Experimental research on the decay charateristics of GIS busbar residual voltage/charge

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Experimental research on the decay charateristics of GIS busbar residual voltage/charge

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Abstract. GIS is the significant equipment in UHV network. However, after the UHV GIS busbar switch is opened, there will be a higher residual voltage on the GIS busbar, which causes the basin insulator flashover during the commissioning of the substation, which seriously affects the insulation and safety performance of the power system. It is very necessary to study the residual voltage on the GIS busbar. Therefore, we established a set of the GIS busbar residual voltage measurement system. Based on electric field measurement method, the GIS busbar residual voltage is measured in sulfur hexafluoride gas. The decay characteristics of the GIS busbar residual voltage under different polarity, different amplitude voltage and different temperature are studied. Research shows that the GIS busbar residual decays exponentially, and the decay of residual voltage is closely related to amplitude, temperature; at 26 °C and 0.4 MPa SF6 gas, the decay time of the GIS busbar residual voltage is as long as 22 hours after applying +450kV DC voltage, and the decay time constant is about 10^4 s order of magnitude.

1. Introduction

Gas insulated switchgear has significant advantages such as small footprint, low environmental impact, low maintenance workload, high operational reliability, and low operating cost, and has been widely used in UHV network[1-3]. When the substation cuts the GIS empty busbar, residual voltage will be generated on the GIS busbar. The DC property of residual voltage makes the influence of particle motion and electric field distribution different from AC. For example, in UHV AC substations, there was a flashover of basin insulators caused by switching GIS empty busbars during the start-up and commissioning process. It is considered that the reason may be due to the accumulation of surface charge on the clean basin insulator under the action of busbar residual voltage or when metal particles are attached, which leads to the decrease of busbar insulation level and the switching over-voltage during superposition closing. The characteristics of the GIS busbar residual voltage level and decay time have an impact on GIS busbar insulation. GIS busbar insulation level is very important for the safe operation of UHV network. Especially with the increasing length of GIS busbar in UHV substation, it is necessary to study the residual voltage decay characteristics of GIS busbar.

Reference [4] measured the residual voltage between the 1000kV GIS circuit breaker and the disconnector, and obtained the decay characteristics of the residual voltage at different temperatures. The residual voltage decay characteristics of different polarity and amplitude voltage are not studied. In reference [5], the surface charge dissipation of GIS basin insulator is simulated. Reference [6-7] used electrometer to measure the surface charge dissipation of GIS basin insulators. Reference [8] studied the influence factors of the insulation characteristics of insulators under DC voltage. Reference [9] adopt three electrodes to measure the surface resistance of irregularly shaped insulators. The above is the research on the accumulation and dissipation of surface charge and insulation of GIS basin insulators at home and abroad, the GIS busbar residual voltage decay characteristics are not studied. Therefore, there are few studies on the decay characteristics of the GIS busbar residual voltage, especially the actual measurement and calculation of decay characteristics are the basic work to improve the insulation level of GIS busbars, which needs further study.

This paper builds a 1000kV GIS busbar residual voltage test platform, establishes a set of busbar residual voltage measurement method based on electric field measurement, and measures the GIS busbar residual voltage decay characteristics. Combined with the measurement results, the main determinants of the GIS busbar residual voltage decay are analyzed.

1.1. GIS busbar residual voltage test platform construction
In order to achieve the measurement of the GIS busbar residual voltage, a GIS busbar residual voltage measurement test platform was built. Figure 1 is a schematic diagram of the test platform.

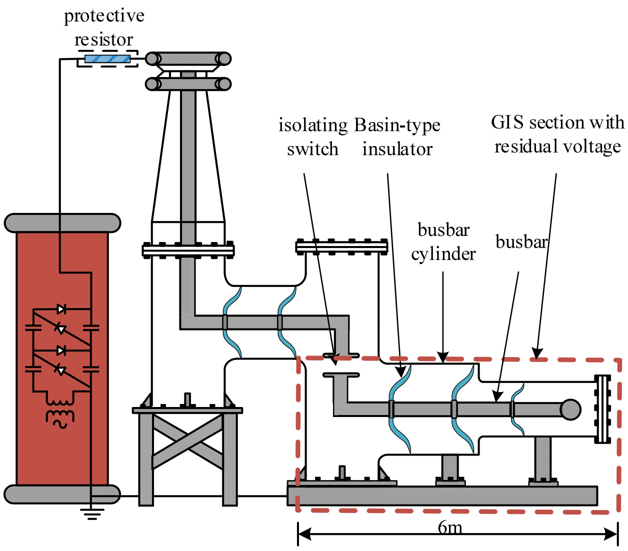

Fig. 1 Schematic diagram of the experiment platform

The left side of Figure 1 shows a ±1200kV/20mA DC voltage generator, which applies DC voltage to the GIS busbar through a protective resistor. On the right is a 1000kV GIS platform with a disconnector inside. After the disconnector break the DC voltage, residual voltage is generated on the GIS busbar on the right. The length of the busbar is about 6m, its radius is 0.1m, and 3 basin insulator, including 2 1000kV basin insulators and 1500kV basin insulator. The length of busbar cylinder with radius of 0.5m and 0.3m is 3.3m and 1.7m respectively, and the material is aluminum.

1.2. Residual voltage measurement method
The GIS busbar residual voltage is measured by field mill instrument. Fig. 2 shows the measurement system of the GIS busbar residual voltage. There is a circular measurement window on the side of GIS busbar cylinder. The field mill instrument can measure the GIS busbar residual voltage value through the measurement window. Its principle is that the GIS busbar residual voltage forms an external electric field. The field mill instrument uses the conductor to generate induced charge in the external electric field to measure the electric field, and then calculates the corresponding potential through the relationship between electric field and potential[10-11].

The GIS busbar residual voltage measurement system can obtain the GIS busbar residual voltage value by measuring the electric field strength. The voltage of 0 ~ 300kV with 25kV interval is applied to the GIS busbar to calibrate the GIS busbar voltage and the electric field strength of the field mll instrument, and the corresponding relationship between the voltage and the electric field strength is obtained, as shown in Fig. 3.

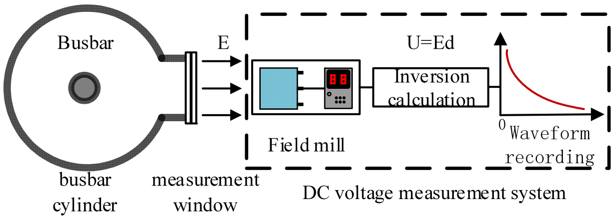

Fig. 2 GIS busbar residual voltage measurement system

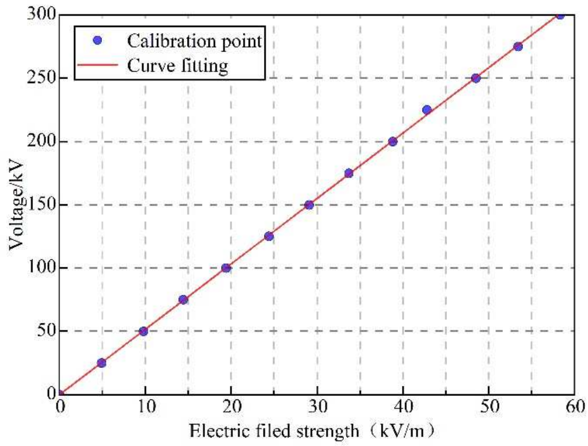

Fig. 3 Correspondence between the electric field intensity of the rotating electric field instrument and the GIS busbar voltage

Figure 3 shows that the corresponding relationship between GIS busbar voltage and electric field strength of field mill meter is 5.17kV, corresponding to 1kV / m. The ratio is used to calculate the GIS busbar residual voltage value in the following experiments.

Before the experiment, check the grounding of the GIS busbar cylinder to ensure the safety of the experiment. Under the conditions of environmental temperature and 0.4MPa sulfur hexafluoride gas, the DC voltage generator applied ±450kV, +300kV and +150kV voltage on GIS busbar respectively, and conducted the GIS residual voltage decay characteristic test under different amplitude and polarity. The duration of voltage application in each experiment is 10 minutes. After 10 minutes, the disconnector breaks the DC voltage, and the DC voltage generator is grounded after the voltage drops to zero. Then, the GIS busbar residual voltage is measured and recorded by using voltage measuring device every 1 hour.

2. GIS busbar residual voltage decay experiment

Fig. 4-6 shows the decay curves of the GIS busbar residual voltage with different polarity, amplitude and temperature. For the convenience of observation, the decay of the GIS busbar residual voltage with different polarities is compared with the absolute value.

Fig. 4 shows the comparison of GIS busbar residual voltage decay curves with different polarity. It can be concluded that the decay of GIS busbar residual voltage is exponentialan. The decay of negative residual voltage is faster than that of positive polarity when the ambient temperature is 26 ℃ and 0.4MPa sulfur hexafluoride gas, busbar length of 5m and 3 basin insulators. The decay of ±450kV GIS busbar residual voltage is 1.6 h and 3 h respectively, and the decay to zero is 22 h and 28 h.

Fig. 5 shows the comparison of residual voltage decay curves of GIS bus with different amplitudes. It can be concluded that the decay time of the GIS busbar residual voltage of +450kV, +300kV and +150kV is 22h, 21h and 19h respectively when the ambient temperature is 26 ℃ and 0.4MPa sulfur hexafluoride gas, busbar length of 5m and 3 basin insulators. The larger the GIS busbar residual voltage, the longer the decay time to zero. However, due to the exponential decline of GIS busbar residual voltage, the decay time of residual voltage of the same order of magnitude is close to zero.

Fig. 6 shows the comparison of residual voltage decay curves of GIS bus with different temperatures. It can be seen that under the condition of 0.4 MPa SF6 gas, 5 m busbar length and 3 basin insulators, the decay time of + 300 kV GIS busbar residual voltage at 2 ℃ and 26 ℃ is 21 h and 75 h respectively, and the difference between them is nearly 3 times. The influence of temperature on the GIS busbar residual voltage is more serious, and the higher the temperature, the faster the attenuation rate of the GIS busbar residual voltage. The analysis shows that the residual charge on the GIS busbar is mainly dissipated by basin insulators. When the temperature rises, the thermal movement of the insulating material molecules increases, so that the volume resistivity and surface resistivity of the insulating material decrease. The dissipation rate of residual charge increases, so the decay rate of the GIS busbar residual voltage increases.

Therefore, combined with Fig.4-6, the temperature has the most serious influence on the decay speed, and the polarity and amplitude have a certain influence, but the influence is small.

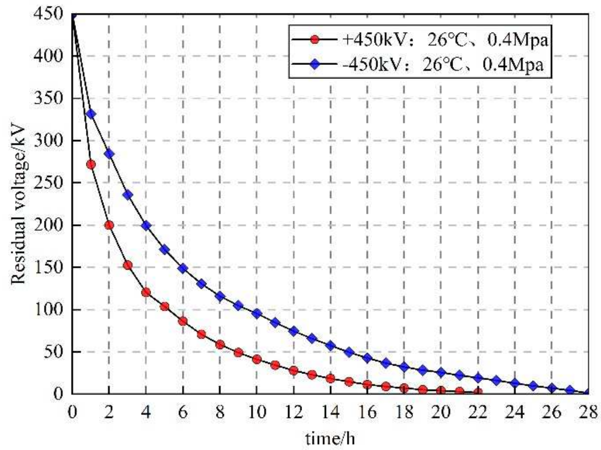

Fig. 4 Different voltage the GIS busbar residual voltage attenuation curve

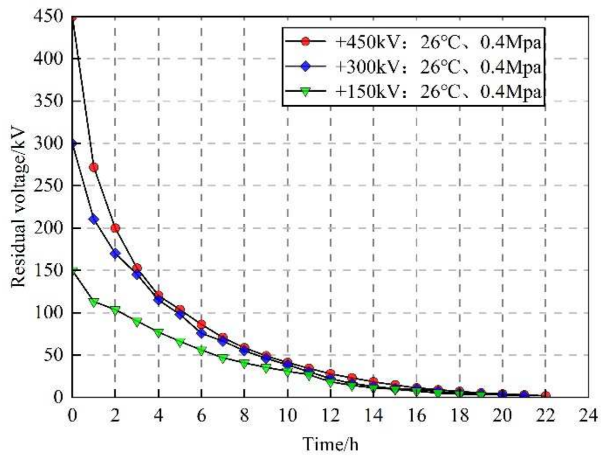

Fig. 5 Different amplitude the GIS busbar residual voltage attenuation curve

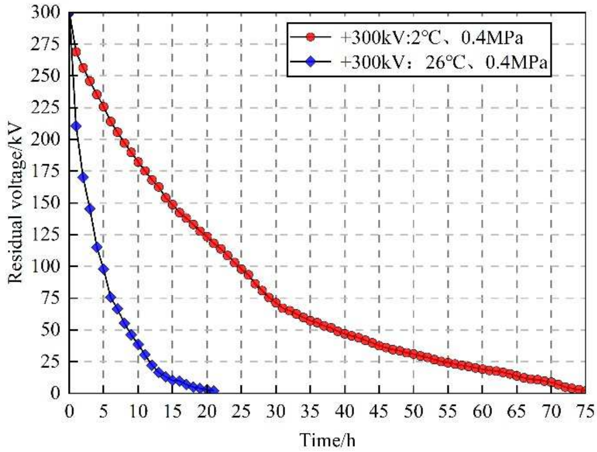

Fig6 the GIS busbar residual voltage attenuation curve at different temperatures

3. Conclusion

Based on the results and discussions presented above, the conclusions are obtained as below:

(1) Using the indirect measurement method of the GIS busbar residual voltage in electric field, the decay of ± 450kV, + 300kV, + 150kV GIS busbar residual voltage is measured under the temperature of 2℃ and 26℃, and the decay approximately presents exponential decay.

(2) The test of the GIS busbar residual voltage with different polarity, amplitude and temperature shows that the decay of the negative GIS busbar residual voltage is faster than the positive residual voltage. The larger the GIS busbar residual voltage amplitude, the longer the decay time. However, the same order of magnitude of the GIS busbar residual voltage decay time is close; Temperature has the most serious effect on the attenuation of the GIS busbar residual voltage. The decay time of 300 kV GIS busbar residual voltage at 2 ℃ is nearly three times that of 26 ℃.

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