Design of PD Test and Measuring System at DC Voltage

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Abstract: A set of PD test and measuring system at DC is built, which is composed of discharge impulse waveform ultra-wide band measuring system and ultra-high frequency signal measuring system. Six kinds of oil-paper insulation PD models are designed. Test results indicate that the defect model discharges stably and its repeatability is good at the same conditions; the measuring system can detect the discharge impulse waveform and ultra-high frequency signal correctly. It provides a research platform for on-line monitoring of PD discharge single waveform, impulse sequence and ultra-high frequency signal.

Key words: DC, Partial discharge (PD), ultra-wide band measuring, ultra-high frequency measurement

Introduction

The DC transmission underwent the development of ±100, ±250, ±400, ±450, ±500 and ±750kV and ±800 UHVDC technology is being developed now. The insulation condition of converter transformer is directly related to the reliability of DC transmission. However, with the continuous improvement of DC transmission voltage stage, related oil-paper insulation of electric equipment will generate DC partial discharge at some weak links, which poses a threat to equipment. Hence, it is of significance to study DC partial discharge of oil-paper insulation.

The PD test and measuring system at DC are established in this paper. Measurement of discharge impulse waveform and ultra-high frequency signal are performed on designed typical oil-paper insulation models (oil-paper needle-plate, oil-paper parallel plate gap, oil-paper surface, oil-paper internal defect, oil-paper wedge and oil-paper floating discharge) at DC.

1. PD Test and Measuring System

1.1 Test circuit

The wiring diagram of test circuit is shown in Fig.1 (220V AC source and voltage regulator). The resistance R_1 and R_0 constitute 10000:1 resistance voltage divider and take readings of DC voltage from both ends of R_0. C_k is 85pF coupling capacitance; R_z is water resistance; Cx is defect model.

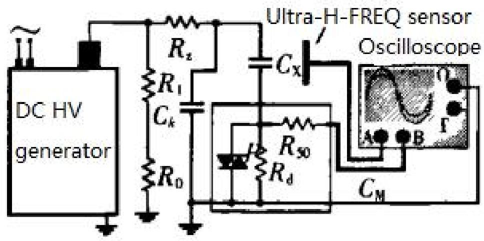


Fig.1 PD test and measuring circuit at DC

In order to get more information about partial discharge at DC, higher sampling frequency is used to collect discharge impulse waveforms and ultrahigh frequency signals. In the test, DPO4054 type is used; the bandwidth is 500MHz; real-time sampling frequency is 2.5GS/s.

1.2 Ultra-wide band measuring resistance

The impulse detection resistance is made of non-inductance resistance R_d (100Ω) and protection unit P in series, which is placed in a shield copper tube. The measuring cable C_M's wave impedance and the resistance of head or tail end R_{50} is 50Ω. In order to check out the frequency response characteristics of impulse wave measuring system, the steep falling edge (2ns) of square wave source is used as input impulse. Besides, compare the input impulse with the signal after measuring resistance. The schematic diagram of calibration system is shown in Fig.2.

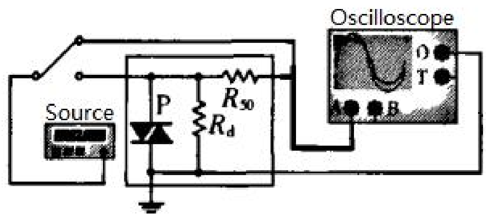


Fig.2 The schematic diagram

The calibrated impulse and impulse which is transmitted through measuring system are shown in Fig.3. From Fig.3, it is found that the dropping edge of square source via the oscilloscope is 2ns while that through the measuring resistance is 3ns; the vibration is not added and only increases 1ns, which indicates that the performance of Rd meets the requirement of test.

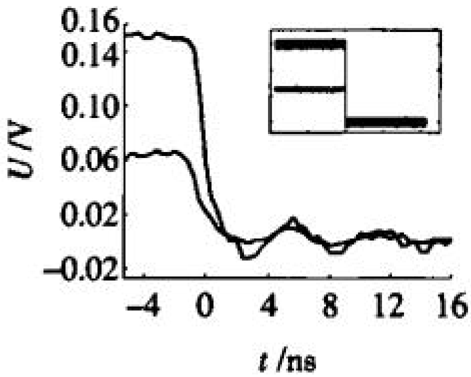
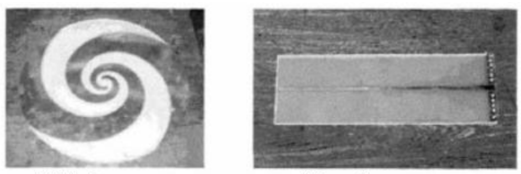


Fig.3 Calibrated impulse and impulse which is transmitted through the measuring system

1.3 Ultra-high frequency sensor

Generally speaking, the rising edge in the oil is steep; the impulse width is ns stages, which can activate more than 1GHz ultra-high-frequency electromagnetic signal. The PD signals taken within 300-3000MHz can avoid external interference, improving the reliability and sensitivity of PD detection. The ultra-high frequency sensor used in the paper is shown in Fig.4.



(a) Helical antenna (b) Impedance converter

Fig.4 Ultra-high frequency sensor

The UHF signal time domain and frequency domain waveform are shown in Fig.5. It is found that the helical antenna can detect the discharge signal well and covers a range of 300MHz-1.5GHz. As for the above discharge, many tests have been conducted. Its spectrum diagram has striking similarity, indicating that the test has repeatability.

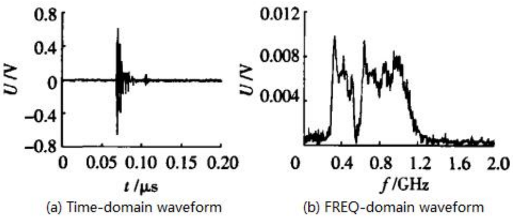


Fig.5 Time-domain and frequency domain waveform

2. Measurement of Discharge Impulse

PD measurements are performed many times on self-designed defected model at DCHV in the HV test shielding hall. The discharge impulse waveforms of needle-plate model and its ultra-high frequency signals combined with corona discharge waveform and ultra-high frequency signals are presented in the paper.

2.1 Corona in the air

In order to verify the stability of test and measuring system, the corona discharge waveforms in the air at DC are measured. When conducting the test, the impulse current signal is used to trigger and two channels of oscilloscope acquire discharge impulse waveforms and ultra-high frequency signals at the same time. During the whole process of boosting the voltage, the waveform of corona discharge is stable and the discharge frequency increases according to the rising of voltage amplitude. Based on Fig.6-I, it is concluded that wave front time is around 30ns and the duration is about 300ns. There is no vibration and overshoot. However, according to Fig.6-II, the ultra-high frequency signal is rarely seen. The reason is that rising and falling edges of corona discharge in the air are not steep (The energy amplitude is small). The test result indicates that the whole system meets the requirements of test.

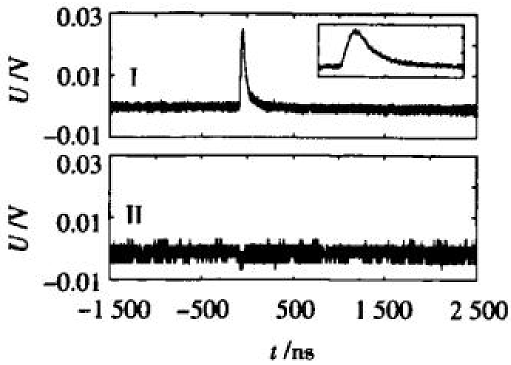


Fig.6 Corona discharge waveform and ultra-high frequency signal

2.2 Oil-paper needle-plate discharge

All designed defect models are put in the organic glass cylinder with gas vent holes which is filled with transformer oil. The discharge model of oil-paper needle-plate is shown in Fig.7. According to the requirements of different tests, the discharge gap can be adjusted and it is allowable to replace insulation plates with different thickness and insulation defect models with different sizes.

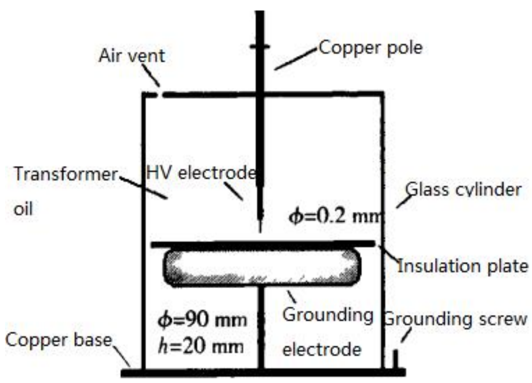


Fig.7 Oil-paper needle-plate discharge

model

At DC the oil-paper needle plate discharges stably and there is no overshoot and vibration. During the test, when DCHV is applied to a certain value, the needle-plate model starts to discharge. The oscilloscope sometimes captures the single impulse shown in Fig.8 (a). The impulse waveform is multi-peak impulse and the impulse envelope can be regarded as single indicator attenuation waveform; the rising edge of 1st peak is 1 ns; the falling edge of envelope is 30ns or so; the width of half-peak is 20ns and the whole impulse lasts 150ns.

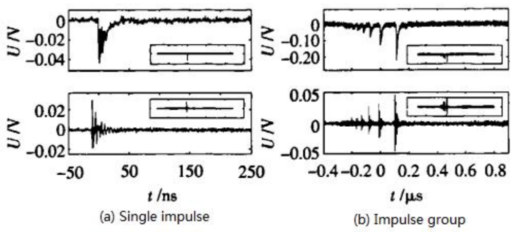


Fig.8 Oil-paper needle-plate discharge impulse waveform and ultra-high frequency signal

If the voltage continues to rise, the discharge frequency increases and its amplitude becomes bigger accordingly. The above 100mV impulse appears. When the voltage rises to a certain value, we start to hear clear discharge sound; the breakdown of oil gap occurs frequently; a group of strong discharge impulses as shown in Fig.8(b) but the parameters of signal impulse waveform do not change.

3. Conclusions

(1) The PD test and measuring system is set up at DC and the detection sensor is calibrated. The result indicates that the measuring system can meet the requirements of test.

(2) The designed oil-paper insulation discharge model is a typical defect

Test results indicate that the defect model discharges stably and the discharge repeatability is good under the same conditions. The measuring system can detect PD impulse waveforms and its ultra-high frequency signals. That provides an platform for studying the PD impulse single waveform, impulse sequence and monitoring the PD ultra high frequency on-line.