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*Surge protection devices...*

# **Inexpensive Electrical System Insurance**

*The concepts are simple, the solutions straightforward.  
You'll find it much less expensive to keep surges and  
electrical noise from frying your equipment and processes  
than to recover from the aftereffects of such events.*

**W**hen it comes to losses from electrical and electronic equipment failure and disruption, few events can match the destruction caused by surges (transients) and electrical noise. These phenomena are responsible for between 30% and 50% of most electronic equipment field failures today—and *that doesn't even begin to take into account the latent damage or degradation to electrical equipment such events cause*. Moreover, although no firm figures have been established, the estimated amount of dollars in lost production and lost revenues associated with these problems is staggering. A company can greatly reduce its risk of equipment damage, component degradation and system disruptions with a robust surge protection system.

### Understanding the issue

To get a real handle on the problems associated with surge and electrical noise, it's important to fully understand a number of key concepts.

■ **Concept #1:** Surges can be generated external to a facility in the form of lightning, as well as originate with a utility system. While these typically are the first sources that come to mind, numerous studies have shown that they account for only 20% of all electrical surges. The remaining 80% can be accounted for by culprits within a facility.

■ **Concept #2:** Most electrical surges are generated within a system, with common culprits being switched mode power supplies (SMPS), fax machines, printers, welding machines, cycling operation of motors and electronic ballasts for fluorescent lighting, to name but a few.

■ **Concept #3:** Many of the same culprits also are the source of electrical noise.

Early on in the development of surge protection, the industry was guided by the idea that a certain voltage threshold had to be reached before a surge caused any real damage. We now relate to this idea via terms such as “clamping voltage” and “let thru voltage.” Transients with voltages less than the clamping voltage were thought to be of little significance.

The problem is that sensitive electronics in our data-centric world are more susceptible to transients and noise that don't reach the clamping voltage and now go undetected more than at any other time in our modern economy. The cumulative effect of these transients that are not diverted or absorbed is negative. For starters, the quantities of surges that are below “clamping voltage” threshold are more numerous than the surges that are “clamped” by the

surge protection device. Not only do these smaller surges contribute to degradation of equipment components such as capacitor dielectric, they also can cause errors if coupled into the communications signal where they can mimic the intended signal's faster operating speeds and lower operating voltages. This coupling becomes easier since circuit board wiring traces are forced to become smaller and, thus, less of a barrier to prevent degradation. This leads us to a fourth important concept that needs to be understood:

■ **Concept #4:** Transients of significantly less voltage levels than previously considered detrimental are now more likely to be the source of many problems.

Many facility owners and managers believe that since they have never had anything burn up, they don't have any problems. This is only partially true as total **destruction** of equipment is only one of the 3-Ds of *Surge and Electrical Noise Damage*, which also includes **degradation** of components and process **disruption**.

## Defining the Problem

### What is a surge?

*“A sub-cycle disturbance in the AC waveform that is evidenced by a sharp, brief discontinuity of the waveform. May be of either polarity and may be additive to, or subtractive from, nominal waveform.”*

...Emerald Book

### What is electrical noise?

*“Unwanted electrical signals that produce undesirable effects...”*

...Emerald Book

Many facility owners and managers believe that since they have never had anything burn up, they don't have any problems. This is only partially true.

■ **Concept #5:** The fifth concept is that all damage done by surges and electrical noise is not totally destructive, but could be any one of the 3-Ds—*destructive, degradation or disruptive*.

The surge and electrical noise issues outlined in these five concepts may appear to be overwhelming at first. However, by taking a scientific approach using industry codes, standards and guidelines, an engineered solution is within economic reach. As a starting point, let's look at the basic function of a surge protection device (SPD) and how it is applied.

## SPD basics

The backbone of every SPD is the metal oxide varistor (MOV). The MOV is a nonlinear device that has very high impedance when not activated with an accompanying leakage current typically in micro-amps. It is seen as a short circuit when the voltage between conductors exceeds the "breakdown voltage."

Internally, the MOV has a myriad of diode-like junctions that shunt surge current through it when biasing voltage thresholds are achieved. The diode-like junctions are made of zinc oxide (which sometime contains small amounts of other metal oxides such as bismuth, cobalt and manganese). It provides bidirectional clamping of surges that must quickly dissipate surge energy as heat while shunting the transient to ground. The MOV typically has an intrinsic response time in the range of 500 picoseconds, which makes it great for events that are in microseconds. The voltage capacity of a MOV is primarily determined by the thickness of the disc while the current-carrying capacity is primarily determined by the surface area of the disc.

Many SPD/TVSS manufacturers stack MOVs in parallel and series to achieve higher performance levels. An important concept about the MOV/SPD is that it is a sacrificial device with degradation of performance over time with exposure to surge energy. It is considered to be at the end of its life when it has lost 10% of its design capacity. Many manufacturers combine the transient suppression capabilities of the SPD with filters tuned to block electrical noise.

## SPD application standards

The first standard to consult regarding SPD application is

the National Electrical Code (NEC®), NFPA-70, Article 285, which provides details on the installation of such a device (also called a Transient Voltage Surge Suppressor or TVSS).

## Grounding and bonding...

Just as important, NEC, Article 250, grounding is a paramount concern in surge protection. Most SPDs on the market today divert surge energy to the facility grounding system. Therefore, the importance of a low-impedance bonding and grounding system for the facility can't be overstated. Anything less than a low grounding and bonding impedance will cause surge energy to be diverted throughout the facility, with potentially negative effects.

## For example:

- The facility staff could be subjected to dangerous voltages during the event.
- A large percentage of microprocessor-based equipment uses the ground as a logical reference point. Surge energy diverted to the ground would pollute this reference point.
- Voltage differentials could be created causing inter-grounding system potential differences and undesirable currents on the grounding network.

Three key points must be addressed regarding grounding and bonding:

- First, it is imperative to have a qualified person evaluate the facility's grounding and bonding network for NEC compliance. All outlets should be checked for proper polarity and an equipment ground conductor impedance that should be less than 1 ohm.
- Second, it is mandatory to determine if the grounding system is robust enough to optimize the function of the SPD (i.e., proper wire size, tightness of connections, etc.).
- Third, it is essential to determine specific corrective action required to bring the grounding network to both NEC compliance and to the level of performance to address transients and electrical noise.



## **Zones of protection...**

After NEC, the next standard to consult is the *IEEE 1100 - IEEE Recommended Practice for Powering and Grounding Sensitive Electronic Equipment* (commonly called the *Emerald Book*). One of the primary recommendations put forth in this guide is the implementation of Zones of Protection. Three zones or levels of SPD deployment within a facility are identified along with corresponding device categories.

- The first zone is at the service entrance where the most robust SPD is placed to divert surges coming from external sources such as lightning. SPDs installed here are listed as Category “C” devices.
- The second zone of protection is within the facility at locations identified as susceptible to surges, as well as generators of surges. SPDs at these locations are listed as Category “B” devices and are installed on equipment such as switchgear, switchboards, panel-boards and branch circuit panels. The SPDs installed in this zone further reduce surge energy and divert it to ground, thereby limiting the surge voltage to a level that is tolerable to the equipment requiring protection.
- The third zone of protection is at the outlet. SPDs installed here are listed as Category “A” devices. Coordination of SPDs is required for optimum protection.

In general the closer the “Clamping Voltages” are to operating voltage, the better the protection. For comprehensive protection within the facility, SPDs should be installed to prevent transient propagation from source generators as well as to protect sensitive loads.

## **Additional standards...**

Other standards that are useful in evaluating SPDs include, but are not limited to:

- UL 1449 2<sup>nd</sup> edition (latest edition 2.5, revision effective 7-February-2007) is the safety standard for all equipment installed on the load side of the AC electrical service (480 V and below), as well as throughout the facility including the plug in outlet TVSS.

- NEMA-LS1 is the primary specification guide for low voltage (< 1000 V) AC power SPD applications.
- ANSI/IEEE C62.41 describes typical surge environments and includes standardized waveforms for testing of protective devices.
- NFPA 780 is the standard for Lightning Protection Systems.

Beyond the standards, many SPD manufacturers provide general information on their respective Web sites. Finally, the NEMA Surge Protection Institute ([www.nemasurge.com](http://www.nemasurge.com)) offers a vendor-neutral (i.e. “unbiased”) SPD presentation.

## **Your next step**

The next logical step is to evaluate the surge risks at your facility. This includes identifying external surge sources and the equipment within the facility that is susceptible to surges and noise, as well as the likely generators of surges and electrical noise within the facility.

A good design segregates the electrical power feeds of susceptible equipment from power feeds of surge and noise generators. Where possible, this segregation ideally should be at the service entrance. Outfit each panel you’ve identified as having susceptible loads or surge and noise generators with a properly sized SPD to mitigate surges.

When you are selecting an SPD, you have many features to consider. These include remote annunciation capabilities, audio alarms, local indicator lights, etc. The most essential function, though, is the SPD’s ability to divert transients. It is important for your chosen device to have a diagnostic indicator (visual, audible or otherwise) to verify that it is still functioning and hasn’t been disabled from the last surge suppression event it experienced. Therefore, some type of indication—*either local indicating lights or remote annunciation*—is critical. Noise filtering also is crucial, given the growing presence of electrical noise contamination. Several manufacturers claim to have sine wave tracking that allows their SPDs to pick up surges and noise on a frequency basis versus voltage thresholds. Another often-touted feature is a surge counter. Keep in

Although surges and electrical noise can't be totally eliminated, through an engineered approach they can be mitigated, thereby reducing their damaging effect.

mind, however, that a surge counter is only an indication of past performance—it's *neither an indication of future performance nor a gauge of existing lifetime of the device.*

### SPD installation

SPDs are either installed in equipment at the factory or installed after the equipment has been shipped and installed on site. There are three advantages to factory installation: a higher probability that the SPD lead lengths are short and as straight as possible; the connections to the buss will be as tight possible; and there is a uniform equipment appearance.

Most major equipment manufacturers provide optional SPD installation with their gear. In many instances, these devices are added after the installation of the major equipment.

When an SPD is installed after major equipment has been set and in operation, it typically is done external to the equipment. The installation practices of external SPDs are critical in order to achieve proper surge protections. It is recommended that external SPDs be installed as close as possible to the electrical buss being protected. Electrical connections must be tight, while connection wiring should be as straight as possible and as short as possible. The effect of excessively long connection cabling is to raise the "let thru voltage" threshold. So use the guide phrase "*Close, Tight, Short & Straight*" when it comes to external SPD installation and cabling: **Close** to the electrical buss being protected, **Tight** connections, **Short & Straight** lead lengths.

### Summary

Once awareness of the problems associated with surges and electrical noise has been achieved, the next step is to identify where the areas of risk exist within the facility and what type of protection is required at each. Selection of an SPD that adequately diverts and filters the transients and electrical noise away from the equipment then follows.

For optimal device performance, installation of each SPD must adhere to strict guidelines. To that end, don't forget

that the facility grounding system must be inspected and upgraded, where necessary. Poor grounding can provide paths of least resistance that divert transients and electrical noise to critical systems instead of away from them.

Many resources are available to help with the needs assessment, evaluation, design, product selection and installation of SPDs. In general:

- Verify that the protection scheme complies with IEEE recommendations and is installed according to both NEC requirements and the manufacturer's guidelines.
- Confirm that zones of protection are coordinated providing maximum surge attenuation and noise contamination filtration.

The threat of damage to electrical and electronic equipment from transients and electrical noise is real and growing. Our data-centric world is more susceptible than ever to damage from transients and noise, be it total destruction, degradation of equipment components or system disruption and malfunction. Since microprocessor-based equipment functions with faster operating speeds and lower operating voltage than other equipment, surges and electrical noise previously classified as non-threatening are significantly more damaging.

Although surges and electrical noise can't be totally eliminated, they can be mitigated through an engineered approach, thereby reducing their damaging effect. This leads to greater reliability and overall improved productivity. In this regard, surge protection really is an inexpensive form of electrical system insurance. ❖

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