

Frequently Asked Questions

Please also refer to Technical Note TN CR 014 for more FAQs.

Surge Protection Issues

What is the difference between the terms "Arrester" and "Suppressor"?

These terms are often used interchangeably and rather loosely. In the USA, the two terms have different meanings as determined by the NEC and their Listing. An Arrestor refers to a surge protective device (SPD) that is Listed for use before the primary disconnect to a facility (the service entrance panel), whilst a suppressor is only Listed to be used after this primary disconnect. A violation of the NEC occurs if an SPD listed as a Transient Voltage Surge Suppressor or TVSS device under (UL 1449 TVSS) is connected ahead of the primary disconnect to a facility. On the other hand, Secondary Surge Arresters, as formally known, can be connected both upstream and downstream of the main-disconnect. Secondary Surge Arresters are generally lower performance devices, and their use after the main disconnect is not recommended.

Are primary SPDs alone sufficient for equipment protection?

There is no one correct answer to this question. For a small facility, a single SPD installed at the service entrance panel can be sufficient, while for a bigger facility it is usually necessary to adopt a distributed protection philosophy where primary protection is installed at the service entrance panel, and secondary protection at branch panels. It can even be necessary to include additional point-of-use SPDs if this equipment is located some distance (100 ft or more) from the supplying panel. In addition to providing protection to the power panels, the installation of additional "multi-service SPDs" is particularly recommended. Such devices provide their greatest benefit by ensuring multiple services entering the facility (such as telephone, cable and power) are all tied to the same ground reference.

Why do I need an SPD when I already have an isolation transformer?

Isolation transformers provide very good common mode rejection but do not provide good differential (normal) mode rejection. In other words, a surge superimposed equally on both the L and N conductors will see rejection by the isolation transformer, while a surge appearing differentially between the L and N conductors will pass through the transformer.

Do SPDs devices need to be coordinated when several are applied in one system?

Yes, the Europeans have perfected this approach to protection by applying robust air gap devices with high energy handling capabilities at the primary service entrance, and then "coordinating" these with downstream devices, which have lower (better) protection levels and generally lower energy handling capabilities. IEC standards, such as IEC61643-12, detail this approach. In the US, manufacturers tend not to use air gap type devices and so the coordination problem is not as big an issue. All said, it is important to coordinate SPDs with different limiting voltages to ensure that one does not conduct to the exclusion of the others. The building wiring between service and branch panels can provide this coordination if adequate in length (>30ft typically). Given that such coordination requires careful understanding and design, which the average installer is not readily equipped to handle, it is probably safer for the installer to specify SPDs with similar clamping characteristics (or MCOV – see later) throughout an installation.

How does installation affect the performance of SPDs?

The installation of SPDs is often poorly understood. A good SPD, incorrectly installed, can prove of little benefit in real-life surge conditions. The very high rate-of-change of current, typical of a surge transient, will develop significant volt drops on the leads connecting



the SPD to the panel or equipment being protected. This can mean higher than desired voltages reaching the equipment during such a surge condition. Measures to counteract this effect include locating the SPD so as to keep interconnecting lead lengths as short as possible, twisting these leads together. Using a heavier gauge AWG cable helps to some extent but this is only a second order effect. It is also important to keep protected and unprotected circuits and leads separate to avoid cross coupling of transient energy.

What are the different power systems in use in the US and what are the protection needs for each?

The US power distribution system is a TN-C-S system. This implies that the Neutral and Ground conductors are bonded at the service entrance of each, and every, facility or separately derived sub-system. This means that the N-G protection mode within a multi-mode SPD installed at the service entrance panel is basically redundant. Further from this N-G bond point, such as in branch distribution panels, the need for this additional mode of protection is more warranted. In addition to the N-G protection mode, some SPDs can include L-N and L-L protection. On a three phase WYE system, the need for L-L protection is questionable as balanced L-N protection also provides a measure of protection on the L-L conductors.

Changes to the 2002 edition of the NEC have precluded the use of SPDs on ungrounded delta power distribution systems. Behind this rather broad statement is the intention that SPDs should not be connected L-G as by so doing these modes of protection are creating pseudo grounds to the floating system. Modes of protection connected L-L are however acceptable. The high-leg delta system is a grounded system and as such allows for protection modes to be connected L-L and L-N or L-G.

What are the SPD issues for USA customers working in other countries?

Different power distribution systems are encountered in various other countries. These can include TT, TN, IT and variants of these. It is important that a clear understanding of the systems being used by a particular country is obtained before specifying SPDs. Too often, only the voltage of the distribution system is considered and inappropriate protection can result. Most countries also have their own standards requirements thus a UL Listing alone can not be sufficient to meet local code requirements.

What are multi-mode SPDs - why do I need L-L and N-G protection?

Multi-mode SPDs are devices, which comprise a number of SPD components within the one package. These "modes" of protection can be connected L-N, L-L, L-G and N-G across the three phases. A three phase SPD offering "all modes of protection", will have as many as 10 modes protected. It is questionable whether this practice adds much to the overall protection effectiveness. In Europe, it is common to only protect L-N (L-PE) and N-PE modes where PE is the Protective Earth connection or ground.

What is a practical surge rating for service entrance protection?

This is a difficult question and depends on many aspects including - site exposure, regional isokeraunic levels and utility supply. A statistical study of lightning strike probability reveals that the average lightning discharge is between 30 and 40kA, while only 10% of lightning discharges exceed 100kA. Given that a strike to a transmission feeder is likely to share the total current received into a number of distribution paths, the reality of the surge current entering a facility can be very much less than that of the lightning strike which precipitate it. ANSI/IEEE c62.41.2 standard seeks to characterize the electrical environment at different locations throughout a facility. It defines the service entrance location as between a B and C environment, meaning that surge currents up to 10kA 8/20 can be experienced in such locations. This said, SPDs located in such environments are often rated above such levels to provide a suitable operating life expectancy, 100kA/phase being typical. Recent changes to the IEEE have introduced a new scenario (known as Scenario II) which covers the situation of a facility sustaining a direct or near-by strike. Under such conditions, a very large ground potential rise can result and significant surge current flow on the G-N and N-L protective modes. Under such conditions, 100kA 8/20 or 10kA 10/350 energy levels can be expected.

What do waveforms such as 8/20, 10/350, and 10/1000 mean and how are they interrelated?

Lightning induced surge currents are characterized as having very rapid rising "front edges" and long decaying "tails". To a first approximation, the first number in each example of the above surge waveforms signifies the time taken for the surge to reach 90% of its peak value, and the second number, the time taken for this surge to decay from its peak to its half way value. These times are measured in microseconds, although convention



does not require that this unit appear after the wave shape. The ratio between these different waveforms is a complicated function based on the integration of the energy content. As a rule of thumb, a 10/350 surge rating is equivalent to about ten times the surge rating at 8/20. Put simply, 10 kA 10/350 is about the same as 100kA 8/20. Most MOV (metal oxide varistor) based SPDs are surge rated using the 8/20 wave shape, while air gap devices are rated using the 10/350 wave shape. SAD (silicon avalanche diode) based SPDs are usually rated using the 10/1000 wave shape.

What about repetitive low level transients?

Concerns have been expressed that electronic components can deteriorate and fail prematurely under repeated low-level transient over-voltage activity. While this can be the case, there is no substantiated body of evidence to support this theory.

Should I be concerned about really fast transients?

Switching pulses and subsequent re-strikes in multi-stroke lightning, can produce very fast transients, with rise times in the fraction of microseconds. These can capacitively and inductively couple to equipment and cause induced over-voltages. To eliminate such fast spikes, it is usual to incorporate a level of filtering in the SPD device. This can simply be a capacitor connected in parallel across the SPD's output, or it might be a true series LC filter – often called a two port SPD where there are distinct sets of input and output terminals. SPDs incorporating series LC filters generally provide superior filtering performance, however they are more expensive and need to be sized for the continuous load current. It should be pointed out that SPDs with so called "filters" would more accurately be described as wave-shaping devices as the filter's prime role is to slow the very fast rate of voltage rise dv/dt rather than to "filter".

What is meant by dB attenuation in an SPD?

Generally this applies to SPDs, which incorporate filters. The dB of attenuation stated is usually the point at which the filter has reduced the incident transient by 3dB (or the voltage by a factor of 20). A more effective surge filter will have a higher dB at a lower frequency. For example, an SPD with 60dB attenuation at 30kHz is more effective than a filter with 60dB at 100kHz. The attenuation can also apply to in-line, series connected, type SPDs used in data communications. In such a case the SPD should have a low attenuation (dB number) at the operating frequency of the data system.

For SPDs protecting AC power circuits, it is common for SPD manufacturers to quote the dB result at 100kHz, rather than the frequency at which 3dB attenuation occurs. Rather than quote a single performance figure, a graph of frequency response from 10kHz to 1MHz is more useful. Performance above 1MHz is of little value as at these higher frequencies large variations will occur between installations. While many specifications call for 60-80dB at 100kHz, little practical performance benefit is obtained beyond 30dB.

The subject of SPDs with filters is not complete without reiterating the point made in the preceding the term "filter" when applied to a power SPD is confusing. Such "filtering" devices would more appropriately be described as wave shaping devices and their performance expressed by the reduction in dv/dt , which they present to the steep rising, edge of the surge, rather than in dBs. Filters per se are linear attenuation whilst SPDs with filtering components exhibit a non-linear action and slope attenuation.

What is Sine Wave Tracking technology?

This is a rather fancy term given to an SPD which includes some form of RFI/EMI filtering.

What is Transient Discriminating technology?

This is a patented technology where an SPD is able to discriminate between on the one hand the relatively low 50/60Hz frequency of long duration abnormal over voltages, such as occur when the utility power is poorly regulated or a "lost neutral" condition occurs, and on the other hand the faster transient activity of surges.

Why should filters have air cored inductors?

SPDs, which comprise LC networks with a series ferrite inductor in the Line side conductor, can experience saturation under the high current levels during surge activity. Air gap inductors do not suffer from problems of saturation, however they are more expensive to produce for the same figure of inductance than ferrite wound inductors.

How can I protect equipment that operates on DC?

Protection of equipment connected to DC sources or power supplies generally involves installing protection at the AC input to the power supply. In some cases, protection might also be required on the DC side of such power supplies, particularly if long cable lengths are involved. Most SPDs will indicate if they are suitable for



DC use and the maximum operating voltage to which they are designed for use on.

What is NEMA LS1?

NEMA LS1 is a voluntary guide established by various manufacturers of surge protection devices under the auspices of the National Electrical Manufacturers Association, which primarily designates how surge protective devices should be specified. This includes labeling and testing. Purchasers of SPDs are encouraged to ensure their supplier adheres to this guide. An example of the value of the guide can be seen in how it recommends that the surge rating of an SPD be specified. It requires that the manufacturer's claimed surge rating be independently tested and verified, rather than the simple, and all too common approach of simply aggregating surge material or components within the SPD and claiming this as the rating. The LS1 approach tests all aspects of the SPD including the ability of the terminals and internal fuses to handle the claimed surge current, and possible failure modes under fault conditions.

What happens to GFIs (RCDs) with downstream SPDs?

When a mode of protection within an SPD operates to divert energy to ground (L-G), an imbalance between currents on the phase conductors and the return neutral current may be noted by the GFI, causing it to trip. This "nuisance" tripping can be reduced if only L-N and L-L modes of protection are used, but this restriction is not always possible, or desirable. Even with just L-N and L-L mode protected, nuisance tripping can still occur with larger transients. This is due to the limited common-mode rejection ability of the GFI.

What are surges, transients and temporary over voltages?

These are all forms of over-voltages and confused by the often loose and interchangeable use of terminology. The significance of the terms usually relates to their understood duration. For example, a transient is generally considered of very short duration ($<10\mu\text{s}$) and relatively low energy content. Such electrical activity is often characterized by voltage switching spikes, which in themselves contain relatively little energy content, but are sufficient in voltage to cause junction breakdown in the substrates of semiconductors and failure. Surges ($>10\mu\text{s}$ & $<1\text{ms}$), on the other hand, have a greater energy component and it is generally this which causes the damage and charring of electronic components and appliances. SPDs are designed to protect equipment

against surges and transients. Temporary over voltages (TOVs) are created by faults on the utility power distribution system and can cause extensive damage since their time domain is much longer (ms to s or several cycles). Note that while UL 1449 Edition 2 ensures that the SPD will not create a fire or safety hazard under these conditions, SPDs are not designed to protect against TOVs.

Speed of response - is this important in itself?

Yes and No! The ability of an SPD or surge component to respond to a voltage which exceeds its "turn-on" threshold, will govern the residual clamping voltage which the downstream equipment will be required to withstand. If the device is too slow, the clamping voltage will be high and the equipment may not be adequately protected. This said, too much is often made of manufacturers of "speed-of-response". What is more important is the "clamping or residual voltage" performance of the SPD. It is also worth noting that nanosecond transients can not travel far on power wiring, thereby limiting their occurrence in practice.

What is distributed protection?

This is the process of coordinating protection between the primary service entrance to a large facility and the internal branch distribution panels. Generally an SPD with high surge handling capacity is installed at the service entrance while SPDs of lower surge ratings will be installed on the branch panels or dedicated supplies feeding sensitive equipment. This approach can be taken further to include point-of-use SPDs on long lines where they terminate to sensitive or critical equipment. A further example of such a distributed protection philosophy might include hardwired SPDs at the main and sub-panels and additional plug-in protectors on select equipment.

Where is the best place to fit protection?

Ideally, protection should be installed at the main service entrance as close to the N-G bond as possible. This will ensure that surge energies are routed to earth by the most direct part. In larger facilities where distances between this primary protection and the equipment being protected are long, it is also good practice to provide point-of-use protection as close to the terminals of the equipment as possible.

What is UL 1449?

UL1449 is the test procedure required to List (or Recognize) a Transient Voltage Surge Protection product to Underwriters Laboratories Inc. It is important



to note that this is a safety, and not performance, specification.

What changes did Edition 2 of UL 1449 bring?

Edition 2 of this standard required SPDs to meet a number of new and more onerous test regimens. In particular a section entitled Abnormal Over-voltage was introduced by which the safety and failure modes of SPDs are more extensively evaluated under elevated operating voltages.

What is the concern about sustained over-voltages?

Sustained abnormal over voltages of the utility distribution system can exceed the SPD's Maximum Continuous Operating Voltage or MCOV. If this happens, the SPD's non-linear clamping elements will begin to clamp on the crest of the utility voltage (120 times a second on 60Hz systems). This will rapidly cause the SPD to accumulate heat, which further lowers the onset of conduction point of the clamping elements. If this condition exists for an extended time, a thermal runaway will begin and catastrophic failure will result with the resultant potential of a fire hazard being created unless the design had made provision to prevent the thermal runaway

Are underground cables protected from lightning?

Underground cables offer greater isolation to the effects of lightning when compared to aerial cables, however they are still subject to induced electromagnetic coupling of energy from nearby ground flashes. As such, surge protection should be installed on facilities supplied by both, overhead and underground, power feeders.

What are NEMA and IP environmental ratings?

NEMA Standards Publication 250-1997, "*Enclosures for Electrical Equipment (1000 Volts Maximum)*" provides a comprehensive definition of NEMA Enclosure Types for interested parties. Those of interest to installers of surge protection products in non-hazardous locations include:

Type 1 - Enclosures constructed for indoor use to provide a degree of protection to personnel against incidental contact with the enclosed equipment and to provide a degree of protection against falling dirt.

Type 2 - Enclosures constructed for indoor use to provide a degree of protection to personnel against incidental contact with the enclosed equipment, to provide a degree of protection against falling dirt, and to

provide a degree of protection against dripping and light splashing of liquids.

Type 3 - Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against incidental contact with the enclosed equipment. To provide a degree of protection against falling dirt, rain, sleet, snow, and windblown dust; and that will be undamaged by the external formation of ice on the enclosure.

Type 3R - Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against incidental contact with the enclosed equipment. To provide a degree of protection against falling dirt, rain, sleet, and snow; and that will be undamaged by the external formation of ice on the enclosure.

Type 4 - Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against incidental contact with the enclosed equipment. To provide a degree of protection against falling dirt, rain, sleet, snow, windblown dust, splashing water, and hose-directed water; and that will be undamaged by the external formation of ice on the enclosure.

Type 4X - Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against incidental contact with the enclosed equipment. To provide a degree of protection against falling dirt, rain, sleet, snow, windblown dust, splashing water, hose-directed water, and corrosion; and that will be undamaged by the external formation of ice on the enclosure.

Type 12 - Enclosures constructed (without knockouts) for indoor use to provide a degree of protection to personnel against incidental contact with the enclosed equipment. To provide a degree of protection against falling dirt; against circulating dust, lint, fibers, and flyings; and against dripping and light splashing of liquids.

What do the markings on a SPD really mean, and which are important?

Unlike norms for surge protection devices such as IEC61643 which defines required markings on SPDs, and have greater adoption in European and Asian countries, the US does not have as clear a standard on these issues. UL specifies certain minimum requirements, but by-in-large manufacturers are given considerable freedom in this area. Some parameters, which are important and should be considered when selecting an SPD, include:

- Nominal voltage – should match the utility system voltage where the device is to be installed
- MCOV – The Maximum Continuous Operating Voltage, this is the maximum voltage the device



can withstand before conduction (clamping) begins. It is higher than the nominal system voltage.

- Single shot surge rating – measured in kA (not Joules). Be careful when trying to compare like with like in this area. Independent test reports should be available if tested and labeled as per NEMA LS1. Also look to see that you are comparing surge ratings of the same wave shape e.g. compare ratings at 8/20 with ratings at 8/20.
- SVR – Suppressed Voltage Rating. Under UL1449, a TVSS device is assigned an SVR. This is the clamping voltage of the device rounded to one of 330, 400, 500, 600V ... etc. under specific conditions of lead length and injected surge current. The SVR provides a very approximate measure of an SPD's clamping performance. It is important to stress that this test is conducted at an extremely low current level of 500A 8/20 and as such can not clearly predict the performance of an SPD under more realistic conditions to which it is rated. It is also important to realize that an SPD designed to be installed on a 110V system, which has an SVR of 400V, is not "better" than an SPD designed to be installed on 240V which has an SVR of 600V. Also bear in mind that an SPD with the lowest SVR can be rendered less than useless if incorrectly installed with excessive lead lengths.
- Enclosure rating – ensure that the NEMA rating of the enclosure matches the environmental conditions at the location where the device is to be installed.

What are the new NEC Short Circuit Current Ratings requirements?

The NFPA 70, NEC 2002 edition, Article 285, introduced a new requirement when installing SPDs on mains powered systems – that the SPD be coordinated with (rated to) the available short circuit fault current at the point to which it is to be connected. At this point in time, TVSS devices passing through UL 1449, have inherently been Listed to short circuit fault currents of 10kAIC. This new requirement is currently being reviewed by UL 1449 as they consider how best to test to higher short circuit fault currents. Products can be Listed with higher ratings if the manufacturer has specifically requested this.

Is the Joule rating of an SPD important?

While conceptually an SPD with a larger energy rating will be better, comparing SPD energy (Joule) ratings can be misleading. More reputable manufactures no longer provide energy ratings. The energy rating is the sum of surge current, surge duration and SPD clamping voltage. In comparing two products, the lower rated device would be better if this was as a result of a lower

clamping voltage, while the large energy device would be preferable if this was as a result of a larger surge current being used. There is no clear standard for SPD energy measurement, and manufacturers have been known to use long tail pulses to provide larger results. Additionally confusing this issue is the possibility that the rating is just the energy absorbed, diverted, or the sum of both. NEMA LS1 by specific omission does not recommend the comparison of SPD's energy ratings. Comparison of single shot surge ratings and let-through voltages is considered sufficient.

Grounding Issues

What is Ground Potential Rise?

When a large amount of energy is rapidly deposited into the ground by a cloud-to-ground lightning strike or by an electrical fault on a utility power system, the ground potential at this injection point rises to a higher level with respect to the more distant ground. This has the effect of creating a voltage potential gradient in the earth, which can cause dangerous touch and step potentials to personnel exist. By creating an equipotential ground plane beneath a facility by electrically bonding all separate "grounds" into a "system" or by burying ground mats and meshes, this danger to personnel and equipment can be reduced. It is also important to note that GPR is not only dangerous to personnel, it can also cause damage to equipment – see below.

I have heard I should not use separate grounding systems?

Indeed! Separate "grounds" or "ground references" can result in damage to equipment during lightning activity. A cloud-to-ground discharge can deposit extensive charge very quickly into the local ground mass of the earth causing the ground at the injection point to rise up in voltage with respect to more remote grounds. The resultant potential gradient established in the ground means that separate grounds could rise to different potentials resulting in a loop current and possible damage to equipment referenced to these two different points. This phenomenon can present itself in a more subtle way when equipment is connected to multiple services. An example of this can be a PC with modem where connections are made to utility power and telecom line. If these two services are not referenced together to create a common, equipotential, ground plane, damage can result. In fact, this is one of the more common causes of equipment damage. A well-designed multi-port protector will ensure such equalization between services at the equipment.



What is single point grounding?

It is important to ensure that ground potential differences are not derived across equipment within a facility during ground potential rises. One way to ensure this is to adopt a single point approach to grounding of the equipment and services in the facility. This usually entails referencing all equipment in the facility to a single ground bar (or a number of ground bars that are solidly electrically bonded together), and ensuring that this internal bonded system is connected to the external ground system. "Single point grounding" refers to the single connection between the internal facility ground system and the external ground network. The external ground network can utilize multiple grounding elements such as ground rods and/or counterpoises.

How do I measure ground resistance?

There are a number of techniques for measuring ground resistance, the more popular being the "fall of potential method". Measurements require a ground resistance testing instrument and qualified personnel. With larger facilities, it is important to take ground resistance readings by placing the injection and reference electrodes in the "far field" – essentially some few hundred feet from the inspection ground point. This will ensure that false or misleading results are not obtained by having electrodes too close to buried parts of the overall ground system. Clamp-on type instruments are not preferred in such situations due to the possibility of large errors in results.

What ground resistance must I achieve?

This is probably one of the most often asked questions of grounding experts. Again there is no one answer. As a rule of thumb, an effective ground for lightning and surge protection purposes should be somewhere around 10 ohms. Obviously this can be difficult to reach in poor soil conditions and a cost benefit relationship comes into play. It is also important to stress that no definitive applies to grounding values. As an example, it is pointless insisting that a contractor achieve a ground resistance of precisely 10 ohms or less, when the testing method can be subject to as much as 2 ohms variation depending on how the test rods are laid. It is also worth keeping in mind that, the soil water content can vary as much as 50%, depending on the season of the year. There are "ground enhancing materials" which can be used to improve (decrease) the local ground resistivity.

More important than the absolute value of the ground resistance, is to ensure that all the equipment in the facility is referenced to an equi-potential ground plane

through adequate bonding. By ensuring this, all separate pieces of equipment will raise to the same potential during a surge condition. This statement can be illustrated by considering the Space Shuttle, it is not "grounded" however all the equipment onboard will be referenced to an internal equi-potential ground plane.

Some people say impedance and some resistance when talking about grounding?

The lightning surge event is characterized by having very fast changes in current and voltage, sometimes called the dv/dt and di/dt . In essence it is a high frequency event and as such the ground system is better considered as an AC impedance rather than DC resistance. The subject is complicated and requires knowledge of transmission line theory and special techniques to measure the effective impedance of the grounding system under impulse condition. Enough said!

