Electromagnetic Interference of Partial Discharge in Ultra High Voltage Substation

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**Abstract.** In order to block the electromagnetic interference source of partial discharge in UHV substation and improve the actual power generation efficiency, in this study, the experimental method of partial discharge in ultra high voltage (UHV) substation is first introduced. Secondly, the types of PD EMI are described in detail. Finally, the principle of blocking electromagnetic source is introduced and the blocking measures of each electromagnetic interference source are analyzed in detail. The results show that the actual equipment test of UHV substation is complex, and there are many factors affecting the test accuracy. Therefore, the field test of UHV substation is the most complex and precise test item at present. The time of noise interference of pulse signal is short and the distribution of signal is wide. This kind of interference is also repetitive, but the orientation of the display is relatively stable, and the waveform also has certain rules. Thyristors use relatively weak current to grasp relatively strong current, and the process is very short. At the same time, the period of application is very long and the stability is very strong. Recursive filters are used. The workload of calculation is greatly reduced, but there are many disadvantages. In practical UHV substation, the sources of PD are closely arranged, so it is suitable to use recursive filter. After using wavelet transform to disperse EMI sources, it can block the sources in different regions.

**Key words:** UHV substation; partial discharge; electromagnetic interference; blocking technology.

1. **Introduction**

With the continuous development of the power system, the scope of its power grid distribution continues to expand, and the transformers in the power grid equipment are constantly changing into the ultra high voltage (UHV) period. The main characteristics of UHV transformer are large volume, high voltage and large internal storage. Whether the transformer can work normally is very important for the operation of power grid equipment \([1]\). The research on partial discharge of UHV transformer plays a key role in the discrimination of insulation state, quality and quantity of transformer, and has a core value for the safe, efficient and stable operation of equipment in the whole power grid system. It is significant to study the partial discharge of UHV Transformer for power grid system.
The utilization rate of UHV Transformer in China has been greatly improved, and a large number of domestic UHV transformer have also been used in practical work. With the efficient use of the transformer, its insulation is relatively fragile, and partial discharge will occur in the damaged part of the insulation. If continuous discharge is carried out frequently, the working efficiency of electrical equipment will be reduced. If the discharge effect is superimposed and the insulation components are damaged, the insulation effect of the equipment will be lost and the equipment will be destroyed [2]. Therefore, the research on partial discharge of UHV transformer determines the insulation performance of power equipment.

In this study, firstly, the experimental method of partial discharge in UHV substation is introduced, and the types of electromagnetic interference in partial discharge are described in detail. At the same time, the principle of blocking electromagnetic signal and blocking measures are introduced, which provide practical guarantee for maintaining the insulation performance of power equipment and ensuring the safe and stable operation of power system.

2. Types of electromagnetic interference in partial discharge

2.1. Partial discharge of UHV substation
The research of UHV partial discharge in UHV substation is mainly to carry out partial discharge experiments to simulate the situation on site, so as to judge the performance and durability of various devices in the power system as a whole, so as to ensure the stable and safe operation of UHV substation. The actual equipment test of UHV substation is complex, and there are many factors that affect the test accuracy. Therefore, the field test of UHV substation is the most complex and precise test item at present. The partial discharge test method for UHV substation is to use the shielding equipment on site to maintain the output power of the generating equipment in a relatively low state, and the collected partial discharge information is relatively accurate at this time. According to the researcher's analysis, the external interference information obtained from the field test is very huge, so it is necessary to analyze and study the interference information [3].

2.2. Measurement method of partial discharge in UHV substation
The partial discharge measurement methods of UHV substation include pulse current detection method, UHF measurement method, ultrasonic measurement method and infrared measurement method [4]. These results are used to analyze the partial discharge data of UHV transformer.

The first is pulse current detection. This method is the most common way to measure the local power generation of UHV substation, which is widely used in the world and can be used as a reference value. The material used is the Rogowski coil sensing equipment, which can measure the frequency range of more than 10 MHz. However, the disadvantage of this method is that the signal is unstable, weakened quickly, and there are many errors and low response.

The second is UHF measurement. In this method, UHF propagator is used to discriminate high frequency signals, so as to judge whether there is an accident in UHV substation. It has high sensitivity, high shielding ability to interference and high response ability. The frequency measured by this method varies from 300 MHz to 3000 MHz. According to the different measurement frequency, it can be divided into short area measurement and wide area measurement. Due to the narrow range and long duration of partial discharge in UHV substation, the signal slope of current is relatively large, so the amount of high-frequency magnetic wave emitted is very large. The magnetic wave energy of partial discharge can dissipate in the process of magnetic wave transmission.

The third is ultrasonic testing. In UHV substation partial discharge, because the friction between molecules will produce sound waves, the information of sound waves can be detected to judge the partial discharge. This method has strong ability of shielding interference and is easy to measure acoustic wave. However, in the process of producing sound waves, the reflection and refraction of sound waves are often accompanied, which makes it more difficult to measure sound waves. Moreover, this method
cannot measure the amount of partial discharge. Therefore, at the same time of acoustic measurement, the partial discharge should be measured.

The fourth is infrared measurement. The partial discharge of UHV substation will be accompanied by the transformation of electric energy into heat energy. The energy of partial discharge can be transformed into the heat fluctuation of discharge area by using infrared ray, and measured in the form of temperature. This method is easy to measure, and the measured data can be used to measure the stability of transformer performance.

2.3. Electromagnetic interference of partial discharge in UHV substation

There are some electromagnetic sources in the air flow around the UHV substation. The sources of these electromagnetic sources are mainly the partial self-sustaining discharge of the gas medium in the uneven electric field, the discharge on the boundary surface between the solid and the gas or between the liquid and the electric field, and the discharge caused by the potential difference between the potential suspension and the surrounding components. In the process of testing, it is necessary to measure and judge the impedance. Another kind of electromagnetic interference may be caused by the electric spark generated in the test environment or the corona generated by the electric equipment. In the air environment, direct air coupling detection reaches the starting point of measurement. The coupling mode and the type and size of electromagnetic interference will be different due to the different parts of the measurement method [5]. Therefore, it is very important to measure and shield electromagnetic interference. The types of electromagnetic interference are as follows.

The first is continuous repetitive noise interference. This kind of interference includes interference caused by radio and clutter. The radio frequency is about 0.5 GHZ, which has the greatest electromagnetic interference. The voltage of power grid equipment will produce non sinusoidal current under special circumstances, which will lead to clutter interference. This is because the current wave will be scattered into special sinusoidal wave and disturbing clutter in the process of repetitive formation. The damage degree of this kind of clutter is very high, which is a serious damage factor in the power system. It will obstruct the partial discharge and cause the repeated high frequency interference seriously.

The second is the noise interference of pulse signal. This kind of interference is generally short-term interference in partial discharge, and the signal distribution is relatively wide. This kind of interference is also repetitive, but the orientation of the display is relatively stable, and the waveform also has certain rules. The noise interference of pulse signal includes: thyristor behavior interference, spark discharge interference in air flow, corona discharge interference in air flow, floating discharge interference in air flow, surface discharge interference and discharge interference generated by power generation equipment.

First, the behavior interference of thyristor refers to that the thyristor can master the electric quantity in the process of partial discharge, and use the weaker current to master the stronger current. The process experience is very short, but the period that can be used is very long and the stability is very strong. The device can use its own performance to take control measures for the discharged electricity. However, in the process of thyristor operation, pulse interference will be generated when it is opened and closed, which has the characteristics of repetition. The duration of the signal is about 30 microseconds and the frequency is less than 500KHz.

The second is the interference of spark discharge in the air flow. When the high point electrified conductor meets the electrified conductor near the ground, the air flow in the middle of the two parts will undergo instantaneous ionization, thus generating spark path, that is, discharge spark. Its discharge degree is very intense, and the duration is very short. The interference of spark discharge will be caused by the shock wave during the rapid rise of temperature in the air flow. The process emits a large amount of electricity and has a wide range of interferences. Its discharge characteristic is that the frequency is very high, basically more than 2.1GHz, and the frequency of occurrence is uncertain.

The third is the interference of corona discharge in the air flow. Corona discharge in power system has a high existence. The electric potential of the contact surface of the electrified conductor is higher, which results in the electric strength of the contact surface is stronger than that of the gas in the air flow,
and the gas in the air flow is electrically decomposed. With the increase of electric field strength, corona discharge is formed. Generally, corona discharge is formed on the air contact surface of power equipment, which causes high-intensity interference to partial discharge. It is also the core mode of partial discharge electromagnetic interference in UHV substation environment. When this kind of interference is carried out, there will also be problems such as illumination, vibration and noise, and O\textsubscript{3} will also be generated. The wave band graph of corona discharge is shown in the figure below:

![Corona discharge wave band chart](image)

Figure 1. Corona discharge wave band chart

As can be seen from the above figure, the characteristic of corona discharge is that the pattern of wave band will change with different test conditions, which is basically lower than 1GHz. However, researchers have proved that the corona discharge of high-voltage lines in UHV substations can be regarded as the detection frequency of 20-100 MHz.

Fourth, the air flow floating discharge interference refers to the fact that the ground potential of the equipment itself will change with the change of the electromagnetic field when the high-level voltage and the voltage contacting the ground have problems. At the same time, the high level voltage and the voltage contacting the ground discharge the electric energy at the top of the electromagnetic field. The duration of this kind of discharge interference is very short, about 100 nanoseconds. By analyzing the spectrum, it can be known that the current floating discharge is basically 0.5-2 GHz, and the shape of the spectrum is basically similar.

The fifth is the surface discharge interference. In the displayed power system, the potential between the equipment and the air flow is unstable, and the surface potential of the solid-state equipment is smaller than that of the air flow. The amplitude of this kind of interference is very weak, and the interference form that can be detected is the measurement value of phase.

The sixth is the discharge interference produced by power generation equipment. Some special power generation equipment can react quickly and cut off the current in the circuit when there is a problem in the circuit system, so as to ensure the stable performance of the power equipment. In the process of opening and closing the switches of these special equipments, friction causes the air flow to release electric energy, which will disturb the current in the power system.

The last is random noise interference with the same energy density. This kind of interference can be found everywhere in power equipment. Its characteristic is that the frequency wave is approximate to a certain value, and there is no rule to follow. The spectrum area is very wide, mainly divided into the noise of power components, the thermal energy of transformer equipment and the noise doped in the
transmission process. The frequencies are basically normal distribution graphs, which can be simulated by the frequency spectrum whose average value is zero and variance is a specific value, as shown in the following figure:

![Spectrum of random noise with the same energy density](image)

**Figure 2.** Spectrum of random noise with the same energy density

The pattern formed by the frequency and wavelength of the above random noise interference can be used in general. In the actual test, random noise interference is everywhere, different random noise interweaves together to form a variety of noise atmosphere. At present, the random noise interference with the same energy density has been paid attention and studied by several research institutions.

3. **The principle and measures of blocking electromagnetic interference source in UHV substation group**

3.1. *The principle of blocking electromagnetic interference source in UHV substation group*

According to the repeatability, the partial discharge electromagnetic interference in UHV substation can be divided into repetitive sources and arbitrary sources. The internal pulse source interference includes repetitive and arbitrary interference sources. Random noise interference with the same energy density is also an arbitrary interference source, and the rest is a continuous repetitive interference source [6].

3.2. *Blocking measures for UHV substation group to block electromagnetic interference source*

The blocking measures for UHV substation group to block the source of electromagnetic interference include the following.

The first is to block the repetitive interference sources. The repetitive electromagnetic interference sources usually exist in the form of dispersive and wide shape, and the core area has qualitative frequency. If there are too many external electromagnetic interference sources, the tighter band range will increase, and the advantages will also increase. For repetitive electromagnetic interference, the common blocking method is digital filtering.

The second is the use of digital filtering equipment. There are two kinds of digital filtering devices used in the blocking measures of electromagnetic interference sources. One is direct filtering equipment, and the other is point filtering equipment. There are two forms of direct filter equipment, one is non recursive filter, and the other is recursive filter [7].

The transmission equation $Y$ of non recursive filter with $N$ stages is as follows:
The derived sources of nonrecursive filters are:

\[ w(X) = \sum_{m=0}^{N-1} C_m d(e - m) \]  

In the above equation, \( C_m \) is the weight coefficient of non recursive filter. The coefficient can be expressed as:

\[ C = [C_0, C_1, \cdots, C_{N-1}] \]

In the actual test, if the high-level non recursive filter is used, the workload of operation is very large. If recursive filter is used, the workload of calculation will be greatly reduced, but there are many disadvantages. When the filter is running, it will have the problem of limit value moving, so the process of obtaining the minimum value will become very difficult. In the actual UHV substation partial discharge, the sources will be closely arranged, so the final calculation task will not be very difficult. Therefore, in the actual measurement of partial discharge electromagnetic interference in UHV substation, recursive filter is used to calculate the source.

Thirdly, the wavelet transform computing method blocks any electromagnetic interference source. First, the Wavelet Transform calculation method is used to study, judge, and quantitatively analyze the code, and then save it to the device of the feature, and then restore it in practice.

At present, numerical source analysis is the basic component of scientific research. Source analysis can be analyzed using the calculation methods in the Wavelet Transform study. In the actual partial discharge of UHV substation, many parts of the source are fluctuating greatly, and the Wavelet Transform calculation method can be applied to the source with relatively large fluctuations. It also has a strong effect on any type of interference source, and at the same time separates the sudden change source in the source from the interference source, thereby blocking any type of interference source.

Second, the algorithm in the Wavelet Transform calculation method is not always constant. The results obtained using different Wavelet calculations are different. Therefore, the selection of the Wavelet base needs to be cautious. The Wavelet base can discriminate between the actual acquired data of the source and the ideally obtained data, and then analyze the small Wavelet base.

Finally, the Wavelet Transform calculation method for interference source blocking includes three programs.

The first step is to use the Wavelet Transform for decentralized calculations of sources containing interference;

The second step is to quantify the decentralized calculation factor with a large number of occurrences;

The third step is to re-establish the above data into a flat form of Wavelet. In general, the composition of the plane-distributed source with a high number of occurrences has a certain influence on the stage of the Wavelet distributed calculation. At the same time, most of the non-morphological electromagnetic interference sources are in the area where the number of occurrences is high. A smaller number of occurrences will only affect the bottom of the Wavelet decomposition calculation class. In the actual partial discharge measurement of UHV substation, the measured data are basically at the bottom level where the number of occurrences is relatively small. After Wavelet Transform, the source of different regions can be blocked.

4. Conclusion

In this study, the experimental method of partial discharge and the type of partial discharge electromagnetic interference in UHV substation are first introduced. The principle of blocking electromagnetic sources and the blocking measures of various electromagnetic interference sources are analyzed in detail. The pulse signal noise interference is repetitive and the orientation on the display is stable. A recursive filter can reduce the actual computational effort. The actual partial discharge of the
UHV substation is suitable for the use of recursive filters to disperse the electromagnetic interference sources and block the sources of different regions.

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