

Field measurement and verification of the UHF calibration platform based on the GTEM cell

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Abstract: The measurable electric field of the partial discharge ultra-high-frequency (PD UHF) detection system calibrated by a gigahertz transverse electromagnetic cell (GTEM) has been used as a key indicator to evaluate the performance of the detection system and regarded as the electric power standard. In this study, the sweep frequency and pulse signal were injected to the GTEM cell, and then the waveform and amplitude of the calibrated field strength were calculated by using the transfer function and voltage response of the monopole antennas. In the case of sweep frequency, comparing the measured result of the Narda field strength metre and the calculated result of monopole antennas, the error was found to be <8%, which verifies the correctness of the calibration of the monopole antennas to the steady-state electric field in the GTEM. In the case of pulse injection, comparing the simulation result of computer simulation technology and the calculated result of monopole antennas, the error of the peak of the field strength was found to be 1.7%, which verifies the correctness of the calibration of the monopole antennas to the pulse electric field in the GTEM.

1 Introduction

Ultra-high-frequency (UHF) partial discharge (PD) detection method is now adopted in the PD detection of electric PD detection widely for its high sensitivity and strong anti-interference capability [1–3]. The sensitivity of the sensor and the system should be calibrated before they are installed to ensure that the sensitivity and reliability of the UHF detection system meet the basic requirements [4–7]. Since the UHF signal of the PD is the nanosecond grade pulse signal, the pulse radiation field is adopted to calibrate the sensitivity that can easily reflect the physical essential of the detected signal, which is convenient for the comparison of the results of the deferent detection system.

The calibration method that is based on the gigahertz transverse electromagnetic (GTEM) cell is widely adopted by the power sector. In this method, the calibration of the sensor is expressed by the mean effective height H (mm).

The sensitivity of the detection system and the maximum detectable signal are expressed by the minimum and maximum peak pulsed electric field E (V/m) [8]. Therefore, an accurate measurement of the field intensity of the install position is very important. There is still the lack of the standard specification of the pulsed electromagnetic field [9–12].

The unipolar probe is adopted as a reference antenna, and the electric field strength of the GTEM cell is measured after injecting the pulse signal to the GTEM cell. The field intensity metre is adopted to measure the steady-state sweep frequency. The results are compared to the unipolar probe measurement results. The effects of the pulse signal method are also compared with the electric field intensity simulation results. Thus, the measurement results of the pulse signal are verified. The work has important value for the calibration of the PD detection system and pulsed electric field.

2 Calibration method of the PD detection system based on the GTEM cell

The field intensity of the installation place can be deduced from the reference sensor and the voltage response of the reference sensor.

The voltage signal $u(t)$ is inputted to the GTEM cell, and then the corresponding electric field $E(t)$ is created. The time-domain output voltage signal of the reference sensor $u_{or}(t)$ can be translated to the frequency-domain signal $u_{or}(f)$. If the transfer function of the reference sensor is known, then the electric field intensity $E(f)$ of the installation place can be deduced from (1). The unipolar probe which has less influence and transfer function $H_{ref}(f)$, which is calculable, are adopted to be the reference sensor:

$$E(f) = \frac{U_{or}(f)}{H_{ref}(f)} \quad (1)$$

where $U_{or}(f)$ is the Fourier transform result, $H_{ref}(f)$ is the theory transform function of the unipolar probe, and $E(f)$ is the frequency-domain electric field of the installation place of the unipolar probe.

The pulse method and frequency sweeping method are adopted to verify the calculated result of the electric field.

2.1 Test platform

The test platform is constituted by the signal source, GTEM cell, unipolar probe, high-speed oscilloscope, and cables, which is shown in Fig. 1.

2.2 Experiment of the pulsed electric field

The experiment equipment of the pulsed electric field include a pulse generator, a GTEM cell, a unipolar probe, and a high-speed oscilloscope. The schematic diagram of the experiment is shown in Fig. 1. The output port is connected with the input port of the GTEM cell. The output port of the probe is connected with an oscilloscope.

3 Pulse electric field simulation based on CST

Computer simulation technology (CST) is a commercial software package based on the finite time-domain integration (FIT), which is suitable for pulsed electric field simulation (Figs. 2–4).

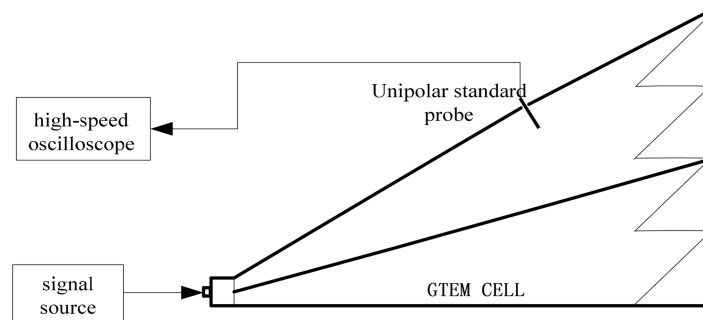


Fig. 1 Structure of the test platform

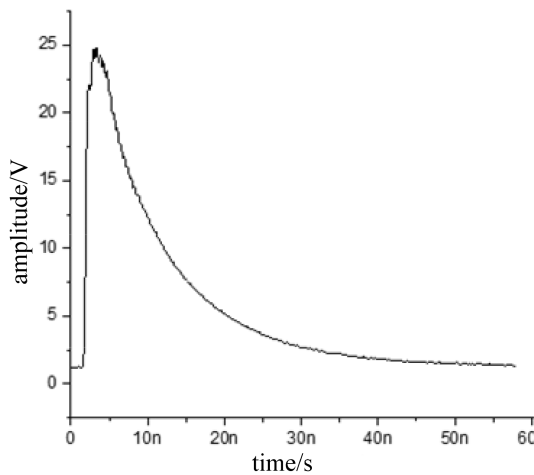


Fig. 2 25 V pulse voltage waveform

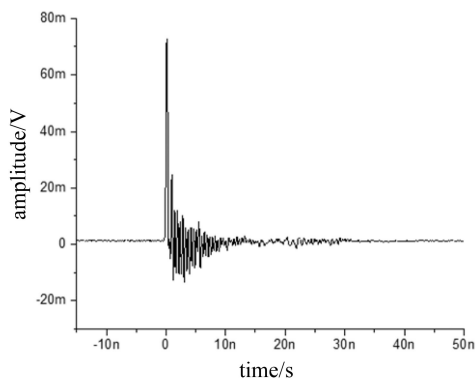


Fig. 3 Voltage waveform of the monopole probe

3.1 Modelling

SolidWorks is used to build the GTEM cell model. The model is shown in Fig. 5. The texture of the GTEM shell and cross-band veneer are set as the perfect conductor (PEC). The star arrow denotes the electric field monitoring point.

3.2 Excitation

The pulsed voltage waveform, as shown in Fig. 2, is used for the excitation waveform. The waveguide port is selected because the GTEM cell is a typical waveguide system.

3.3 Simulation results

The star arrow in Fig. 5 denotes the electric field monitoring point. The convergence domain is set at -30 dB. The calculation is done 6 times. The simulation results of the electric field of the monitoring point are shown in Fig. 6.

From Fig. 6, it can be found that the electric field of the monitoring point is 350 V/m, that is, greater than the experimental electric field, that is, 117 V/m. The connector of the GTEM cell is constituted by the circular coaxial line and rectangular coaxial line

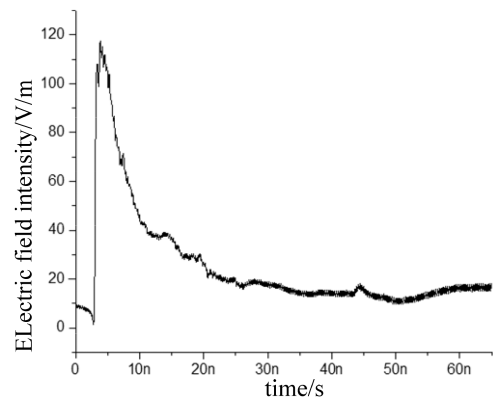


Fig. 4 Electric field waveform of the monopole probe test

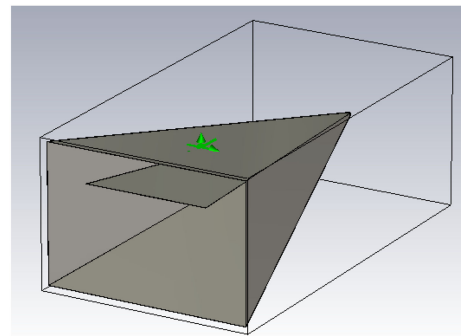


Fig. 5 GTEM simulation model

which cause power attenuation of the injected signal. However, there is no power attenuation in simulation results, because the excitation signal injects from the former port of the GTEM cell. Therefore, the injected signal did not suffer from attenuation. To adjust this result, the same GTEM model with 400 MHz and 2.1 GHz sinusoidal signal is selected for simulation. The correction factor is used to adjust the pulse electric field. The simulation results of 400 MHz and 2.1 GHz are shown in Fig. 7. The simulation results with the correction factor are shown in Table 1. It can be found that the correction factors of 400 MHz and 2.1 GHz are 2.92 and 3.16, respectively. The average value 3.04 is used for the correction factor of the pulsed electric field. The peak value of the simulation result is 350 V/m, and the adjusted result of it is 115 V/m. The measured result is 117 V/m. Electric field simulation results after correction with the measured result is shown in Fig. 7, which shows that the both waveform and amplitude are similar. This result demonstrates the veracity of the unipolar probe (Fig. 8).

4 Conclusion

The electric field of the monitoring point is deduced from the response of the unipolar probe with the swept-frequency signal. The result is in accordance with that of the field intensity metre. The result is also compared with the simulation results in CST, which demonstrates the accuracy of this method.

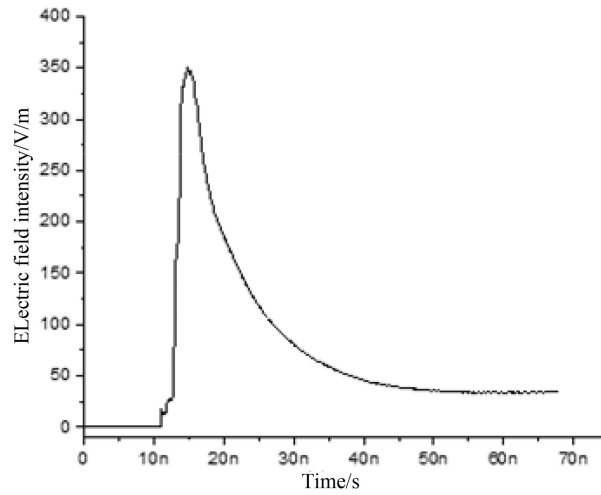


Fig. 6 Simulation result of the electric field of the 25 V pulse

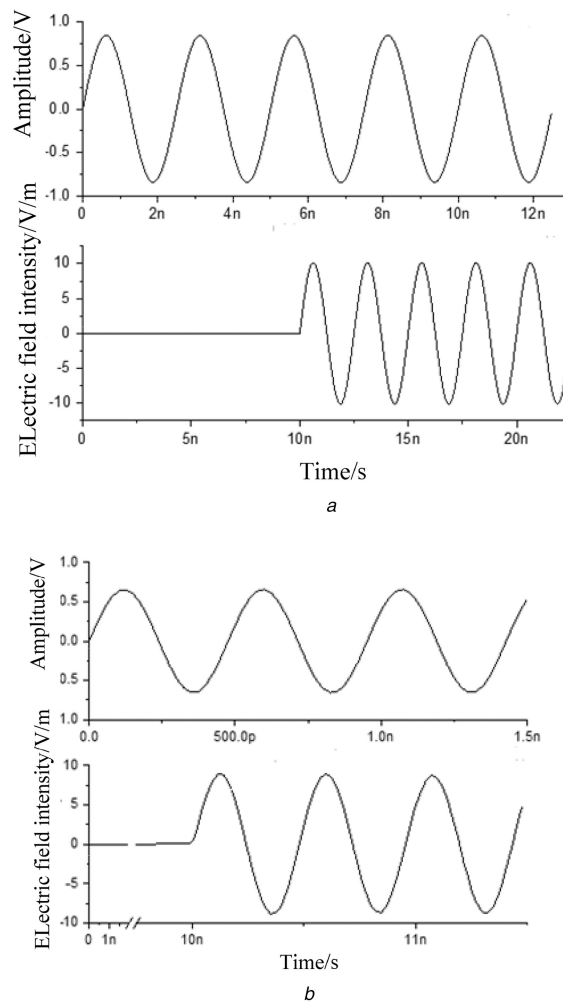


Fig. 7 Simulation results and excitation of the static field

(a) The simulation results and excitation of 400 M, (b) The simulation results and excitation of 2.1 G

Table 1 Simulation results of the static field and correction coefficient

Frequency, GHz	Excitation amplitude, V	Simulation results/ amplitude, V/m	Simulation results/ effective value, V/m	Measured results/ effective value, V/m	Correction factor
0.4	0.84	10.15	7.18	2.46	2.92
2.1	0.66	8.90	6.29	1.99	3.16

5 Acknowledgment

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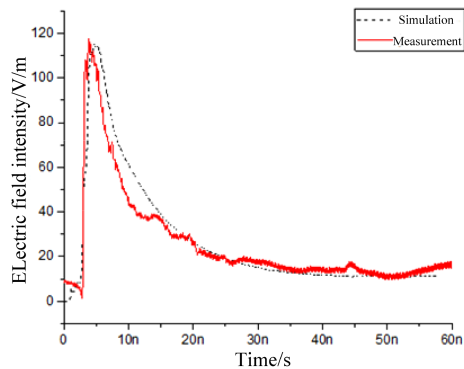


Fig. 8 Pulse excitation simulation and measured electric field waveform of pulse excitation

6 References

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