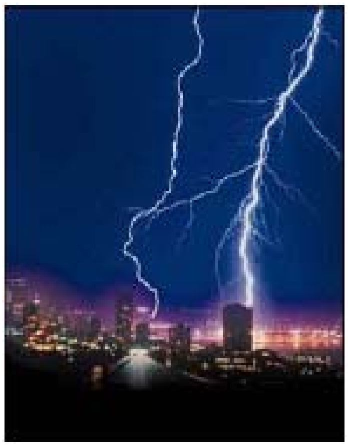
Surge Protection

Welcome

Welcome to this subject, surge protective devices. A surge protective device is used to protect electronic equipment from harmful voltage surges.

Figure ١. Facilities and Electronic Equipment are constantly at Risk from Voltage Surges



You are the best judge of how well you grasp the material. Review the material as often as you think necessary. The most important thing is establishing a solid foundation to build on as you move from topic to topic and module to module.

A Note on Font Styles Key points are in bold.

Glossary terms are underlined and italicized the first time they appear.

Viewing the Glossary

Printed versions have the glossary at the end of the module.

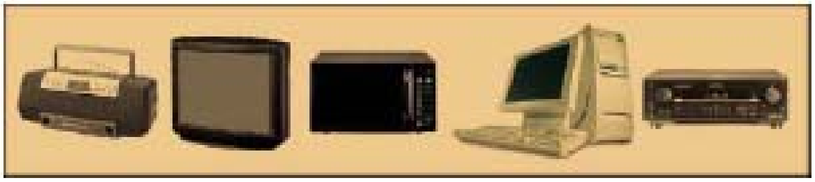
Introduction

The popularity of solid-state electronic devices has grown dramatically over the last few decades. This is true for all market segments: consumer, commercial and industrial. In fact, roughly half the electrical power produced worldwide passes through such a device.

Proliferation of Solid- State Electronic Devices

Just consider today's typical home. It is filled with all manner of electronic gadgetry. Televisions, VCRs, microwave ovens, stereo equipment, home computers… the list goes on.
It's easy to see why solid-state electronic devices are so popular. The devices are small in size. They are convenient to use. They are very precise in their function, offering superior performance. And, with no moving parts, they are exceptionally durable and long-lasting.

Figure ٢. Solid-State Electronic Devices



The Downside of Solid- State Electronic Devices

However, solid-state electronic devices have a downside. To provide the precise, dependable function people have come to expect, these devices require an equally dependable source of power. Microprocessors rely upon digital signals, which are fast on/off coded sequences.
If the sequences are distorted, the signals could be disrupted. Performance could be hampered or even stopped. **In the case of a major *Voltage* surge (١٠٠V-٢٠kV), these devices could be damaged or even destroyed,** resulting in potentially very expensive equipment replacement costs. Clearly, this problem must be addressed.
Because it is impossible to prevent voltage surges from either entering a building or from occurring inside a building, surge protection was invented.
The function of the surge protector is to stop (or at least limit) the effects of less than- perfect *Power Quality* on solid state electronic devices.
Surge protection is a cost-effective solution to prevent downtime and equipment damage. It is suitable for any facility or load (٦٠٠ volts and below). Surge protection should be applied not only to the AC power system, but also to the incoming telephone, cable and other communication lines.

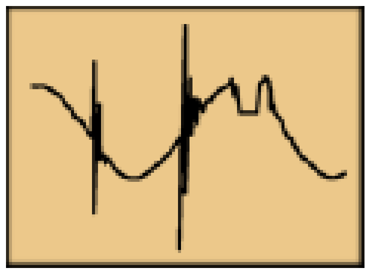
Power Quality Disturbances

A power quality disturbance can range from a microsecond to constant steady state. A microsecond may not seem like a long time to you and I, but to a delicate piece of electronic equipment, it is a lifetime. Power quality disturbances can be caused by forces of nature, equipment START/STOP cycles, or distortion inducing devices.
There are some very common disturbances that can affect a system. These include:
• *Transients* or *Surges*
• Multi-cycle voltage variations (i.e., *Sag* and *Swell* conditions)
• *Noise Distortion*
• *Harmonics* (covered in Module ١٥, Power Management)
Let's look briefly these disturbance types.

Surges or Transients An electrical surge or transient is a random, high energy, short duration electrical disturbance. By definition, it is a sub-cycle event. Common usage terms for transient are *Voltage Impulse* and *Spike* (a single surge).
Sources for such transients include:

- Lightning
- Switching loads (capacitive and inductive)
- Short circuits
- Variable speed drive operation
- Imaging equipment operation (photocopiers and scanners)
- Arc welders
- Lighting dimmers

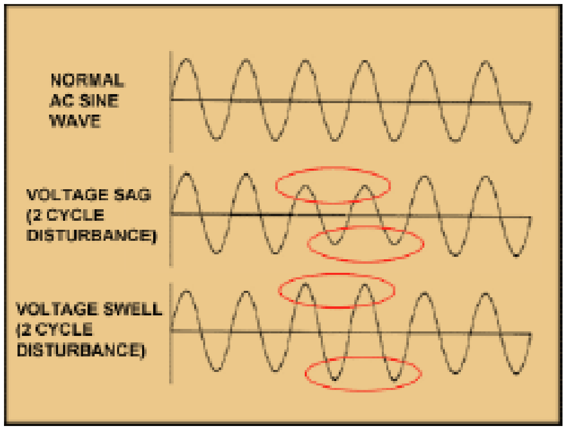
Figure ٣. Typical Voltage Impulse Waveform



A surge can travel on any metallic conductor entering a building. Electrical, telephone and coaxial cable lines make great surge conductors.
Transients are of short duration; typically ٠.٥ – ٢٠٠ microseconds. They can be impulse or oscillatory (ringing) in nature. They are **too fast to be stopped by circuit breakers or fuses**. They can damage solid-state devices, and corrupt microprocessor data.
The use of lightning arrestors, and *Surge Protective Device (SPD)*, or *Transient Voltage Surge Suppressor (TVSS)*, can help alleviate some of the problems caused by electrical surges.

Multi-Cycle Voltage Variations
Sag and swell conditions can be caused by multiple large loads turning on or off at the same time.
A sag in voltage can be caused when several large motors start at once. Faults in distribution systems or utility equipment malfunctions may also cause sags. Sags can affect operating coils of motor starters, which are designed to drop off-line at less than ٨٥% voltage.
Swells are often caused when there is a sudden load decrease. Single line-to ground faults or switching on large capacitor banks may result in swells or *Over voltage* conditions.

Figure ٤. Waveforms for Normal AC Power, a SAG Condition, and A Swell Condition



The duration of a sag or swell is generally between ١/٢ cycle and ١ minute.
(When the duration exceeds one minute, the disturbance is called an under voltage or over voltage disturbance.) They can cause computers and PLCs to shut down or lock up in a program, motors to stall, and contactors and relays to open.
Voltage arcing and component failures can also occur.
The use of voltage regulators and power line conditioners can solve these problems.
In addition, custom power products, which utilize power electronics, are becoming viable solutions to mitigate voltage sags and interruptions.
Noise Distortion Noise distortion takes the form of unwanted electrical signals present on the steady-state voltage waveform.
Radio Frequency Interference (RFI), produced by communication system components, can contribute to system noise. Have you ever experienced static on your TV caused by a hair dryer or a nearby CB radio? These are examples of RFI.
Single filters or combinations of multiple filters can decrease noise in a line to increase the quality of your power.
Another form of noise is brought about by the differences in ground potentials throughout an electrical system. The surge suppression, wiring, shielding and grounding of the building's electrical system, including communication cabling, can have a pronounced effect on the levels of noise to which electronic equipment is exposed.

Grounding

Introduction

All electrical distribution systems must be properly grounded to ensure system safety. Another important benefit of proper grounding is reliable operation of electronic equipment.
Electricity always takes the path of least *Resistance*. A person coming into contact with an ungrounded electrical system would most likely become the ground himself, and receive a high-voltage shock.

The ground connection is just what the name suggests: an electrical connection to the earth. This is usually accomplished by attaching a *Conductor* to a metal electrode (rod), which is then buried in the ground. This connection provides a *Grounding Path* for the entire electrical distribution system of a building, right at the *Service Entrance*.

Grounding and Surge Production

It should be easy to make the connection between grounding and surge protection.

The system ground provides a path for the surge to follow, preventing damage to the system. If the ground is not solid, surge protection will not work properly.

Imagine lightning striking a facility equipped with a lightning protection system, a special type of surge protection system. (We'll discuss lightning in more detail shortly.) The lightning protection system's job is to transport the lightning-generated *Current* through the facility to the earth grounding connection. This is done through providing the lightning with a highly conductive path to ground, minimizing alternate paths through other items (expensive electronic equipment, for example).

If the earth grounding connection is poor or inoperative, the lightning-generated current may follow a much more damaging path through the facility, leading to equipment damage and/or personal injury. This situation is more common than you may think. In fact, **roughly ٨٠% of power quality issues are tied to grounding problems.**

The effectiveness of the earth grounding connection is also related directly to the system resistance. The lower the ground resistance, the more effective the ground will be.

Because grounding is so vital to the safety of an electrical distribution system, it should be inspected and tested on a regular basis.

Lightning

Now let's talk about the most destructive power disturbance of all: lightning. First, let's consider a few statistics from the National Lightning Safety Institute (*NLSI*).

• At any given time, over ١,٠٠٠ thunderstorms are in progress worldwide.

• Lightning strikes the ground somewhere on our planet over ١٠٠ times every second.

• Tall structures, such as radio towers and office high-rises are struck by lightning ٥ to ١٠ times a year. Smaller buildings can expect to be struck once per year.

• Lightning strikes in the United States cost over $٢ billion in annual economic losses, mainly through computer damage and data loss. This figure is climbing rapidly as microchip-driven devices continue to gain popularity.

Pretty jarring numbers, aren't they? Lightning is a more serious problem than most people think. In fact, NLSI states that lightning is an under-rated hazard. Here is the truly remarkable part: With proper implementation of surge protection devices and shielding equipment, the vast majority of these losses are preventable.

After a violent thunderstorm, the facility manager at Eaton Corporation's Westerville, OH facility was greeted by several firefighters with their axes drawn.
The automatic fire alarm system sent out a false signal when induced lightning entered the building through the HVAC system. In that split second, tens of thousands of dollars in electrical and electronic equipment were destroyed.

Eaton's Cutler-Hammer CPS Surge Protector Installed at the Electrical Panel board

The facility manager decided that surge suppression needed to be installed as part of a complete facility-wide power protection plan.
This small investment could have spared the high cost of replacing the destroyed equipment.
If a building is hit directly, an impulse current measured in thousands of *Amperes* can find its way into the facility's electric power, data, and telephone lines.

Computers and peripheral devices, telephone switches, and data interface equipment can easily be damaged or destroyed by this sort of power spike.
The National Fire Protection Association (*NFPA*) publishes **NFPA ٧٨٠**, the Lightning Protection Code. It addresses protection requirements for facilities such as:
• Ordinary structures
• Miscellaneous structures and special occupancies
• Industrial operating environments
The following articles are directly excerpted from the ١٩٩٢ edition of the NFPA ٧٨٠ code publication.

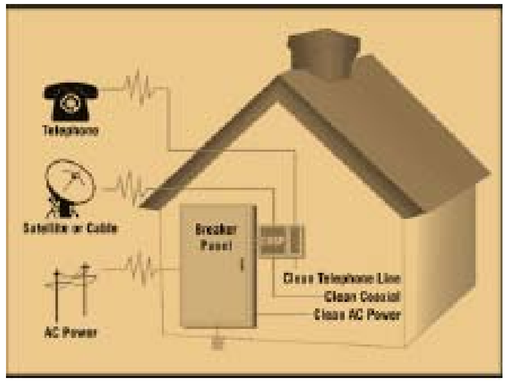
NFPA ٧٨٠ defines a lightning protection system as "a complete system of air terminals, conductors, ground terminals, interconnecting conductors, **surge suppression devices**, and other connectors or fittings required to complete the system."

Section ٣-٢١ of the code relates to surge suppression. It states: "**Devices suitable for protection of the structure shall* be installed on electric and telephone service entrances, and on radio and television antenna lead-ins** (*shall indicates a mandatory requirement). Note: Electrical systems and utilization equipment within the structure may require further surge suppression."
Section D-٤.٨ of the code describes the installation location for surge suppression devices. It states: "**Surge suppression devices should be installed on all wiring entering or leaving electronic equipment, usually power or data communication wiring.**"

Applying Surge Protection

The design goal of a surge protective device is to **divert as much of a transient power disturbance away from the load as possible**. To accomplish this, a **low impedance *Shunt* device, such as a surge suppressor, redirects the transient to ground**.
Of course, the SPD needs to be located upstream from the load it is intended to protect, but **what layout configuration should be used**?
Using a Surge Strip No doubt, you've seen these inexpensive devices: **a grouping of five or six receptacles connected to an extension cord, usually with an integrated circuit breaker or fuse**. You can pick one up at any hardware store for less than twenty dollars. You may even have one or two in use in your home.
At the risk of alarming you, if this is all that stands between your expensive electronics (stereo, television, computer, etc.) and a lightning strike, **your investment is not as safe as you think**. It's a common misapplication that could cost the homeowner or small business owner a fortune in repair and/or replacement costs.
The typical surge strip provides a surge current rating of only ٢,٠٠٠ to ٦,٠٠٠ amps. IEEE defines the maximum lightning surge as ٢٠,٠٠٠ volts and ١٠,٠٠٠ amps. When the lightning strike overwhelms that surge strip, you can guess where the rest of that surge goes.
Another consideration: **surges do not enter facilities just on the AC power lines**. Coaxial cable and phone lines are also at risk. A fax machine or computer should have protection for the AC power line and the phone line. A television should have protection for the AC power line and the coaxial cable.
Now, don't throw away your surge strips. They do provide vital protection for your electronic devices. But, **surge strips alone can't provide sufficient protection**.
Let's take a look at a more comprehensive protection strategy.
AC power lines are not unique in their ability to serve as surge conductors. In fact, surges can travel on any metal conductor.
A surge could just as easily enter a facility through communication lines (for phone and fax), data lines (for computer networks), or coaxial cable (for cable television service).

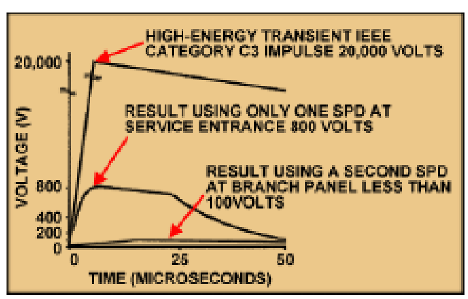
Whole Home Surge Protection



For this reason, surge protective devices (SPDs) should be installed at the service entrance on all metal conductors.
One handy solution is a combination surge protective device, such as the one shown here. It provides service entrance protection for AC, telephone and coaxial lines, all in one package.

Two Stage Approach
IEEE (Emerald Book ١٩٩٢) recommends that **SPDs be coordinated in a staged or cascaded approach**. IEEE and NFPA ٧٨٠ say that the starting point is at the service entrance. The first SPD should be placed here to suppress a large percentage of the initial event. That is to say, that the first level surge protector is installed on to a loadcenter (service entrance) to reduce a voltage surge to an acceptable level for any downstream devices including smaller SPD devices (point of use surge strips).
To deal with any residual voltage, **a second SPD should be installed just ahead of critical loads**, such as the power panel at a facility's computer room. This twostage approach will reduce a ٢٠ kV lightning surge to well under ٣٣٠ volts peak, which is the recommended limit imposed by the IEEE.

Figure ٥. IEEE Two-Stage Approach is extremely effective

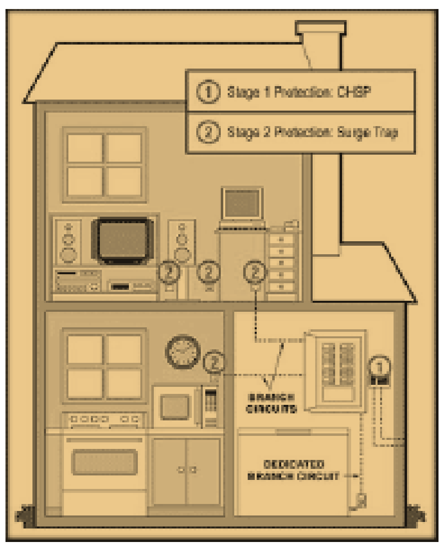


In the case of a residential application, the second-stage protection can take the form of a surge strip. That is, provided it offers protection for all of a load's exposures:
AC power lines, telephone lines and/or coaxial cable. The first stage would be a device that is directly installed to the electrical panel to safely shunt the majority of the surge away from critical loads (appliances and electronics).

Figure ٦. First Stage: Loadcenter Protector

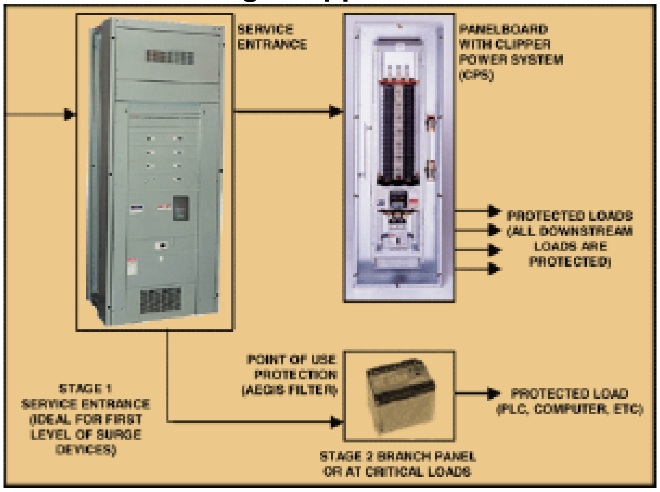
Figure ٧. Second Stage: Surgetrap Strips

Figure ٨. Two-Stage Protection in a Residential Application



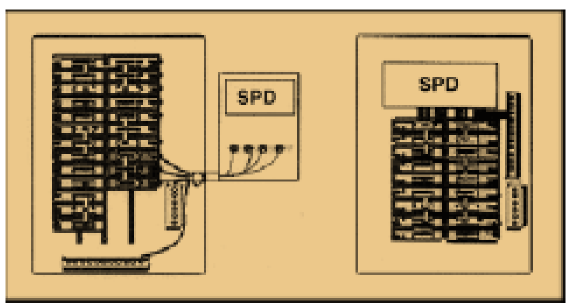
Let’s also consider an industrial application. The first stage of protection is provided at the service entrance, with an SPD integrated into the *Switchboard* or main *Panelboard*. **The second-stage protection can take the form of a critical load protector (such as a filtering device), or an SPD at the power panel that feeds critical loads.**

Figure ٩. Two-Stage Protection in an Industrial Application Integrated Surge Suppression



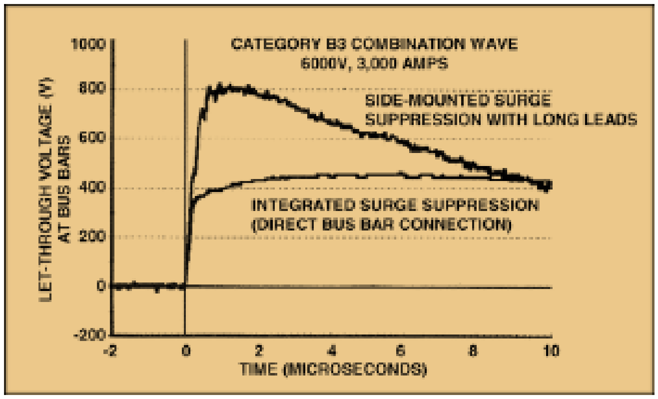
Historically, surge suppression devices were purchased as standalone devices. They were simply mounted next to a panelboard or switchboard, and connected by cable and available circuit breaker. This type of design is still in widespread use today for retrofit applications.

Figure ١٠. Standalone Surge Suppression (on left) vs. Integrated Surge Suppression



Over the past few years, **switchgear manufacturers have begun integrating surge protective devices right into electrical distribution equipment**. Today, surge suppression is available on many types of switchboards, panelboards, busway, and motor control centers.
This integrated design has solved many problems associated with the standalone approach. The most significant benefit is improved suppression performance.
The suppression device is connected directly to the bus bars, eliminating much of the *Impedance* associated with running a cable to an external suppression device. Lower impedance translates directly into lower *Let-Through Voltage*.

Figure ١١. Standalone Surge Suppression not as Effective as Integrated Surge Suppression



Additional benefits of integrated surge suppression over retrofit include:

Reduced installation cost

There is no need to hire a contractor or maintenance electrician to mount the SPDs.

Reduced wall space usage

Integrating the suppressor frees up as much as three feet of wall space per unit.

Space is a premium in any electrical room. Saving wall space is a significant benefit to facility owners and engineers.

Peace of mind

Because the suppressor is factory-installed and tested, the specifier does not have to check the installation. The retrofit solution, if installed incorrectly, would lead the specifier to force the contractor to reinstall the device; a costly and timeconsuming process. Future claims are reduced with the integrated solution, as are headaches for the engineer and end customer.

No warranty conflicts

Should a problem arise, the customer needs to deal with only one manufacturer.

There are several types of surge protection components used by SPD manufacturers.

These are:

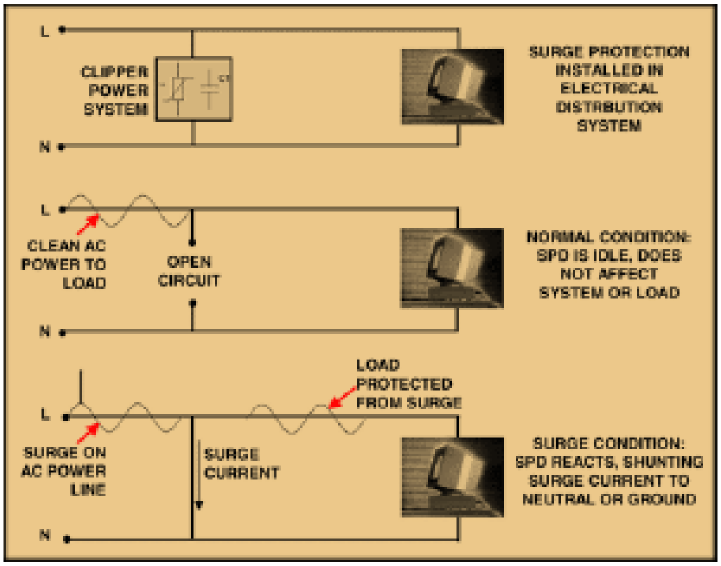
- MOVs
- SADs
- Gas tubes (not covered in this ١٠١ module)
- Selenium cells
- Hybrid devices

Metal Oxide Varistor

The most reliable and proven technology available for reducing a transient voltage is the *Metal Oxide Varistor (MOV)*. Not coincidentally, it is also the most widely used in the industry. In AC power applications, **over ٩٩% of**

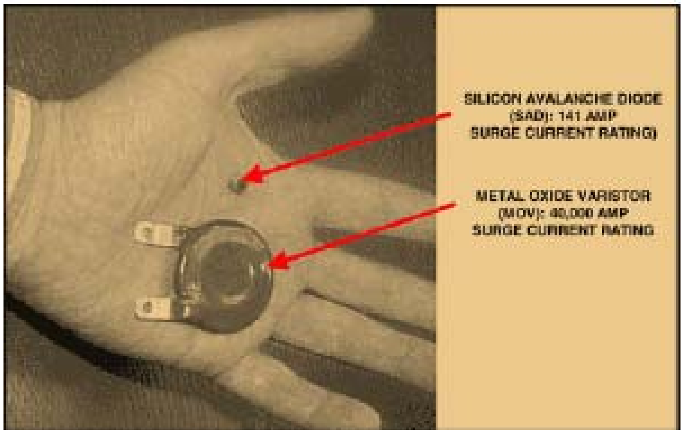
SPDs incorporate MOV technology because of the high-energy capability and reliable performance as a *Clamping Device*.
Under normal operating conditions, the MOV is a high-impedance component which has a small leakage current passing through it. But, **when subjected to a voltage surge of, say, ١٢٥% system nominal voltage, the MOV reacts in nanoseconds, becoming a low impedance path to divert the surge away from the load.**

Figure ١٢. The MOV Protects Equipment from Harmful Surges



A filter element is often used in conjunction with an MOV. This hybrid arrangement provides a number of advantages, including faster response, better clamping and longer life.
Silicon Avalanche Diode The *Silicon Avalanche Diode (SAD)*, is **frequently used in dataline and communication surge protectors**. It is not recommended for use in high-exposure AC applications, due to its limited energy-handling capabilities.
The SAD's capacity is somewhat limited. To handle a typical Category B (on feeder and short branch circuits) transient surge, a circuit would require many SADs to be incorporated. This is because **the SAD is a poor heat dissipator**. In fact, the largest capacity SAD available commercially is rated at only ١٥٠٠ *Watts*, equivalent to a ١.٥ Joule device. For this reason, **the SAD is not recommended for use in panelboard or switchboard applications**.

Figure ١٣. Typical SAD (top) and MOV (bottom)



Selenium Cell Though the *Selenium Cell* was once a popular SPD component, it is now considered outdated. It was replaced in the ١٩٦٠s by the MOV. Selenium cells are metallic rectifiers (diodes) with a maximum reverse voltage of only ٢٥ VDC; many cells are required for higher voltages. There is one SPD manufacturer still producing a form of the selenium cell, referred to as “selenium enhanced surge protection.” **The device combines a selenium cell in parallel with an MOV.** Although this seems to offer the best of two worlds, the effectiveness of such a device is questionable.
When selenium cells are used in parallel with MOVs, there is no advantage gained in performance, cost or application flexibility. In fact, their cost and physical bulkiness are considerable disadvantages. Many selenium plates must be stacked together to create sufficient voltage breakdown for use in AC circuits.

Technology Comparison
Let’s compare the SPD technologies side by side.

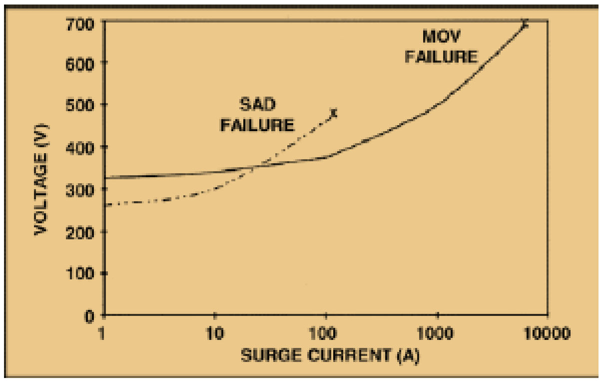
SPD Technology	Advantages	Disadvantages
Metal Oxide Varistor	• High energy capability • Excellent reliability • Consistent performance • Better mechanical connectivity for paralleling multiple components	• Gradually degrades, requiring multiple components mounted in parallel
Silicon Avalanche Diode	• Ideal for dataline applications • Consistent performance	• Low energy capability • High cost • Sensitive to overvoltages • Multiple units required

SPD Technology	Advantages	Disadvantages
Selenium Cell	• High energy capability	• High leakage current • High let-through voltage • Bulky • High cost

MOV vs. SAD in AC Power Systems: Myth and Fact
A small number of surge protective device manufacturers still promote the use of silicon avalanche diodes (SADs) for AC applications. (Eaton Electrical is not one of those manufacturers.)
As previously stated, **over ٩٥% of SPDs incorporate MOV technology**. The SAD continues to hang on in spite of this fact, largely due to some incorrect beliefs about the technology. Let's put these myths to rest onc
e and for all with an examination of the facts.
Myth #١:
"SADs respond faster than MOVs. This superior response time results in improved SPD performance."
Fact:
NEMA LS-١ and IEEE committees do not mention response time as an SPD specification. All SPDs, no matter the technology, respond in plenty of time to shunt surges.
Fact:
Even if response time was a factor, **SAD-based devices and MOV-based devices have equivalent response times**. Internal wiring and connections also affect device response time. The internal wiring and connective leads on a SADbased device add inductance. **Inductance is the dominating factor in overall response time. It slows the reaction speed of the typical SAD-based device to roughly that of the MOV-based device.**
Myth #٢:
"SADs provide tighter clamping than MOVs."
Fact:
When exposed to IEEE-defined test waveforms and UL ١٤٤٩ ٢nd edition test results, **the two devices have the same Suppression Voltage ratings**. UL does not regard SAD devices as providing better clamping than MOV devices.
Myth #٣:
"MOVs degrade over time, while SADs do not. Therefore, the SAD has a longer life and is safer to use."
Fact:
Life expectancy of a SAD is much lower than that of an MOV. A single SAD can be damaged by a surge of less than ١,٠٠٠ amps. IEEE C٦٢.٤١ requires an SPD to withstand surges of ١٠,٠٠٠ amps. MOV-based designs allow reliable surge protection that far exceeds the life of the facility.
SAD designs have lower energy capabilities, especially in service entrance locations. Look at the chart below. The limited energy-handling capability of the Selenium Cell • High energy capability • High leakage current
• High let-through voltage
• Bulky

• High cost
SPD Technology Advantages Disadvantages SAD is clear to see. SAD-based devices are also prone to catastrophic failure due to swells (overvoltage disturbances).

Figure ١٤. The SAD has Less Energy Capability, Shorter Lifespan than the MOV



A quality SPD with MOVs in parallel can achieve surge ratings of over ٢٥٠,٠٠٠ amps, per phase. With this rating, **the SPD will operate effectively for the entire life of the building**, even in a high lightning area, such as Florida. This makes the MOV much more reliable for use in an AC power system.

Surge Protection Device Standards

Standards established by *UL*, *IEEE*, *ANSI*, *NEC* and others provide uniformity in the SPD world. **Standards provide testing benchmarks that allow surge protection devices to be judged and categorized.**
To make informed application decisions regarding surge protection, you should be familiar with all current surge protection standards. Though we have hinted at various standards previously in this module, it is important for us to take some time to examine the standards in detail.

Summary of Standards

Standard	Rev Date	Purpose	
UL 1449	2nd edition: 1996	Safety Tests	Specifies safe construction materials and methods to ensure product safety for SPDs used on AC power lines.
		Surge Test	Checks let-through voltage rating using small "surge current" test wave. Note: This standard does not require a maximum surge current test or test the performance of SPDs.
UL 497, 497A, 497B	Various	Safety standard for primary telephone line protectors, isolated signal loops and surge protection used on communication/data lines. No performance tests conducted on communication/ data lines.	
ANSI/IEEE C62.41	1991	The ANSI document "Recommended Practice on Surge Voltages in Low Voltage AC Power Circuits" defines recommended surge tests.	
IEEE 1100	1992	This Emerald Book, entitled "Recommended Practice for Powering and Grounding Sensitive Electronic Equipment" is the standard reference book for facility-wide power quality solutions.	
NEMA LS-1	1992	NEMA Technical Committee guide for specification of SPDs, including physical and operating parameters.	
NFPA 780	1992	Lightning Protection Code recommendations for use of SPDs at a facility's service entrance.	
NEC 285	New Code-2002	"This article covers general requirements, installation requirements, and connection requirements for transient voltage surge suppressors (TVSS) permanently installed on premises wiring system."	

Now, let's consider some of these standards more closely. UL ١٤٤٩ ١st Edition is the standard for all equipment installed on the load side of the AC electrical service, and throughout the facility for low-voltage distribution systems. This includes both hardwired and plug-in products. To obtain a UL listing, **a suppressor must pass over a dozen performance tests**, including:

Standard Rev Date Purpose
UL ١٤٤٩ ٢nd edition:
١٩٩٦ Safety Tests Specifies safe construction materials and methods to ensure product safety for SPDs used on AC power lines. Surge Test Checks let-through voltage rating using small “surge current” test wave.
Note: This standard does not require a maximum surge current test or test the performance of SPDs.
UL ٤٩٧, ٤٩٧A, ٤٩٧B Various Safety standard for primary telephone line protectors, isolated signal loops and surge protection used on communication/data lines. No performance tests conducted on communication/ data lines.
ANSI/IEEE C٦٢.٤١ ١٩٩١ The ANSI document “Recommended Practice on Surge Voltages in Low Voltage AC Power Circuits” defines recommended surge tests.
IEEE ١١٠٠ ١٩٩٢ This Emerald Book, entitled “Recommended Practice for Powering and Grounding Sensitive Electronic Equipment” is the standard reference book for facility-wide power quality solutions.
NEMA LS-١ ١٩٩٢ NEMA Technical Committee guide for specification of SPDs, including physical and operating parameters.
NFPA ٧٨٠ ١٩٩٢ Lightning Protection Code recommendations for use of SPDs at a facility’s service entrance.
NEC ٢٨٥ New Code-٢٠٠٢
“This article covers general requirements, installation requirements, and connection requirements for transient voltage surge suppressors (TVSS) permanently installed on premises wiring system.”

• Transient voltage surge suppression
• Duty cycle
• Temperature
• Leakage current
• Overvoltage
• Grounding continuity

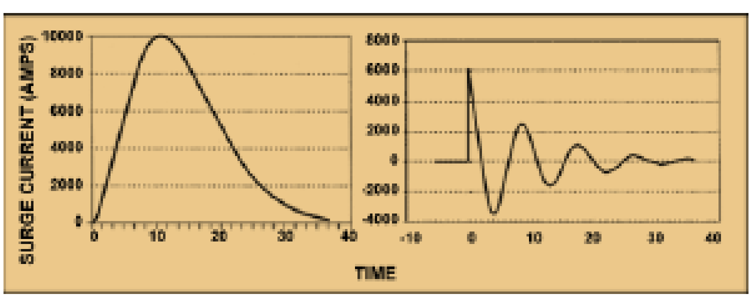
It must also meet safety standards in areas such as:
• Enclosure construction
• Corrosion protection
• Insulation
• Internal wiring
• Grounding

UL also conducts a Let-Through Voltage test, and assigns the suppressor a Suppressed Voltage Rating (SVR). **It is important to note that ratings under this standard are component ratings only, not the actual let-through voltage rating of the electrical distribution system.** This means installation lead length and overcurrent protection are not taken into account.
UL ١٤٤٩ ٢nd Edition The core of testing procedures remained the same into the ٢nd edition. However, **some procedures were updated**.
A substantial change was made in the surge testing methodology. Surge current for hardwired devices was changed from ٣,٠٠٠ amps to ٥٠٠ amps, matching the standard applied to plug-in devices.

Additional abnormal fault tests were put in as well. The SPD is exposed to high voltage to ensure the unit does not fail in an unsafe manner.
UL ٤٩٧, ٤٩٧A and ٤٩٧B UL ٤٩٧ is a safety standard for safeguarding people, not devices. While UL ٤٩٧ protectors must protect personnel, they are not designed with safety for sensitive electronic equipment in mind.
As such, UL ٤٩٧ is not really our primary concern. However, it is good for you to have a familiarity with the standard.
UL ٤٩٧ is the safety standard for single- or multi-pair telecommunications primary protectors. Every telephone line provided by a telephone operator must have a UL-approved T١ protector to meet with NEC Article ٨٠٠. This primary protector is a safety requirement, designed to protect personnel from excessive potential or current in phone lines, caused by lightning, power conductor contact, and rises in ground potential.
Surge suppressors meeting this standard are listed as either UL ٤٩٧A or UL ٤٩٧B. Let's look briefly at each.
UL ٤٩٧A applies to secondary protectors for telephone and communication circuits. Such protectors are intended for use on the protected side of telecommunication networks with less than ١٥٠ operating *RMS* volts to ground, assuming that primary protectors are in place. Secondary protectors are used at the facility incoming service, or other areas requiring protection for communication equipment.

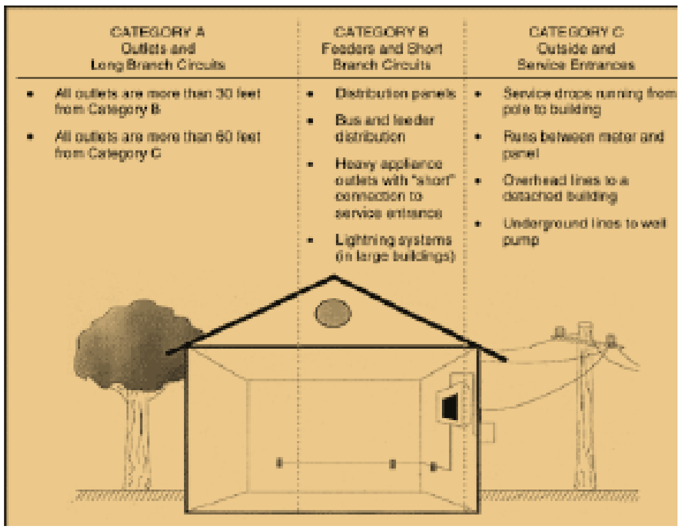
UL ٤٩٧B applies to data communication and fire alarm circuit protectors (communication alarm-initiating or alarm-indicating loop circuits). This includes most dataline protectors in the electrical industry.
ANSI/IEEE C٦٢.٤١ This document describes a typical surge environment, based on the following factors:
• Location within a facility
• Powerline impedance to the surge
• Total wire length
• Proximity
• Type of electrical loads
• Wiring quality
• Geographic location
It does not specify a performance test, but it does include standardized waveforms to use for testing surge protective equipment.

Figure ١٥. Combination Wave (current), Shown at Left, and Ring Wave



The combination wave waveform is a unipolar pulse, similar to a lightning strike.
The rise time of this current wave is ٨ microseconds.
The ring waveform is an oscillating waveform that most often occurs inside a facility.
The amplitude and available energy of the standard waveforms are dependent upon the location within a facility. For this reason, **the standard classifies locations into three categories**:

Figure ١٦. Location Categories A, B and C



This table describes commonly used category A, B, and C test surge waveforms.

Category	Voltage (V)	Current (A)	
		Ring Wave 0.5 µS x 100kHz	Combination Wave (Impulse) 8 x 20 µ S (A)
A3	6,000	200	N/A
B3	6,000	500	3,000
C3	20,000	N/A	10,000

IEEE ١١٠٠ (١٩٩٢) IEEE Standard ١١٠٠ is presented in an emerald book entitled "Recommended Practice for Powering and Grounding Sensitive Electronic Equipment."
This standard is the recommended reference book for facility-wide power quality solutions.
The defined scope of the publication is "to recommend design, installation and maintenance practices for electrical power and grounding of sensitive electronic equipment used in commercial and industrial applications."
The following chapters apply to surge protective devices:

• Chapter ٣, especially sections ٣.٤.٢ and ٣.٤.٣
• Chapter ٤, especially sections ٤.٤ and ٤.٥
• Chapter ٨, especially section ٨.٢
• Chapter ٩, especially section ٩.١١

NEMA LS-١ This document is a specification guide for low-voltage (under ١٠٠٠ V) AC power applications.
NEMA used concepts and recommendations from established IEEE and UL guidelines in developing this guide.
NEMA LS-١ identifies key parameters and evaluation procedures for specifications.
Some of the key parameters are:
• *Maximum Continuous Operating Voltage (MCOV)*
• Modes of protection
• Maximum surge current for each mode of protection
• Clamping voltage for:
• B٣ Ring wave
• B٣/C١ Impulse
• C٣ Impulse
• EMI noise rejection (insertion loss)
• Safety UL approvals (including UL ١٤٤٩)
• Application environment
Joule ratings and response time are not mentioned as performance criteria for SPDs in NEMA LS-١ or other organizations.
NFPA ٧٨٠ As stated earlier, **NFPA ٧٨٠ is the code for lightning protection systems**. It addresses protection requirements for facilities such as:
Category Voltage (V) Current (A) Ring Wave ٠.٥ μS x ١٠٠kHz
Combination Wave (Impulse) ٨ x ٢٠ μ S (A) A٣ ٦,٠٠٠ ٢٠٠ N/A
B٣ ٦,٠٠٠ ٥٠٠ ٣,٠٠٠ C٣ ٢٠,٠٠٠ N/A ١٠,٠٠٠
• Ordinary structures
• Miscellaneous structures and special occupancies
• Industrial operating environments
Section ٣-٢١ of the code relates to surge suppression. It states: "**Devices suitable for protection of the structure shall be installed on electric and telephone service entrances, and on radio and television antenna lead-ins** (*shall indicates a mandatory requirement). Note: Electrical systems and utilization equipment within the structure may require further surge suppression."

Helping the Customer
Surge protective devices are standard on most specifications for industrial and commercial facilities.

Specification Criteria For Distribution Surge Protection
A specification should focus on the essential performance, installation and safety requirements. But what criteria are important when specifying a surge protection device?
The following are considered essential performance, safety, and installation criteria for a specification:

Surge Current Per Phase
Eaton Electrical recommends ٢٥٠ kA per phase for service entrance, ١٢٠ kA per phase for panelboards or other locations.

Let Through Voltage
Performance should be specified based on the three standard IEEE test waveforms
(IEEE C٦٢.٤١ Category C٣ and B٣ combination waves, and B٣ ringwave).
Specify the required ratings for applicable nominal voltages on LG and L-N modes.

Effective Filter
Based on the MIL-STD-٢٢٠ insertion loss test, noise attenuation at ١٠٠ KHz should exceed ٥٠ dB (L-N modes). Specify that test results (bode plots) are provided as submittals.

Integrated Installation
The SPD should be factory-installed as part of the distribution equipment. Ensure the installation minimizes lead length.

Internal Fusing
For safety and over current protection, a ٢٠٠ kAIC internal fusing system should be provided.

Reliable Monitoring and Diagnostics
This should include foolproof status indication for each phase. A popular option is to include Form C contacts for remote monitoring.

Independent Testing
To ensure a reliable construction and design, specify that all manufacturers submit results from an independent test lab, verifying the device can achieve the published surge current ratings (on a per mode and per phase basis).
To help you understand the importance of these criteria, let’s answer a few commonly asked specification criteria questions.

What is Surge Current Capacity?
Surge Current Capacity is defined by NEMA LS-١ as **the maximum ٨/٢٠ us surge current pulse the SPD device is capable of surviving on a single impulse basis, without suffering either performance or degradation of more than ten percent (١٠%) deviation of clamping voltage**.
Industry standards publish surge current per-phase, by summing modes L-N and L-G in a *Wye* system, or L-L and L-G in a *Delta* system.
Surge current capacity is used to indicate the protective capability of a particular SPD design, and should be used on a per-phase and per-mode basis when specifying a SPD for a given application.

What Surge Current Capacity is Required?
Surge current capacity is dependent on the application and the amount of required protection. The facility's geographic location and exposure to transients should be considered. Also, consider how critical the equipment is to the facility in terms of downtime and repair costs.
Based on available research, the maximum amplitude of a lightning-related surge on a facility's service entrance is a ٢٠ kV, ١٠ kA combination wave (refer to IEEE C٦٢.٤١). Above this amount, the voltage will exceed *Basic Insulation Level (BIL)* ratings, causing arcing in the conductors and/or the distribution system.
Cutler Hammer recommends ٢٥٠ kA per phase for service entrance applications (large facilities in high exposure locations), and ١٢٠ kA per phase at branch panel locations.
If the maximum surge is ١٠ kA, why do many suppliers suggest installing a device that can handle up to ٢٥٠ kA per phase? The answer is **life expectancy**.
A service entrance suppressor will experience thousands of surges of various magnitudes. Based on statistical data, **a properly constructed suppressor with a ٢٥٠ kA per phase surge current rating will have a life expectancy in excess of ٢٥ years** in a high-exposure location.
Some manufacturers recommend installing SPDs with surge current ratings of up to ٦٠٠ or ١٠٠٠ kA per phase. This level of capacity offers no benefits to the customers.
A ٤٠٠ kA/phase device would have approximately ٥٠٠-year life expectancy for medium exposure location – well beyond reasonable design parameters.
Today's SPDs will not fail due to lightning surges. Based on two decades of experience, the failure rate of an SPD is extremely low; below ٠.١%.
Should a suppressor fail, it is likely the result of excessive over voltage (swell), due to a fault on the utility power line (i.e., the nominal ١٢٠ VAC line exceeds ١٨٠ VAC for many cycles). A severe swell will damage surge protectors and other electronic loads, such as computers. Should this rare event occur, call the utility to investigate the problem.

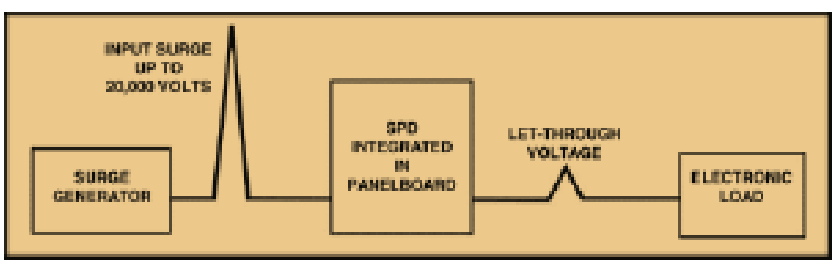
Why Shouldn't Joule Ratings Be Used to Compare SPDs?
Joule ratings are not an approved specification for surge protective devices. IEEE, IEC, and NEMA do not recommend using **Joule ratings when specifying or comparing surge suppressors because they can provide misleading and conflicting information**.

For example, on a ١٢٠ Volt system, a ١٥٠ Volt or ١٧٥ Volt MOV could be used.
Even though the ١٧٥ Volt MOV has a higher Joule rating, the ١٥٠ Volt has a much lower let through voltage.
Joule ratings are a function of let through voltage, surge current, and surge duration.
Each manufacturer may use a different standard surge wave when publishing Joule ratings. For this reason the power quality industry does not Recommend the use of Joule ratings in performance specifications.

Why is Independent Testing Important?
Manufacturers are not required to have their units independently tested to their published surge current capacity rating. Most published ratings are theoretical.
They are calculated by summing the individual MOV capabilities.
For example, a manufacturer may claim a rating of ١٠٠ kA, but due to the poor construction integrity, the unit may be unable to share current equally to each MOV. Without equal current sharing, the expected life expectancy cannot be met.
Specifies should request that manufacturers submit independent test reports From lightning labs confirming the published surge ratings.

What is Let-Through Voltage?
Let-through voltage (or *Clamping Voltage*) is the amount of voltage that is not suppressed by the SPD and passes through to the load.
Let-through voltage is a performance measurement of a surge suppressor's ability to attenuate a defined surge. IEEE C٦٢.٤١ has specified test waveforms for service entrance and branch locations. A surge manufacturer should be able to provide let through voltage tests under the key waveforms.
Lower let-through voltage offers better surge protection for downstream loads.

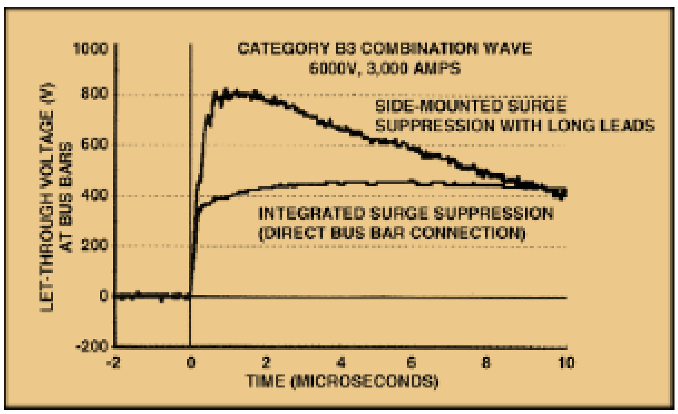
Figure ١٧. Example of SPD Integrated in a Panelboard



What Effect Does Installation Have on SPD Performance?
Installation is the most important factor in determining the effectiveness of a particular SPD.
Installation lead length (wiring) reduces the performance of any surge suppressor.
As a rule of thumb, each inch of installation lead length adds between ١٥ to ٢٥ Volts to the let-through voltage. Because surges occur at high frequencies

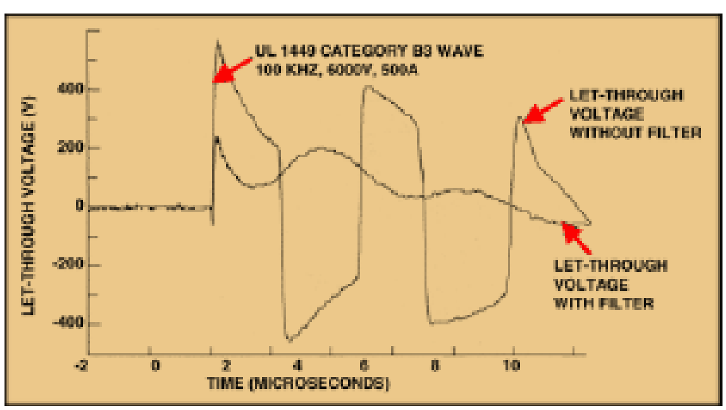
(approximately ١٠٠ kHz), **the leads from the bus bar to the suppression element creates impedance in the surge path**.
Published let-through voltage ratings cover the device or module only.
These ratings do not include installation lead length, which is dependent on the electrician installing the unit.
Therefore, the actual let through voltage for the system is measured at the bus bar and is based on two factors:
• the device rating (quality of the suppressor)
• the quality of the installation work
For example, consider an SPD with a ٥٠٠ Volt rating. This is the true rating only if the SPD is integrated into the panelboard it is protecting. If it is connected to a panelboard with ١٤ inches of #١٤ wire, it allows approximately ٣٠٠ Volts to be added to the let through voltage. The true let-through voltage at the bus bar is ٨٠٠ Volts.

Figure ١٨. Installation Plays a Large Role in Determining Let-Through Voltage (Based on IEEE ٦KV ٣KA Combination Wave)



What is the Benefit of Filtering?
Filtering eliminates electrical line noise and ringing transients by adding capacitors to the suppression device.

Figure ١٩. The Benefit of Filtering



Filtering is often referred to as “sine wave tracking” or “active tracking.” These are marketing terms, and are not relevant to filter performance. Also, not all SPDs provide filtering. Many SPDs claim to possess sine wave tracking, sine wave contour, or EMI/RFI noise attenuation, but may not employ a quality filter.
With all the confusion on the subject, make sure the manufacturer can provide proof that the SPD meets these key filtering specifications:

MIL-STD-٢٢٠A Insertion Loss Test
Attenuation at ١٠٠ KHz, measured in dB. A dB rating above ٤٠ dB (at ١٠٠ kHz) reflects better performance. The higher the dB rating, the better the filtering.

Let Through Voltage - IEEE C٦٢.٤١ Category B٣ Ringwave
On a ١٢٠-volt system, L-N should be less than ٢٠٠ volts.

Is Maintenance Required for an SPD?
Maintenance is not a requirement for a quality SPD. A quality SPD should last over ٢٥ years without any preventive maintenance program.
The SPD should come with a diagnostic system that will provide continuous monitoring of:
• fusing system and protection circuits (including neutral to ground)
• open circuit failures
• overheating (in all modes) due to thermal runaway

Does an SPD Give Me ١٠٠% Coverage on All Electrical Loads?
No, it does not.
SPDs protects against surges, one of the most common types of electrical disturbances.
Some SPDs also contain filtering to remove high *Frequency* noise (٥٠ KHz to ٢٥٠ KHz).
An SPD does not reduce harmonic distortion (٣rd through ٥٠th harmonic equals ١٨٠ to ٣٠٠٠Hz).
An SPD cannot prevent damage caused by a direct lightning strike. No device can. A direct lightning strike is a very rare occurrence. In most cases, lightning causes induced surges on the power line, which can be reduced by the SPD.
An SPD cannot stop or limit problems due to excessive swells (overvoltage).
A swell is a rare disturbance caused by a severe fault in the utility power, or a problem with the ground (poor or non-existent N-G bond). A swell occurs when the AC voltage exceeds the nominal voltage (١٢٠ volts) for a short duration (milli second to a few minutes). If the voltage exceeds ٢٥% of the nominal system voltage, the SPD and other loads may become damaged.
An SPD does not provide back-up power during a power outage. An *Uninterruptable Power Supply (UPS)* is required to provide battery back-up power.

What Causes an SPD to Fail?
Most people think that the main cause of SPD failure is a direct lightning strike.
This is not true. The number one cause of failure for SPDs is **exposure to severe swells and overvoltage disturbances**.
Under normal operation, the internal components of an SPD are designed to conduct a short-duration (microsecond or millisecond) surge to ground.
A swell (increased RMS voltage lasting a half cycle to a few seconds) or an overvoltage condition (swell lasting more that a few seconds) causes the SPD to conduct beyond specifications. The result is a reduction of life expectancy, or in severe cases, SPD failure.

Glossary

Ampere Unit of current.

ANSI American National Standards Institute.

Basic Insulation Level (BIL)
The voltage that an insulation is able to withstand. This is measured using a ١.٢ x ٥٠ microsecond wave.

Clamping Device A component which is activated and deactivated by predetermined voltages.

Clamping Voltage See “Let-Through Voltage.”

Conductor A material that permits a very free exchange/movement of electrons from one atom to another.

Current The flow of electrons in the same direction from atom to atom.

Delta A motor connection arrangement where each winding is wired end to end to form a completely closed loop circuit.

Frequency The number of cycles in one second of alternating current. Expressed in hertz (Hz). For example, ٦٠ Hz is ٦٠ cycles in one second.

Grounding Path The path in an electrical system that electrical power will follow to ground.

Harmonics Multiples of the AC power fundamental frequency. When added to the fundamental frequency, a distorted waveform is produced.

IEEE Institute of Electrical and Electronics Engineers.

Impedance The apparent opposition of current flow with application of voltage.

Let-Through Voltage The portion of a transient which is not suppressed by an SPD and is let through to the load.

Maximum Continuous Operating Voltage (MCOV)
The turn on voltage when the MOV starts to shunt current to ground.

Metal Oxide Varistor (MOV)
A solid-state surge suppression component that can handle large amounts of current and react within nanoseconds.

NEC National Electrical Code.

NFPA National Fire Protection Association.

NLSI National Lightning Safety Institute.

Noise Distortion An unwanted disturbance superimposed on a useful signal.

Overvoltage A swell lasting more than one minute.

Panelboard A wall-mounted electrical power distribution device for use in commercial and industrial applications. It provides circuit control and over current protection for light, heat or power circuits. NEC defines it as a single panel or group of panel units designed for assembly in the form of a single panel; including buses, automatic over current devices, and equipped with or without switches for the control of light, heat, or power circuits; designed to be placed in a cabinet or cutout box placed in or against a wall or partition and accessible only from the front.

Power Quality A general term referring to many different type of disturbances and distortions to a power signal. IEEE defines it as “The concept of powering and grounding sensitive equipment in a manner that is suitable to the operation of that equipment.”

Radio Frequency Interference (RFI)
A type of system noise caused by communication system components.

Resistance The restriction to the flow of electrons.

RMS Root Mean Square current. Also referred to as effective current. It is the square root of the average of all the instantaneous currents (current at any point on a sine wave), squared.

Sag A decrease in RMS voltage lasting from half a cycle to a minute.

Selenium Cell An early surge suppression device made up of metallic rectifiers. This device was replaced by the MOV in the ١٩٨٠s.

Service Entrance The point at which electrical power enters a building.

Shunt A low-resistance parallel circuit used to divert current.

Silicon Avalanche Diode (SAD)
A solid-state surge suppression component which is extremely fast, but lacks the ability to handle heavy current. It is not commonly used in AC applications.

Spike See “Surge.”

Standards Guidelines and regulations for the manufacturing of electrical equipment.

Surge A single, non-repeating voltage distortion of less than ٠.٥ cycles in duration. (Also called “Spike,” “Transient,” or “Voltage Impulse.”

Surge Current Capacity
The maximum ۸/۲۰ us surge current pulse the SPD device is capable of surviving on a single impulse basis, without suffering either performance or degradation of more than ۱۰ percent deviation of clamping voltage.

Surge Protective Device (SPD)
A device used to protect electronic equipment from harmful variations in power quality.

Swell An increase in RMS voltage lasting from half a cycle to a minute.

Switchboard A floor-standing electrical power distribution device for use in commercial and industrial applications. It divides large blocks of electrical current into smaller blocks of current used by electrical equipment. NEC defines it as a large single panel, frame, or assembly of panels on which are mounted, on the face or back, or both, switches over current and other protective devices, buses and usually instruments.

Transient See "Surge."
Transient Voltage
Surge Suppressor
(TVSS)
See "Surge Protective Device."

Transformer A device used to raise (step up) or lower (step down) a voltage level.

UL Underwriters Laboratories.

Un interruptible Power Supply (UPS)
A system designed to automatically provide power, without delay or transients, during any period when the normal power supply is incapable of performing acceptably.

Voltage The force applied to a conductor to free electrons, causing electrical current to flow.

Voltage Impulse See "Surge."

Watt The basic unit of power, indicating the amount of work accomplished when one volt causes one ampere to pass through a circuit.
Wye A motor connection arrangement where one end of each of the three-phases is connected to the other phases internally. The remaining end of each phase is then brought out externally.