Experimental research on the optimization scheme of protective device

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Abstract. Many factors, such as over-voltage and switch on or off, could produce FREMP which will affect the normal work of electrical equipment. High voltage disturbance signal may lead to the function degrade of equipment and the equipment will be damaged when the disturbance signal voltage exceeds a certain threshold. In order to work better, some devices should be used to protect equipment. Even after protected by TVS or GDT, the equipment may still be influenced by residual voltage disturbance or overshoot voltage, which will make equipment degrade. In this paper, the protective performance is obtained under different connection schemes via a large number of experiments. It can be concluded that the lowest response peak voltage and limiting voltage can be acquired when TVS and GDT are connected in parallel. Thus the parallel scheme is recommended in engineering applications.

1. Introduction

Sensitive electronic equipment is easy to be disturbed by outside electromagnetic pulse (EMP) signal, which can cause varying degrees of equipment malfunction. Lightning is a high voltage discharge process and can produce strong EMP signal, which will influence the normal work of surrounding electrical and electronic equipment and may even damage them [1]. In order to make the equipment work normally, it is necessary to add electromagnetic pulse protective device in the working circuit. Therefore, it makes sense for us to study the performance of the protective device [1]. In this paper, a test on the protective device is designed in order to obtain its protective performance. Among various protective devices, the application of TVS diode is very extensive. However, its protection also has certain insufficiency. When pulse voltage through the circuit protected by TVS, there will be residual voltage. At the same time, if the circuit is protected by GDT, the high overshoot voltage may damage the equipment. The two protections could do well in most occasions, but for sensitive electrical equipment, the residual voltage or the overshoot voltage may still affect their normal work. In this paper, the protective performance is obtained under different connection schemes via a large number of experiments. It can be concluded that the lowest response peak voltage and limiting voltage can be acquired when TVS and GDT are connected in parallel.

2. Protective Performance Test

In order to measure the response parameters of the protective device, we designed a test circuit, its principle is shown in Fig.1 below.

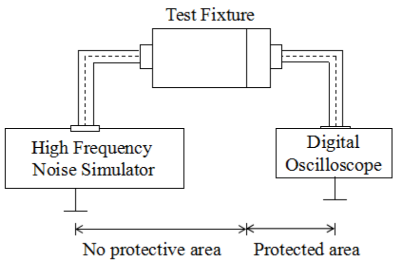

Fig. 1 Protective device performance test principle

In this experiment, high frequency noise simulator is used to produce high voltage pulse signal. A test fixture is employed to effectively inject the pulse voltage into the device under test. And digital oscilloscope is used to record signals.

3. Protective Performance Research

3.1 TVS Protection Performance Research

The silicon PN junction is the core part of TVS diode. Both the cross-sectional area of the PN junction and the cooling layer are bigger than normal diode, so its ability to discharge pulse is strong. Some of the advantages of TVS are fast response speed, large transient power, low leakage current, low breakdown voltage deviation, simple clamping voltage control, and small volume [2]-[3]. Therefore, it is widely applied in protective areas.

Its working principle can be summarized as: TVS is connected in parallel with the protected circuit. When instantaneous high voltage pulse causes a threatening signal, TVS will change the high impedance to a low impedance at the rate of 10-12 seconds [4]. Leading the high voltage discharge, the voltage between the poles clamp is located in a predetermined value. When the instantaneous voltage pulse signal is gone, TVS automatically return to the initial state. We have tested it for its response characteristic.

First of all, When the test circuit is not connect Device Under Test (DUT), close switch then adjust the simulator make its output is 1800V, signals through the oscilloscope collected are shown in Fig.2 .And then we add TVS into test Fixture to check whether the circuit is correct. Then instantaneous high voltage pulse is adjusted according to the regulations of DUT. When the TVS and the circuit conform to the test standard, adjusting the high frequency noise simulator make its output voltage is 1800V, measured the response curve of TVS protective device are shown in Fig.2 below.

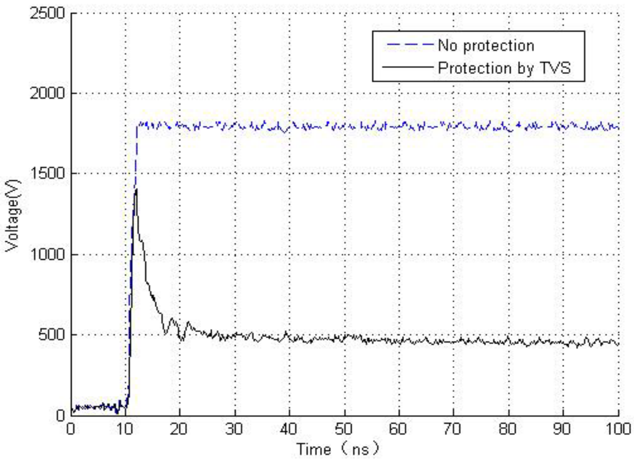

Fig.2 The response curve of TVS protective devices

As is shown in Fig.2, after a few nanoseconds, the high voltage pulse becomes low, and is finally limited to a certain value. In the test result, overshoot voltage is 1364.4V and limiting voltage is 442.2V.

It is demonstrated by experiments that, with a voltage of about 1800V, the TVS protection device will fall about three-quarters of the voltage. Inevitably, there is a quarter of the residual voltage. In some cases, it is in conformity with the protection requirements. But for equipment with higher sensitivity, the protective requirements cannot be satisfied. So in order to satisfy higher engineering standards, we should look for a better way of protection.

3.2 GDT Protection Performance Research

GDT is actually a discharge gap sealed in a ceramic cavity, which is filled with inert gas to stabilize the discharge voltage, its main characteristic is high insulation resistance, no leakage flow, no aging failure, etc.

The working principle of GDT is summarized as the following: when no current, electrode plates of the discharge tube is in the open circuit state; when there is current, the plate will in the conduction state. When the instantaneous voltage pulse signal is gone, GDT automatically return to the initial state [5]. We have tested it for its response characteristic. The protective response characteristics curves are shown in Fig.3 below.

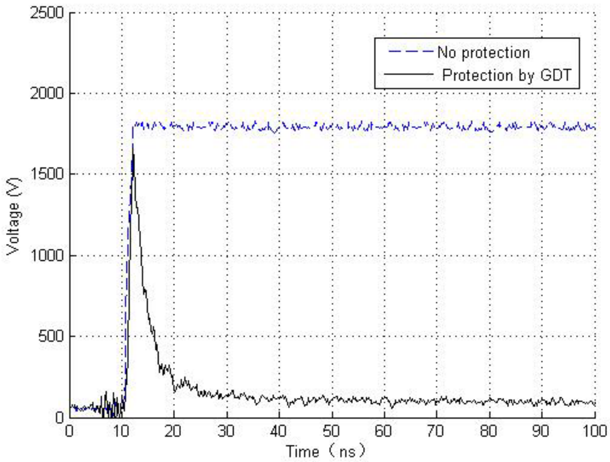

Fig.3 The response curve of GDT protective devices

As is shown in Fig.3, after a few nanoseconds, the high voltage pulse becomes low, and is finally limited to a very low value. In the test result, the overshoot voltage is 1577.4V, and the limiting voltage is 79.4V.

It is demonstrated by experiments that, with the same voltage of about 1800V, the voltage of GDT protection device will fall down with a much faster speed than TVS. While a higher overshoot voltage is observed. In some circuits, this overshoot may damage the equipment.

3.3 TVS and GDT Connecting Protection Research

It can be found from the measured data that TVS has a lower overshoot voltage and higher limiting voltage, while GDT has a higher overshoot voltage and lower limiting voltage. In order to make sensitive equipment work normally and reduce the instantaneous high voltage pulse impact on circuit, we must ensure that both overshoot voltage and limiting voltage are low. When combined to use [6], the combination of TVS and GDT protective features are measured to analysis whether meet the high engineering standard.

When TVS and GDT are used in series, the response characteristics of the protective performance are verified in our tests as high limiting voltage and overshoot voltage. So this combination way of protection is unfavorable. By contrast, when they are used in parallel, the response of the protective performance is verified as low overshoot voltage and limiting voltage. Response characteristic curve are shown in Fig.4.

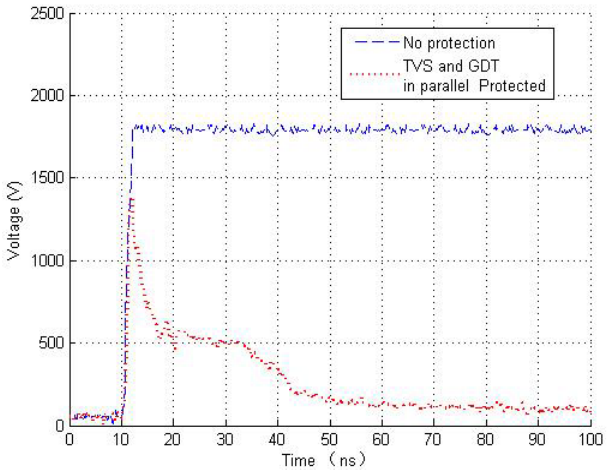

Fig.4 The response curve of TVS and GDT in series protective devices

The corresponding parameters of protective characteristics measured are shown in Table 1 below.

Table 1 The corresponding parameters of protective characteristics

Protection scheme	TVS	GDT	TVS and GDT in series	TVS and GDT in parallel
Overshoot voltage (V)	1346.4	1577.4	1623.6	1333.2
Limiting voltage (V)	442.2	79.4	495	82.2

As is shown in Table 1, we can conclude that the limiting voltage is higher under the TVS protection. And we can get much lower limiting voltage if we use the GDT protection, but its overshoot voltage is high. When they are used in series, both the limiting voltage and overshoot voltage are higher. By contrast, when they are used in parallel, the response of the overshoot voltage and limiting voltage are lower. The contrast curves of response characteristic are shown in Fig.5 below.

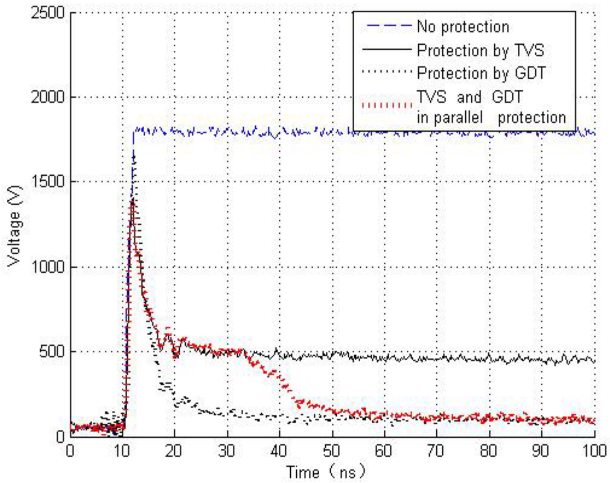

Fig.5 The contrast curve of response characteristic

4. Summary

From the test result, we can find that the equipment protected by TVS may be influenced by the higher limiting voltage, and the equipment protected by GDT may be influenced by higher overshoot voltage.

When TVS and GDT are used in series, the response characteristics of the protective performance are verified in our tests as high limiting voltage and overshoot voltage. Besides, if either of the devices is damaged, the circuit will work without protection. When they are used in parallel, the response of the protective performance is verified as low overshoot voltage and low limiting voltage. In addition, if one of the devices is damaged, the circuit will be protected by the other, thus the reliability of protection is greatly enhanced. Based on the above facts, the parallel scheme is recommended for practical apply.

References

[1] Shanghe Liu, Zhancheng Wu. Electrostatic discharge and hazard protection [M]. Beijing University of Posts and Telecommunications Press. 2004,158-179.

[2] Guangxiao Luo, Xiang Cui, Lei Qi, et al. Equivalent Circuit Parameter Estimation and Application of TVS Electrostatic Discharge Suppressor [J]. Proceedings of the CSEE. Vol (33) No (2013) 16,204-211.

[3] Lei Qi, Hongzhi Li, Xiang Cui, et a1. Prediction of electromagnetic disturbance by lightning strike in UHV substation [J]. High Voltage Engineering, Vol (35) No (2009) 8, 1796-1801.

[4] Xijun Zhang, Jie Yang, Qinghai Zhang. Transient Response of Transient Voltage Suppressor Device Under EMP with Fast Rise Time [J]. High Voltage Engineering. Vol (38) No (2012) 9, 2242-2246.

[5] Gongchang Yue, Weidong Liu, Weijiang Chen, et al. Measurement methods of very fast transient overvoltage in gas insulated switchgear wittl complete process [J]. Proceedings of the CSEE. Vol (31) No (2011) 31, 18-27.

[6] Xiangchao Li, Zhongshan Zhou, Zehuang Chen, et al. Analysis on Energy Coordination Between Gas Discharge Tube and Varistor [J]. Nanjing University of Information Science and Technology. 2014No.21, 26-31.