

## Technical Report

### Impulse Current and Impulse Voltage Withstand Levels for LPI STORMASTER ESE-15, ESE-30, ESE-50 and ESE-60 Air Terminals

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**Date:** 5<sup>th</sup> February 2015

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A handwritten signature in purple ink that reads "Michael Austin".

#### Version Control

Version	Release Date	Approved	Comments
1.0	5 <sup>th</sup> February 2015	MAA	

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## 1. Summary

Based on independent current and voltage tests conducted on the LPI Stormaster ESE series of terminals, the following was confirmed:

- Impulse current test: able to withstand a lightning impulse of 93.5kA 10/350  $\mu$ s. This was shown to be equivalent to a lightning impulse of 547kA 4/10 $\mu$ s and 383kA 8/20 $\mu$ s
- Impulse voltage test: withstand a switching impulse of 700kV 262/2500  $\mu$ s. This was shown to be equivalent to a lightning impulse of 1330kV 1.2/50 $\mu$ s

## 2. Impulse Current Withstand

### 2.1. Test Method

The LPI Stormaster ESE series of terminals have been subjected to multiple impulses of current in accordance with C.3.4 of UNE 21186:2011. This test involves applying a current impulse,  $I_{imp}$  meeting the following peak current, total charge and W/R requirements, and verifying at the end of the tests that the device was still functioning normally.

$I_{peak}$ (kA)	Q (A.s)	W/R (kJ/ $\Omega$ )
$100 \pm 10\%$	$50 \pm 20\%$	$2,500 \pm 35\%$

**Table 1 - Parameters of applied impulse current**

A typical waveshape able to achieve these parameters is the 10/350  $\mu$ s wave.

The test was applied 3 times, with sufficient time in between each test to allow the Device Under Test (DUT) to cool to room temperature.

The DUT was deemed to have passed the test if a visual inspection did not reveal any indications of deterioration or perforation of the sample.

### 2.2. Results

Impulse tests were performed by Instituto Tecnológico de la Energía, Laboratorio de Alta tensión de ITE, Edificio 84, U.P.V C<sup>o</sup> de Vera s/n. 46022 Valencia, Spain. Details of the three current impulses applied are shown in Table 2.

Impulse No.	Polarity	I	W/R	Q
		(kA)	(kJ/ $\Omega$ )	(A.s)
1	+	94.03	2189	49.75
2	+	93.59	2129	48.73
3	+	92.94	2025	43.97

**Table 2 - Details of applied current impulses**

No indication of damage or perforation of the DUT was observed.

### 2.3. Equivalent peak currents using other impulse wave shapes

The energy in the applied test can be related back to the peak current of any other wave shape by comparing the applied work function, as given by the integral of the square of current:  $\int_0^{\infty} I^2 dt$ .

Any waveshape of a similar form to the 10/350  $\mu\text{s}$  can be described using the equation:

$$I = A(1 - e^{-t/\tau_1})e^{-t/\tau_2}$$

Where:

- $I$  = current (A)
- $A$  = constant to give a peak current of 1 (normalised)
- $t$  = time (s)
- $\tau_1, \tau_2$  = constants that define rise and fall times

For the 10/350 $\mu\text{s}$ , 4/10 $\mu\text{s}$  and 8/20 $\mu\text{s}$  waveshapes, the values of these parameters to give the required waveshape and the value of the applied work function, based on a waveshape with peak current of 1A, is:

Waveshape	A	$\tau_1$	$\tau_2$	$\int_0^{\infty} I^2 dt$
10/350 $\mu\text{s}$	1.064	5.25	464	$253.96 \times 10^{-6} \text{ A}^2 \cdot \text{s}$
8/20 $\mu\text{s}$	1.883	4.0	16.0	$15.13 \times 10^{-6} \text{ A}^2 \cdot \text{s}$
4/10 $\mu\text{s}$	1.90	2.0	7.8	$7.41 \times 10^{-6} \text{ A}^2 \cdot \text{s}$

**Table 3 – Waveshape parameters**

Thus, there is 34.27 times more energy contained within a 10/350  $\mu\text{s}$  impulse when compared to a 4/10  $\mu\text{s}$  impulse of the same peak current. Thus, in order to get an equivalent level of applied energy from a 4/10  $\mu\text{s}$  impulse, the peak current needs to be  $\sqrt{34.27} = 5.85$  times the peak current of the 10/350  $\mu\text{s}$  waveform. For the 8/20  $\mu\text{s}$  waveform, there is 16.79 times more energy in the 10/350  $\mu\text{s}$  impulse and so the peak current in the 8/20  $\mu\text{s}$  waveform needs to be 4.1 times higher to achieve the same level of work function.

The average peak current from the applied impulses was 93.52kA, and so an equivalent peak current for a 4/10  $\mu\text{s}$  impulse that would provide the same level of work function is  $5.85 \times 93.52 = 547\text{kA}$ . For the 8/20  $\mu\text{s}$  impulse, this figure is 383kA.

### 3. Impulse Voltage Withstand

#### 3.1. Test Method

The LPI Stormaster ESE series of terminals have been exposed to multiple switching impulse voltages in accordance with Clause 4.2 of NFC 17-102. This test involves placing the Device Under Test (DUT) between two large electrical plates separated by a distance of at least 2m. A DC voltage is applied to the top plate relative to the group plate sufficient to give a DC electric field strength of between 10 – 25kV/m.

A switching impulse, with rise time of between 100 – 1000  $\mu$ s is then applied to the upper plate of sufficient peak voltage so as to achieve a rate of change of electric field of between  $2 \times 10^8 - 2 \times 10^9$  V/m/s.

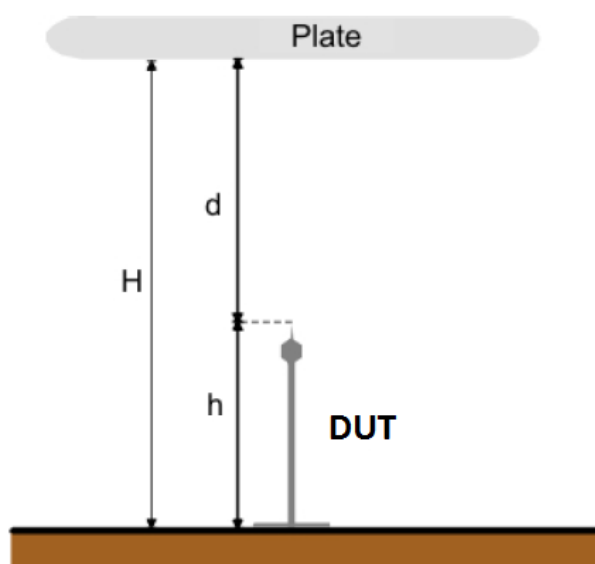


Figure 1 - Test setup for switching impulse voltage test

#### 3.2. Results

Switching impulse tests were performed by Korea Electrotechnology Research Institute (KERI), Sungju-dong 28-1, Changwon, Korea, 641-120. Details of the impulse applied are shown in Table 4.

Parameter	Value	Units
DC voltage applied	70	kV
Peak switching voltage applied	700	kV
Rise time	262	$\mu$ s

Table 4 - Details of applied switching voltage impulse

### 3.3. Equivalent 1.2/50µs lightning impulse voltage

It is well known from work undertaken in the study of high voltage electrical isolation that in order to cause electrical breakdown significantly higher peak voltages are needed with fast front waveforms, such as lightning impulses (LI) with a 1.2/50 µs waveshape when compared to waveforms with much slower rise times, as is the case with switching impulses (SI) with typical waveshapes 250/2500 µs.

In the technical paper, “Mechanisms to explain the switching impulse phenomena”<sup>1</sup> Feser provides a relationship between the breakdown voltage, U (in kV) and the rise time of the impulse, T<sub>s</sub> (in µs):

$$T_s = \frac{U - 600}{2.08}$$

Rearranging this, we get a relationship for the breakdown voltage based on the wavefront rise time:

$$U = 600 + 2.08 \times T_s$$

So, for a 1.2 µs wavefront, U = 602.5kV and for a 262 µs wavefront, U = 1145kV. Thus, the ratio of peak voltage when comparing equivalent 1.2/50 µs lightning impulses to switching impulses with a rise time of 262 µs is 1145/602.5 = 1.90.

Thus, the equivalent 1.2/50 µs lightning impulse based on the applied switching impulse of 700kV peak voltage and 262 µs rise time is 1.90 x 700 = 1330kV.

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<sup>1</sup> K. Feser: Mechanisms to explain the switching impulse phenomena, Schweizerische Technische Zeitschrift Nr. 46, (1971), S937-946