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The Importance of Single-Impulse Testing

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In 1992 NEMA came out with published recommendations for Transient Voltage Surge Suppressors (TVSS) or Surge Protective Devices (SPDs). The purpose was to have manufacturers prove their product performance. Why? Historically, there has been a lot of confusion about TVSS product performance claims, specifically, does the product do what the manufacturer claims it will do?

It is easy for a manufacturer to publish performance claims on a data sheet. However, unless those claims can be proven through real-world testing, the published data is questionable. Why is it important to substantiate manufacturers' claims?

The difference between a transient voltage surge suppressor that can perform to its published specifications and one that cannot is the difference between a *protected* facility and an *unprotected* facility.

When NEMA issued these recommendations, it was to help establish a level playing field. The foreword of NEMA LS 1-1992 states,

> "A properly derived and professionally presented product specification enhances the credibility and reputation of a manufacturer because the actual performance or independently verified characteristics and capabilities of its product are accurately described by its own published product specifications.
>
> This document represents the collective view of the Technical Committee of NEMA's Low-Voltage Surge Protective Device Section. It is intended to serve primarily as a guide to manufacturers and others affiliated with the Low-Voltage SPD marketplace in the hope that uniformity of specifications, in terms of valid, understandable physical parameters, will improve the understanding of SPD literature."

The question comes to mind, if this document represents the collective view of the NEMA Technical Committee, then who makes up this committee. These 24 manufacturers comprised the committee when the LS 1 document was written:

APT	GE	MCG
American Electric	GTE	Northern Technologies
Atlantic Scientific	Harris	P & S
Bryant Electric	Hubbell	Square D
Cooper Power	Innovative Technology	General Semi-Conductor
Current Technology	Joslyn	Transtector
Delta	LEA	Winders & Geist
FL Industries	Leviton	Wiremold

The Scope of NEMA LS 1-1992 states,

> "In presenting a specification format, it is not the intent of this document or that of NEMA (Low-Voltage SPD Section) to introduce new standards, derive test and evaluation methodology, or define extensive vocabulary. Rather, those parameters considered essential, and above all measurable, using current, off-the-shelf test equipment and referencing established standards and measurement guidelines, are introduced as constituting the body of a proper specification format. The methods associated with their measure or derivation will be referenced, though most are not extensively addressed, since adequate procedural definition and discussion is readily available in ANSI, IEEE, and other technical publications.
>
> Above all, this document is intended to be general in nature. As such, some terms and procedures may not apply to certain devices. Others may require additional technical information in order to adequately define unique application capability or special characteristics. Therefore, specification format and reference to existing standards are emphasized."

In particular, Sections 2.2.9 and 3.9 discuss the maximum single-pulse surge current rating of a device. Based upon NEMA's recommendation the value published by a manufacturer should be the one-time maximum surge current the device has been **tested** to withstand **per mode**. It is tested *per mode* because the number and type of components in any SPD can vary by mode. *NEMA does not recognize per phase ratings* – a method whose origination can vary from manufacturer to manufacturer. Per phase is the sum of L-N and L-G. Some manufacturers have been known to add N-G also. If L-N was 100KA and L-G was 200KA, the per phase rating would be 300KA. Typically, per phase is two times the per mode rating. This would lead an unsuspecting person to think the device was 150KA per mode, which is far from correct.

If a manufacturer makes reference to NEMA LS 1 by saying the surge generator was set to equal the rated per phase surge current of the unit per NEMA LS 1 or if the device was tested per phase per NEMA LS 1, it is not a correct statement.

To test the SPD's single-pulse surge current per NEMA LS 1 Sections 2.2.9 and 3.9, the following is done:

1. The unit is pulsed with a pre-strike 6KV/500A, 8/20 μsec combination wave and the clamping voltage is measured.

2. The unit is given an 8/20 μsec pulse of its rated surge current.

3. The unit is pulsed again with a post-strike 6KV/500A, 8/20 μsec combination wave and the clamping voltage is measured.

This is done in each mode the unit has suppression components. If the device survives the test (i.e., no fuses blow, the disconnect remains intact and still functions, the monitoring circuits survive, etc. **and** the pre-strike and post-strike clamping voltages do not vary by more than 10%), then the unit is said to have passed its single-pulse surge current per NEMA LS 1-1992.

The testing should be done at a third-party independent laboratory. Why? The Foreword says the independently verified characteristics and capabilities of a manufacturer's product that are accurately described in its own product literature enhance the manufacturer's credibility and reputation.

Some manufacturers will say this opens the door for malfeasance because the manufacturer is the client of the lab and the lab will do what is asked of it. This is true. However, a reputable laboratory will **document everything** done in the test report because their reputation and credibility also are at stake.

A test report is typically about 40 pages in length and contains model number of the device tested, date of the test, lab personnel present, manufacturer's employees present, the testing setups, calibration of the equipment, executive summary, results of the test, scope traces of the pre- and post-strike wave forms with the clamping voltage for each mode, photographs of the product under test, and scope traces of the single-pulse surge current in each mode.

NEMA recommends that the entire assembled unit be tested, not a sub-part or module. Why? Because the device as installed by the customer is a complete unit and not as a sub-part, module, without a disconnect, without fuses, or without monitoring.

One manufacturer who is on the NEMA LS 1 Technical Committee says the sections in NEMA LS 1 on single-impulse testing "*are ambiguously worded with no reference given to either testing methodology or testing criteria. With such ambiguity, LS-1 should be questioned in justifying any type of single-impulse testing requirement*."

However, reading on this manufacturer's web site about the NEMA LS 1 document, they state in direct contradiction to the above statement the following:

> "The intent of the document is to outline those SPD parameters that are considered essential, and above all measurable, using current off the shelf testing equipment and referencing established standards and measurement guidelines. This document does not introduce new standards, derive test and evaluation methodology, or define vocabulary. LS1 does reference the methods associated with measurement and derivation but most are not extensively addressed since adequate procedural definition and discussion is readily available in ANSI, IEEE, and other technical publications.
>
> One should always remember that LS1 is intended to create uniformity in manufacturer's specifications, in terms of valid, understandable physical parameters, and to improve the understanding of surge protective device literature. The document should never be misconstrued as the only viable source for technical understanding of these devices whether in design or testing. LS1 **clearly defines** (emphasis added) the specification parameters and their definitions as well as the appropriate test and evaluation procedures. One must also consult such documents as IEEE C62.41 & C62.45 for a comprehensive awareness of origins of surge voltages, wave shapes, energy, rate of occurrence, exposure levels, etc."

As was stated above, the difference between a transient voltage surge suppressor that can perform to its specifications and one that cannot is the difference between a protected facility and an unprotected facility. Why is this the case? A lightning strike in excess of what the device is able to handle, but less than what a manufacturer's product literature states, will render the unit inoperable and leave the facility unprotected.

Some manufacturers will state that it is irrelevant for a TVSS device to pass its rated single-pulse surge current. They say when examining the main standard ANSI/IEEE C62.41-1991 (IEEE Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits) the largest magnitude surge that can be delivered to a service entrance is a Category C3 surge having a magnitude 20KV/10KA. They then ask, "Did the IEEE arbitrarily choose these values?"

What does C62.41 actually say? C62.41 states in Appendix B1 the last paragraph,

> "The voltage and current amplitudes presented in the tables in Section 9 attempt to describe the effect of **typical** (emphasis added) lightning strikes but should not be construed as 'worst case,' since the definition of what represents a worst case is open-ended and subjective (see Section B25)."

From Table 3 Ring Wave and Table 4 Combination Wave in Section 9 the double asterisk denoting a footnote for Peak Values says,

> "The three values shown for each location category, for the three system exposures within the location category, have been set by consensus to provide guidance and uniformity in test procedures."

C62.41 is actually saying the C3 combination wave is not the worst case scenario and the values in the tables were more to provide uniformity in testing.

These same manufacturers also state that according to C62.41-1991, the largest transient that can enter a facility is in the 6-8KV range because any transient larger than that flashes over. They say this flash over becomes a release valve that shorts out the driving voltage; which limits the current.

Let's see what ANSI/IEEE C62.41-1991 actually says. In Section 7.3.1 it states,

> "It is essential to recognize that a surge voltage observed in a power system can be either the original surge or the remnant resulting from the sparkover of some clearance or the operation of a protective device in the system. Hence, the term 'unprotected circuit' should be understood to be a circuit in which **no known low-voltage protective device has been installed** (emphasis added), but in which the **sparkover of clearances** will eventually limit the maximum voltage of the surges.
>
> The distribution of surge levels, therefore, is influenced by the surge-producing mechanisms as well as by the sparkover level of clearances (between energized parts, as well as between energized parts and ground) and the operation of unidentified protective devices. It is important to recognize the effect of the increasing number of surge-protective devices installed in and around equipment (see **changes in the environment** in Appendix B3)."

ANSI/IEEE C62.41 Appendix B3 (3) states,

> "The surge-voltage limitation function previously performed by the flashover of clearances is now more likely to be assumed by the new surge-protective devices that are constantly being added to the systems."

The whole point behind an SPD is to limit voltage to a level safe for equipment, not to depend on the limited BIL of the distribution system to justify using a less robust SPD!

A civil engineer when designing a storm sewer system designs for a 100-year flood. He knows that he will have many storms of a lesser magnitude, but when that worst case scenario happens, he does not want flooding of homes or businesses.

ANSI/IEEE C62.41 Appendix B25. Worst Case states,

> "In the case of lightning strikes, one should think in terms of the statistical distribution of strikes, accepting a reasonable upper limit for most cases. … Where the consequences of a failure are not catastrophic but merely represent an economic loss, it may be appropriate to make a tradeoff of the cost of protection against the likelihood of a failure caused by a high but rare surge."

Specifying engineers and end-users need to know when comparing surge protective devices that they are making an apples-to-apples comparison. If two products are rated by their respective manufacturers as having 100KA per mode of protection, but one will only pass 10KA and the other 100KA, it is not an equal comparison.

As was stated above from the Foreword of NEMA LS 1-1992,

> "(NEMA LS 1-1992) is intended to serve primarily as a guide to manufacturers and others affiliated with the Low-Voltage SPD marketplace **in the hope that uniformity of specifications, in terms of valid, understandable physical parameters, will improve the understanding of SPD literature**" (emphasis added).

Specifying engineers look to NEMA to define parameters needed to properly specify and compare electrical equipment in all sectors of the industry. Why should surge protection devices be any different?

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