

Zhang, Weiwei; Xu, Dongdong; Zhou, Wei; Yun, Yuxin; Wang, Nan

Article

Research on equivalent height compensation measurement method of UHF partial dispenser based on GTEM cell

Energy Reports

Provided in Cooperation with:

Elsevier

Suggested Citation: Zhang, Weiwei; Xu, Dongdong; Zhou, Wei; Yun, Yuxin; Wang, Nan (2020) : Research on equivalent height compensation measurement method of UHF partial dispenser based on GTEM cell, Energy Reports, ISSN 2352-4847, Elsevier, Amsterdam, Vol. 6, Iss. 2, pp. 434-438,
<https://doi.org/10.1016/j.egyr.2019.11.099>

This Version is available at:

<https://hdl.handle.net/10419/243913>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.



<https://creativecommons.org/licenses/by-nc-nd/4.0/>

The 6th International Conference on Power and Energy Systems Engineering (CPESE 2019),
September 20–23, 2019, Okinawa, Japan

Research on equivalent height compensation measurement method of UHF partial dispenser based on GTEM cell

Weiwei Zhang^{a,*}, Dongdong Xu^a, Wei Zhou^b, Yuxin Yun^a, Nan Wang^a

^a State Grid Shandong Electric Power Research Institute, Jinan 250002, China

^b China Electric Power Research Institute, Wuhan 430074, China

Received 6 October 2019; accepted 22 November 2019

Abstract

Based on the GTEM chamber for the equivalent height detection method of UHF partial discharge tester, this paper simulates the electric field at the top of the GTEM window. The results show that the electric field strength changes significantly along the position of the top fenestration axis. This change will have a non-negligible effect on the accuracy of the UHF partial discharge equivalent height measurement. In this way, an equivalent height compensation method for the UHF partial discharge tester is proposed. The method compensates for the electric field of the reference sensor position by using the electric field of the measured sensor position as a standard. Through the comparison before and after compensation, the method can effectively improve the accuracy of the equivalent height measurement of the UHF partial discharge tester.

© 2019 Published by Elsevier Ltd. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Peer-review under responsibility of the scientific committee of the 6th International Conference on Power and Energy Systems Engineering (CPESE 2019).

Keywords: GTEM cell; Effective height; Ultra high frequency (UHF); Partial discharge (PD); Compensation amount

1. Introduction

At present, GIS partial discharge UHF partial discharge (UHF) detection technology has been greatly developed and widely used in the power grid [1]. Through several successful discoveries of partial discharge caused by insulation defects inside the gas chamber, it has made great contributions to ensuring the safe and reliable operation of the power system [2]. The UHF PD tester is an important testing device for UHF detection technology. The accuracy of its key performance indicators directly affects the scientific and effective diagnosis results [3].

At present, based on the GTEM cell UHF sensor performance verification method, the reference sensor is used to detect the equivalent height of the measured sensor using the GTEM cell top test window. This method has been recognized by many scholars at home and abroad. However, since the test window at the top of the GTEM cell is not a conventional uniform electric field test area, the electric field changes significantly at different test

* Corresponding author.

E-mail address: weiwei.1302@163.com (W. Zhang).

positions. Therefore, it is necessary to conduct an in-depth study on the electric field at which the reference sensor and the measured sensor are located, thereby ensuring the accuracy of the equivalent height measurement of the UHF sensor.

2. The principle of the equivalent height of the UHF PD

The equivalent height verification platform of the UHF PD tester based on the GTEM cell is mainly composed of a GTEM cell, a radio frequency signal source, a radio frequency power amplifier, a measurement and control computer, a high speed oscilloscope, a measured sensor, and a unipolar standard probe (reference sensor). As shown in Fig. 1.

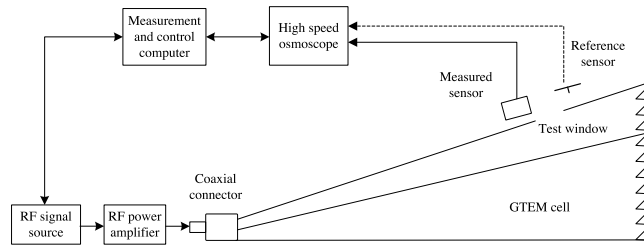


Fig. 1. The equivalent height verification platform of the UHF PD tester based on the GTEM cell.

The RF signal source and the RF power amplifier are used to input a voltage signal $U_I(f)$ to the GTEM cell, and the frequency range of the signal is 300 MHz to 3 GHz. The electric field established inside the chamber is expressed as E_I . The output voltage signals of the measured sensor and the reference sensor are respectively expressed as $U_{Ms}(f)$ and $U_{Mr}(f)$. The transfer function of the GTEM cell, the reference sensor, and the measured sensor are expressed as H_{cell} , H_{ref} and H_{sens} . The transfer function of the measurement system is expressed as H_{sys} . Then the measured output of the reference sensor and the measured sensor can be expressed as Eq. (1) [4].

$$\begin{cases} U_{Mr}(f) = U_I(f) H_{cell} H_{ref} H_{sys} \\ U_{Ms}(f) = U_I(f) H_{cell} H_{sens} H_{sys} \end{cases} \quad (1)$$

In order to get the expression of the equivalent height of the measured sensor, the two formulas of Eq. (1) are divided to obtain Eq. (2).

$$H_{sens} = \frac{U_{Ms}(f)}{U_{Mr}(f)} H_{ref} \quad (2)$$

Although the test window is used to measure the sensor, the effect of the sensor on the electric field inside the GTEM cell can be weakened. However, the GTEM cell top test window position is not the “1/3” uniform field test area of the GTEM cell. The value of the electric field varies greatly with position and signal frequency. Since the reference sensor and the measured sensor are different in size and the test positions are not identical. The electric field in which it is located must be different. Therefore, it is necessary to study the electric field in the case of opening the window at the top of the GTEM cell. In this way, the variation law of the electric field strength of the reference sensor and the measured sensor due to different test positions is determined. This can improve the equivalent height measurement accuracy of the measured sensor.

3. The simulation analysis of electric field at the top of GTEM cell

This paper takes a cross section at the center of the window at the top of the GTEM cell and parallel to the bottom of the chamber. The electric field strength at the cross section is simulated and analyzed at a frequency of 1.5 GHz. The simulation results are shown in Fig. 2.

It can be seen from Fig. 2 that the “Area1” is a “1/3” uniform electric field region inside the GTEM cell, and the electric field distribution is uniform. However, the “Area2” at the top of the cell is the equivalent height test area of the UHF sensor, and the value of the electric field changes significantly with the position change. Therefore, when the measured position of the measured sensor and the reference sensor are deviated, the change of the electric

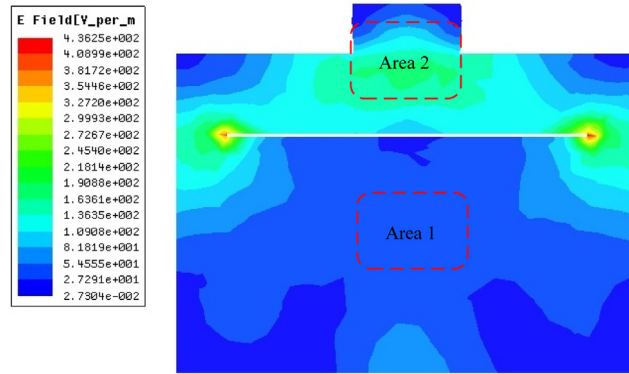


Fig. 2. The simulation results of electric field distribution of cross section of GTEM cell.

field will have an important influence on the measurement accuracy of the equivalent height of the measured sensor represented by the reference sensor transfer function.

In order to study the electric field change at the top window of the GTEM cell, the electric field at the top window position was studied. Select the center of the window as point 1, and take point 2 along the center of the circle, perpendicular to the center axis of the ceiling of the chamber, and take the point 3 below. Point 2 and point 3 are symmetrically distributed with respect to point 1, as shown in Fig. 3.

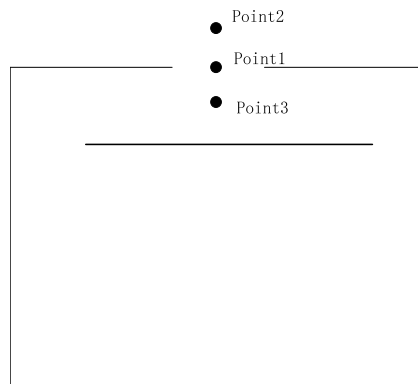


Fig. 3. The GTEM cell window position take test point diagram.

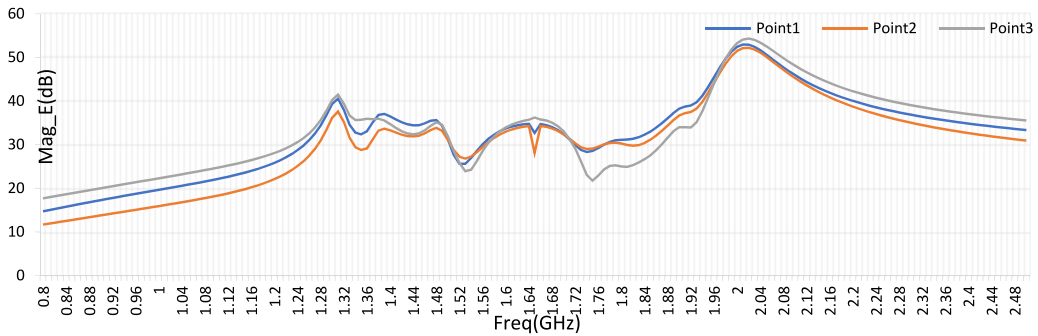


Fig. 4. The electric field simulation results at selected points.

The electric field strength at point 1, point 2, and point 3 was simulated and analyzed in the 0.8 GHz-2.5 GHz sweep frequency range. The simulation results are shown in Fig. 4. It can be seen from Fig. 4 that in the frequency

range of 0.8 GHz to 2.5 GHz, the electric field strength at point 1, point 2, and point 3 tends to be consistent with the frequency. Taking point 1 as the reference point, the electric field strength at point 2 above the reference point is lower than the reference point, and the electric field strength at the frequency point of 73.7% in point 3 is higher than the reference point. Compared with point 1, the frequency point where the relative error of the electric field value of point 2 and point 1 exceeds 10% accounts for 31.6% of the total frequency, and the frequency point where the relative error of the electric field value of point 3 and point 1 exceeds 10% accounts for 34.5% of the total frequency.

Therefore, it can be concluded that along the center axis of the ceiling window of the chamber, the electric field strength trends at each point are basically the same, and the electric field strength above the chamber window is lower than the lower electric field strength. The electric field strength changes significantly along the position of the axis. About 1/3 of the frequency point electric field strength relative error is higher than 10%. This error can have a non-negligible effect on the accuracy of the equivalent height measurement of the UHF PD tester.

4. The equivalent height compensation measurement method

In order to solve the above problems, an equivalent height compensation measurement method is proposed. Let the GTEM cell input voltage signal be $U_1(f)$, and establish the electric field as E_1 inside the cell. Let the electric field value of the reference sensor be $E_1(f)$ and the electric field value of the measured sensor is $E_2(f)$. Then, the electric field compensation amount of the reference sensor converted to the sensor under test is Eq. (3).

$$\Delta\gamma(f) = \frac{E_1(f)}{E_2(f)} \quad (3)$$

The measured voltages of the measured sensor and the reference sensor are expressed as $U_{os}(f)$ and $U_{or}(f)$. Then the measured sensor and reference sensor transfer function can be expressed as Eqs. (4) and (5).

$$H_{sens}(f) = \frac{U_{os}(f)}{E_2(f)} \quad (4)$$

$$H_{ref1}(f) = \frac{U_{or}(f)}{E_1(f)} \quad (5)$$

The reference sensor's electric field is compensated using the measured sensor so that the electric fields are the same. Combining Eqs. (3) and (5), the reference sensor transfer function is obtained as $H_{ref2}(f)$.

$$H_{ref1}(f) = \frac{U_{or}(f)}{\Delta\gamma(f) \cdot E_2(f)} = \frac{1}{\Delta\gamma(f)} \cdot H_{ref2}(f) \quad (6)$$

It can be known from Eq. (2) that when the measured sensor and the reference sensor are in the same electric field $E_2(f)$, the equivalent height of the measured sensor can be expressed as Eq. (7).

$$H_{sens}(f) = \frac{U_{Ms}(f)}{U_{Mr}(f)} \cdot H_{ref2}(f) \quad (7)$$

Since $H_{ref2}(f)$ is unknown, combined with Eq. (6), the equivalent height of the measured sensor after compensation can be expressed as Eq. (8).

$$H_{sens}(f) = \frac{U_{Ms}(f)}{U_{Mr}(f)} \cdot H_{ref1}(f) \cdot \Delta\gamma(f) \quad (8)$$

5. The equivalent height compensation simulation analysis

Assume that the electric field of the measured sensor is at point 2, and the electric field of the reference sensor is at point 1 position. Through the Eq. (3), the simulation result of the compensation amount can be obtained as shown in Fig. 5.

As can be seen from Fig. 5, the amount of compensation exhibits different values as the frequency changes, and compared with the value 1 line, the larger the deviation from 1 is, the larger the amount of compensation is needed. By comparison, the compensation amount is large in the low frequency range of (0.8–1.5) GHz, and the compensation amount is relatively small in the middle frequency band (1.5–2.2) GHz. Through statistics, in the (0.8–1.5) GHz full frequency band, by performing compensation, the average equivalent height accuracy of the measured sensor can be increased by 9.39% compared with before compensation.

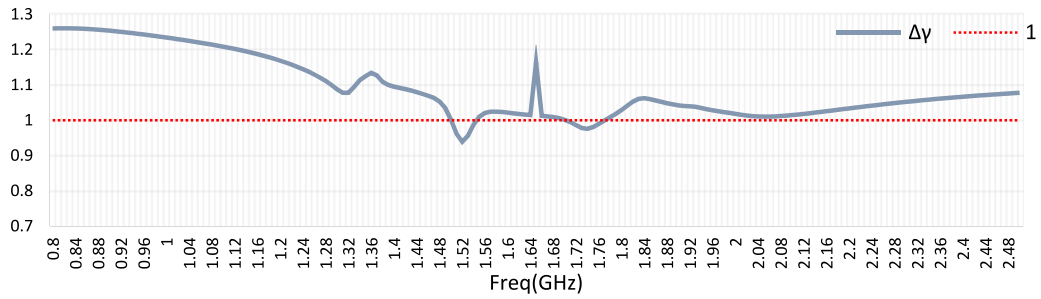


Fig. 5. The curve of compensation amount.

6. Conclusions

Through the simulation analysis of the top window of the GTEM chamber of the UHF PD tester, it is found that the test points are taken along the axis of the top window, and the electric field intensity changes at each point are basically consistent with the change of frequency. The electric field strength above the chamber window is lower than the electric field strength below. The position of the test points is different, and the error of the electric field strength will have a non-negligible influence on the accuracy of the equivalent height measurement of the UHF partial discharge.

The amount of compensation represented by the electric field of the measured sensor and the reference sensor exhibits different values as the frequency changes. By adding the compensation amount $\Delta\gamma(f)$ to compensate the original equivalent height, the equivalent height measurement accuracy of the UHF PD tester can be effectively improved.

References

- [1] Li Xingwang, Lu Qifu, Tang Zhiguo, et al. Study on receiving characteristics of the UHF sensor for GIS partial discharge. *Guangdong Electr Power* 2013;26(9):55–60.
- [2] Liu Yazhou. Study on the key problem in UHF sensor performance calibration based on GTEM cell. *School of Electrical and Electronic Engineering*; 2016, p. 1–4.
- [3] Li Duanjiao, Tang Zhiguo. Research on the Calibration of UHF partial discharge detection system in GIS. *High Volt Eng* 2015;41(10):3348–54.
- [4] Zheng Wenwen, Li Gongxin, Shu Shengwen. Review of Calibration methods for UHF detection system performance of GIS partial discharge. *Electr Eng* 2016;10:1–7.