What is Test Method of Impulse Limiting Voltage on Signal SPD

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1. Introduction

Signal surge protection device (SPD) is extensively applied in the communication, signal, measurement and industrial control systems, and is used to protect the port, which is sensitive to over-voltage. As for this equipment, impulse limiting voltage directly represents the performance of limiting over-shoot. Both manufacturers and users pay close attention to this indicator.

However, it is found that measured value of signal SPD impulse limiting voltage fluctuates widely. The measured value of the same test object used in different pieces of equipment is very different. Even if the equipment and test object are the same, the measured value still varies greatly according to different test time. The change ranges from 20% to 60%, even higher. This will have severe influence on accurate measurement of parameter and result comparison, and also not helpful for the promotion and application of the whole series of signal SPD.

The root cause for great difference is that test method regulated by test standards has its own defects, resulting in the uncertainty of test conditions. For instance, proposed test method is not suitable for precise data measurement, and we lack technical code for managing test equipment.

2. Standard Requirements

The GB/T 18802.21-2004 regulates that manufacturers have to mark product withstand parameter of X-C impulse current under C-type impulse condition, and to measure the impulse limiting voltage under the same condition. The C-type impulse uses complex waves to carry out the test; open-circuit voltage is 1.2/50us impulse voltage wave; short-circuit current is 8/20us impulse current wave.

The GB/T 16927.1-2011 High-voltage Test Techniques Part 1: General Definitions an Test requirements puts forward a regulation on standard impulse voltage waveform. The regulation is similar to that stated in GB/T17627.1-1998. Moreover, the oscillation below 30% peak is further detailed as follows: as for common impulse voltage generator circuit, the influence of the oscillation of wave front below 90% peak on test result can be ignored. If these oscillations and overshots are regarded important, it is suggested that the amplitude of these oscillations is below A’B’ straight line, which is shown in Fig.1.
Fig.1 Limitation on oscillation amplitude below 90% peak in GB/T 16927.1-2011

At present, national standards GB/T 17626.5-2008 Electromagnetic Compatibility-Testing and Measurement Techniques - Surge Immunity Test also adopts IEC61000-4-5. It describes complete definition and testing principle of test equipment, for instance, different simulation & application fields of internal resistance 2Ω, 12Ω and 42Ω of complex wave generator. In this standards, test result of applying complex wave is determined through EUT function loss and performance reduction, not surge voltage variation in the circuit.

Hence, the standards for complex wave generator of signal SPD are not complete, especially lack of regulation on front impulse wave. In terms of signal SPD, test parameter of impulse limiting voltage can be selected between C2:0.5kV/0.25kA and C2:20kV/10kA. Take C2:5kV/2.5kA as an example, 30% of open-circuit voltage peak reaches 1.5kV, exceeding the limitation described by the product. That is a common problem. In other words, the main reason for the test result uncertainty is that impulse limiting voltage of signal SPD is lacking of standard regulations.

3. Principle of Impulse Generator

The typical circuit of complex wave generator is presented in GB/T 17626.5-2008, which is shown in Fig.2

The generator circuit simulates the lightning in nature, and can be described by transition theory. Assume that all circuit elements of generator are linear elements of lumped parameter, impulse voltage waveform represented by double exponential function will appear at the test terminal. Moreover, the waveform below 30% peak will never oscillate. The function is as follows:

\[ u_t = U \times \left( e^{\frac{t-t_0}{t_1}} - e^{\frac{t-t_0}{t_2}} \right) \]

Where:

\[ t_0 = 0, \quad t_1=70, \quad t_2=0.15 \]

The standard 1.2/50 impulse voltage waveform is calculated, which is shown in Fig.3.
double exponential function

However, as a circuit system, it is inevitable that distributive parameter exists. This distributive parameter will play an important role in the impulse process -- causing attenuated oscillation in the circuit. The oscillation frequency, first peak amplitude and attenuation coefficient is closely related to internal structure of some special device. In the process of transition, attenuated oscillation occurs to common wave front, which is called “impulse phenomena”.

The calculation formula of attenuated oscillation:

\[ u_t = \frac{\phi_0}{\phi d} \times U_0 \times e^{-at} \times \sin (\omega_d \times t + \theta) \]

Oscillation frequency: 20MHz
First peak: 1500V
Attenuation coefficient: 12

The attenuated oscillation waveform is below:

Fig.4 Attenuated oscillation during the transition process

The voltage wave front range of generator output end contains two parts. The compound waveform is shown in Fig.5. The added voltage change ratio generated by attenuation and oscillation can reach 100V/ns. Overlapped oscillation will cause voltage rising rate of front part of impulse wave to vary within a broad range. The amplitude of test voltage applied on the test object will vary greatly.

Fig.5 includes output waveform of attenuated oscillation

4. Measured Data and Analysis

The part below 30% peak includes the special electric features of the equipment, and is the equipment “fingerprint”. Fig.6 presents measured waveform of open-circuit voltage of several complex wave generators. Based on that, it is clear that the difference of the part under 30% peak is great regarding different equipment.

Fig.6 (a) Open-circuit voltage of some complex wave generator
Fig.6 (b) Open-circuit voltage of some complex wave generator
Any SPD is a electric combination. After SPD is connected to generator output terminal, SPD and circuit form a new electric system. Even if the impulse condition is the same, voltage and current of output terminal will change. The change is not only related to test object, but also internal electric parameter of equipment. Hence, although the generator conforms to standards, it is still likely that different limiting voltage amplitude and different shaped waveform are obtained when the same test object is connected to various generators.

Fig.6 (c) Open-circuit voltage of some complex wave generator

Fig.6 (d) Open-circuit voltage of some complex wave generator

Fig.7 (a) 1.2/50 open-circuit voltage waveform of the equipment
Fig. 7 (b) The voltage waveform of output terminal with SPD

Based on Fig. 7 (a), there is no obvious oscillation for front waveform at 400ns/div. After one SPD is connected to output terminal, limiting voltage waveform is obtained, which is shown in Fig. 7 (b) with the same impulse parameter. The difference is that there is obvious oscillation for front wave, and the rising rate of voltage increases obviously at the initial range. The waveform change indicates that “equipment + SPD test object” is a whole electric system. The voltage of output terminal will vary according to the variation of parameters of both parts.

Because the numerical value of impulse limiting voltage of signal SPD is low, attenuated oscillation wave of impulse voltage rising edge will have great influence on test result. Both volt-second attribute of gas discharge tube and reverse recovery time of semi-conductor protection element will lead to the fact that protection elements have operation time parameter. The operation time is not only related to voltage amplitude, but also is closely related to voltage rising rate. The chance of element operation would vary according to rising rate, thus limiting the change of numerical value of voltage. Therefore, unstable output condition of generator will have negative effect on measuring result.

5. Suggestions

To be simple, test method is very important. Given that available test standards GB/T 18802.21-2004 presents clear test condition, only revising standard content can improve this situation fundamentally.

On the one hand, owing to limitation of generator production technologies, it is hard to obtain stable and clean waveform trace at the 30% peak area; on the other hand, even if the output is perfect, it is not easy to do the stable and precise voltage measurement within one range with high change rate due to different attributes of electric system combined by equipment and test object. The ultimate purpose for people to conduct the impulse limiting voltage test is to objectively evaluate the limiting voltage capability of test objects. As for test objects falling into the same category, this evaluation should be comparable. There is no uniform standard parameter for the surge impulse in nature, and the impulse test itself is a kind of simulation test. There must be a discrepancy between impulse limiting voltage data measured in standard condition and limiting voltage capability of actual product.

The impulse waveform with low rising rate is recommended to take place of complex wave. Reducing the voltage rising rate can cut down the
oscillation during the process of measurement. For instance, 1kV/us voltage wave. This voltage wave has been widely used in the element impulse limiting voltage test.

The other method is also adopting available complex wave generator. The test voltage is selected as a increasing sequence to make open-circuit voltage of generator fall between 1.1 times and 1.3 times of final measuring results. Within the range close to the peak, rising rate of voltage falls obviously, and oscillation phenomena also declines at the same time. For this method, it is not necessary to change equipment condition. It only needs a little more work during the test.

The pure resistive serial impedance with great numerical value can be added to available 2 Ω complex wave generator. This method is helpful for cutting the proportion of distributive parameter in the “generator + SPD test object” system, and thus reducing the negative influence of oscillation on measuring results. However, the method needs to be verified.

REFERENCES


