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Study of UHF Frequency Response Characteristics of the Semicircle Dipole Inner Sensor for Partial Discharge Detection in GIS

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Abstract. The paper designed a semicircle dipole inner sensor for UHF partial discharge detection in GIS. By comparing the symmetric semicircle dipole sensor and asymmetric semicircle dipole sensor characteristics, the symmetric semicircle dipole sensor's coupling property is better than that of asymmetric semicircle dipole sensor. At the same time, by changing the symmetric semicircle dipole transducer radius, the position of the feeder pole , the height of the feeder pole, analyze its influence on sensor features.

1 The introduction

In the mid - 1960 - s, the birth of GIS, makes the high voltage power equipment qualitative leap. In recent decades, the GIS with its compact structure, space and building cover an small area, the advantages of the high reliability and easy installation, obtained the rapid development [1]. At the same time, the safe and reliable operation for a long time also become the focus of attention. Studies have shown that [2-4], GIS has internal SF6 gas leakage, switch fault, internal discharge hidden trouble. In all kinds of fault, large of the failure caused by the insulation defect [5, 6]. Therefore, on-line insulation monitoring of GIS is very necessary.

UHF is more effective for monitoring GIS partial discharge, with strong anti-interference ability, high sensitivity of monitoring [7-9]. Depending on the location of the sensor installation, UHF sensor is divided into inner sensor and external sensor. Inner sensor installed in the body of the GIS, can effectively resist the outside electromagnetic interference, and has higher efficiency of sensor. As the special inner sensor installation position, it determines that the design and installation is better done when manufactured the GIS . If it really needs to install the inner sensor on equipments which have been put into operation, it only chooses at GIS hand hole, has certain limitations. For the GIS equipment has been put into operation, can install the external sensors, it is usually installed on the GIS basin insulator, through testing the leaked electromagnetic wave signal of the insulator to realize the partial discharge detection. The shortcoming of this method is the sensor works in the complex electromagnetic environment , vulnerable to the effects of electromagnetic radiation around. The anti-interference ability is poor. Visible, the inner sensor installed on GIS shell can obtain high detection sensitivity, and it has the characteristics of flexible installation, good safety.

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2 Measure of sensor performance metrics

Uhf inner sensor is a kind of uhf antenna which used to receive electromagnetic waves that produced by internal partial discharge of GIS . Therefore, we can use the antenna performance indicators to judging the performance of the sensor. For antenna input impedance, standing wave ratio, gain are the important parameters, so these parameters for evaluating the performance of the inner sensor is of great significance. However, from the perspective of monitoring partial discharge signals, we pay more attention to the sensor output voltage amplitude which is the sensor's output characteristic in the same field environment, Here, we introduce the sensitivity [10] as the main evaluation index of the sensor performance. To sum up, the input impedance and the sensitivity are the mainly measure of the sensor.

2.1 The input impedance

The sensor receive signals as a receiving antenna. The signals which coupling to the partial discharge that can be converted into voltage signal output, as the power of the peripheral receiving circuit, based on thevenin theorem, the circuit can be equivalent to the ideal voltage source and the resistance in series, a simplified circuit resistance can be understood as the input impedance of receiving antenna (sensor) looking from peripheral circuit terminal [11].

When the sensor input impedance matched with the impedance of peripheral circuit, it can achieve the maximum output power. Starting from the equipment, only when the sensor and the transmission lines realize the impedance matching, the peripheral circuit can receive the partial discharge signals that coupled by the sensor for maximum efficiency. From macro available, Impedance matching can be measured by reflection coefficient or standing wave ratio.

In radio frequency circuit, on a point of the transmission line, the reflection coefficient (voltage) is defined as the reflected wave voltage ratio the incident wave voltage, such as type 1.

$$\eta = \frac{U_2}{U_1} \quad (1)$$

U_2 is the reflected wave voltage, U_1 is the incident wave voltage.

Standing wave coefficient (voltage) is defined as the signal antinode point voltage and the ratio of the node voltage, such as type 2.

$$\rho = \frac{|U|_{max}}{|U|_{min}} = \frac{1+|\eta|}{1-|\eta|} \quad (2)$$

2.2 The sensitivity

Sensitivity is a kind of transfer function of the coupling characteristics of the sensor, it is to point to in a certain frequency range, when the incident electric field for the 1vm-1, the ability of the sensor output voltage [10]. Visible, the sensitivity is the most key performance indicators measure uhf inner sensor.

As a receiving antenna, sensor receives electromagnetic signals generated by partial discharge, converted to voltage signal and output. Thus, according to the practical significance of the sensitivity, the sensitivity of the sensor can be defined as: the amplitude frequency response of the sensor H_e as the sensor output voltage $U_{(f)}$ the ratio of the incident field strength $E_{(f)}$, the unit is m [10]. Such as type 3.

$$H_e = \frac{U_{(f)}}{E_{(f)}} \quad (3)$$

H_e characterization of the ability of the sensor that converts the incident electric field to output voltage signal, Its amplitude is proportional to the sensor detection sensitivity. In the same frequency band, when H_e the larger, shows that the sensitivity of the sensor is the better, the sensor performance is fine.

3 Performance analysis of semicircle dipole inner sensor

Semicircle dipole sensor uses semicircle board instead of symmetric oscillator. Semicircle dipole inner sensor can be divided into symmetric semicircle dipole and asymmetric semicircle dipole according to the structural characteristics .As shown in figure 1, figure 2. Figure 1 shows simulation model of symmetrical semicircle dipole .Figure 2 is asymmetric semicircle dipole, its radius ratio of 1.4:1.

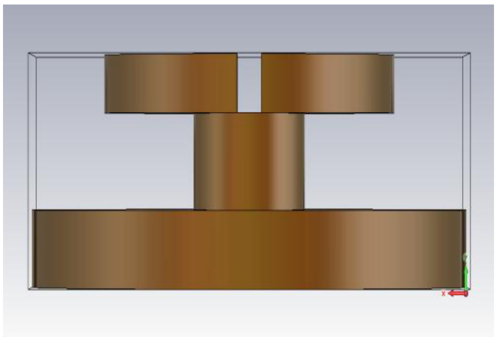

Figure 1. Symmetric Semicircle Dipole Inner Sensor

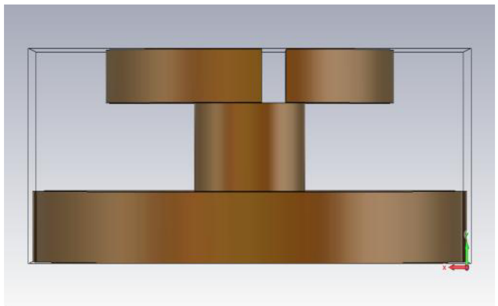

Figure 2. Asymmetric Semicircle Dipole Inner Sensor

Compared the sensitivity characteristics and standing wave ratio of the symmetric semicircle dipole and asymmetric semicircle dipole semicircle inner sensors, figure 3 shows the sensitivity graph of the two sensors, figure 4 is the standing wave ratio characteristic of the two sensors. It can be seen from the figure 3 that the coupling characteristics and coupling frequencies of the symmetrical semicircle dipole sensor are more accord with the GIS internal wave spectrum characteristics of partial discharge. From figure 4,it can be seen that the start frequency which the value less than 2 of the standing wave ratio curve of the symmetrical dipole is lower than that of the asymmetric dipole.

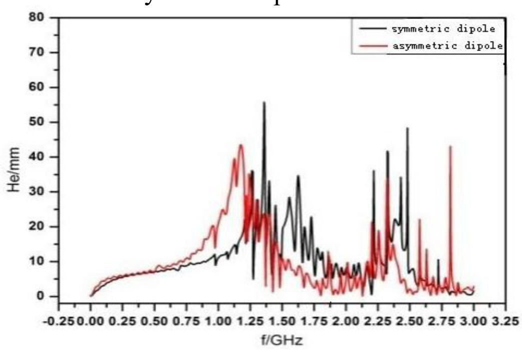

Figure 3. Contrast Sensitivity

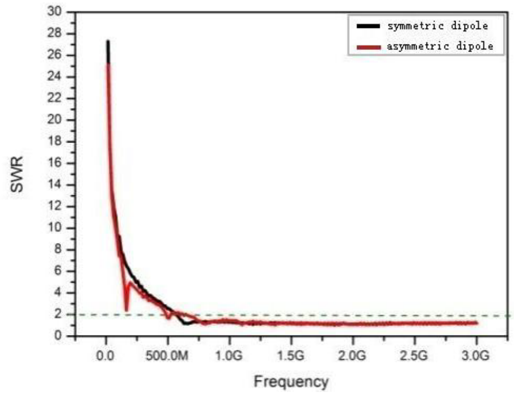

Figure 4. Contrast Standing Wave Ratio

4 Characteristics analysis of symmetrical semicircle dipole transducer

The factors that affect the semicircle dipole transducer characteristics are the radius of the round plate, the feeder pole position , The location of the semicircular shell from the GIS (the height of the feeder pole), etc. By simulation analysing the influence of these factors on the sensor performance.

4.1 Analysis the influence of radius of semi-circle plate of sensor characteristics

Compared the sensitivity of the symmetric semicircle dipole sensor when the semi-circle plate radius are 50 mm , 75 mm and 90 mm, shown in figure 5.

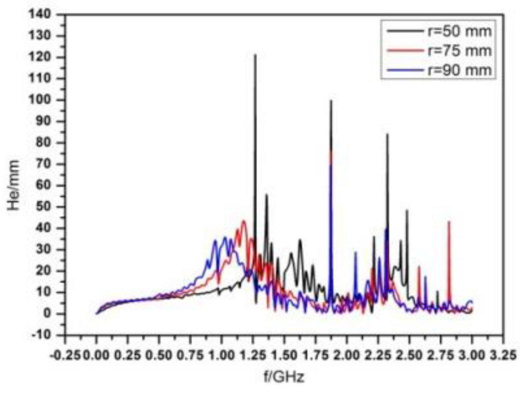

Figure 5. Effecting Sensitivity by Semi-circle Plate Radius

From figure 5 , along with the increase of the radius of semi-circle plate sensor, the peak of the sensitivity moves to the lower frequency band, In combination with the frequency characteristic of GIS internal partial discharge signals,it can be seen that when the radius of semicircle dipole is 90 mm, conform to the principle of design.

4.2 Analysis the influence of the feeder pole location of sensor characteristics

The feeder pole position of sensor sensitivity has a certain impact. Compared the sensor sensitivity when feeding point in the center of the symmetric semicircle dipole and 10 mm from the center. The sensitivity curve as shown in figure 6. From the figure, for symmetrical dipole senor, when center feeding, its sensitivity curve peak is almost four times higher than that of noncentral feeding. Visible, using the center feeding can more improve the sensitivity of the sensor.

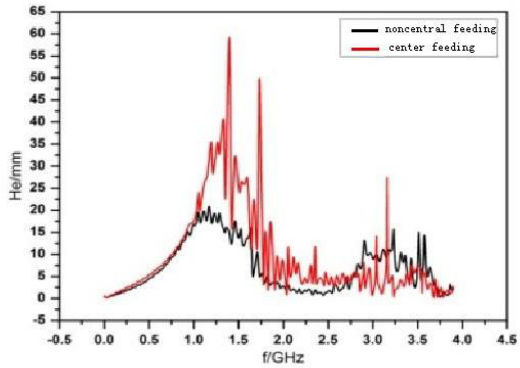

Figure 6. Effecting Sensitivity by feeding point location

4.3 Analysis the influence of the feeder pole height of sensor features

The distance of the symmetric semicircular dipole sensor from the GIS shell (the height of the feeder pole) has great effects on the sensitivity of the sensor. Compared the sensitivity influence of the symmetric semicircle dipole sensor when the height of the feeder pole are10 mm, 20 mm, 30 mm and 40 mm. Shown as figure 7.

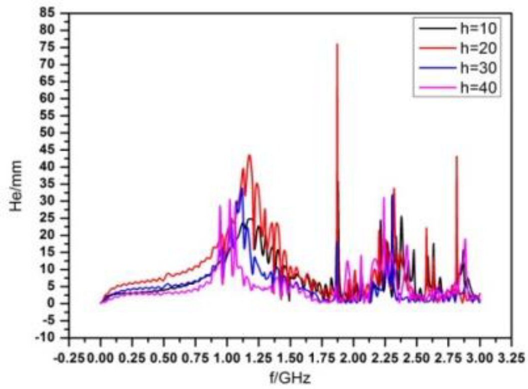

Figure 7. Effecting Sensitivity by feeder pole height

From the above, when the height of the feeder pole is 20 mm, the sensitivity characteristic of the sensor amplitude is the highest, the coupling characteristics is the best.

5 Summary

In this paper, compared the symmetry semicircle dipole and the asymmetric half inner sensors. At the same time, the influence sensitivity factor of symmetrical semicircle dipole inner sensor was analyzed, as the following conclusion:

The symmetric semicircle dipole sensor's coupling property is better than that of asymmetric semicircle dipole sensor.

The symmetric semicircle dipole sensor ‘s radius, the feeder pole position and the height of the feeder pole are affect the sensitivity of the sensor characteristics.

With the increase of radius of semi-circle plate, the peak of the sensor sensitivity moves to the lower frequency band.

For symmetrical dipole senor, when center feeding, its sensitivity curve peak is almost four times higher than that of noncentral feeding.

Visible, for the symmetrical semicircle dipole inner sensor, when the radius of semi-circle plate for 90 mm , using center feeding and when the height of the feeder pole is 20 mm, the sensitivity of the sensor characteristics is the best.

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