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Experimental Research of Electromagnetic Interference Caused by Disconnecter Operation in Gas Insulated Switchgear

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Abstract. In order to intensively study the exterior transient electromagnetic interference characteristics caused by disconnecter operation in Gas Insulated Switchgear, experimental research of exterior transient electromagnetic interference under switching conditions is performed in this paper. Based on 330kV GIS test platform, with the method of resistive impedance divider, TEV is measured with Pintech P6039A high-voltage probe and Yokogawa DLM2054 oscilloscope by using resistor voltage divider GIS exterior radiation electromagnetic circuit is also established using antenna theories, biconical antenna and spectrum analyzer etc. The exterior transient electromagnetic interference waveform and characteristics are precisely measured. By the contrast analysis of TEV and radiation electromagnetic waveforms, results can be summarized as followed: ① The TEV waveform caused by opening and closing of disconnecting switch is front sparse and rear dense, and its amplitude is low at the fore and high over the back; The electric field strength is weaker compared to the electromagnetic compatibility of normal substation.

1. Introduction

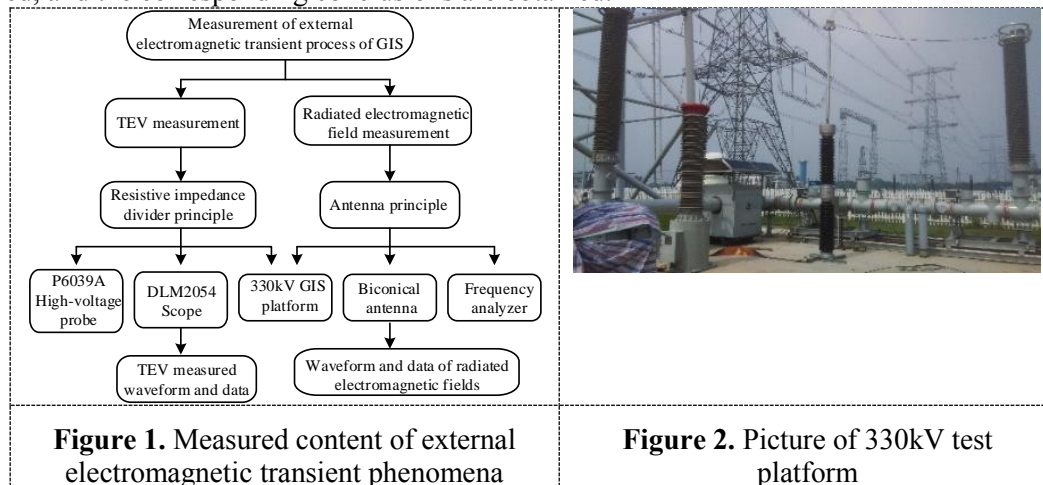
Because of its less land occupation, reliable operation, long maintenance cycle and low maintenance cost, GIS has been widely used in the power grid of our country and has been successfully applied to the UHV project. At the same time, more and more intelligent secondary equipment with control, communication and protection function are placed in the switch field and installed next to the primary equipment. Once they suffer from electromagnetic interference, they will affect the normal operation of intelligent components, and threaten the safe and reliable operation of substations. The research shows that the electronic equipment failure caused by electromagnetic interference has become the weak point of the reliability of Intelligent Substation[1-3].

Switching operation is the most typical and important electromagnetic interference source in substation, which causes transient potential rise of the GIS enclosure and radiation electromagnetic field around GIS shell[4]. On the one hand, the transient potentials generated by shell will affect the insulation performance of power system stability and GIS shell equipment; on the other hand, the radiated electromagnetic field of shell will also affect the secondary equipment; therefore, it is of great significance to study the electromagnetic transient process and its influence on the mechanism of related equipment of the GIS shell[5-6].



At present, the research of TEV and radiation electromagnetic field is mostly based on theoretical calculation. The theoretical analysis of these two transient phenomena is mainly carried out from the point of view of mathematical modeling. Compared with the actual measurement, it is still lack of convincing[7-8].

Therefore, based on the above problems, the synthetic measurement of TEV and radiation electromagnetic field is carried out on the 330kV GIS test platform, as shown in figure 1. Based on the measurement of two kinds of electromagnetic transient characteristics, the transient characteristics and the correlation between these two electromagnetic transient phenomena on the same platform is analyzed, and the corresponding conclusions are obtained.



2. Radiation electromagnetic field test platform

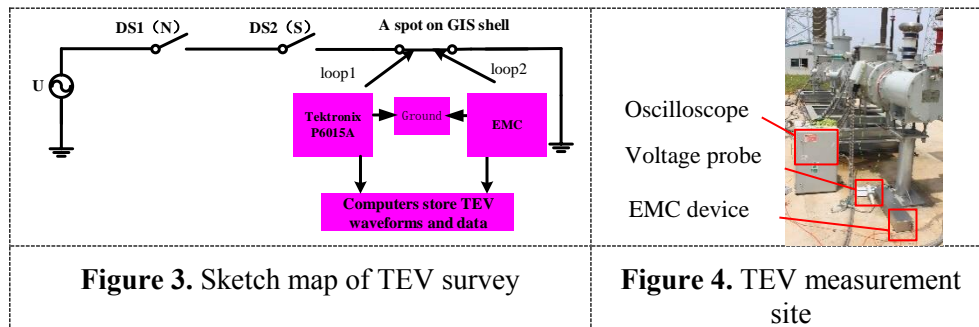
Based on the 330kV GIS test platform of China UHV Power Research Institute as the research object, the characteristic of external electromagnetic transient phenomena in GIS caused by the disconnecting switch operation is analyzed, on this basis, a comprehensive survey is carried out of TEV and GIS shell radial electromagnetic field in external electromagnetic transient phenomena. The object of the 330kV GIS test platform is shown in figure 2.

The test platform consists of two bushings, 2 isolation switches, a section of GIS busbar, transformer, and connecting rod. A set of current transformers and current transformer configuration standards are installed on one side of the bus; the other side bus installed a variety of tank type electronic current transformer; A tank type of SF₆ test transformer is installed by the outlet bushing; the center distance of two bushings is 10 meters apart, connected by a guide rod, which is supported by a capacitor placed in the middle of the rod, The installation position of electronic transformer is near the isolation switch. The radiated electromagnetic fields are measured for the operation of one of the isolation switches, and another disconnecting switch is in a closed state. The voltage of test platform, taking into account the high voltage capacity of transformers and other related equipment, is 200kV.

3. Electromagnetic field measurement

3.1. TEV measurement process

During the TEV measurement process in this paper, the measurement device mainly comprises shielding layer with a wire resistive impedance, voltage divider, data processing and control system, UPS, shielding box, synchronous trigger system, remote control system of optical fiber communication and online display and control system, the resistive impedance voltage divider using Pintech P6039A commercial pressure probe. Data processing control system using Yokogawa DLM2054 digital storage oscilloscope, the measurement schematic is shown in figure 3.

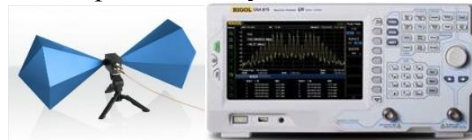


According to the measurement principle above, based on the 330kV GIS test platform, the isolated switches DS1 and DS2 are operated in this process by continuously raising the voltage until it reaches 190kV. The measuring circuit consisting of voltage probes P6015A, Tektronix, oscilloscope and platform, the complete TEV measurement field is shown in figure 4.

3.2. Radiation electromagnetic measurement process

According to the analysis of electromagnetic interference characteristics during the operation of disconnecting switch, the electromagnetic frequency and type are produced. The biconical antenna is used to measure the radiation electromagnetic field, and the main equipment is shown in figure 5.

In the charged GIS test platform, there is a certain amount of electromagnetic radiation near the platform. The electromagnetic radiation is especially serious during switch operation. The measurement focuses on the electromagnetic field size of the 330kV GIS test platform during the operating process of insulating switches. The principle of electromagnetic radiation test for disconnecting switches is shown in figure 6. The test circuit is mainly composed of three parts, GIS test platform, biconical antenna and spectrum analyzer.



(a) biconical antenna (b) spectrum analyzer

Figure 5. Major equipment for radiation measurement

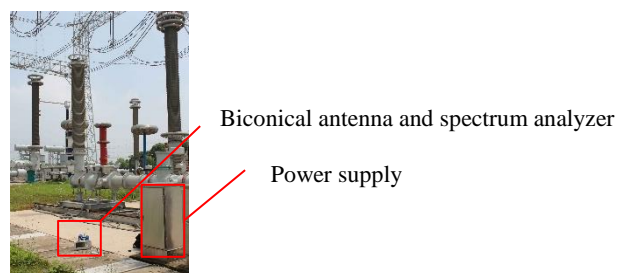


Figure 6. Picture of electromagnetic radiation test for disconnecting switch

4. Analysis of electromagnetic interference test results

4.1. TEV measurement result

Based on the 330kV GIS test platform, the TEV generated by DS operation is measured and the result is shown in figure 7. In the Yokogawa DLM2054 digital storage oscilloscope, the stored TEV data is imported into the MATLAB, and then the single amplification waveform in the full wave of TEV is shown in figure 8.

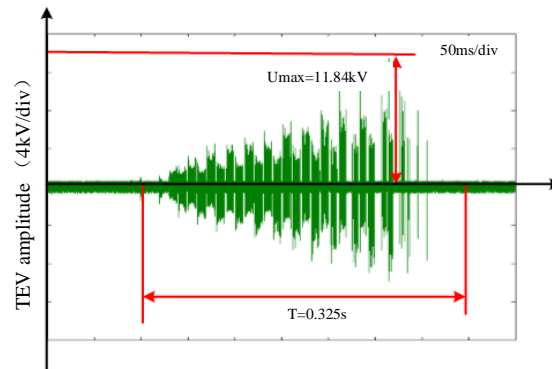


Figure 7. TEV measured waveform generated by DS operation in GIS

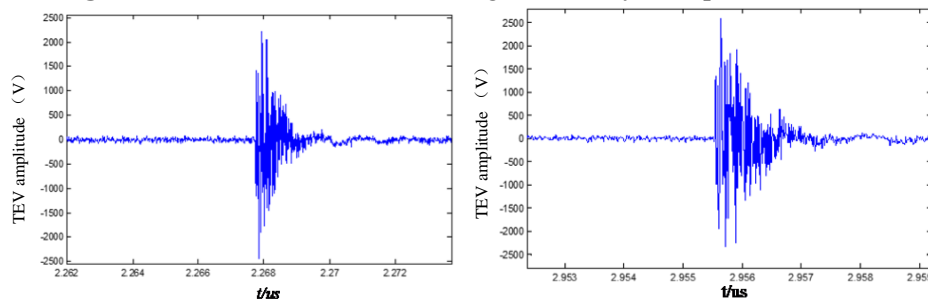


Figure 8. TEV measured single waveform generated by DS operation in GIS

4.2. Analysis of TEV measurement results

An analysis of the above TEV measurements is available.

In contrast to the operation of disconnecting switch, the TEV waveform generated by on-off operation is known:

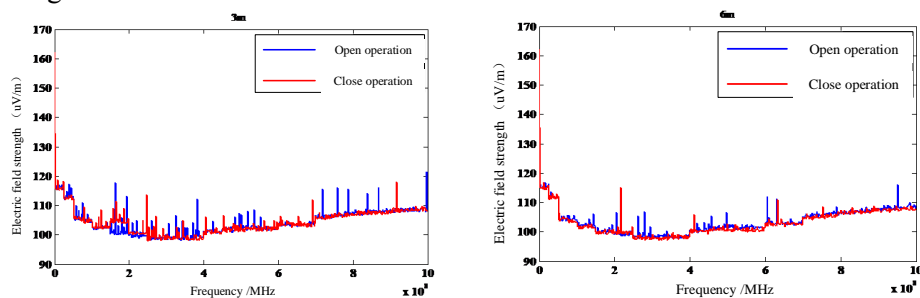
(1) During opening process, the TEV waveform shows front sparse and rear dense. The main reason is that in the process of disconnecting, the distance of switch contact is from small to large; the breakdown voltage of disconnecting switch is becoming larger and larger, and the gap breakdown time becomes longer.

(2) The TEV waveform generated by switching operation during opening process is characterized by clusters, the single cluster represents single breakdown process of disconnecting switch, clusters indicate the breakdown process repeat many times during closing process.

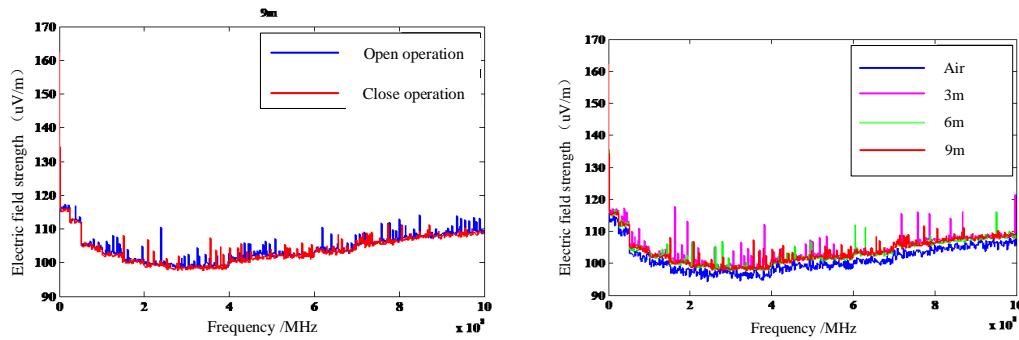
(3) When the TEV full waveform in single cluster is magnified, as shown in figure 7; TEV single waveform basically shows the same declining trend, and finally the amplitude decay to zero.

4.3. Radiation electromagnetic measurement results

Through the above measurements, we can get the electromagnetic field distribution of GIS disconnecting switch at different distances and different switching modes. The measurement results are shown in figure 9 and table 1.



(a)Electrical radiation waveform at 3m (b)radiation waveform at 3m



(c) radiation waveform at 6m (d) radiation waveform at 9m

Figure 9. Electromagnetic field distribution at different distances**Table 1** Main frequency and amplitude distribution of electromagnetic radiation

3m	Open	frequency	163.3	193.3	383.3	718.3	996.7
		Electric field amplitude	117.7	113	112.1	115.5	121.3
	Close	frequency	165	224.7	246.7	697.3	916.7
		Electric field amplitude	111.6	113.7	110.8	112	118.1
6m	Open	frequency	195	311.7	618.3	935	951.7
		Electric field amplitude	111.1	107.1	114	114.4	115.9
	Close	frequency	188.3	216.7	411.7	633.3	708.3
		Electric field amplitude	108.1	115.1	105.9	111.1	109
9m	Open	frequency	150	405	485	861.7	991.7
		Electric field amplitude	112.7	109.7	114.1	119.3	119.2
	Close	frequency	128.3	270	631.7	840	951.7
		Electric field amplitude	114.8	110.6	115	118.2	118.1

Formula (1) is used for unit conversion of measured and simulated data.

$$dBuV / m = 20 \log(V / m) + 120 \quad (1)$$

Conversion from the above formula can be obtained:

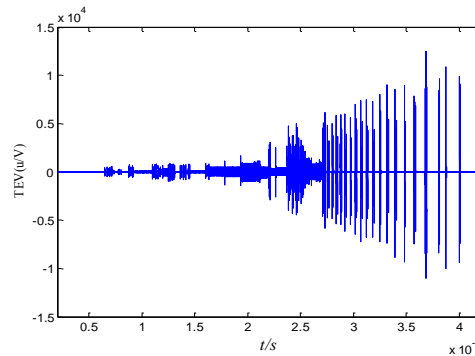
$$V / m = 10^{\frac{dBuV / m - 120}{20}} \quad (2)$$

According to table data, the maximum value of electric field measurement is mostly concentrated in 110-122dBuV/m. After the unit conversion, the measured electric field intensity is mainly between 0-1.259V/m.

4.4. Analysis of radiation electromagnetic source

Since the GIS is sealed, the VFTO and VFTC generate smaller radiation electromagnetic fields that are coupled to the GIS shell. Therefore, the intensity of the radiated electromagnetic field generated by the transient circulation of the shell is analyzed emphatically.

The transient characteristics of TEV have been calculated by paper [9]. On this basis, in view of the calculation of the voltage difference at the ends of the GIS line bushing, as shown in figure 10.

**Figure 10.** TEV difference at line bushing**Table 2** The peak value of electromagnetic field at different distances of GIS shell

	3m	6m	9m
Electric field(V/m)	69.8	33.2	23.3
magnetic field (A/m)	0.019	0.0092	0.0063

Through the table 2, it is found that the measured data is obviously biased by comparing the calculated results with the measured ones. The existing VFTO pulsed electric field measurement data shows that the radiation pulse electric field amplitude can reach 7kV/m when the circuit breaker is closing with no-load, far greater than measured and simulated values in this paper, which shows that the radiated electric field in this paper is likely to come from the radiation electromagnetic field generated by the transient circulation of the shell, but not the VFTO radiation field inside the GIS.

5. Conclusions

In this paper, through the field measurement of GIS transient electromagnetic, that is, the measured TEV and the electromagnetic radiation field measurement, compared with the corresponding calculation results above, the following conclusions are obtained:

- (1) The TEV waveform produced in the opening process is front sparse and rear dense. These features are caused by the increasing distance and the increasing breakdown time between contactors of the disconnecting switch.
- (2) The GIS shell radiation field data shows that when the disconnecting switch operations in GIS, the radiation electromagnetic field around the GIS shell is large, proving that on the one hand, we should take measures to reduce the radiation electromagnetic field caused by disconnector switching operation; on the other hand, we should be enhancing shielding of peripheral smart components.
- (3) The radiation measurement of the GIS shell mainly comes from the radiated electromagnetic field caused by the transient circulation of the shell on the GIS shell. It is unlikely that the radiation electromagnetic field produced by VFTO or VFCTC from GIS.

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