Research on the SF_6 decomposition components of the GIS bus spike PD and the insulator surface PD

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Abstract. According to the problem that the intelligence is not high of the recognition of GIS PD types by SF_6 decomposition components, using the real 110kV GIS platform, simulating two kinds of insulation defects PD of SF_6 gas, and making the research on the change of the four kinds of gases of CO_2，CF_4，SO_2F_2,and SOF_2,then making the research on the ratio of components of $c(SOF_2)/c(SO_2F_2)$, and $c(CF_4+CO_2)/c(SOF_2+SO_2F_2)$. The results show that the two types of ratio of components of the GIS bus spike PD and the insulator surface PD are significantly different. Therefore, the two types of ratio of components can as the features to identify the GIS bus spike PD and the insulator surface PD.

Introduction

SF_6 gas is widely used in gas insulated switchgear (GIS) as an excellent insulating medium. Under normal circumstances, the chemical property of SF_6 is very stable, and not easy to break down. But in the case of the GIS device has internal insulation defects and partial discharge, SF_6 gas will break down and produce a trace of the gas. [1].

High energy electron impact caused by high electric field in the partial discharge will cause SF_6 gas decomposition.

$$e + SF_6 \rightarrow SF_X + (6 - X)F, X = 1 \sim 5 \quad (1)$$

$$e + SF_X \rightarrow SF_{X-1} + F \quad (2)$$

Most primary decomposition products SF_X (X=1,2,... 5) will compound to SF6 molecules, but there is water, oxygen and other impurities in the electric chamber. The water, oxygen and other impurities will be associated with the SF_X (X=1,2,... 5) to generate CF_4, SO_2F_2, SOF_2, SO_2, SOF_4 and other products [2].

If the discharge area is surrounded by carbon material (such as stainless steel metal electrodes, solid insulating materials, etc.), the F and O atom in the gas chamber will react with C atom, producing CF_4 and CO_2 and other products. At high temperature, the C atom also reacts with CO_2 to generate CO [3].

In this paper, using the real 110kV GIS platform, two kinds of insulation defects GIS of bus spike PD and the insulator surface PD will be tested.

This paper will focus on four kinds of gases of CO_2，CF_4，SO_2F_2 and SOF_2,and the ratio of components of $c(SOF_2)/c(SO_2F_2)$ and $c(CF_4+CO_2)/c(SOF_2+SO_2F_2)$. Finally find out the methods to identify the GIS bus spike PD and the insulator surface PD.

Overview of experimental system

The whole experimental system is composed of the GIS experimental model, the pressure device, the SF_6 component analysis device and the PD monitoring device. The structure of the GIS experimental model is a three phase, and the insulation level is 110kV which is divided into 6 gas chambers. The gas chamber is separated by a basin insulator, and each gas chamber is provided with the air outlet and the barometer. The gas chamber which is horizontally placed is 1# and the gas chamber which is vertically placed is 2#. Gas chromatograph of Huaai GC9760B will be used to analysis SF_6 components.

Fig.1.GIS experimental model

Construction of insulation defect

In the 2# gas chamber, the electric wire is arranged on the edge of the surface of the insulator. Wire ground clearance is 60mm, and the surface distance is 63mm. The bus spike partial discharge model is set up in the 1# chamber. Spike length is 4.7cm, and the gap length is 2.4cm.

(a) 2# gas chamber (b) 1# gas chamber

Fig.2. The construction of insulation defect

Experimental data acquisition and data processing

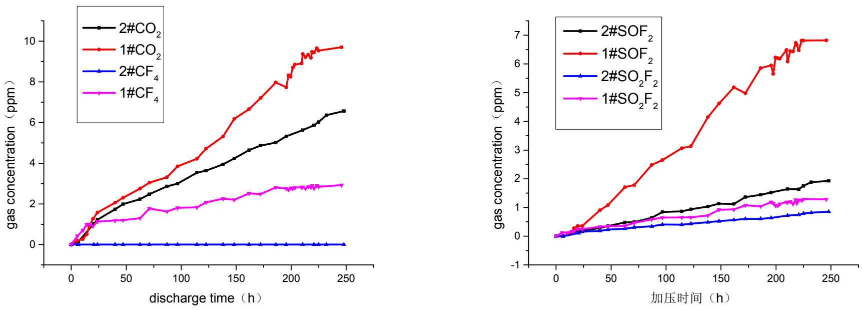
In this experiment, high purity SF_6 gas (99.999%) was used. In this paper, the SF_6 gas was measured after filling in the electric chamber. The results show that the content of CO_2 in 2# was 1.5895ppm, the content of CO_2 in 2# was 1.5771ppm, the content of CF_4 in 1# was 1.4895ppm, the content of CF_4 in 1# was 1.4762ppm.

In order to compare the trend of SF_6 decomposition components of two kinds of insulation defects, a constant volume of PD will be ensured as far as possible by adjusting the voltage.

The experiment used the mode of three phases of the common pressure, and the experimental voltage was maintained between 31kV~35kV, and the volume of PD of the gas chamber of 2# and 1# was1300pC to 800pC. The SF_6 gas pressure of two gas chambers was 3.5MPa. The experimental voltage was maintained to 240h continuously of insulation defects in 2# and 1# gas chambers, and gas chromatography was used to trace the SF_6 discharge (every 12h~24h), and the quantitative results were obtained.

(1) The comparison of the same decomposition components of the two gas chambers

After deducting the initial content of the same composition of the two gas chambers, the change rule is obtained by the curve fitting.



(a) Concentration of CO_2 and CF_4 (b) Concentration of SOF_2 and SO_2F_2

Fig.3. Comparison of the contents of the two gas chambers

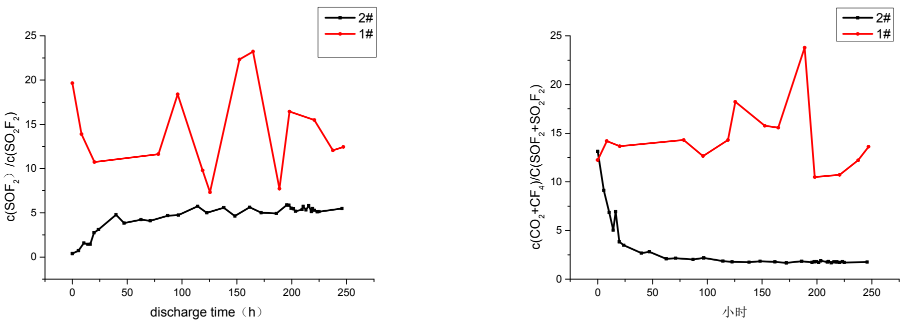
The contents of CO_2, SOF_2, CF_4 and SO_2F_2 in the two gas chambers increased with the discharge hours, and the saturation trend was presented. The formation and growth rate of each component of 1# gas chamber is greater than that of 2#.

In principle, the discharge process of 1# gas chamber involved epoxy resin solid insulating material, so CO_2 and CF_4 were produced in larger quantities. 1# gas chamber only produced a small amount of C atom in iron spikes, so less CO_2 was generated and CF_4 almost had no changed. While SO_2F_2 and SOF_2 were generated by SF_2 and SF_4 and O atoms, the discharge amount of 1# gas chamber is likely larger than that of 2# gas chamber.

(2) The relationship between the ratios of the two gas chambers

The value of c (SOF_2) /c (SO_2F_2) and c (CF_4+CO_2) /c (SOF_2+SO_2F_2) were used to identify the characteristics of two kinds of insulation defects, because these three components were significantly different in size, and these three components had clear physical meaning. The value of c (SOF_2) /c (SO_2F_2) can be used to characterize the size of PD energy. The value of c (CF_4+CO_2) /c (SOF_2+SO_2F_2) can be used to characterize the deterioration of insulating materials and metal materials.

The ratio of each component was calculated and put together, and then curve fitting was performed, and the change of the ratio of the two gas chambers was obtained.



(a) The value of c (SOF_2) /c (SO_2F_2) (b) The value of c (CF_4+CO_2) /c (SOF_2+SO_2F_2)

Fig.4. Comparison of the ratios of the two gas chambers

The value of c (SOF_2) /c (SO_2F_2) of two gas chambers were significantly different with the time of discharge. The content of c (SOF_2) /c (SO_2F_2) in 1# is larger than that of 2#.

SF_5 and SF_4 are low fluoride decomposition of SF_6. SF_5 is not stable, and it is easy to restore to SF_6 quickly. SF_4 has symmetrical structure, and it is stable, and the content of it is large so as the content of SOF_2. When the power consumption is low, the amount of SF_4 is higher than SF_2, so the content of SOF_2 in 1# is higher than that of SO_2F_2, and the value of c (SOF_2) /c (SO_2F_2) in 1# is large.

The value of c (CF_4+CO_2) /c (SOF_2+SO_2F_2) in the two gas chambers was significantly different with the discharge time. The value of c (CF_4+CO_2) /c (SOF_2+SO_2F_2) of 1# gas chamber was larger than that of 2# gas chamber.

Conclusion

The mechanism of the occurrence of SF_6 gas by PD was analyzed, and the decomposition of SF_6 gas in the typical insulation defects of the surface of insulator surface along the GIS basin was simulated. When the electrode material was iron and copper, the stable gas decomposition products are CO_2, CF_4, SO_2F_2, SOF_2, and these products increased with the discharge time.

When the kind of insulation defects was bus spike PD, the value of CO_2, CF_4, SO_2F_2, SOF_2 are larger than that of the insulator surface PD. Because the kind of insulation defects of bus spike PD can break out more carbon element, and the power of PD was also relatively large.

The ratio of components of c(SOF_2)/c(SO_2F_2), and c(CF_4+CO_2)/c(SOF_2+SO_2F_2) of two kinds of insulation defects PD had obvious difference. When the kind of insulation defects was bus spike PD, the value of c(SOF_2)/c(SO_2F_2) and c(CF_4+CO_2)/c(SOF_2+SO_2F_2) were much larger than that of the insulator surface PD.

Therefore, the ratios of components of c(SOF_2)/c(SO_2F_2) and c(CF_4+CO_2)/c(SOF_2+SO_2F_2) can be used to distinguish the different types of the two insulation defects.

References

[1] Lv Z, Tek A, Da Silva F, et al. Game on, science-how video game technology may help biologists tackle visualization challenges[J]. PloS one, 2013, 8(3): 57990.

[2] Su T, Wang W, Lv Z, et al. Rapid Delaunay triangulation for randomly distributed point cloud data using adaptive Hilbert curve[J]. Computers & Graphics, 2016, 54: 65-74.

[3] Lin Y, Yang J, Lv Z, et al. A Self-Assessment Stereo Capture Model Applicable to the Internet of Things[J]. Sensors, 2015, 15(8): 20925-20944.

[4] Yang J, Chen B, Zhou J, et al. A Low-Power and Portable Biomedical Device for Respiratory Monitoring with a Stable Power Source[J]. Sensors, 2015, 15(8): 19618-19632.

[5] Lv Z, Halawani A, Fen S, et al. Touch-less Interactive Augmented Reality Game on Vision Based Wearable Device[J]. Personal and Ubiquitous Computing, 2015, 19(3): 551-567

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