Comparing Surge Test Parameters

Initial inspection of waveform parameters may not accurately reveal the energy deposited into the EUT.

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INTRODUCTION

A leading consumer magazine recently conducted tests on a variety of surge suppression devices. The surge suppressors tested were those used for the protection of home computing equipment against transients. All suppressors were intended to protect the power lines, while several also contained telephone line suppression. Although the testing appeared to be performed quite thoroughly, several areas were not addressed.

The specifications tested to were not included. Admittedly, this is beyond the scope of the intent of the article. This article mentioned that the devices should pass the UL 1449 standard for transient voltage surge suppressors and that the let-through voltage is a concern. It is assumed that this is the test that was performed. The waveform time parameters and the source impedance of the generator were also not mentioned. These topics were probably not of concern to the casual reader as long as the source impedance and time parameters were constant throughout the testing and they were of the values given in the appropriate test specification. These test parameters are very important when specifying what tests and what levels should be imposed on the equipment under test (EUT). If comparisons are to be made between tests, or if failure analysis is to be performed, these test parameters must be considered.

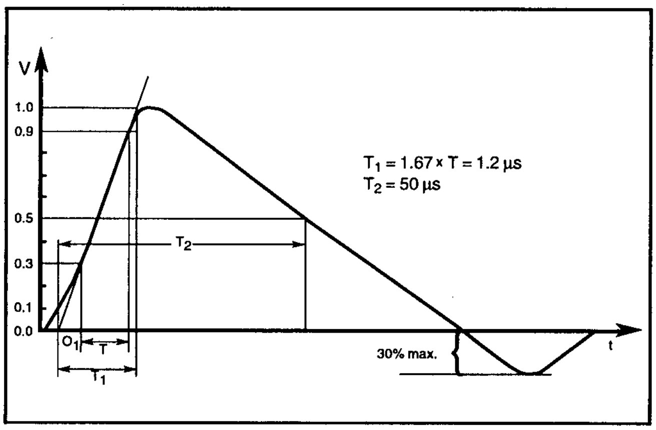

Figure 1. *1.2/50 µs Waveform.*

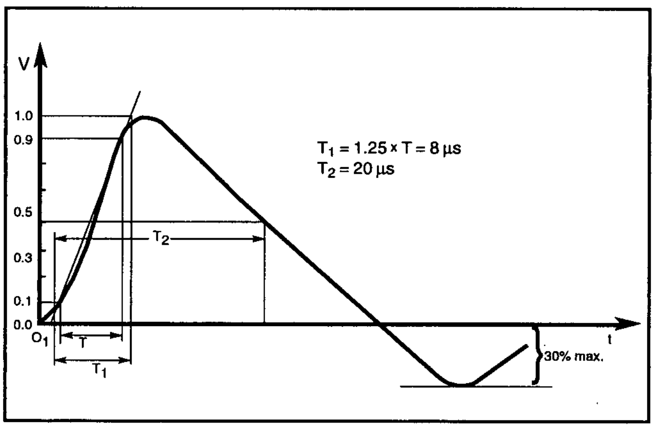

Figure 2. *8/20 µs Waveform.*

TEST SPECIFICATIONS

The UL specification stipulates that a 1.2/50 µs double exponential waveform be used to perform the test. It also states that other waveforms may be used according to IEEE C62.41-1991, "IEEE Recommended Practice on Surge Voltages in Low-voltage AC Power Circuits." This IEEE specification details standard and additional non-standard surge waveforms. Several of the standard waveforms and other surge waveforms are found in IEC-1000-4-5, "Electromagnetic Compatibility, Testing and Measurement Techniques, Surge Immunity Test." Several of the specified waveforms will be examined more carefully to determine the impact of the various test waveform parameters on the EUT.

Both the IEEE and IEC documents call for testing with a combination wave generator. This generator delivers, on an open circuit, a 1.2/50 µs double exponential waveform (Figure 1). When the generator is short-circuited, an 8/20 µs double exponential waveform is developed. Figure 2 displays this waveform. The source impedance of the combination wave generator in both documents is specified to be 2 ohms. The IEC specification allows for higher effective source impedances, depending on the test level, by adding series resistors at the generator output.

IEEE C62.41-1991 has six equipment location categories that define the test levels (Table 1).

IEC-1000-4-5 defines 5 test levels. Class X is an open class. This level can be specified in the product specification. The levels for the other 4 classes are listed in Table 2.

For comparative purposes one other waveform will be examined. It is a double exponential waveform found in IEC 1000-4-5. This waveform is defined as 10/700 µs

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LOCATION CATEGORY	PEAK VOLTAGE (kV)	PEAK CURRENT (kA)
B1	2	1
B2	4	2
B3	6	3
C1	6	3
C2	10	5
C3	20	10

Table 1. *IEEE C62.41-1991 Combination Wave Test Levels.*

LEVEL	VOLTAGE (kV)	2-Ω Z_{SOURCE} CURRENT (kA)	12-Ω Z_{SOURCE} CURRENT (A)
1	0.5	0.25	42
2	1.0	0.50	83.3
3	2.0	1.0	167
4	4.0	2.0	333

Table 2. *IEC 1000-4-5 Surge Immunity Test – Combination Wave Test Levels.*

LEVEL	PEAK VOLTAGE (kV)	PEAK CURRENT (kA)
1	0.5	12.5
2	1.0	25
3	2.0	50
4	4.0	100

Table 3. *IEC 1000-4-5 5/300 µs Test Levels.*

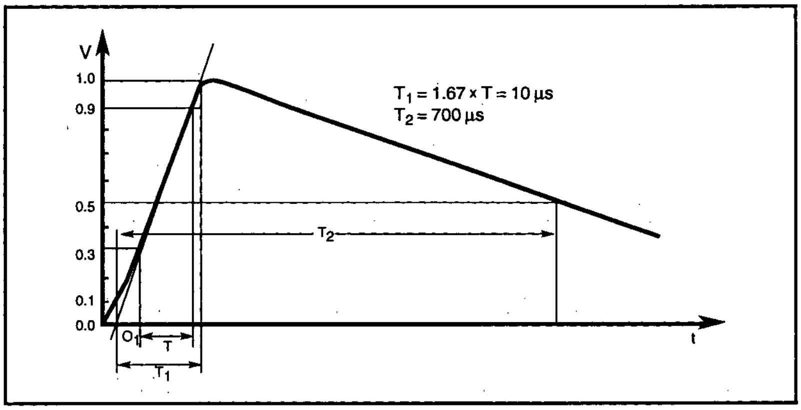

Figure 3. *Waveform of Open-circuit Voltage (10/700 µs).*

WAVEFORM	CURRENT LIMIT (kA)	ACTION INTEGRAL
8/20 µs	1	12.2
	2	48.7
	3	109
	5	304
	10	$1.22 \cdot 10^{3}$

Table 4. *IEEE C62.41-1991 Action Integral Values.*

WAVEFORM	CURRENT LIMIT (A)	ACTION INTEGRAL
8/20 µs	12	$1.75 \cdot 10^{-3}$
	42	$2.15 \cdot 10^{-2}$
	95	$1.10 \cdot 10^{-1}$
	250	$7.60 \cdot 10^{-1}$
	333	1.35
5/300 µs	12.5	$3.39 \cdot 10^{-2}$
	25	$1.36 \cdot 10^{-1}$
	50	$5.43 \cdot 10^{-1}$
	100	2.17

Table 5. *IEC 1000-4-5 Action Integral Values.*

open circuit voltage. Although the IEC specification does not refer to that short-circuit waveshape, the generator circuit that it recommends for producing the 10/700 µs voltage waveform will produce a 5/300 µs current waveshape into a short circuit (Figure 3). The test levels for this waveform are found in Table 3.

THE ACTION INTEGRAL

The above mentioned waveforms will be investigated using the action integral which is defined as follows:

$$AI = \int i^2 (t)\, dt \qquad (1)$$

This parameter is a gauge of the energy delivered by the test current. The integral is evaluated over the time interval of interest. Since the actual energy delivered cannot be calculated without knowing the resistance of the system under test, the action integral is used to compare the delivery of energy through the injections of the various waveform test current levels to be investigated.

The 8/20 µs current portion of the combination wave is studied for the action integral. This waveform follows the equation:

$$i\,(t) = 1.243\ 10^{16}\ i_p\, t^3 \exp\,(-t\ 2.557\ 10^{-7}) \qquad (2)$$

The 5/300 µs waveform follows the equation:

$$i\,(t) = 1.029\ i_p\,(\exp\,(-t\ 2.045\ 10^{3}) - \exp\,(-t\ 5.446\ 10^{5})) \quad (3)$$

Although the test specifications in question list the current levels as short-circuit calibration levels, they will be considered as a worst case test current level. Inserting Equation 2 into Equation 1 and evaluating the action integral for the IEEE current values in Table 1 yields the values listed in Table 4.

Inserting Equation 2 into Equation 1 and evaluating the action integral for several of the IEC 8/20 µs current values in Table 2 yields the values listed in Table 5. Also listed are the results of inserting Equation 3 into Equation 1 and evaluating the action integral for the 5/300 µs current values listed in Table 3.

CONCLUSIONS

As is shown in the data presented in Tables 4 and 5, it is very important to take certain waveform parameters into consideration when investigating surge test specifications and surge testing results. At the highest level, the current for the IEC 8/20 µs waveform is over three times that of the 5/300 µs waveform. However, at those levels the action integral of the 5/300 µs waveform is almost double that of the 8/20 µs. It is important to note that if the current level of a certain waveform is doubled, the action integral, and therefore the energy deposited in the equipment under test, is increased by a factor of four. Therefore, if a piece of equipment is tested at the incorrect level, the possibility for unnecessary overstress is higher than it readily appears to be. When comparing results, the same is true. On the surface, pieces of equipment tested to different specifications may appear to be tested to similar stress levels. An investigation of the specified waveform parameters using the action integral may reveal that the difference in energy content of the tests could be much higher than first suspected.

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