Companies spend billions of dollars on equipment and facilities every year. But few of them realize that this investment is at risk if the power source is not properly protected.

This guide will explain the importance of protecting your power, identify the challenges and solutions for power protection, describe the quality standards and applications involved, and much more.
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This guide will explain the importance of protecting your power, identify the challenges and solutions for power protection, describe the quality standards and applications involved, and much more.
The Importance Of Protecting Your Power

A Growing Need

Today, we're seeing dramatic increases in the use of electronic equipment, controls, and processes in most industries. Tools and equipment are becoming electronically-based as factories become more automated and process-intensive. In many cases, the mechanical aspects of these processes, such as spindle acceleration, conveyor speed, extruder flow, or spray pressure, cannot tolerate variations caused by momentary voltage fluctuations.

And of course, the proliferation of PCs, printers, copiers, and electronic communications has affected the commercial market – while everything from microwaves to home-entertainment systems are placing increased demand on the power needs for the residential sector. Many of these electronics are also sensitive to voltage variations that were not noticed in the past.

With more electronics in the power system than ever before, and all indications pointing to continued increases, the question becomes: can the power supply as it is before, and all indications pointing to continued increases, tolerate variations caused by momentary voltage fluctuations. And of course, the proliferation of PCs, printers, copiers, and electronic communications has affected the commercial market – while everything from microwaves to home-entertainment systems are placing increased demand on the power needs for the residential sector. Many of these electronics are also sensitive to voltage variations that were not noticed in the past.

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Dirty power has the potential to affect your company's bottom line in a myriad of ways:

- Lost productivity
- Increased downtime
- Greater capital expenditures on equipment repair and replacement
- Budget "surprises"
- Angry customers
- Lost business and revenue

What Makes It Dirty? Types Of Power Disturbances

There are three “Ds” that affect power quality: degradation, disruption, and destruction. Power disturbances may be called a surge, sag, spike, swell, transient, fluctuation, interruption, or electrical line noise. All these disturbances are abnormalities and deviations from the normal performance of voltage sources. They may last for a short period, a long time, or be continuous.

Approximately 70% of electrical threats are internally generated by transients and electrical line noise, such as dips and interruptions, electrostatic discharge and surges. The remaining 30% of issues can be attributed to variations in the power supplied by utilities caused by lightning, outages, over- and under-voltages, and swells/sags.

In fact, lightning strikes are probably the most destructive example of a high-voltage transient: a direct hit can deliver thousands of volts and amperes. But lightning does not have to strike your facility to do significant damage. Via mutual induction, any conductive circuit within a few miles of a lightning strike can still experience a several-thousand-volt transient ...

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Capacitor switching can have a similar negative effect. Utilities and large commercial power users add power factor correction capacitors to a network to compensate for excessive inductive loads (e.g. motors) and boost power at the distribution extremities. Banks of capacitors are typically switched on at the same time every morning and switched off at the same time each night. When switching occurs, transients can reach hundreds or thousands of volts, depending on the impedance or distance of the affected equipment from the capacitor banks.

Faults on a utility’s distribution system can generate surges. Damaging voltage transients and electrical line noise can be introduced by using elevators, air-handling equipment, or even arc welders in construction projects that are close to other buildings.

The mere operation of air-conditioning systems, PCs, telephone systems, or other electronics can damage sensitive microelectronics in products that share the same line. Daily fluctuations from internal electrical equipment – such as a copier that gets turned on and off frequently and runs in cycles – can cause cumulative damage. The more electrical equipment your company uses, the more transients accumulate to create potential power disturbances and damage.
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With more electronics in the power system than ever before, and all indications pointing to continued increases, the question becomes: can the power supply as it is currently designed handle this increased load? For us, the solution is to ensure that the power you’re using is “clean,” able to keep your equipment operating properly.

...70% of electrical threats are internally generated...

Power Quality: Keeping It “Clean”

We refer to power quality as “clean” (good) or “dirty” (bad). Power quality is measured by the interaction of electric power with electrical equipment.

Good-quality – “clean” – power is critical to ensure an uninterrupted supply of electricity that does not cause damage or downtime. If your electrical equipment operates reliably and properly – without stress, damage, fatigue, or impact on processes – your power is clean. On the other hand, if your electrical equipment is damaged, unreliable, or malfunctioning, your power quality may be dirty.

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Utility switching is another type of power disturbance that can lead to compromised power quality. The path of electrical power from a utility generator to a commercial building is not a dedicated line – it’s a network of generators and substations interconnecting many facilities over hundreds or thousands of miles. Frequent changes in electrical demand or other service requirements often result in the switching of network grid tie points. Each time a substation is switched in or out of the network, a voltage transient is produced that can reach hundreds or thousands of volts, depending on the current, impedance, and facility distance from the switching points.

...any conductive circuit within a few miles of a lightning strike can still experience a several-thousand-volt transient ...

If you may have effective surge protection at your service entrance panel, but this does not exempt you from potential equipment damage in an event like this.
The Importance Of Protecting Your Power (Continued)

Examples Of Power Disturbances And Solutions

As you've seen, there are many sources of power disturbance, from RF to ground faults, to utility switching and more. Below is a chart outlining many of these conditions, along with definitions, sources of the disturbances, and solutions.

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<th>DEFINITION</th>
<th>SOURCES</th>
<th>SOLUTION</th>
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<tbody>
<tr>
<td>Electrical Line Noise</td>
<td>Noise is high amplitude, low current, and high frequency in nature.</td>
<td>Devices such as televisions, radios, light fixtures, and computers.</td>
<td>Active Tracking® Filter or Low Pass Filter</td>
</tr>
<tr>
<td>Transients and impulse</td>
<td>High voltage/high current, low frequency disturbance.</td>
<td>Sources such as Lightning, Arcing Contacts, Starting Large Loads, and Generators</td>
<td>Voltage Regulator</td>
</tr>
<tr>
<td>Harmonics</td>
<td>Continuous distortion of the normal sine wave, of frequencies that are multiples of the operating frequency.</td>
<td>Sources such as Motor Speed Controllers, Switching Power Supplies, and Normal Computer Operation</td>
<td>Harmonic Filter</td>
</tr>
<tr>
<td>Overvoltage</td>
<td>Abnormally high or low voltage conditions lasting for more than a few seconds.</td>
<td>Sources such as Lightning, Ground Faults, and Utility Switching</td>
<td>Voltage Regulator</td>
</tr>
<tr>
<td>Undervoltage</td>
<td>Abnormally low voltage conditions lasting for more than a few seconds.</td>
<td>Sources such as Lightning, Ground Faults, and Utility Switching</td>
<td>Voltage Regulator</td>
</tr>
<tr>
<td>Voltage Sustained</td>
<td>Voltage sustained conditions on one or more phases.</td>
<td>Sources such as Lightning, Ground Faults, and Utility Switching</td>
<td>Voltage Regulator</td>
</tr>
<tr>
<td>Voltage Sag</td>
<td>Voltage sustained conditions on one or more phases.</td>
<td>Sources such as Lightning, Ground Faults, and Utility Switching</td>
<td>Voltage Regulator</td>
</tr>
<tr>
<td>Outage to Dropout</td>
<td>Kilo-watt condition lasting longer than a half cycle.</td>
<td>Sources such as Lightning, Ground Faults, and Utility Switching</td>
<td>UPS</td>
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The Impact Of Power Disturbances

Different types of dirty power can affect electrical loads, resulting in a number of problems, as shown below:

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<th>IMPACT TO ELECTRICAL LOADS</th>
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<tr>
<td>Circuit Board Failure</td>
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<td>Data Transmission Errors</td>
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<td>Memory Scramble</td>
<td>Yes</td>
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<td>Yes</td>
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Source: The Dranetz Field Handbook for Power Quality Analysis

Consequences of Transient Damage

Transient damage is “electronic rust” that gradually eats away at the circuit traces that allow electricity to flow between electronic components on a printed circuit board of a computer, printer, or other device. Hard drive crashes, data transmission errors, and circuit board failures are just some of the consequences of electronic rust. If unchecked, it will eventually stop a computer in its tracks. If you don’t identify issues with low-energy transients and/or high-frequency electrical line noise early, then you will certainly experience problems over time, as evidenced in these photos.

The Benefits Of Power Quality And Protection Products

To maintain high-quality power within your facility, you must start with a solid foundation. This begins by ensuring that the wiring, grounding, and bonding are up to standards. Once you’ve verified this, you can install elements such as surge protection devices (SPDs), low-pass filters, and data and signal line protectors to prevent damage from surges and electrical line noise. To improve your facility’s uptime, you should consider uninterruptible power supplies (UPS), voltage regulators, and generators.
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<td>Low to high amplitude, low-current, and high-frequency disturbances. Conists of impulse (amplitude of up to 500 volts) and broadband noise (amplitude of millivolts to several volts).</td>
<td>Radiotron transmission</td>
<td>Low-pass filter or Active Tracking Filter</td>
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<td>Transients and impulses</td>
<td>High voltage/high current, low frequency disturbance. Amplitude of 50 to 1000 volts in half cycle. Duration is typically less than 1 millisecond.</td>
<td>Switching transients out of phase. Normal computer operation.</td>
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<td>High-voltage conditions on one or more phases. Voltage below 90% of nominal voltage. Duration of 1/2 to 1 minute.</td>
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<td>Voltage Dip</td>
<td>Voltage sag conditions on one or more phases. Voltage between 95% and 105% of nominal voltage. Duration of 1/2 to 1 minute.</td>
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“Electronic rust” gradually eats away at the circuit traces...
The Importance Of Protecting Your Power (Continued)

Safety Agencies Recognize The Need For Power Quality Products


3.2.6.1 Surge: “If lightning strikes on or near overhead electric power or telephone line, a large current will be injected into or induced in the wires, and the current can do considerable damage both to the power and telecommunications equipment and to anything else that is connected to the system.”

3.4.3 “Surges can have many effects on equipment, ranging from no detectable effect to complete destruction… electronic devices can have their operation upset before hard failure occurs. The semiconductor junctions of electronic devices are particularly susceptible to progressive deterioration… few solid state devices can tolerate much more than twice their normal rating. Furthermore, data processing equipment can be affected by fast changes in voltage with relatively small amplitude compared to the hardware-damaging over-voltages … ”

For large surge currents, this diversion is best accomplished in several stages. The first diversion should be performed at the entrance to the building… a second protective device at the power panel …”

4.6.5 Potential impact of EMI: “Depending on the severity of the surge and the susceptibility of the equipment, three types of occurrences are possible… data disruption, hardware stress, and hardware destruction.”

4.6.5.1 EMI, Type I, signal-data disruption: “Signal-carrying circuits are susceptible to surge interference via conduction, inductive and capacitive coupling, and electromagnetic radiation.”

4.6.5.2 EMI, Type II, gradual hardware stress and latent failures: “A single lightning or switching surge often causes immediate, but not readily apparent physical damage to semiconductor devices. This damage then finally appears at some later time …”

4.6.5.3 EMI, Type III, immediate hardware destruction: “The third possible impact of surges is the immediate obvious and total destruction of hardware components in a single incident.”

7.2.4 Surge suppressors: “… Effective surge protection requires the coordinated use of large-capacity current-diverting devices at the service entrance followed by progressively lower voltage-clamping devices.”

8.6 Lightning/surge protection considerations: “… A listed and properly rated surge protective device should be applied to each individual or set of electrical conductors (e.g., power, voice, and data) penetrating any of the six sides forming a structure.”

8.6.1 Selection: “… Surge protective devices for three-phase, four-wire circuits are generally recommended to be connected in all combinations of line-to-line, line-to-neutral, line-to-ground, and neutral-to-ground.”

8.6.2 Installation: “… Recommended installation practice is for all lead lengths to be short and shaped to minimize open loop geometry between the various conductors … by twisting all the phase, neutral, and equipment grounding conductors together; and by avoiding any sharp bends and coils in the conductors.”

8.6.3 Service entrance surge protection: “Facilities housing electronic load equipment of any type should have service entrances equipped with … Category “C” surge protective devices, as specified in IEEE Std C62.41-1991.”

8.6.4 Premise electrical system surge protection: “… recommended that additional surge protective devices of listed Category “B” or Category “A,” as specified in IEEE Std C62.41-1991, be applied to downstream electrical switchboards and panelboards, and panelboards on the secondary side of separately derived systems if they support communications, information technology equipment, signaling, television, or other form of electronic load equipment.”

8.6.5 UPS system surge protection: “… It is recommended practice that both the input circuit to the UPS and the associated bypass circuits (including the manual bypass circuit) be equipped with effective Category ‘B’ surge protective device.”

8.6.6 Data/communication/telecommunication systems surge protection: “Electronic equipment containing both ac power and data cabling should also be properly protected via surge protective devices on both the ac power and data cables.”

8.6.8 Exterior building systems and piping lightning/surge protection: “All exterior mechanical systems (e.g., cooling towers, fans, blowers, compressors, pumps, and motors) … should be considered targets for a lightning strike. … it is recommended practice to individually provide surge protective device protection on both the power input and data circuits connected to all such equipment.”

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Power Quality Standards

Why We Need Standards

Technical standards are developed by panels of experts, and designed to be independent of proprietary products or specific vendors. These standards are then maintained and revised as needed by the organization that issues them (e.g., Underwriters Laboratories).

National and international product safety standards and guidelines are created to:

- Reduce risks to human health and safety.
- Improve the quality of manufactured goods and services.
- Promote interoperability, making it possible for equipment from one vendor to function efficiently in coordination with equipment from other vendors.
- Improve the efficiency of constructing and equipping industrial, medical, and commercial facilities.
- Result in consistent products and reliable manufacturing and safety processes.
- Improve environmental protection where standards-compliant products are installed.

Surge Suppression Standards Overview

When it comes to SPDs, specific standards are developed by Underwriters Laboratories (UL) and the National Fire Protection Association. Over the last several years, there have been many changes in the codes and standards for SPDs. The most significant are changes to UL 1449. There is also a new standard for safety, of surge protective devices (article 285), which involves changes to the National Electric Code.

This standard specifies the waveforms to be used in testing American-manufactured SPDs, defines terminology related to SPD manufacture and test procedures, establishes proper labeling for SPD products, and specifies required testing and minimum acceptable performance.

Previous versions of UL 1449 identified only two types of SPDs: permanently connected or cord-connected. The third edition of UL 1449 has combined all categories into a formal classification and identified them as four different types, each of which has consistent testing and application requirements. The most common SPDs generally fall into Type 1 and Type 2 categories.

- Type 1 SPDs are Secondary Surge Arresters and are installed between the secondary side of a service transformer and the primary side of a service entrance disconnect. They must have overcurrent protective devices either installed internally on the SPD or included with it. While these are primarily intended for installation before the main service disconnect, Type 1 SPDs can be installed in Type 2 and Type 4 locations such as distribution panels, end-use equipment, etc.

- Type 2 SPDs are intended to be connected on the secondary side of the main service disconnect. While some will have internal overcurrent protective components, Type 2 SPDs can rely on the service entrance overcurrent disconnect device for overcurrent protection. These can be installed in service equipment, distribution panels, and end-use equipment. Type 2 SPDs are permanently connected.

- Type 3 SPDs are intended to connect at least 33 feet from the service entrance; this does not include the length of the SPD conductors. These devices are cord-connected devices, and intended to be used in end-equipment locations. They can rely on external overcurrent protective devices for overcurrent protection. Type 3 SPDs that are cord-connected are required to comply with the leakage current requirements to ensure unwanted (objectional) currents are not injected on the ground conductor.

- Type 4 SPDs are component or assembly drives. They are incomplete in their construction or safety testing (e.g., limited-current abnormal overvoltage test, intermediate current tests) and are intended to be tested in the final assembly. Those that are incomplete in construction or testing have the identifying information noted in the requirements section of the manufacturer’s UL report. Unfortunately, there is no documentation of the additional testing requirements for a Type 4 SPD on the labeling or installation instructions. These can range from single components (MOV, SAD) to complex devices intended for installation into distribution equipment (panel boards, switchboards, etc.).

In addition to the new categorization, ANSI/UL 1449 Third Edition specifies that surge suppression products formerly identified as Transient Voltage Surge Suppressor (TVSS) will be called Surge Protective Devices (SPD). It modified the Suppressed Voltage Rating (SVR) test from 6kV, 500A to 6kV, 3,000A, which represents six times more surge current. And let-through voltage is now termed the Voltage Protection Rating (VPR).

There’s also a Nominal Discharge Current rating up to 20kA. This is part of the Voltage Protection Rating test and is a measure of the SPD’s endurance capability. Manufacturers will choose the applicable rating and show the data on literature, specifications, and products.

Additional important UL standards addressing surge protection include:

UL 1283: Electromagnetic Interference Filters

This document establishes requirements for electromagnetic interference (EMI) filters. It covers filters installed on, or connected to, 600 V or lower potential circuits, 50-60 Hz, according to the National Electrical Code (NEC). These factory-installed filters are used to attenuate unwanted radio frequency (RF) signals, such as noise or interference generated from electromagnetic sources. These filters consist of capacitors and inductors used alone or in combination with each other and may be provided with resistors. This category does not cover SPDs or EMI filters for outdoor use, but does include:

- Cord-connected filters – these are provided with a supply cord that has an attachment plug that connects the filter to a branch circuit receptacle. It also has a receptacle for distributing the filtered voltage to an external load (an appliance or other equipment).
- Direct plug-in filters – these have blades at the filter body that plug directly into a 15A, 120 V branch circuit receptacle. Like the cord-connected filter, it includes a receptacle for distribution of the filtered voltage to an external load (an appliance or other equipment).
- Facility filters – these are installed as part of the electrical service, feeder, or branch circuitry of a building wiring system.

UL 497 Series: Protectors For Fire Alarm Signaling Circuits

This establishes performance standards and testing procedures for enclosures, corrosion protection, field-wiring connections, and components of SPDs, as well as product labeling and installation instructions.
Why We Need Standards

Technical standards are developed by panels of experts, and designed to be independent of proprietary products or specific vendors. These standards are then maintained and revised as needed by the organization that issues them (e.g., Underwriters Laboratories).

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There’s also a Nominal Discharge Current rating up to 20kA. This is part of the Voltage Protection Rating test and is a measure of the SPD’s endurance capability. Manufacturers will choose the applicable rating and show the data on literature, specifications, and products.

Additional important UL standards addressing surge protection include:

- UL 1283: Electromagnetic Interference Filters

This document establishes requirements for electromagnetic interference (EMI) filters. It covers filters installed on, or connected to, 600 V or lower potential circuits, 50-60 Hz, according to the National Electrical Code (NEC). These factory-installed filters are used to attenuate unwanted radio frequency (RF) signals, such as noise or interference generated from electromagnetic sources. These filters consist of capacitors and inductors used alone or in combination with each other and may be provided with resistors. This category does not cover SPDs or EMI filters for outdoor use, but does include:

- Cord-connected filters – those are provided with a supply cord that has an attachment plug that connects the filter to a branch circuit receptacle. It also has a receptacle for distributing the filtered voltage to an external load (an appliance or other equipment).
- Direct plug-in filters – these have blades at the filter body that plug directly into a 15A, 120 V branch circuit receptacle. Like the cord-connected filter, it includes a receptacle for distribution of the filtered voltage to an external load (an appliance or other equipment).
- Facility filters – these are installed as part of the electrical service, feeders, or branch circuitry of a building wiring system.

UL 497 Series: Protectors For Fire Alarm Signaling Circuits

This establishes performance standards and testing procedures for enclosures, corrosion protection, field-wiring connections, and components of SPDs, as well as product labeling and installation instructions.

Power Quality Standards

- Type 1 SPDs are Secondary Surge Arresters and are installed between the secondary side of a service transformer and the primary side of a service entrance disconnect. They must have overcurrent protective devices either installed internally on the SPD or included with it. While these are primarily intended for installation before the main service disconnect, Type 1 SPDs can be installed in Type 2 and Type 4 locations such as distribution panels, end-use equipment, etc.
- Type 2 SPDs are intended to be connected on the secondary side of the main service disconnect. While some will have internal overcurrent protective components, Type 2 SPDs can rely on the service entrance overcurrent disconnect device for overcurrent protection. These can be installed in service equipment, distribution panels, and end-use equipment. Type 2 SPDs are permanently connected.
- Type 3 SPDs are intended to connect at least 33 feet from the service entrance; this does not include the length of the SPD conductors. These devices are cord-connected devices, and intended to be used in end-equipment locations. They can rely on external overcurrent protective devices for overcurrent protection. Type 3 SPDs that are cord-connected are required to comply with the leakage current requirements to ensure unwanted (objectional) currents are not injected on the ground conductor.
- Type 4 SPDs are component or assembly drives. They are incomplete in their construction or safety testing (e.g., limited-current abnormal overvoltage test, intermediate current tests) and are intended to be tested in the final assembly. Those that are incomplete in construction or testing have the identifying information noted in the requirements section of the manufacturer’s UL report. Unfortunately, there is no documentation of the additional testing requirements for a Type 4 SPD on the labeling or installation instructions. These can range from single components (MOV, SADs) to complex devices intended for installation into distribution equipment (panel boards, switchboards, etc.).

In addition to the new categorization, ANSI/UL 1449 Third Edition specifies that surge suppression products formerly identified asTransient Voltage Surge Suppressors (TVSS) will be called Surge Protective Devices (SPDs). It modified the Suppressed Voltage Rating (SVR) test from 6kV, 500A to 6kV, 3,000A, which represents six times more surge current. And let-through voltage is now termed the Voltage Protection Rating (VPR).

National and international product safety standards and guidelines are created to:
- Reduce risks to human health and safety.
- Improve the quality of manufactured goods and services.
- Promote interoperability, making it possible for equipment from one vendor to function efficiently in coordination with equipment from other vendors.
- Improve the efficiency of constructing and equipping industrial, medical, and commercial facilities.
- Result in consistent products and reliable manufacturing and safety processes.
- Improve environmental protection where standards-compliant products are installed.

This standard specifies the waveforms to be used in testing American-manufactured SPDs, defines terminology related to SPD manufacture and test procedures, establishes proper labeling for SPD products, and specifies required testing and minimum acceptable performance.

Previous versions of UL 1449 identified only two types of SPDs: permanently connected or cord-connected. The third edition of UL 1449 has combined all categories into a formal classification and identified them as four different types, each of which has consistent testing and application requirements. The most common SPDs generally fall into Type 1 and Type 2 categories.
Power Quality Standards (Continued)

Institute Of Electrical And Electronics Engineers (IEEE) Standards

The IEEE develops standards and guidelines for recommended practices for a broad range of industries, including biomedical/healthcare, information technology and assurance, power and energy, telecommunications, and transportation.

IEEE has a trilogy of guides that address the surge environment, characterize surges, and define surge testing in low-voltage AC power circuits.


This first guide provides comprehensive information about surges and the environment in which they occur. It describes the surge voltage, surge current, and temporary overvoltages (TOV) environment in low-voltage (up to 1000V root mean square [RMS]) AC power circuits. It is a reference for the second document, which describes the surge environment.

IEEE C62.41.2 (2002): Recommended Practice On Characterization Of Surges In Low-Voltage (1000V And Less) AC Power Circuits

This second guide presents recommendations for selecting surge waveforms, and the amplitudes of surge voltages and currents used to evaluate equipment immunity and performance of SPDs. Its recommendations are based on the location within a facility, power line impedance to the surge, total wire length, proximity, type of electrical loads, wiring quality, and more.

The document describes typical surge environments and does not specify a performance test. The waveforms included in the document are meant as standardized waveforms that can be used to test protective equipment.

IEEE C62.45: Recommended Practice On Surge Testing For Equipment Connected To Low-Voltage (1000V And Less) AC Power Circuits

This third guide in the trilogy focuses on surge testing procedures using simplified waveform representations (described in IEEE C62.41.2) to obtain reliable measurements and enhance operator safety. This guide provides background information that helps determine whether equipment or a circuit can adequately withstand surges. However, it does not address signal and data lines, or specify the withstand levels that might be assigned to specific equipment.

4.4.1.2.1 Lightning-induced surges: "... As many as 40 return strikes have been observed (see McCann [B4]). Their current range from a few hundred amperes to more than 500 kA as shown in Figure 4.9. In much of North America, 20 kA to 40 kA is the value that is often used to estimate typical lightning current conditions. The typical strike durations last 50μs to 100μs.”

7.2.4 Surge suppressors: "... Effective surge protection requires the coordinated use of large-capacity current-diverting devices at the service entrance followed by progressively lower voltage-clamping devices.”

8.1 Recommended design/installation practices: “Desired performance of electronic load equipment typically depends on various items, such as the proper selection and arrangement of the electrical distribution system, the proper selection and installation of electrical distribution equipment, the proper selection and installation of a grounding system for both the electrical power system and the electronic load equipment, and the proper selection and application of surge protective devices (SPDs).”

8.6.2 Installation: “... Recommended SPD installation practice is for all lead lengths to be short and shaped to minimize open-loop geometry between the various conductors... by twisting all the phase, neutral, and equipment grounding conductors together; and by avoiding any sharp bends and coils in the conductors.”

9L.1.3.1 Damage caused by SPDs: “... SPD overcurrent protection is the most important (and often overlooked) aspect of reliability and safety. Any SPD component can fail, open or shorted, due to surge voltage stress or temporary overvoltage (TOV) stress (such as a lost neutral). This TOV stress causes many more SPD failures than actual transient surges. The result may be smoke, fire, or explosion for some of the metal-oxide varistor (MOV) based SPDs. This occurs regularly in real world SPD installations, but can be controlled with component level fusing or thermal fusing. Done properly, this fusing will interrupt excessive continuous current through the component, interrupt available utility fault current, and yet pass transient current. Component level fusing in an SPD can provide a fail-safe system preventing catastrophic failure or complete loss of protection.”

National Electrical Code (NEC) And National Fire Protection Association (NFPA)

Developed by the NFPA, the NEC was established in 2002 to address electrical safety in the workplace. While the code is updated every three years, not all states and municipalities have adopted the same version of the NEC. The 2005 revision of the NEC had two types of SPDs: secondary surge arrestors and transient voltage surge suppressors (now called SPDs).

Article 285

When UL and the American National Standards Institute (ANSI) adopted the Standard for Safety, Surge Protective Devices, some changes were required to the NEC. In the 2008 revision of the NEC, you’ll now find the requirements for connecting all SPDs rated 1000V or less to the electrical distribution system of a facility. The SPD’s location ranges from secondary terminals of the service transformer to end-use equipment.

The standard addresses surge protection to help electricians properly install hardwired SPDs. It also provides guidelines for electrical inspectors to ensure proper safety and fault current coordination where SPDs are installed.

Article 285.6

This requires every SPD to be marked with a short circuit current rating (SCCR). This rating must be equal to or greater than the available fault current present at the point where the SPD is installed on the system.

This document provides manufacturers and specifiers with guidelines to describe and compare low-voltage (less than 1000V RMS) SPDs using a uniform terminology and formats. It also outlines essential and measurable SPD parameters using off-the-shelf testing equipment and reference established standards defined by the IEEE and American National Standards Institute (ANSI)/UL.

Article 285.6 consists of three sections:

• Specifications, introduction, and definitions.
• Selection and application criteria.
• Test and evaluation procedures.

Please note that these are guidelines only; this document does not introduce new standards or test methodologies, nor does it define an extensive vocabulary for SPDs.

Article 285.21

NEC Article 285.21(B) requires surge suppressor connecting conductors to be at least #14 copper or #12 aluminum. According to the National Electric Code, Type 1 SPDs should be installed as follows:

• Type 1 SPDs are permitted to be connected to the supply side of the service disconnect as permitted in 230.82(4) or
• Type 1 SPDs are permitted to be connected in Type 2 locations as specified in 285.24.

When installed at the services, the grounding conductor of a Type 1 SPD shall be connected to one of the following:

(1) Grounded service conductor
(2) Grounded electrode conductor
(3) Grounding electrode for service

(4) Equipment grounding terminal in the service equipment

Type 2 SPDs (ULPE, HA Series) should be installed in accordance with 285.24.

• Service Supplied Building or Structure: Type 2 SPDs shall be connected anywhere on the load side of a service disconnect overcurrent device required in 230.91, unless installed in accordance with 230.82(B).
• Feeder-Supplied Building or Structure: Type 2 SPDs shall be connected at the building or structure anywhere on the load side of the first overcurrent device at the building or structure.
• Separately Derived System: Type 2 SPDs shall be connected on the load side of the first overcurrent device in a separately derived system.

Article 285.23

This identifies the applicable installation locations for a Type 1 SPD. These are allowed to be installed on the supply side or line side of a service disconnect. When these SPDs are installed on the supply side, the grounding conductor must be connected to either the grounded service conductor, the grounding electrode conductor, the grounding electrode for the service, or the grounding terminal in the service equipment.

(Continued)
Power Quality Standards (Continued)

Institute Of Electrical And Electronics Engineers (IEEE) Standards

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8.6.2 Installation: “… Recommended SPD installation practice is for all lead lengths to be short and shaped to minimize open-loop geometry between the various conductors... by twisting all the phase, neutral, and equipment grounding conductors together; and by avoiding any sharp bends and coils in the conductors.”

9L.1.3 Damage caused by SPDs: “… SPD overcurrent protection is the most important (and often overlooked) aspect of reliability and safety. Any SPD component can fail, open or shorted, due to surge voltage stress or temporary overvoltage (TOV) stress (such as a lost neutral). This TOV stress causes many more SPD failures than actual transient surges. The result may be smoke, fire, or explosion for some of the metal-oxide varistor (MOV) based SPDs. This occurs regularly in real world SPD installations, but can be controlled with component level fusing or thermal fusing. Done properly, this fusing will interrupt excessive current continuous through the component, interrupt available utility fault current, and yet pass transient current. Component level fusing in an SPD can provide a fail-safe system preventing catastrophic failure or complete loss of protection.”

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The standard addresses surge protection to help electricians properly install hardwired SPDs. It also provides guidelines for electrical inspectors to ensure proper safety and fault current coordination where SPDs are installed.

Article 285.6

This requires every SPD to be marked with a short circuit current rating (SCCR). This rating must be equal to or greater than the available fault current present at the point where the SPD is installed on the system.

This document provides manufacturers and specifiers with guidelines to describe and compare low-voltage (less than 1000V RMS) SPDs using a uniform terminology and formats. It also outlines essential and measurable SPD performance test methodologies, or test methodologies, to introduce new standards or test methodologies, nor does it define an extensive vocabulary for SPDs.

Article 285.21

NEC Article 285-21(b) requires surge suppressor connecting conductors to be at least #14 copper or #12 aluminum.

According to the National Electric Code, Type 1 SPDs should be installed as follows:

• Type 1 SPDs are permitted to be connected to the supply side of the service disconnect as permitted in 230.82(4) or

• Type 1 SPDs are permitted to be connected in Type 2 locations as specified in 285.24.

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(2) Grounded electrode conductor

(3) Grounding electrode for service

(4) Equipment grounding terminal in the service equipment

Type 2 SPDs (ULPE, HA Series) should be installed in accordance with 285.24.

• Service Supplied Building or Structure: Type 2 SPDs shall be connected anywhere on the load side of a service disconnect overcurrent device required in 230.91, unless installed in accordance with 230.82(B).

• Feeder-Supplied Building or Structure: Type 2 SPDs shall be connected at the building or structure anywhere on the load side of the first overcurrent device at the building or structure.

• Separately Derived System: Type 2 SPDs shall be connected on the load side of the first overcurrent device in a separately derived system.

Article 285.23

This identifies the applicable installation locations for a Type 1 SPD. These are allowed to be installed on the supply side or line side of a service disconnect. When these SPDs are installed on the supply side, the grounding conductor must be connected to either the grounded service conductor, the grounding electrode conductor, the grounding electrode for the service, or the grounding terminal in the service equipment.
National Electrical Code (NEC) and National Fire Protection Association (NFPA) (Continued)

Article 285.24
This identifies the application requirements and installation locations for a Type 2 SPD. These SPDs are permitted to be installed only on the load side of the service disconnect overcurrent device. In installations with multiple buildings or structures, a Type 2 SPD can only be installed downstream of the first overcurrent device. On separately derived systems, these SPDs must be connected on the load side of the first overcurrent device.

National Fire Protection Association (NFPA) – 780
Lightning Protection Code NFPA 780 addresses the protection requirements for ordinary structures, miscellaneous structures, special occupancies, industrial and operating environments, etc. It requires that devices suitable for protecting the structure be installed on electric and telephone service entrances, and on radio and television antenna lead-ins.

International Electrotechnical Commission (IEC)
As the primary trade organization for all electrical, electronic, and related technologies, the IEC publishes and assesses compliance with manufacturing and safety standards that form the basis for standards in many countries.

IEC standards are drafted by experts from a minimum of five countries, and are iteratively drafted and reviewed. The prevalent set of standards includes:

• Technical Committee 65 WG4, for EMC of industrial process control equipment. This working group has produced and continues to update a family of documents that addresses surge immunity, fast transients, and ESDs (IEC 61000-4-4).

• Technical Committee 77, for EMC. Within the broad scope of all possible disturbances to EMC, this committee develops documents related to conducted disturbances. These documents are generic descriptions and classifications of the environment, leading to the specification of immunity tests in general. Detailed test specifications for equipment are left to product committees.

IEC 61643 addresses surge protective devices connected to low-voltage power distribution systems. This is applicable to devices for surge protection against indirect and direct effects of lightning or other transient overvoltages. These devices are packaged to be connected to 50/60 Hz AC and DC power circuits, and equipment rated up to 1000V RMS or 1500VDC Performance characteristics, standard methods for testing, and ratings are established for these devices that contain at least one nonlinear component that is intended to limit surge voltages and divert surge currents. IEC 61643-1 Edition 2.0 (01/2005) defines the characteristics of and tests for SPD connected to low voltage distribution systems. The test is similar in many ways to UL’s 1449 third edition test; however, there are some key differences worth noting. The following compares the two test standards and identifies the standard with the best approach:

ANSI/UL 1449 Third Edition Versus IEC 61643-1 – Key Differences in Testing

The following examines a few of the key differences between Underwriters Laboratory’s required test for surge protective devices (SPDs), ANSI/UL 1449 Third Edition and the International Electrotechnical Commission (IEC) required test for SPDs, IEC 61643-1.

Short Circuit Current Rating (SCCR): The capacity of current with which the tested SPD can withstand at the terminals where connected, without breaching the enclosure in any way.

• UL: Tests the full product at twice the nominal voltage to see if the entire product is completely offline. The entire product (as shipped) is tested; including metal oxide varistors (MOVs).

• IEC: Test only looks at the terminals and the physical connections to determine if they are robust enough to handle the fault. MOVs are replaced with a copper block and a manufacturer’s recommended fuse is placed in line (external to the device).

Best Practice: Underwriters Laboratory – Recognizing the differences between complete SPDs and those intended for use within an additional enclosure or other piece of equipment is a critical distinction. Under technical considerations, UL sets conditions of acceptability for recognized components; including wire size, enclosure size, and spacing to name a few. Components (or recognized) devices should be evaluated in their final shipped form, or at the very least, the buyer should be made aware that the entire device has not been tested in its final form. UL’s designation allows for this.

Imax: Per IEC 61643-1 – The crest value of a current through the SPD having an 8/20 wave shape and magnitude according to the test sequence of the class I operating duty test.

• UL: Does not recognize the need for an Imax test.

• IEC: An operating duty cycle test is used to ramp up to an Imax point (determined by the manufacturer). This is meant to find “blind points” within the design when subjected to a high level impulse. This is conducted as a life expectancy or robustness test. The fuse needs to withstand Imax, and the test checks thermal stability of the SPD (after each duty cycle impulse bringing the SPD up to its maximum continuous operating voltage MCOV) and its physical condition.

Best Practice: IEC – Trying to determine the I maximum point of an SPD is appropriate considering the purpose of the device is to operate within a (potentially) high-surge environment. Products are specified and marketed with an Imax rating. One area of improvement is to determine the level of degradation as a means of determining the status of the internal components. The current requirements offer no pre/post strike to check. Surge test data should be required in lieu of the IEC duty cycle test.

I nominal: The crest value of the current through the SPD having a current waveform of 8/20.

• UL: I nominal test is similar to the IEC’s, however, the I nominal results do not link to a Up value (a value used internationally for electrical coordination). Instead, UL uses an I nominal to determine a product’s Voltage Protection Rating (VPR). Levels are limited to a maximum of 20 kA. The SPD remains functional after 15 surges.

• IEC: Does not limit I nominal testing to 20kA, however, the manufacturer’s selected In level is used to get a Up value, a value considered to be the protective performance of the SPD. This value is used for electrical coordination (ratings of building wire, equipment).

Therefore the goal of the manufacturer is to try to attain the highest I nominal level with the lowest Up results. Many manufacturers opt to only test as high as 20 kA so they will appear to have a low Up.

Best Practice: Both versions have some positives and some negatives; UL’s approach allows for a greater degree of comparison between products, however, the SPD category type and I nominal level need to be considered as part of the comparison. The IEC recognizes levels beyond 20 kA, which is in line with UL 96A-2007, “Surge Protective Devices (SPDs) rated 20 kA or more nominal discharge current (In),” however, higher test levels should be examined with cascaded devices, especially at the service entrance as a way of simulating a “real world” installation (and IEEE Emerald Book recommendation).

Class versus category

• UL: Type designation is a location designator with a difference to the way it is nominalized (for device which provides SCCR needs to be included and survive when doing I nominal testing).

• IEC: Designates certain tests as a class I, II, or III. Class designation between I and II has to do with the impulse applied – Class I, an I imp test (10x350) and a class II – 8 x 20 μs.

Best Practice: The IEC designates certain tests as a class I, II, or III and can be confused with UL’s Type I, II, III, or IV designations. There is some validity to both identifying the product’s approved installation location (UL) and applying a more robust impulse/waveform to those products that will be installed in harsher locations (IEC).

Waveforms:
A graph of an impulse wave that shows its shape and changes in amplitude with time.

• UL: Recognizes the 8 x 20 μs waveform.

• IEC: The IEC incorporates 2 waveforms into their test, the 8 x 20 μs which is used for class I testing to represent surges induced on power lines. And the 10 x 350 μs waveform which is used for class III testing that represents external or lightning currents (due to building or power line strikes). The IEC also uses other ringwave type waveforms for point of use (class II) tests.

Best Practice: IEC – Many variables affect the waveform/energy an SPD is likely to experience. Knowledge of the SPD’s performance under different scenarios is advantageous (close strike, near strike, distant event, internally generated noise, etc). The IEEE acknowledges various wave forms.
Power Quality Standards (Continued)

National Electrical Code (NEC) and National Fire Protection Association (NFPA) (Continued)
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This identifies the application requirements and installation locations for a Type 2 SPD. These SPDs are permitted to be installed only on the load side of the service disconnect overcurrent device. In installations with multiple buildings or structures, a Type 2 SPD can only be installed downstream of the first overcurrent device. On separately derived systems, these SPDs must be connected on the load side of the first overcurrent device.

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Best Practice: Underwriters Laboratory – Recognizing the differences between complete SPDs and those intended for use within an additional enclosure or other piece of equipment is a critical distinction. Under technical considerations, UL sets conditions of acceptability for recognized components; including wire size, enclosure size, and spacing to name a few. Components (or recognized devices) should be evaluated in their final shipped form, or at the very least, the buyer should be made aware that the entire device has not been tested in its final form. UL’s designation allows for this.

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• UL: Recognizes the 8 x 20 μs waveform.
• IEC: The IEC incorporates 2 waveforms into their test, the 8 x 20 μs which is used for class II testing to represent surges induced on power lines. And the 10 x 350 μs waveform which is used for class III testing that represents partial or direct lightning currents (due to building or power line strikes). The IEC also uses other ringwave type waveforms for point of use (class III) tests.

Best Practice: IEC – Many variables affect the waveform energy an SPD is likely to experience. Knowledge of the SPD’s performance under different scenarios is advantageous (close strike, near strike, distant event, internally generated noise, etc.). The IEEE acknowledges various wave forms.
Should You Consider A Hybrid Design?

Hybrid surge protection devices combine at least two types of surge components – typically MOVs and SADs. An effective hybrid design limits the amount of surge current through the MOV module, sharing the surge. When properly designed, a hybrid SPD will outperform an SPD that uses only MOVs. However, an effective hybrid SPD requires significant engineering.

Some of the pitfalls of a hybrid approach include:

• Designs with all components on-line at all times can result in component failure during surge or overvoltage events.
• Some components may not be appropriate for the application of the end unit.
• Some manufacturers may claim a capacitor constitutes a hybrid design, but this may not be the case.

The key to a successful hybrid design is to maximize each individual component’s strengths and transition away from the weaknesses.

A Quick Overview Of Protective Devices

Within the three types of protection described above, there are many devices designed for specific applications.

One-Port Parallel-Connected Devices

Designed to limit high-voltage spikes to a level acceptable to most electronic equipment. These are considered the first line of defense, using components placed in parallel with the line. These devices are typically installed at service entrances, larger distribution panels, branch panel boards, and motor control centers.

Surge Protective Device (SPD)

SPDs are parallel-connected, non-linear protective devices for limiting surge voltages on equipment by discharging, bypassing, or diverting surge current. They prevent continued flow of follow current and can repeat these functions as specified.

Domestically, the term SPD is used to describe both Surge Arresters and Transient Voltage Surge Suppressors (TVSS). However, internationally, the term SPD is synonymous with the IEC 61643-1 definition that describes a surge component, not a stand-alone device. This component has no short-circuit current rating so it requires additional fusing and must be mounted inside an enclosure.

Integral SPD Issues

Today, all the major electrical panel manufacturers offer some form of surge protection, integrated directly within their power distribution or branch panels. Product performance, ease of installation, and less wall space are some of the advantages that have been traded over externally mounted surge devices. While there may be some credibility to these claims, the end user should also be aware of the risks involved with integrating SPDs directly into the power distribution equipment.

The first risk is the failure of the SPD within the distribution equipment. When SPDs fail and the internal MOVs reach an end-of-life condition, they can create a significant amount of power which is dissipated in the form of heat. This heat can be so intense that it can cause significant collateral damage to the distribution equipment.

Additionally, when that failed SPD needs to be repaired in the field, the service technician has two options: remove all power from the panel; or remove only the power feeding the SPD, leaving the rest of the panel energized. The first option, albeit the safest, may not be feasible if the connected loads cannot be shut off due to their criticality. Then, considerable measures need to be taken to work in a live panel. Special gear must be worn and tools used to protect the technician from shock, electrical faults, and potential arc flash.

Performance is another major area of concern when integrating an SPD. Even though performance is touted as an advantage over externally mounted SPDs, in reality it may be far worse. For safety reasons, UL dictates the location of the SPD within the gear. This can result in the device being mounted a long distance away from the connection points. The neutral bus bar for example may be as far as four feet away from the installed SPD. This would cause the performance to be considerably worse than an optimally placed, externally mounted SPD.

### Types Of Protection

There are three key types of power quality devices: SPDs, filtering/line conditioning units, and data/signal line devices. Each of these has a specific role to play and delivers a certain kind of protection. These devices cannot create or destroy energy – they manage it. For example, they can divert high-energy impulses from sensitive equipment or dissipate them in the form of heat.

### AC Power Protection

A graphical representation of a hybrid surge protection device is shown. The diagram illustrates the components and their interactions during a surge event.
Should You Consider A Hybrid Design?

Hybrid surge protection devices combine at least two types of surge components – typically MOVs and SADs. An effective hybrid design limits the amount of surge current through the SAD module to an acceptable level and diverts the remaining surge current through the MOV module – sharing the surge. When properly designed, a hybrid SPD will outperform an SPD that uses only MOVs. However, an effective hybrid SPD requires significant engineering.

Some of the pitfalls of a hybrid approach include:

- Designs with all components on-line at all times can result in component failure during surge or overvoltage events.
- Some components may not be appropriate for the application of the end unit.
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Two-Port (Series-Connected) Devices

Filtering line conditioning units are designed to provide clean AC power by helping to eliminate or dramatically reduce high-voltage transients and low-voltage electrical line noise that degrade microprocessor-based equipment. They are generally applied in front of or in series with critical load or industrial equipment, such as PLCs and motion control systems.

Active Tracking Filter™ (ATF)

Active Tracking Filters™ offer a comprehensive level of protection by providing clean AC power for highly sensitive equipment. Composed of series inductors, shunt-absorbing components, and fast-reacting surge protective components, these hybrid devices eliminate low-level noise as well as protect against destructive high-energy events. Ideal applications include microprocessor-based equipment such as programmable logic controllers, motion control equipment, broadcast transmitters, and computers.

Harmonic Filter

A harmonic filter is also a series-connected filter, but is designed to attenuate frequencies that are a multiple of the fundamental 60 Hz frequency, such as the 5th, 7th, and 9th harmonic.

Voltage Regulator

Voltage regulators control the output voltage, eliminating voltage sags and swells in the input voltage that lasts from 15 milliseconds to one-half second. They are typically inexpensive, feedback-controlled transformers.

Line Conditioner

A line conditioner contains multiple protection devices in one package to provide, for example, electrical noise isolation and voltage regulation.

Uninterruptible Power Supply (UPS)

Non-mechanical (static) uninterruptible power supplies provide protection against all power disturbances. An on-line or “true” UPS converts a utility’s AC power to DC and uses this to charge a battery and to power an inverter that delivers power to the critical load. An off-line UPS, called a standby power supply (SPS), supplies the utility power directly to the critical load and transfers the load to a battery-powered inverter to deliver power during outages.

What is the difference between series connected filters and parallel connected surge protectors?

Parallel devices protect equipment from high-energy transient diversion and impulse clamping from internally and externally generated transients. These SPDs provide protection from spikes by limiting let-through voltage that could destroy downstream equipment. Series filter technology protects from low-voltage noise caused by everyday events, such as turning on appliances or motors, which cause long-term degradation of equipment. Filter products are typically SPDs combined with inductors, capacitors, and resistors.

Parallel connected and series connected Active Tracking Filters™ (ATF), both are effective power quality devices. This illustration shows connection diagrams for both types of systems. The parallel connected device is tapped off the load side of a service panel. Typically, a dedicated circuit breaker in the service or branch panel is used as the means of connection. On the other hand, the series connected filter, also wired to the load side of the service panel, is directly in line with the protected equipment.

Series Connected Filter

Parallel SPDs protect against high-energy transients by limiting or clamping the surge voltage and diverting transient surge currents away from the load. The technologies most commonly used are gas discharge tubes (GDT), silicon avalanche diodes (SADs) and metal oxide varistors (MOVs). SPDs are voltage-dependent only and are sized based on the surge current rating on the device. On the other hand, series connected Active Tracking Filters™ use a low-pass circuit to protect downstream equipment from high-frequency electrical line noise. ATFs are load dependent, which means that the series element is sized to handle the maximum current draw of the load. Inductors, together with the capacitors and resistors, form a circuit capable of absorbing a large bandwidth of noise.

Using Surge Suppression To Control High-Voltage Transients

High-voltage transients, such as those caused by lightning or grid switching, are relatively rare. However, they get more attention than low-voltage events because their ability to cause catastrophic damage is so dramatic. Surge suppressors provide protection from spikes by limiting let-through voltage that could destroy downstream equipment.

Applications: Ideally installed at service entrances and larger distribution panels.

Surge Suppression Before

High-voltage spikes appearing on 120V, 60 Hz sine wave.

Surge Suppression After

Surge suppression limits high-voltage spikes, it’s your first line of defense for power quality.

Using Active Tracking Filters™ To Control Low- And High-Voltage Transients

Low-voltage noise is caused by everyday events such as turning on appliances or motors. Although less dramatic than high-voltage transients, the long-term effect of these frequent disturbances can be just as damaging. Filtering systems, such as our Active Tracking Filters™, provide clean AC power by eliminating lower-voltage noise.

Applications: Ideally installed at specific sensitive loads or branch panels, or on individual pieces of equipment.
Surge Protection Devices (Continued)

- **Two-Port (Series-Connected) Devices**
  Filtering/line conditioning units are designed to provide clean AC power by helping to eliminate or dramatically reduce high-voltage transients and low-voltage electrical line noise that degrade microprocessor-based equipment. They are generally applied in front of or in series with critical load or industrial equipment, such as PLCs and motion control systems.

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  Active Tracking Filters™ offer a comprehensive level of protection by providing clean AC power for highly sensitive equipment. Composed of series inductors, shunt-absorbing components, and fast-reacting surge protective components, these hybrid devices eliminate low-level noise as well as protect against destructive high-energy events. Ideal applications include microprocessor-based equipment such as programmable logic controllers, motion control equipment, broadcast transmitters, and computers.

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  A harmonic filter is also a series-connected filter, but is designed to attenuate frequencies that are a multiple of the fundamental 60 Hz frequency, such as the 5th, 7th, and 9th harmonic.

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  Voltage regulators control the output voltage, eliminating voltage sags and swells in the input voltage that lasts from 15 milliseconds to one-half second. They are typically inexpensive, feedback-controlled transformers.

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  A line conditioner contains multiple protection devices in one package to provide, for example, electrical noise isolation and voltage regulation.

- **Uninterruptible Power Supply (UPS)**
  Non-mechanical (static) uninterruptible power supplies provide protection against all power disturbances. An on-line or “true” UPS converts a utility’s AC power to DC and uses this to charge a battery and to power an inverter that delivers power to the critical load. An off-line UPS, called a standby power supply (SPS), supplies the utility power directly to the critical load and transfers the load to a battery-powered inverter to deliver power during outages.

- **What is the difference between series connected filters and parallel connected filters?**
  Parallel devices protect equipment from high-energy transient diversion and impulse clamping from internally and externally generated transients. These SPDs provide protection from spikes by limiting let-through voltage that could destroy downstream equipment. Series filter technology protects from low-voltage noise caused by everyday events, such as turning on appliances or motors, which cause long-term degradation of equipment. Filter products are typically SPDs combined with inductors, capacitors, and resistors. Parallel connected and series connected Active Tracking Filters™ (ATF) both are effective power quality devices. This illustration shows connection diagrams for both types of systems. The parallel connected device is tapped off the load side of a service panel. Typically, a dedicated circuit breaker in the service or branch panel is used as the means of connection. On the other hand, the series connected filter, also wired to the load side of the service panel, is directly in line with the protected equipment.

- **Using Surge Suppression To Control High-Voltage Transients**
  High-voltage transients, such as those caused by lightning or grid switching, are relatively rare. However, they get more attention than low-voltage events because their ability to cause catastrophic damage is so dramatic. Surge suppressors provide protection from spikes by limiting let-through voltage that could destroy down-stream equipment.

  **Applications:** Ideally installed at service entrances and larger distribution panels.

- **Using Active Tracking Filters™ To Control Low- And High-Voltage Transients**
  Low-voltage noise is caused by everyday events such as turning on appliances or motors. Although less dramatic than high-voltage transients, the long-term effect of these frequent disturbances can be just as damaging. Filtering systems, such as our Active Tracking Filters™, provide clean AC power by eliminating lower-voltage noise.

  **Applications:** Ideally installed at specific sensitive loads or branch panels, or on individual pieces of equipment.

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**Surge Suppression Before and After**

**High-voltage spikes appearing on 120V, 60 Hz sine wave.**

**Surge suppression limits high-voltage spikes. It’s your first line of defense for power quality.**

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**Filtering Before and After**

**Active Tracking Filtering™ eliminates potentially damaging noise, providing clean and reliable AC power.**

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**High-voltage Transients**

**Before**

**Active Tracking Filtering™ virtually eliminates high-voltage transients.**

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**High-Voltage Transients (High-frequency noise) appearing on 120V, 60 Hz sine wave.**

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**Lower-voltage transients appearing on 120V, 60 Hz sine wave.**

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**Series Connected Filter**

- **Before**
  - High-voltage transients
  - Low-Voltage Transients

- **After**
  - High-voltage transients
  - Low-Voltage Transients
Surge Protection Devices (Continued)

DC Low Voltage Surge Protection

Low voltage surge protection devices safeguard the integrity of data networks, communication systems, and video lines from dangerous "backdoor" transients and currents. A three-stage hybrid design approach is one method used to mitigate surges and "sneak currents" in order to reduce expensive equipment downtime.

DC Power Protection
Surge protection designed to protect the DC power going to cameras or other sensitive equipment generally used in the security industry.

Video Line Protection
Surge protection devices designed to protect camera, television or computer equipment from harmful surges that may be induced on to wires or cable lines. These devices may be used in the security, telecom or traffic industry.

Data Line Protection
Surge protection devices primarily designed to protect high-speed data transmission lines used for network communication systems. Data lines typically travel throughout a facility and sometimes even between buildings, leaving the system vulnerable to both externally and internally generated transients.

Signal Line Protection
Surge protection devices designed to protect signal lines from harmful surges. These devices are typically used in the telecom industry to protect analog and digital phone lines as well as intercom systems. Other applications may include security lines and traffic signal lines.

Components Of A Surge Protector

The surge components of an SPD begin to conduct once it experiences voltages above a predesigned threshold (e.g., in the event of a surge). The dangerous transient is suppressed or reduced to a level that is safe, but it's not totally removed. Components may include:

Metal Oxide Varistor (MOV) – A solid-state device that becomes conductive when the voltage across it exceeds a certain level. When the voltage exceeds the MOV's threshold, current flows through the MOV.

Advantages
• Cost
• Availability
• Usability
• Surge current capability

Disadvantages
• Energy capability
• TOV susceptibility
• Capacitance

Silicon Avalanche Diode (SAD) – A semiconductor device that normally acts as an open circuit, but changes to a short circuit when the trigger voltage exceeds a certain amount.

Advantages
• Clamping
• TOV susceptibility
• Usability
• Pulse power

Disadvantages
• Cost
• Availability
• Surge current

Gas Discharge Tubes (GDT) – A voltage switching device that has conductance properties that change very rapidly from open-circuit to quasi-short circuit when breakdown occurs and arc voltage occurs.

Advantages
• Surge current, TOV
• Pulse power
• Low capacitance

Disadvantages
• Clamping
• Usability
• Cost
• Follow current

Comparisons – Fuse Vs. PTC
Both provide a means of disconnect from high current.

Minimizing Electrical Youth

Surge Protection Devices

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Surge Protection Devices
### DC Low Voltage Surge Protection

Low voltage surge protection devices safeguard the integrity of data networks, communication systems, and video lines from dangerous “backdoor” transients and currents. A three-stage hybrid design approach is one method used to mitigate surges and “sneak currents” in order to reduce expensive equipment downtime.

#### Power Lines

- **Surge Protector**

#### Video Lines

- **Surge Protector**

#### Data Lines

- **Surge Protector**

#### Components Of A Surge Protector

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    - Pulse power
  
  - **Disadvantages**
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    - Surge current

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    - Surge current, TOV
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  - **Disadvantages**
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    - Usability
    - Cost
    - Follow current

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Surge Protection Devices (Continued)

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**Three-Stage Hybrid Signature Circuit**

- **In+**
- **In-**
- **Gas Tube**
- **SAD**
- **Out+**
- **Out-**

**Components Of A Surge Protector**

- **Diode** – A current limiting device, used in an electric circuit, containing a conductor that melts under heat produced by an excess current, thereby opening the circuit.

- **PTC (Positive Temperature Coefficient)** – Thermally sensitive resistors manufactured from semiconductor material. As the temperature approaches a predetermined value, the resistance of the part begins to rise rapidly, and eventually levels off. Thermal expansion of the material reduces the current to a safer level.

**Comparisons – Fuse Vs. PTC**

Both provide a means of disconnect from high current.

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**Surge Protection Devices (Continued)**

**Three-Stage Hybrid Signature Circuit**

1. **In+**
2. **In-**
3. **Gas Tube**
4. **SAD**
5. **Out+**
6. **Out-**
7. **PTC (Positive Temperature Coefficient)**

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**Components Of A Surge Protector**

- **Metal Oxide Varistor (MOV)**
- **Silicon Avalanche Diode (SAD)**
- **Gas Discharge Tubes (GDT)**

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**Surge Protection Devices (Continued)**

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Selecting The Right Power Quality Device

Start With The Big Questions

When it comes time to choose the right power quality device, there are several issues to consider. Your specification should focus on the essential performance, installation, and safety requirements. As you begin, be sure to look at the big picture.

What are you protecting – and how valuable is it to your business?
Consider the value of your equipment and your data. Dirty power can destroy or corrupt data so that it becomes unreadable, and it can cause significant equipment damage. Review the equipment to be protected, the cost of repair or replacement, loss of productivity, cost of annoyed customers and loss of business, and inconvenience to get the equipment repaired or replaced.

What level of protection do you need?
The more protection you need, the greater the cost will be – but keep in mind that the cost of not protecting your power supply could be much greater still!

What is the cost of downtime?
• 40% of companies take a day or longer to bring records back online.¹
• 7% of companies take longer than a week to bring records back online.²
• 38% of large businesses estimate that one full business day of downtime would result in at least $500,000 of lost revenue.³

Where should you install surge protection within your facility?
Since every facility is different, there is no cut-and-dried method of deciding where an SPD should be installed within your power system. Surge protection needs for a small business differ from that of larger ones.

For optimum transient surge protection, coordinated surge suppression should be applied to the interconnecting wiring (data cables).

The one-line diagrams below show how SPDs of different sizes may be placed in key locations throughout a business or residence. SPD1 represents protection placed at the incoming service entrance of a building, which is common practice. SPD2 and SPD3 may represent protection placed at panels that feed sensitive equipment, where SPD4 is a direct plug in surge protection that could protect a computer or home theater.

Installation Considerations

Parallel Connected SPDs
• SPDs do not conduct a large amount of current in their normal state so they are independent of the circuits’ ampacity. NEC requires conductors to be either #14 copper or #12 aluminum.
• SPDs are voltage-sensitive devices. Close attention must be paid to the nominal operating voltage of the panel connected to avoid permanent damage to the SPD.

Typical Parallel Connections

Typical Series Connections

Performance of the SPD hinges on the length of the conductors used to connect the SPD to the protected panel. General rule is to keep conductors less than 5 feet in length.

What makes a high quality surge protection device?
• Component level fusing
• MOV matching
• Long life cycle
• Warranty
• All mode
• Modularity
• Component level monitoring

Active Tracking Filters™
• Pay attention to the total current draw for all loads, since overheating the unit can permanently damage the device.
• Be sure to install the unit at its nominal operating voltage to avoid permanent damage to the device.
• If the unit has exposed terminal blocks, they must be installed inside an enclosure and located where it will not come into contact with terminals during maintenance or servicing.
• Do not use extension cords or power strips. Route data cables as far away as possible from power cords.
• If input and output ground terminals are provided, they must be connected for proper operation. This grounding is required for both safety and optimal equipment performance. Incorrect grounding can reduce or impede the operation of the unit.
• Filter must be installed as close to the protected load as possible.

Essential Criteria – ATF
When selecting an Active Tracking Filter™, it is important to know the rated voltage, current and connection type of the protected load.

Low-Voltage SPDs
• SPDs recommend the ground be short and straight (#10 gauge is recommended).
• Each SPD requires its own ground. Do not daisy chain.
• Make sure in-line devices are not wired backwards in the circuit, to avoid premature failure.
• Wire the SPD to the closest AC power ground.

When selecting a low voltage SPD, it is important to know the rated operating voltage, continuous current, connection type and data rate of the protected load.
Selecting The Right Power Quality Device

Start With The Big Questions

When it comes time to choose the right power quality device, there are several issues to consider. Your specification should focus on the essential performance, installation, and safety requirements. As you begin, be sure to look at the big picture.

What are you protecting – and how valuable is it to your business?

Consider the value of your equipment and your data. Dirty power can destroy or corrupt data so that it becomes unreliable, and it can cause significant equipment damage. Review the equipment to be protected, the cost of repair or replacement, loss of productivity, cost of annoyed customers and loss of business, and inconvenience to get the equipment repaired or replaced.

What level of protection do you need?

The more protection you need, the greater the cost will be – but keep in mind that the cost of not protecting your power supply could be much greater still!

What is the cost of downtime?

• 40% of companies take a day or longer to bring records back on-line.
• 7% of companies take longer than a week to bring records back on-line.
• 38% of large businesses estimate that one full business day of downtime would result in at least $500,000 of lost revenue.

Where should you install surge protection within your facility?

Since every facility is different, there is no cut-and-dried method of deciding where an SPD should be installed within your power system. Surge protection needs for a small business differ from that of larger ones.

For optimum transient surge protection, coordinated surge suppression should be applied at the:
• Service entrance of a building, which is common practice.
• SPD1 represents protection placed at the incoming service entrance of a building, which is common practice. SPD2 and SPD3 may represent protection placed at panels that feed sensitive equipment, where SPD4 is a direct plug in surge protection that could protect a computer or home theater.

For interconnected electronic loads (e.g., via data cabling), transient surge suppression should also be applied to the interconnecting wiring (data cables).

The one-line diagrams below show how SPDs of different sizes may be placed in key locations throughout a business or residence. SPD1 represents protection placed at the incoming service entrance of a building, which is common practice. SPD2 and SPD3 may represent protection placed at panels that feed sensitive equipment, where SPD4 is a direct plug in surge protection that could protect a computer or home theater.

Installation Considerations

Parallel Connected SPDs

• SPDs do not conduct a large amount of current in their normal state so they are independent of the circuits’ ampacity. NEC requires conductors to be either #14 copper or #12 aluminum.
• SPDs are voltage-sensitive devices. Close attention must be paid to the nominal operating voltage of the panel connected to avoid permanent damage to the SPD.

Typical Parallel Connections

<table>
<thead>
<tr>
<th>Phase(s)</th>
<th>Ground</th>
<th>Safety</th>
<th>Protected Load</th>
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<td></td>
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<td>Service Entrance</td>
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<td>(e.g., phone, CATV)</td>
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<tr>
<td>Known surge-generating loads within the building (e.g., large motors, arc welders, switched capacitors)</td>
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<tr>
<td>Sensitive electronic loads (e.g., computers, electronic appliances, solid state motor drives)</td>
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<td>SPD1: Surge Suppression at Service Entrance</td>
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<td>SPD2: Surge Suppression at Panel</td>
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<td>SPD3: Surge Suppression at Panel</td>
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<tr>
<td>SPD4: Surge Suppression at Individual Load</td>
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</table>

Typical Parallel Connections

Series Connected SPDs

• Performance of the SPD hinges on the length of the conductors used to connect the SPD to the protected panel. General rule is to keep conductors less than 5 feet in length.

What makes a high quality surge protection device?

• Component level fusing
• MOV matching
• Long life cycle
• Warranty
• All mode
• Modularity

Active Tracking Filters™

• Pay attention to the total current draw for all loads, since overloading the unit can permanently damage the device.
• Be sure to install the unit at its nominal operating voltage to avoid permanent damage to the device.
• If the unit has exposed terminal blocks, they must be installed inside an enclosure and located where it will not come into contact with terminals during maintenance or servicing.
• Do not use extension cords or power strips. Route data cables as far away as possible from power cords.
• If input and output ground terminals are provided, they must be connected for proper operation. This grounding is required for both safety and optimal equipment performance. Incorrect grounding can reduce or impede the operation of the unit.
• Filter must be installed as close to the protected load as possible.

Typical Series Connections

Essential Criteria – ATF

When selecting an Active Tracking Filter™, it is important to know the rated voltage, current and connection type of the protected load.

Low-Voltage SPDs

• SPDs recommend the ground be short and straight (#10 gauge is recommended).
• Each SPD requires its own ground. Do not daisy chain.
• Make sure in-line devices are not wired backwards in the circuit, to avoid premature failure.
• Wire the SPD to the closest AC power ground.

When selecting a low voltage SPD, it is important to know the rated operating voltage, continuous current, connection type and data rate of the protected load.
Industry-Specific Applications

Who Needs To Protect Their Power?
Every business needs reliable, consistent, high-quality power to ensure its continued operation. Proper power protection can:

- Deliver grid-to-chip protection for critical equipment and processes in electronics.
- Keep data centers secure.
- Provide peace-of-mind for communications’ infrastructures.
- Defend fire, alarm, and security systems from downtime and damage.

Industries That Benefit From Power Protection Include:

- **Commercial/Industrial**
  - Agriculture – Prevent productivity loss, as well as material or stock waste from unexpected power outages.
  - Education – Maintain power for critical load areas, such as data centers, emergency lighting facilities and storage facilities that require uninterrupted power supply.
  - Government – Maintain critical load areas such as lighting, communication and data centers vital to government facilities.
  - Hospitality – Back up power without disrupting operations and lighting.
  - Manufacturing – Meet increasing production volumes and time-to-market rates.
  - Offices – Ensure continued protection of the growing number of electrical devices, even during maintenance.
  - Retail – Ensure continued business operations and prevent losses from going to waste.
  - Telecommunications – Ensure continuous service for applications, and maintain and monitor systems for optimal performance.
  - Transportation – Keep vital transportation equipment going despite extended power loss.
  - Utilities – Secure emergency power systems for reliable power quality and protection.

- **Mission Critical**
  - Air Traffic Control – Protect critical load centers; get efficient power monitoring programs for seamless operations.
  - Data Center – Prevent information loss, ensure business-critical continuity, and stay ahead of the competition.
  - Healthcare – Support operations and ensure constant uptime for critical medical facilities.
  - Telecommunications – Ensure reliable support for vital telecom infrastructures for uninterrupted service to customers.

- **Residential / Light Commercial**
  - Gas and Convenience Stores – Continue business operations with emergency power systems.
  - Residential – Protect critical load areas to minimize inconveniences of unexpected power loss.
  - Restaurant – Meet minimum load requirements and prevent food spoilage; or continue operations despite extended power outages.

Spotlight On Healthcare
Healthcare is probably the best example of an industry that absolutely needs clean power. With increasingly advanced technological equipment, dirty power can literally put people’s lives at stake.

Six out of 10 healthcare institutions in the U.S. will launch new construction or renovation projects to accommodate increasing demand, and more than 25% will add new data centers as the nation moves to increased reliance on electronic medical records (EMRs). The rapidly increasing need for consistent, high-quality power cannot be overemphasized. In addition, patients’ health, property and capital investments are also at risk.

For ultimate protection, healthcare institutions need cascading surge protection that includes:

- Type 1 SPDs installed at SE locations, emergency power sources, and external ATS terminals.
- Type 2 SPDs installed at all distribution locations and internal ATS.
- Active Tracking Filters™ installed “upstream” of key essential equipment.
- Data lines protected at transmission and receiving ends.
- All security (cameras and line) and fire-alarm panels protected.

Spotlight On Telecommunications
Telecommunications companies are also extremely vulnerable to power quality issues, since their operations begin and end with transactions moving through electronic systems.

Most switch providers understand the importance of effective surge protection and the associated costs of equipment or system failure if there are gaps in that protection. However, the challenge remains to protect voltage and time-sensitive solid-state equipment from voltage sags, swells, outages, and transients that can seriously affect their operation. And as with so many other industries, telecoms must also focus on heading off the threats that nature poses to their power-reliant systems.

Spotlight On Fire/Alarm/Security
FAS equipment is generally wired in a manner that can introduce harmful outside elements to sensitive inside equipment. FAS circuits typically need to protrude from exterior facility walls. This provides a backdoor for surges and transients, which are commonly overlooked until it’s too late.

Prevent damage to CCTV systems by installing proper surge protection on the video, power and data lines running from the monitoring and recording equipment to the exterior cameras. The power feeding the inside equipment should also be protected.

Fire and burglar alarm systems should also have surge protective devices installed on circuits, wires and loops that penetrate the outside walls. The power and telephone lines going to the fire alarm panels must also have surge protection.

Damage to access control systems can be prevented by placing surge protection on transmit lines, card reader lines, or any other circuit that exits a building such as gate switches, gate lock controls or phone lines. Always, the power coming to the control panel should also be protected.
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Every business needs reliable, consistent, high-quality power to ensure its continued operation. Proper power protection can:

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Industry-Specific Applications (Continued)

Spotlight On Transportation

Sensitive transportation equipment like highway lighting, traffic signals, control cabinets, cameras and dynamic messaging signs are all exposed to the outside elements in one fashion or another, making them susceptible to surge damage. You can only imagine the ripple effect that could occur if just one of these systems went out during rush hour traffic.

The application of surge protection devices in front of critical transportation equipment can eliminate dangerous situations before they occur. For example, the installation of surge protection directly inside light poles can prevent highway lighting from going out. Surge protective devices installed inside traffic cabinets can keep traffic lights running correctly. Pole-mounted cameras should have surge protection installed inside traffic cabinets: they can keep traffic lights running correctly. Pole-mounted cameras should have surge protection installed inside traffic cabinets: they can keep traffic lights running correctly. Pole-mounted cameras should have surge protection installed inside traffic cabinets: they can keep traffic lights running correctly.

Spotlight On Data Centers

For today’s communications, banking, and financial sectors, the reliance of data centers to obtain, store, retrieve, communicate, and utilize data is vital. Large data centers can be a standalone structure or specified rooms or floors within a facility. Small data centers range from a single room to a standalone equipment rack.

Whether the data center is categorized as large or small, the demand to process more data continues to grow. For this reason, organizations have replaced existing equipment with newer, smaller, and more powerful technology. However, this newer IT equipment is also more susceptible to power fluctuations and transient conditions. Providing adequate transient protection requires that SPDs be installed throughout the facility. The IEEE Emerald Book recommends that SPDs be installed at these specific areas within the data center:
• Each service entrance location
• Each distribution level switchgear, UPS, or PDU
• All point of use locations (specific IT and HVAC equipment)
• Any system (HVAC, fire alarm, security) that requires components to be located external to the structure of the facility

SPDs perform an important function in the data center by reducing transient conditions, equipment downtime and extending IT equipment life.

AC Power Surge Protection Devices (SPDs)

What aspects of installation affect an SPD’s performance?
The wire size and length of the connecting leads will affect the performance of parallel-connected transient voltage SPDs. Transients have fast-rising wavefronts, with typical rates of rise of current of 100 amps per millisecond. The connecting wire’s self-inductance is significant and can hamper the suppression of high voltages while the wavefront passes.

The voltage drop across the connecting leads is added to the voltage across the suppression elements, degrading the SPD’s performance by increasing the residual voltage.

What if your installation requires a long connection run?
If a long connection run (more than five feet) is unavoidable, you should use a low impedance cable. These cables (such as Liebert ACG Series AccuGuide®) help minimize voltage drops and transmit transients that are generated by lightning and switching. They’re usually made from coaxial cable, and they minimize the inductance through a reduced coaxial aspect ratio. These cables can deliver extremely low impedance (2-10Ω) that you could achieve with conventional interconnections. They can keep your losses under 4.2V/ft/kA — much less than losses with standard conductors!

What are the proper installation techniques?
First, keep the connection as close as possible, since losses exceed 161V/ft/kA with standard conductors. There are several basic considerations:
1. Your lead lengths should be short and as straight as possible.
2. To reduce the wiring impedance to surge currents, we recommend that the phase, neutral, and ground conductors be twisted together and routed in the same raceway (conduit). Be sure to avoid any sharp bends in the conductors.
3. Connect to equipment through a dedicated circuit breaker wherever possible.
4. External mounting is the preferred method. This gives you the flexibility to mount close to the neutral lug, ground lug, and breaker.

How much surge current capacity is recommended for your installation?
Surge current capacity is the maximum surge current that an SPD is rated to carry without excessive overheating and consequent premature breakdown or combustion risk. The surge current capacity of the SPD you select must match the current required by

Typical Questions

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the equipment you need to protect. This can be affected by your equipment’s geographic location, its risk of exposure to transients, and its value to your organization (impact of downtime, repair costs).

Is your UPS properly protected from surges?
The typical UPS uses single-shot surge arrester technology for internal surge protection, which provides minimal protection and high clamping levels. Surge protection provided inside UPS units does not provide protection when the UPS is in bypass mode. Experts recommend that both the input circuit to the UPS and the associated bypass circuits (including the manual maintenance bypass circuit) be equipped with effective SPDs.

Can a surge protection device save energy?
There are some SPD manufacturers who have claimed that surge suppression devices can save on electric utility bills. Surge protection devices were designed to protect equipment from conditions that normally cause component degradation, not to save energy costs. The application of MOVs, gas tubes, or other high-energy surge suppression components do not contribute to any type of energy conservation. In addition, because these are generally non-linear devices and conduct very little current, they virtually have no effect on the electrical system under normal conditions. The only exception to this is during a transient condition that has a potential great enough to send the surge suppression device into conduction, and this period of time is in the microseconds. Although there are claims and affidavits of customers who have saved on their utility bills by applying SPDs at their facilities, there have been no studies published that supports these claims.

How is self-inductance determined?
The wiring’s self-inductance is proportional to its length and to the logarithm of its thickness. If you half the length of connecting wires, this halves the inductance, but the thickness would have to be increased tenfold to achieve the same effect. The stranded wires are more effective than equivalent-sized solid conductors because of the skin effect on the total surface area. Big, short, stranded connecting wires will give the best SPD performance. But keep in mind that short length is much more important than large wire size.

Why is the response time of an SPD misleading?
NEMA’s definition of response time is the time required, after the initiation of a specific disturbance to a device or system, for an output to reach a specific value. In other words, the time it takes a surge protector, after a surge occurs, to clamp the transient voltage down to a safe level. This value is not easy to measure, so manufacturers tend to publish the response time of the actual surge component, such the metal oxide varistor (MOV) or silicon avalanche diode (SAD), used within the device. This is misleading and offers little value to the customer.
Industry-Specific Applications (Continued)

Spotlight On Transportation

Sensitive transportation equipment like highway lighting, traffic signals, control cabinets, cameras and dynamic messaging signs are all exposed to the outside elements in one fashion or another, making them susceptible to surge damage. You can only imagine the ripple effect that could occur if just one of these systems went out during rush hour traffic.

The application of surge protection devices in front of critical transportation equipment can eliminate dangerous situations before they occur. For example, the installation of surge protection directly inside light poles can prevent highway lighting from going out. Surge protective devices installed inside traffic cabinets can keep traffic lights correctly running. Pole-mounted cameras should have surge protection installed throughout the facility. The IEEE Emerald Book recommends that SPDs be installed at these specific areas within the data center:

- Any system (HVAC, fire alarm, security) that requires components to be located external to the structure of the facility
- SPDS perform an important function in the data center by reducing transient conditions, equipment downtime and extending IT equipment life.

Whether the data center is categorized as large or small, the demand to process more data continues to grow. For this reason, organizations have replaced existing equipment with new, smaller, and more powerful technology. However, this newer IT equipment is also more susceptible to power fluctuations and transient conditions.

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AC Power Surge Protection Devices (SPDs)

For today's communications, banking, and financial sectors, the reliance of data centers to obtain, store, retrieve, communicate, and utilize data is vital. Large data centers can be a standalone structure or specified rooms or floors within a facility. Small data centers range from a single room to a standalone equipment rack.

What aspects of installation affect an SPD’s performance?

The waveform is fast rising, with typical rates of rise of current of 100 amps per millisecond. The connecting wire's self-inductance is significant and can hamper the suppression of high voltages while the waveform passes.

The voltage drop across the connecting leads is added to the voltage across the suppression elements, degrading the SPD’s performance by increasing the residual voltage. The connection run on another SPD should be short to reduce this voltage drop.

What is the proper installation technique?

- Flexible conduit is best, but rigid conduit is acceptable. Rigid conduit must be fitted with flexible grommets.
- Whichever method is used, the SPD should be as close as possible to the equipment it is protecting.
- When using flexible conduit, be sure to use the proper size to prevent attenuation of the surge current.
- The size of the connecting wire should match the current rating of the SPD.

How much surge current capacity is recommended for your installation?

The surge current capacity of the SPD you select must match the current required by the equipment you need to protect. This can be affected by your equipment’s geographic location, its risk of exposure to transients, and its value to your organization (impact of downtime, repair costs). Is your UPS properly protected from surges?

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Spotlight On Data Centers

As the number of devices requiring high-quality power increases, so does the need to ensure reliable, consistent power delivery. This is especially true in high-density data centers, where the efficiency of critical transportation equipment can eliminate dangerous situations before they occur.

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Typical Questions

What is a SPD?

SPD stands for Surge Protective Device. It is a component, such as the metal oxide varistor (MOV) or silicon avalanche diode (SAD), used within the device. This is misleading and offers little value to the customer.

What are the proper installation techniques?

- Insure the connection is as close as possible, since losses exceed 4.2V/ft/kA – much less than losses with standard conductors!
- First, keep the connection as close as possible, since losses exceed 4.2V/ft/kA – much less than losses with standard conductors!
- These cables can deliver extremely low impedance (2-10 Ω) that you usually made from coaxial cable, and they minimize the inductance through a reduced coaxial aspect ratio.
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NEMA’s definition of response time is the time required, after the initiation of a specific disturbance to a device or system, for an output to reach a specific value. In other words, the time it takes a surge protector, after a surge occurs, to clamp the transient voltage down to a safe level. This value is not easy to measure, so manufacturers tend to publish the response time of the actual surge component, such as the metal oxide varistor (MOV) or silicon avalanche diode (SAD), used within the device. This is misleading and offers little value to the customer.
Typical Questions (Continued)

The speed at which a surge suppressor responds can be based in numerous criteria, such as: the type of surge component used, the overall design of the device, and the conductor length used in installation. Most MOVs respond at similar rates, SADs due to their material composition respond slightly faster than MOVs. The way SPDs are designed can also affect the overall response time of the device. For example, designs that use gold-copper bus bars may have lower overall impedance than those that use wire connections and subsequently respond faster. However, nothing will affect the speed at which an SPD responds more than the installed lead length from the SPD to the connected electrical panel. Therefore, if optimum performance is desired, more attention should be paid to the installation of the SPD than the published response time.

How many incoming lines should be protected?

Some suppressors only protect one line, Line to Neutral. This is good, but including Line to Ground and Neutral to Ground, in addition to Line to Neutral, will give you far better protection.

What is the operating voltage required?

Operating voltage is the nominal voltage that a circuit component needs to function properly under normal conditions, at a given point in the system. The maximum safe operating voltage for a system is determined by the component conditions, at a given point in the system. The maximum safe operating voltage for a system is determined by the component conditions, at a given point in the system. The maximum safe operating voltage for a system is determined by the component conditions, at a given point in the system. The maximum safe operating voltage for a system is determined by the component conditions, at a given point in the system. The maximum safe operating voltage for a system is determined by the component conditions, at a given point in the system.

What type of warranties are there?

Limited Warranty: Most surge protection devices come with a limited warranty covering product defects in materials and workmanship for a predefined period of time. The terms of these limited warranties generally range from 1 to 10 years depending on the type of product covered. A few manufacturers offer warranties up to 20 years, however 5 year warranties seem to be the most common. No matter how long the warranty is, close attention should be made to limitations, items not covered by warranty and instructions for obtaining a claim.

Connected Equipment Warranty: Some direct plug-in devices (strip type protectors) come with a warranty that advertises the replacement of equipment damaged from a surge or transient while connected to a properly installed surge protector. Claims made on these types of warranties are not easy to collect on because of the amount of paperwork required to file.

On-Site Labor Warranty: Emerson offers a labor warranty on their premium products in which a factory trained customer engineer will come to the site where the SPD is installed and perform service. The standard terms of this warranty is 5 years from time of sale.

What are the differences between normal current, surge current, short-circuit current, and fault current, and how do they relate to surge protection devices?

Normal Current:

Under “normal” conditions, when the AC power is clean and free of transients, the SPD will only consume a small amount of power. Sometimes called idle current, this is typically used to simply power the surge protectors monitoring circuit. Surge protectors that have filtering capacitors will use slightly more power in the idle state.

Surge Current:

When an SPD senses a transient, the surge components will begin to go into conduction. This is required to divert the high-current impulses away from the load and eventually to ground. Surge impulses are fractions of a cycle, lasting only microseconds in duration. The amount current the SPD can safely divert is called the device’s surge current capacity. This value is generally calculated by summing up all the surge components within the device. The surge current rating is generally measured in thousands of amperes (KA) and may be published per each mode, per each phase or as a total amount for the entire device.

Short-Circuit Current:

As with any electrical load, SPDs needs to have some type of current-limiting component such as a fuse protecting it against internal faults. These occurrences generally happen when a surge component fails short-circuit and large currents flow for an extended period of time. If left uninterrupted, the failure to the device can be catastrophic. The amount of current available to flow through this failed component is driven by the power system.

SPD failures are generally caused by the following:

- SPD exceeds the maximum surge current capacity
- Misapplication of a product for its voltage rating
- Sustained over-voltage events

Fault Current:

Sometimes fault conditions happen outside the device in the power distribution system that the SPD needs to protect itself against. These faults could be caused by two or more phases coming in contact with each other causing a “phase fault” or “phase short”. The outcome is large levels of current flowing through the power conductors, circuit breakers, SPDs and any other devices connected in the fault path. Unlike fast-acting surge currents, faults can last a quarter of an AC cycle or even longer.
Typical Questions (Continued)

The speed at which a surge suppressor responds can be based in numerous criteria, such as: the type of surge component used, the overall design of the device, and the conductor length used in installation. Most MOVs respond at similar rates, SADs are considered to be the slowest, and devices which use wire connections and subsequently respond slower. However, nothing will affect the speed at which an SPD responds more than the installed lead length from the SPD to the connected electrical panel. Therefore, it is highly recommended that a design be used that does not rely solely on wire connections for the installation of the SPD than the published response time.

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**What is the operating voltage required?**

Operating voltage is the normal voltage that a circuit component needs to function properly under normal conditions, at a given point in the system. The maximum safe operating voltage for a system is determined by the component with lowest safe operating voltage. An SPD with an operating voltage significantly under or over the requirements of the system it protects will not give the best protection, and may lead to unnecessary damage.

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**What is the steady-state current of the system?**

Steady-state current is the current drawn by the load over an extended period of time. For example, equipment draws steady-state current while it is running. It is important to note that steady-state current should not be measured when a load cycles (e.g., when a heating element switches on or off) or when the equipment is first turned on (rush current).

You'll save time and money by matching your steady-state current requirements to the steady-state range of the SPD you are considering – this will help ensure that you install the right device, avoid under-sized devices (which will not adequately protect your sensitive equipment), or pay too much for features you don't need.

**What mode of protection do you need?**

There are several paths that transients can take to reach sensitive equipment. A three-phase wye system consists of 10 modes (line to line x 3), (line to neutral x 3), (line to ground x 3) and (neutral to ground x 1). Of course, the best protection addresses each of these modes (L-N, L-G, N-G with L-L being derived through the L-N wiring for a wye configuration, or L-L and L-G for a delta configured circuit). The circuit diagrams below illustrate how this is accomplished:

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Typical Questions (Continued)

Regardless of how infrequently faults may occur, it’s critical that over-current protection is in place to minimize equipment damage and personal injury.

Low Voltage Protection

Do you need low-voltage surge protection?

Low-voltage lines are typically 300 V or less. DC current, and applied to any application where data signal is transmitted and/or received. Examples include transmitters and sensors, communication systems, telecommunications, and more. This equipment is vulnerable to transients and noise, it’s highly susceptible to surges, and commonly overlooked.

Low-voltage lines can be a direct pathway of destruction, degradation, and disruption for sensitive semiconductor circuits. This directly affects your PCs, electronic communication, and data. You definitely need to consider SPDs to protect your low-voltage lines.

What termination type do you need?

Termination types are the cable connections between components or between an SPD and the system it protects. The individual devices must be compatible with each other. Select a surge protection product that can accommodate the required type of connector.

What happens if the SPD is plugged in backwards?

You will experience premature protector failure and possible damage to your equipment.

Where do you connect the ground wire?

To the power ground (green wire ground) of the protected equipment.

Does the ground wire length make any difference?

Yes – the shorter the better. Ideally, keep the ground wire less than one foot. If you can’t keep the ground wire less than one foot, then the data or signal pair may have to be rerouted to a location where SPD suppressor is located near the AC power outlet.

What about a panel that has no AC power supplied to it?

Power is supplied down the signal conductors. How do you ground the SPDs?

Bond to the closest building approved ground point. Also provide surge protection between signal conductors and the ground conductor.

Can you run ground wires inside metal conduits?

Yes, but only if the ground wire is bonded to the conduit at each end.

Over-current protection is used with SPDs to ensure that the device is safely and promptly removed from the electrical distribution system. Some SPD manufacturers incorporate current limiting fuses directly within their device, while others require an external fuse block or circuit breaker to disconnect from the system. Either way, care should be taken to confirm these important factors:

- Proper coordination of the SPD’s fault rating with that of the connected distribution panel.
- Testing to determine how the internal or external fuses affects the overall performance of the SPD.
- Compliance with all applicable UL and NEC requirements concerning the fault current rating.

Properly coordinated over-current protection allows the SPD to handle the published surge current rating without taking itself off-line, as well as remove itself from the distribution system in the event of an internal failure or fault condition.

While oftentimes confusing, the selection of a surge protective device must include a basic understanding of the differences between normal current, surge current and fault current. Also essential to the selection process is knowledge about the application of an SPD, the intended installation environment and the device’s operating characteristics. Understanding these informational building blocks will help ensure a well-designed protection system.

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The Emerson Advantage

**Put the Power Of Emerson To Work For You**

When you choose Emerson Network Power Surge Protection as your surge protection partner, you’ll benefit from the deep experience, the broad range of products and the unparalleled service of Emerson.

**Emerson – The Global Technology Leader**

Emerson Network Power (ENP) is a business unit of Emerson, a diversified global manufacturing and technology company with a wide range of products and services in process management, climate technologies, storage solutions, professional tools, appliance solutions, motor technologies, and industrial automation.

Widely recognized for its engineering capabilities and management excellence, Emerson has over 125,000 employees and 250 manufacturing locations worldwide.

With manufacturing and/or sales presence in over 150 countries, Emerson was ranked number 2 in FORTUNE’s 2009 “World’s Most Admired Companies” in the electronics industry.

**Emerson Network Power: Enabling Business-Critical Continuity**

For nearly a century, ENP has been protecting power and combating dirty power. Our experience uniquely positions us in today’s rapidly changing environment. We’re constantly adapting and enhancing our products to meet the evolving challenges of an increasingly microprocessor-based world.

By taking an integrated approach to protection, we look at your entire facility – from grid to chip. Our innovative products are ready to protect everything from your inbound power, power systems, and connectivity all the way down to your data/signal communications.

Our research and development efforts help us stay ahead of the curve as industries evolve and expand. We hold more than 750 active patents, and we’re constantly working to create new solutions to meet tomorrow’s challenges.

Above and Beyond Today’s Standards

ENP’s products comply with industry standards – from UL to NEC. In many cases, our products’ performance far exceeds these standards. Although regulations and standards frequently change, you can be confident that we’re proactively working to meet new standards even as they are being developed.

**Superior Service And Support**

ENP delivers exceptional service and support. We offer acclaimed, benchmark-quality service:

- Nearly 200 global locations
- Over 2,000 fully certified, highly trained and experienced field engineers
- 550+ technical support/response team members
- More than 3,000 global service team members

We support customers around the globe with on-line, telephone, and on-site service.
The Emerson Advantage (Continued)

- Emerson Network Power Surge Protection: Surge Specialists

Emerson Network Power Surge Protection (ENPSP), one of Emerson Network Powers’ 12 Centers of Expertise, has been a power quality company for more than 35 years. It offers a broad range of power line filters and state-of-the-art surge suppression equipment. Markets from broadcast; industrial; telecommunications; residential; traffic; transportation; and fire, alarm and security areas rely on us. Our solutions are easy to install, cost-effective, and essential for safeguarding sensitive data and equipment. ENPSP is the source for the Edco, Haltrol, Liebert, and PowerSure products. These brands are leaders in protecting power quality and continuity – all with the goal of helping your business succeed.

- The Brand You Can Count On

ENP is committed to Business-Critical Continuity™ – the promise that our customers’ technology infrastructure and products will always be available and reliable. We take care of the technology that supports your business so you can concentrate on what you do best and achieve “power peace of mind.”

Our dependable solutions are backed by service that’s equally outstanding. Customers such as Alcatel, Lucent, AT&T, Dell, Ericsson, HP, IBM, Motorola, Nokia, China Mobile, China Netcom, Huawei, and others all trust their power to ENP.

The Cost/Value Continuum

While cost containment is critical in today’s economy, you can’t cut corners when it comes to power protection. ENP builds quality, performance, and durability into all of our products. We price them fairly and know that customers understand their true value. Our innovation, craftsmanship, service, and quality deliver peace of mind – and that’s priceless.

- Glossary Of Terms

These are some of the common terms you’ll hear when researching surge protection.

Alternating Current (AC) – Flow or movement of electrical charge that periodically reverses direction.

American National Standards Institute (ANSI) – Leading standards-setting organization for a wide range of products and applications.

Attenuation – The reduction of a signal or electrical surge from one point to another. Wire resistance, surge protective devices (SPDs), high voltage arresters, and power conditioners attenuate surges to varying degrees.

Bonding – Complete and permanent electrical interconnection between two or more points that reduces any difference in voltage.

Capacitor – A discrete electrical device which has two electrodes and an intervening insulator, which is called the dielectric.

Clamping Voltage – The peak voltage that SPDs allow into an electric circuit based on a specific test waveform.

Direct Current (DC) – Unidirectional flow of electric charge, produced by batteries, thermocouples, solar cells, etc.

Electronic Rust – Transient damage that gradually eats away at the circuit traces that allow electricity to flow between electronic components.

Fuse – A protective device, used in an electric circuit, containing a conductor that melts under heat produced by an excess current, thereby opening the circuit.

Gas Discharge Tube (GDT) – When electrical breakdown occurs, as the result of a surge, a GDT transforms from an open-circuit to a quasi-closed circuit. As long as the component’s ratings have not been compromised it will return back to its normal state once the system stabilizes.

Harmonic Distortion – Excessive harmonic content that distorts the normal sinusoidal waveform is harmonic distortion. This can cause overheating of circuit elements and might appear to a device as data-corrupting noise.

Impedance –Measured in ohms, impedance is the total opposition to current flow in a circuit where alternating current is flowing. It includes inductive reactance, capacitive reactance, and resistance.

Institute of Electrical and Electronics Engineers (IEEE) – Nonprofit standards-setting organization that has developed a wealth of standards for a broad range of industries and applications, including the surge protection environment.

Maximum Continuous Operating Voltage (MCOV) – The maximum designated root-mean-square (RMS) value of power-frequency voltage that may be continuously applied between the terminals of an arrester.

Maximum Surge Current Rating – The maximum 8/20 ms single impulse the SPD is capable of surviving without performance degradation.

Measured limiting voltage – The maximum magnitude of voltage that appears across the terminals of an SPD during the application of an impulse of specified waveform and amplitude.

Metal Oxide Varistor (MOV) – A non-linear, voltage-sensitive device that becomes conductive as the voltage between connected conductors increases.

Modes of Protection – Stated in “kA” (e.g., 100kA per phase); per phase rating by summing two or more modes.

National Electric Code (NEC) – Guidelines for electrical safety developed by the National Fire Protection Association (NFPA).

Over-voltage – An increase in the normal voltage level, lasting for seconds or minutes, that exceeds the reading of a device or component. The term can also apply to transients and surges. When applied to a long-duration variation, it refers to overvoltage with a value of at least 10% above the nominal voltage for a period of time greater than one minute.

Positive Temperature Coefficient (PTC) – Thermally sensitive resistors manufactured from semiconductor material. As the temperature approaches a predetermined value, the resistance of the part begins to rise rapidly, and eventually levels off. Thermal expansion of the material reduces the current to a safer level.

- State-of-the-art R & D test lab.

Surge Protection Headquarters, Binghamton, NY.
Emerson Network Advantage (Continued)

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Short Circuit Current Rating (SCCR) – The capacity of current that the tested SPD can withstand at the terminals where it’s connected, without breaching the enclosure in any way.

Silicon Avalanche Diode (SAD) – A diode made from silicon that is designed to break down and conduct at a specified reverse bias voltage area, breakdown occurs across the entire P-N junction, voltage drop is essentially constant and independent of current.

Spike – Also called an impulse, switching surge, or lightning surge, this refers to a voltage increase of very short duration (microsecond to millisecond). Spikes may be caused by lightning, switching of heavy loads, and/or short circuits or power system faults.

Suppressed Voltage Rating (SVR) – The discreet rating per UL 1449 standard, signifying the rounded up average clamping voltage of an SPD when subjected to the measured limited voltage test.

Surge Protective Device (SPD) – The generic term used to cover both surge arresters and transient voltage surge suppressors (TVSS) devices. An SPD is a non-linear protective device for limiting surge voltages on equipment by discharging, bypassing, or diverting surge current. It prevents continued flow of follow current and is capable of repeating these functions as specified. SPDs can be connected in series or in parallel with the load they are protecting.

Rated Temporary Overvoltage (TOV) Withstand Level – Combination of magnitude and duration of temporary overvoltage that the SPD can withstand without changes in characteristics or functionality.

Transient – An electrical event of a non-repetitive nature. While the term is sometimes interchangeably used with “impulse,” it relates more to the intermittent occurrence of surge. It’s a short duration, fast-rise-time voltage caused by lightning, large motor starting, utility switching operations, and other appliance switching.

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**Under-voltage** – A decrease in the normal voltage level, also called a sag, dig, or brownout.

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