Study on the Relationship between the Size of Resin Sprue on GIS and Intensity of UHF Electromagnetic Waves Radiated from Partial Discharge

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Abstract— Gas insulated switchgear (GIS) of different manufacturers have different sizes of resin sprues and the size of resin sprue has direct effects on the ultra high frequency (UHF) electromagnetic waves motivated by partial discharge (PD), which brings about many difficulties in accurate estimate of the severity of PD. On the platform of a 252 kV GIS, we used UHF sensors which were mounted on resin sprues of different sizes that had been set up in advance to detect electromagnetic wave signals emitted by a needle-plane PD model in GIS and found that with an increment of the length of resin sprue's long edge, the signal intensity enhances first and weakens later and reaches its maximum at 75 mm. Another simulation experiment which used pulse signal generator to provide excitation source for the transmitting antenna in GIS to simulate PD and detected signals in the same way to the former also found the same conclusion. This conclusion offers important references for the options of the optimal size of resin sprue and development of external UHF sensor.

1. INTRODUCTION

Gas insulated switchgears (GIS) are widely used as main switching equipment in the power system. Partial discharge (PD) reflects the insulation performance of GIS, which is not only the precursor of GIS internal defects but also leads to gradual insulation deterioration and eventual breakdown. As PD detection can discover the early defects in GIS, which provides a chance to take effective measures to prevent its development, it is remain the most important tool in dielectric detection and diagnosis for GIS equipment. In recent years, the ultra high frequency (UHF) method is becoming more and more popular for on-site PD detection of GIS, because of its features such as high sensitivity high S/N ratio and capacity of defect location and identification.

To make GIS enclosure reliable grounding and prevent the insulation material from chemical corrosion, most basin-type insulators of GIS are overlaid by metal ring. In this situation the UHF electromagnetic waves can only radiate from a rectangular hole on the metal ring, which is called the resin sprue since it is used to inject epoxy resin into basin-type insulator when it being manufactured. However, GIS of different manufacturers have different sizes of resin sprues and the size of resin sprue has direct effects on the UHF electromagnetic waves motivated by PD, which brings about many difficulties in accurate estimate of the severity of PD. So it is very necessary and urgent to study the effects of resin sprue and determine the optimal size for it.

Currently, some scholars have done some research into the issue of resin sprue and they derived some meaningful conclusions such as the propagation mode of UHF electromagnetic waves passing through the hole, the structure of electric filed on the surface of the hole and so on. However, there are few papers concentrating on the effects of resin sprue's size on the UHF electromagnetic waves.

On the platform of a 252 kV GIS, the authors accumulated a great number of data through a lot of experiments. On this basis, combining experiment results and simulation calculation, we focused our study on the relationship between the size of resin sprue and the intensity of UHF electromagnetic waves radiated form the hole. Then we drew a conclusion that offers important references for the options of the optimal size of resin sprue and development of external UHF sensor.

2. STRUCTURE OF RESIN SPRUE

GIS has fully enclosed metal structure and every basin-type insulator connects two adjacent gas tanks. Currently most basin-type insulators have their surfaces covered by metal rings, which are safely grounded and provide effective prevention from erosion and radiation. There is a small hole on each metal ring, as shown in Fig. 1. It's called the resin sprue since it is used to inject epoxy resin into the basin-type insulator when it being manufactured. The cross-section of the basin sprue is rectangle with rounded corners and its size is different due to the different manufactures and voltage levels. For now the common sizes of the resin sprue are: depth: 25 mm, length of the long edge: 45 mm, length of the short edge: 20 mm.

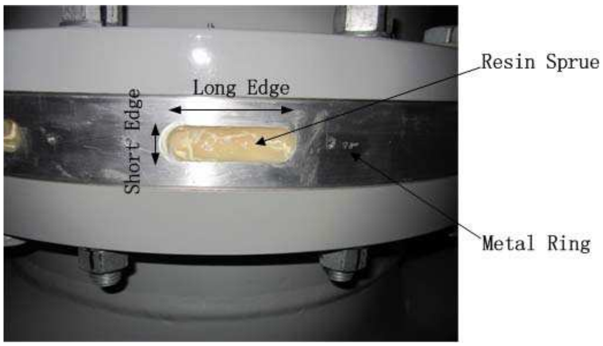

Figure 1: Rein sprue in the metal ring.

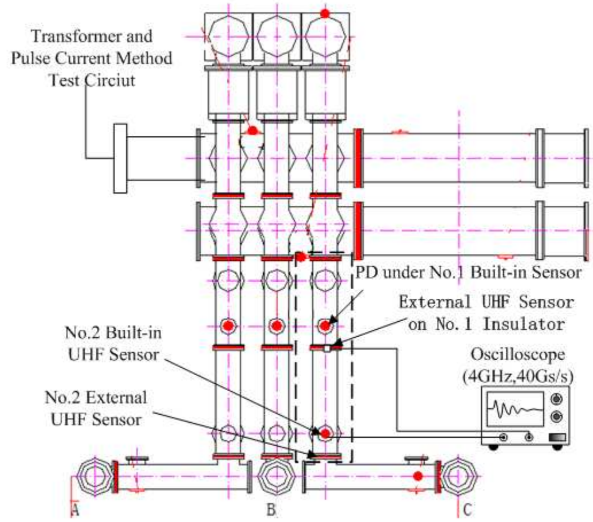

Figure 2: 252 kV GIS experiment platform (top view).

3. EXPERIMENTAL SETUP

The authors built up a 252 kV PD detection platform of UHF sensors, as shown in Fig. 2. The experiment was mainly carried out in two of the gas tanks in phase C of the GIS, which is in the box of dotted line in Fig. 2. Each of the basin-type insulator in phase C has 4 resin sprues of different sizes distributed along the circumference of it and the size of them were respectively 15 mm × 45 mm, 15 mm × 55 mm, 15 mm × 75 mm and 15 mm × 85 mm.

Given that the PD can't be very stable, which means even under the same voltage level PDs of same discharge quantity may excite UHF signals of different amplitude. In order to minimize the this factor's unfavorable effects, the experiment was taken as follows: the external sensor connected to an oscilloscope (4 GHz, 20 GS/s) through a power amplifier (Gain 20 dB) was fixed on the 4 resin sprues of different sizes on No. 1 basin-type insulator successively. Simultaneously the No. 2 built-in sensor was used as a reference sensor directly connected to the oscilloscope to check the results. Under a relative stable discharge quantity (with the voltage unchanged), the external sensor on each resin sprue and the built-in sensor collected at least 200 sets of data respectively. Then we averaged the data to reduce noises and divided the signal amplitude (that had been averaged) collected from the external sensors by signal amplitude (that had been averaged) collected from No. 2 built-in sensor to characterize the intensity of the UHF signals passing through the resin sprues. The external sensors we used were produced by DMS.

Figure 3: Needle-plane discharge model.

We applied power frequency voltage step by step at a needle-plane PD model set in the gas tank filled up with SF_6 gas (0.4 Mpa) to generate PD through a 550 kV gas-insulated transformer. The PD model, of which the PD quantities is under 30 pC, was mounted on the center conductor beneath No. 1 built-in sensor, as shown in Fig. 3.

4. EXPERIMENT RESULTS

4.1. Experiment Results Based on PD Model

After processing the experiment data according to the method mentioned early, we got the results shown in Fig. 5.

As is shown in Fig. 4, we can see that with the length of resin sprue's long edge increasing, the signal intensity enhances first and weakens later and reaches its maximum at 75 mm. The trend of the variation is independent of discharge quantity and the amplitude of UHF electromagnetic waves.

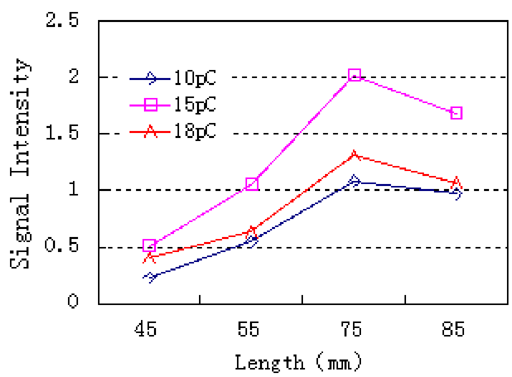

Figure 4: Signal intensity produced by the PD model for the different lengths of the long edge.

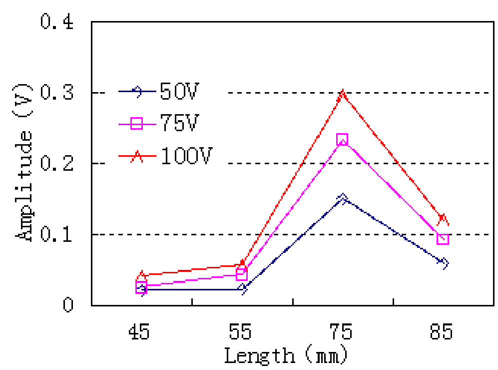

Figure 5: Signal intensity produced by the pulse injection for the different lengths of the long edge.

4.2. Experiment Results Based on Pulse Injection

In order to validate the accuracy of the experiment results, we conducted another set of experiments which used a pulse signal generator to provide excitation source for the transmitting antenna in GIS to simulate PD. As the pulse signals generated in this way is stable, we can minimize the accidental error and random interference to a great extent, which is more beneficial to study on the propagation characteristic of UHF electromagnetic waves passing through the resin sprue.

The rise time of the pulse was less than 0.3 ns and the output amplitude had three values which are 50 V, 75 V and 100 V. No. 1 built-in sensor was used as the transmitting antenna and two same external sensors — one was fixed on No. 1 basin-type insulator, the other on No. 2 basin-type insulator were used to collect UHF signals radiated from the resin sprues of different sizes. Under each output amplitude, each sensor collected at least 200 sets of data respectively. Then we averaged the data to reduce noises and the final results are shown in Fig. 5.

As is shown in Fig. 5, we can see that with the length of resin sprue's long edge increasing, the signal intensity enhances first and weakens later and reaches its maximum at 75 mm. The trend of the variation is independent of the output amplitude of the pulse and the distance between the excitation source and resin sprues.

The experiment results based on PD model and that based on pulse injection are consistent.

5. CONCLUSION

From this paper we could obtain a conclusion that with the length of the resin sprue's long edge increasing, the UHF signal intensity enhances first and weakens later and reaches its maximum at 75 mm.

For reason of the limited equipment condition, the resin sprues used in the experiment have only 4 sizes, thus leading to fewer points in the curves of the figure, which to some extent might affect the accuracy of the curves and the reliability of the results. This is what should be improved and overcame in the future work.

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