hz [7]. The ultra high-frequency signal is transmitted through a 0.5 GHz to 7.5 GHz UHF sensor transmitting antenna to release an ultra-high frequency signal. The UHF sensor connected to the oscilloscope is received at a forward direction of 0.1 m to observe whether it can effectively detect the signal, and high frequency signal and display correctly.

3.3. Pattern Recognition Ability Evaluation
The metal tip discharge and suspension potential body discharge have distinct and stable features that are easy to distinguish from other types of partial discharge and are easy to simulate. Therefore, the pattern recognition ability is evaluated. Using an ns class steep pulse generator produces analog signals that are similar to metal tip discharge and suspension potential body discharge [9]. Use a signal generator to generate a square wave signal with a frequency of 50 Hz, a phase of 270°, or a frequency of 100 Hz, and a phase of 90° of the power frequency period. This signal triggers an arbitrary waveform generator and causes the arbitrary waveform generator to repeatedly emit a steep leading edge pulse at a repetition rate of 50 Hz or 100 Hz, and the steep leading edge pulse is fixed at a phase frequency of 270° or 90° and 270°. The formation of a steep front pulse sequence, as shown in Figure 4. The steep-edge pulse sequence is a broad-band, steep-edge, signal that occurs at a power frequency period of 270° (to simulate a metal tip discharge) or 90° and 270° (to simulate a suspension body discharge) phase. It is very similar to the partial discharge waveforms detected in the laboratory or on site. It can be used to simulate the real partial discharge waveform [10].

![Analog metal tip discharge](image1)

![Simulated floating potential body discharge](image2)

Figure 4. Discharge analog signal

3.4. Anti-jamming capability assessment
Anti-jamming capability assessment is mainly through mobile phone interference, using the mobile phone to repeatedly dial and hang up the phone in order to form a strong mobile phone communication...
interference. In the distance of 0.5 m from the mobile phone and the direction of the mobile phone antenna, UHF sensors are used for receiving and judging its interference ability [11].

4. Test results

4.1. Test Capability Evaluation
For the UHF sensor detection capability, the UHF sensors used can clearly display the received electromagnetic wave signals on the oscilloscope, indicating that the UHF sensors can detect the UHF signals transmitted and received. The result is shown in Figure 5.

![Simulink simulation](image)

**Figure 5. Simulink simulation**

4.2. Pattern Recognition Test
In order to analyze the characteristics of partial discharge, and in order to accurately identify the partial discharge within the electrical equipment during on-site testing, a partial discharge measurement study was conducted to analyze the characteristics and regularity characteristics of the partial discharge. The maps correspond to the single-cycle detection method (three-dimensional map), single-cycle detection method (two-dimensional map), peak-hold detection method, and PRPD spectrum detection method.

The characteristics of the metal tip discharge are the number of discharges, the dispersion of the discharge amplitude is small, and the time interval is uniform. The polarity effect of the discharge is very obvious and usually occurs only during the negative half cycle of the power frequency phase.

The characteristics of the floating potential body discharge is that the discharge pulse amplitude is stable, and the adjacent discharge time intervals are basically the same. When the suspended metal body is asymmetric, the positive and negative half-wave detection signals have polarity differences.

Simulated metal tip discharge, the pattern recognition capability of the UHF PD monitoring device (test prototype) is shown in Figure 6.
a. Single cycle detection method (3D)  
b. Single-cycle detection method (2D)  
c. Peak hold detection method  
d. PRPD spectrogram detection

**Figure 6. Simulation of metal tip discharge results**

Figures a and b show the three-dimensional and two-dimensional maps of the phase-resolved pulse sequence of a single-cycle simulated partial discharge, respectively. It can be observed very clearly that the polarity effect of discharge is very obvious; c and d are the peak hold and PRPD spectra, respectively. It can be observed that the peak negative axis can observe one pulse peak, and the PRPD spectrum negative axis can observe one mark point, then the dispersion of the discharge amplitude is small and the power frequency phase appears in the negative half cycle; therefore, the pattern recognition result is the metal tip discharge.

Simulated suspension potential body discharge, the pattern recognition ability of the special high-frequency partial discharge monitoring device (test prototype) is shown in Figure 7.

a. Single cycle detection method (3D)  
b. Single-cycle detection method (2D)  
c. Peak hold detection method  
d. PRPD spectrogram detection

**Figure 7. Simulation result of simulated suspension potential discharge**

In Figures a and b, it can be observed that the partial discharges of the single-cycle adjacent discharges are basically the same; the c and d can observe that the peak value of the peak can be observed in both the positive and negative half-axis, and the polarity of positive and negative half-wave detection signals can be observed in both the positive and negative axis of the PRPD spectrum.

**4.3. Anti-jamming capability assessment**

The evaluation results of the anti-interference ability of the UHF partial discharge monitoring device (test prototype) are shown in Figure 8.
a. Single cycle detection method (3D)  
b. Single-cycle detection method (2D)  
c. Peak hold detection method  
d. PRPD spectrogram detection  

Figure 8. Evaluation results of anti-interference ability

From Figure a and b, it can be directly observed that the detected interference signal has submerged the discharge signal, the peaks in Figures c and d remain full, and the PRPD has no marking point, so the pattern recognition result is that the partial discharge type is non-partial discharge. Thus, the anti-interference ability of the UHF partial discharge monitoring device is very good.

5. Conclusion
Since the output of the photovoltaic cell is a non-linear output, it is necessary to find the maximum power point to achieve the maximum conversion efficiency of the electric energy in order to fully utilize the solar energy.

1. UHF sensors can detect UHF signals and have good detection capabilities;
2. For the metal tip discharge model and suspension potential body discharge model, the detection sensitivity is high, the detection ability is good, and the consistency of the detection results of each channel is good, and the partial discharge type pattern recognition results are basically consistent with the actual discharge type;
3. Strong anti-cell phone communication interference;
4. UHF signal detection capability, partial discharge mode identification, and anti-jamming capability are some of the necessary inspection items for the UHF Bureau to put on line monitoring devices for network evaluation, which can effectively monitor the quality of online monitoring devices.

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