Discharge Analysis of 1100kV GIS Equipment in Lightning Impulse and Power Frequency Withstand Voltage

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Abstract. The fully enclosed combined electrical appliance gas insulated substation (GIS) is an important large-scale substation equipment, which has been widely used in power systems. In order to ensure the safe and reliable operation of this equipment, UHV GIS will conduct the text of lightning impulse and power frequency withstand before delivery of this equipment. In this paper, the method of vibration was used to analyze the lightning phenomenon caused by lightning impulse and partial discharge of 1100kV GIS equipment. Put forward the problems that should be paid attention to when installing GIS equipment, in order to provide reference for troubleshooting GIS equipment in the future.

1. Introduction

Gas Insulated Substation (GIS) is an important large-scale substation equipment. It has the advantages of compact structure, safety and reliability, and simple maintenance, which has been widely used in power systems [1]. However, in the manufacture and operation of GIS, internal insulation surface may dirty, spikes, free particles and solid insulation internal defects, which causing it internal electric field distortion under high voltage, and the distortion electric field develops to a certain extent to form partial discharge [2].

In order to maximize the insulation performance of the equipment at the factory, UHV GIS will conduct the text of lightning impulse and power frequency withstand voltage according to 100% rated insulation level and carry out partial discharge measurement of power frequency withstand voltage [3]. However, during equipment transportation and on-site installation, foreign matter remaining inside the equipment may be transferred from the low field strength area to the high field strength area, and new foreign objects may be generated or brought in during installation and equipment operation [4]. Because the lightning impulse voltage is sensitive to the electric field distortion caused by foreign matter. It can eliminate the internal defects and hidden dangers such as component damage and foreign matter during transportation, storage and installation. Complement with the field AC withstand voltage test, verifying that the insulation performance is good, and ensuring its safe and reliable operation.

Since the GIS includes multiple components, multiple intervals and completely enclosed. When the withstand voltage test breaks down, it is very difficult to find the point of failure. At present, the fault location technology mainly includes the tester's listening sound, ultrasonic, vibration and grounding current [5].

In this paper, the vibration method is used to analyze the discharge of 1100kV GIS equipment during lightning impulse and power frequency withstand voltage and clarify the reason, in order to provide reference for troubleshooting GIS equipment in the future.

2. Equipment situation

The overall structure of the equipment is that the aluminum alloy casing contains all the charged parts, and the outer casing is filled with SF_6 gas as the insulation and arc extinguishing medium. A high quality basin insulator supports the live part of the enclosure. The conductors in the separate chamber are connected by silver-plated plug contacts, and the switchgear is mounted on a hot-dip galvanized steel base. The parameters and performance requirements of the specific equipment are shown in **Table.1.**

Table1. GIS sharing parameters and performance requirements

Name	Unit	Supplier Warranty
Rated voltage	kV	1100
Rated current (in and out line/main bus)	A	6300/9000
Rated power frequency 1min withstand voltage	kV	1100
Rated lightning impulse withstand voltage peak (1.2/50μs) (relatively low)	kV	2400
Partial discharge measurement voltage	kV	1.2×1100/√3
Partial discharge capacity (per air compartment/ single insulation)	pC	≤5/≤3
Rated short-circuit breaking current	kA	63
Rated short circuit closing current	kA	170
Auxiliary and control loop short-duration power frequency withstand voltage	kV	2
SF_6 gas pressure (20℃ gauge)	Circuit breaker room	0.58
	Isolation switch room	0.58
	Casing chamber	0.48
	Other air compartment	0.36
SF_6 gas leakage rate per compartment	%/year	≤0.5
SF_6 gas moisture content	Arc decomposition gas chamber	≤150
	Arc-free decomposition gas chamber	≤250

The equipment used in the test is as follows:

Figure1. Equipment used in the test

3. Discharge situation

3.1. Basin insulator discharge

When the power frequency voltage rose to 1066 kV, a discharge phenomenon of basin insulator was occurred. After disintegration on site, it was found that one of the insulating basins had discharge marks and burrs on the surface (**Figure.2)**. According to the disintegration inspection, the reason for this discharge is that the burr is not cleaned after the bump at the R angle of the tooling cylinder during the assembly of the test piece, which causes the electric field distortion result in the surface of the basin to climb.

Figure 2. Basin insulator discharge trace

3.2. Page Numbers

When the isolation switch form and the circuit breaker shape are subjected to the lightning impulse test in the closed state, the first negative polarity is cut at 2435 kV. The discharge indicator of the circuit breaker form interface is fully illuminated, and the indicator switch interface indicator of the test is not illuminated (**Figure.3**). Then disassemble the device to find the reason. First, the circuit breaker is detached from the fixture and check the interface. No discharge point is found. The inside of the circuit breaker was then inspected and no discharge point was found. Finally, the discharge trace was found in the ES moving contact and the static side shield inside the tool housing (**Figure.4**). Through inspection and analysis, it is concluded that the discharge position is located in the disassemble fixture, and the air chamber is mainly composed of a three-way spherical shell and a grounding switch. After analyzing the discharge position and the appearance of the discharge trace, it is judged that the discharge is caused by foreign matter. Because of the tooling chamber is used for a long time, the pressure reduction and inflation operations are required for each use, and the effective maintenance is not performed during use. In the charge and discharge operation, foreign matter may be blown onto the ES static side shield, resulting in a lightning impulse test cutoff.

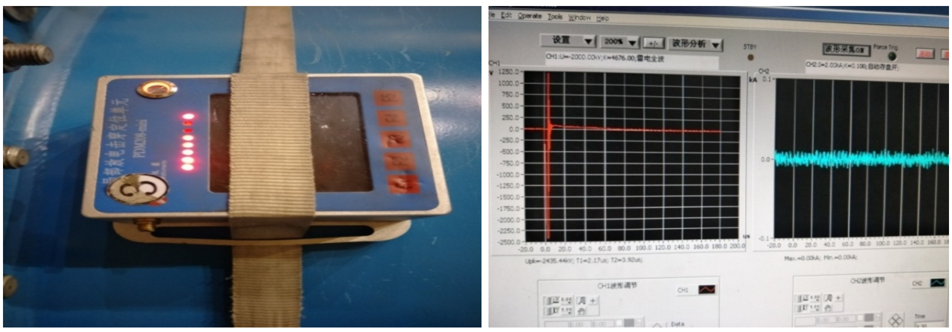

Fig.3 Discharge indicator and cutoff diagram

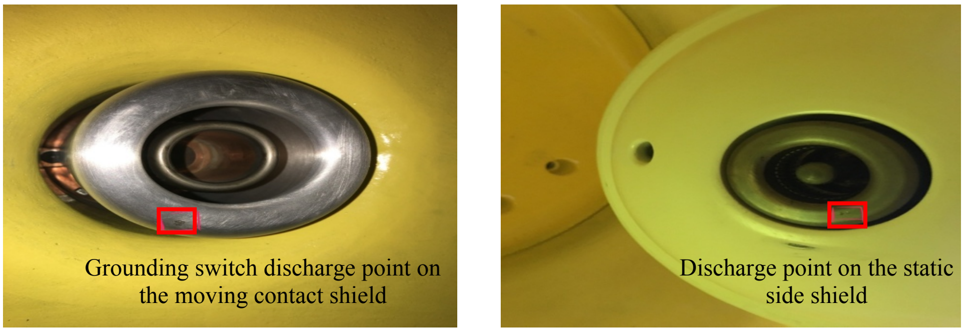

Fig.4 ES moving contacts inside the tool housing and static side shields found discharge marks

3.3. Tooling disconnector discharge

The lightning impulse withstand voltage test was performed on the composite bushing and the discharge was occurred at the first negative polarity pressurization test (the peak value of the cutoff was 2425 kV), and the discharge indicator light was all bright. After disintegration, it was found that there was obvious discharge trace on the shield inside the casing interface tooling isolating switch (**Figure.5**). Through inspection, a trace of discharge was found in the tooling disconnector. After inspection and analysis, it is judged that the lightning impulse cut-off is caused by the foreign object at the moving side shield and the support connection of the isolating switch.

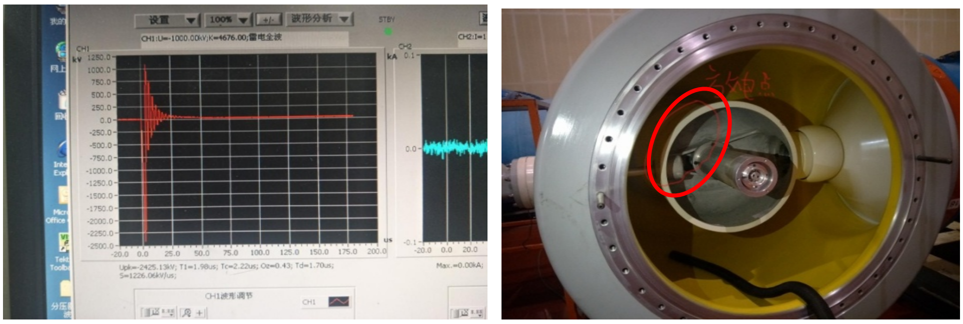

Fig.5 Lightning shock chopping pattern and equipment discharge point

3.4. Casing body discharge

The lightning impulse withstand voltage test was performed on the bushing and the discharge occurred again at the first negative polarity pressurization test (the peak value of the cutoff was 2,504 kV). After disintegration, it was found that there was a significant discharge trace on the inner shield surface of the sleeve center conductor (**Figure.6**).

Fig.6 Shielding center conductor inner shield discharge photo

3.5. Tooling discharge in circuit breaker test
In the closing state of the lightning impulse test on the circuit breaker, the discharge occurs at the first test of the negative polarity (the peak value of the cutoff is -2435 kV), and the discharge positioning indicator placed at the interface of the circuit breaker is fully illuminated. After disintegration, it was found that the grounding switch moving contact shield at the end of the circuit breaker discharges the conductor shield, and the conclusion is that the tool discharges.

Fig.7 Grounding switch moving contact shield discharges the conductor shield

4. Conclusion
This paper mainly analyzes some common discharge cases that occur during the 1100kV GIS factory test in actual work, including some equipment such as casing, basin and isolation switch in GIS. The discharge traces formed after a typical discharge are given, and the type and cause of the discharge are judged based on the traces. The case is mainly tooling discharge, but in the field test, the tooling and equipment have the same function, the discharge type is similar, and all have reference value. The results of this paper can provide some reference materials for the future analysis of GIS field discharge.

Acknowledgments
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References
[1] Dong Feifei, Research on situation and developmenttrend of UHV power transmission and transformationtechnology, J. Shaanxi Electric Power. 44 (2016) 1-3, 8.
[2] Standard for acceptance fest of electric equipment of 1000 kV system electric equipment installation engineering: GB/T 50832-2013, S. Beijing: China Planning Press, 2013.
[3] Lu Peng, Han Shumo, Zhao Wenqiang, et al, Study on key technology of 1100 kV GIS, J. High Voltage Apparatus. 46 (2010) 1-5.
[4] Liu Junhua, Yao Ming, Huang Chengjun,et al, Experimental research on partial discharge localization in GIS using ultrasonic associated with electromagnetic wave method, J. High Voltage Engineering. 35 (2009) 2458-2463.
[5] Xupeng, Su Yongling, He Lin, Ni Hao, Zhai Tinghua, Tian Haoyang, Vibration Test System Using in Breakdown Location of GIS withstand Voltage Test, J. East China Electric Power. 42 (2014) 23-26.