

Next Generation Surge Protection

UL 1449 Third Edition

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White Paper

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UL 1449 3rd Edition is the most comprehensive overhaul of a surge protection standard the industry has ever seen. This paper attempts to summarize the most important features of the new standard in an effort facilitate understanding of the complexities involved with the design and application of hardwired surge suppressors.

Next Generation Surge Protection

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Introduction

For the second time in two years, Underwriters Laboratories revised their surge protective device safety standard. UL 1449 3rd Edition, effective September 2009, goes beyond the adoption of new safety and performance tests. It is an overhaul of safety standards for low voltage surge protective apparatus previously classified as surge arrestors and transient voltage surge suppressors. Both devices are now combined with surge protective plug strips and point of use protectors under one standard classified as surge protective devices (SPD).

The inclusion of surge arrestors under the 1449 umbrella radically changes the low voltage hard wired arrestor market. Suppliers now have to incorporate COORDIATED safety controls limiting a SPDs fault current exposure. Coordination is verified through full spectrum (high, intermediate, and low) fault current testing.

Also added to UL 1449 3rd Edition is the inclusion of a 10kA and 20kA single impulse surge current performance test. This test complicates an already complex fault current coordination structure. In order to account for these changes, new terminology familiar with European standards was adopted to better classify suppressors based upon their installation location and intended use. Those familiar with previous UL terminology will now need to adjust to new terms like Type 1, Type 2, and In.

IEEE Review

In order to understand what influenced Underwriters Laboratories to adopt a stricter testing regimen, a brief historical review of IEEE standards and surge protector operation will provide a basis of understanding the safety revisions leading up to where we are today.

Nearly 30 years ago, IEEE released IEEE 587, the first iteration of surge environment and characterization guides and surge testing practices. As the surge knowledgebase increased, this standard was renamed and subdivided into today's trilogy C62.41.1-2002, C62.41.2-2002 and C62.45-2002. The first two guides (C62.41.1 and C62.41.2) collectively list the 5 most common surge waveforms that could be seen on electrical distribution systems. Surge magnitudes and durations are categorized based upon a facilities geographical location, exposure to thunderstorm activity, and electrical system location. The following diagram shows the IEEE location Categories C, B, and A (Figure 1) and surge magnitudes and wave shape are shown in (Tables 1, 2, and 3).

Table 1 – Scenario 1 test for SPDs intended for location Category C

Exposure	Standard Tests		Optional Test
	1.2/50µs Voltage generator	8/20µs Current generator	100kHz Ring Wave for front of wave response evaluation
	Minimum open circuit voltage to be applied to SPD	Current to drive through SPD	
Low	6kV	3kA	6kV
High	10kV	10kA	6kV

Table 2 – Standard 1.2/50µs – 8/20µs Combination Wave

Location Category	Peak Values		Effective impedance (Ω)
	Voltage (kV)	Current (kA)	
A	6	0.5	12
B	6	3	2

Table 3 – Standard 0.5µs – 100kHz Ring Wave

Location Category	Peak Values		Effective impedance (Ω)
	Voltage (kV)	Current (kA)	
A	6	0.2	30
B	6	0.5	12

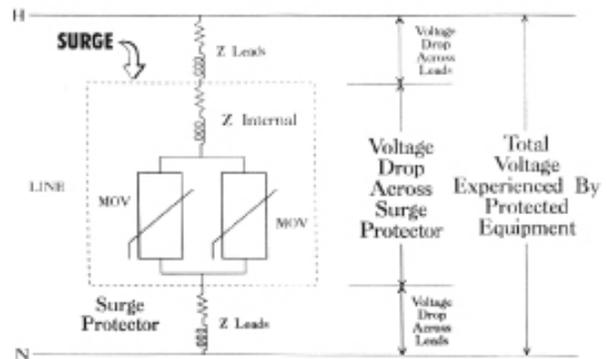
Facility exposure to larger magnitude surges entering through the utility distribution system is limited to the listed surge levels due to inherent relief mechanisms from clearances within electrical distribution equipment.

When surges enter a facility, surge current is driven by a corresponding high surge voltage. As voltage increases and exceeds roughly 10kV, the dielectric of air between a switchboard's or panelboard's buss bars will breakdown. Flashover occurs creating a temporary short circuit between two phases. This phenomenon is demonstrated during stormy weather when flashover occurs at a utility transformer substation resulting in flickering lights within a residence or commercial facility.

As our lives rely more and more on electronics, users looking for surge immunity use surge protective devices as part of the electrical system design. Over time, hard wired SPDs installed throughout an electrical system starting from the incoming service down to branch panel locations proved most effective. However, the data base of incidences of SPD field failures increased. Studies showed surge protectors are non-discriminatory and cannot tell the difference between a surge voltage and a sustained over voltage caused by a distribution system anomaly. Reviewing surge protection operation will explain why this occurs.

How SPDs work?

The circuit shown below represents a typical hard wired surge protector installed in parallel across phase to neutral (L-N). The operational description that follows is applicable to other modes of protection including, L-G, L-L, and N-G. Parallel (One-Port) installations are advantageous for electrical distribution system when compared to in series (two -Port) designs. Series designs typically incorporate in-line inductors sized for the service's current capacity, and this added impedance needs to be taken into account when developing the systems fault current coordination study. On the other hand, parallel suppressor designs offer better cost/benefit ratio while not affecting a facilities fault current coordination.



A parallel hard wired surge protective device (SPD) is represented by the components within the dashed box. This box consists of internal impedance as well as a circuit consisting of two MOVs. But first, what is a MOV?

MOV stands for Metal Oxide Varistor, and it can be simply described as a voltage sensitive resistor. Other technologies like Silicon Avalanche Diodes, Gas Tubes, Selenium rectifiers, etc.. all function in the same manner, but MOVs remain the most commonly used surge protective technology. During surge conditions, MOVs change their impedance from mega ohms to virtually a short circuit. The voltage triggering level changing the MOVs impedance state is called Maximum Continuous Operating Voltage (MCOV). With this basic MOV operational understanding, we will cover how a MOV based SPD protects sensitive electronics.

Protection Steps

As shown previously by the IEEE, surges consist of the following three characteristics:

- High Voltage, Thousands of Volts
- High Current, Thousands of Amps
- Short Duration, Millionths of a second

MOVs are ideal devices to control this anomaly. They are designed to handle large amounts of current for the micro second (μs) surge time frame. Taking advantage of a surge's corresponding high voltage, the surge voltage is used as a trigger to activate the MOVs short circuiting capability.

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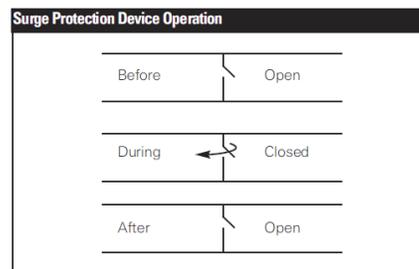
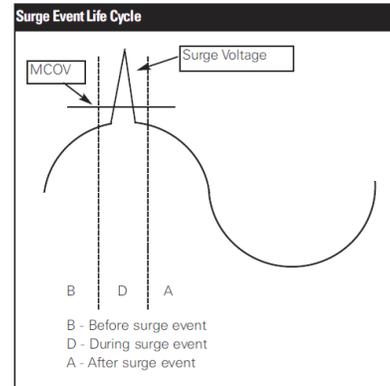
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SPD operation is seen by examining the states of operation before, during and after a surge event:

- **Before** a surge, the surge protector's impedance is an open circuit. It draws little to no load current.
- **During** a surge, MOVs change state from an open circuit to a short circuit. This does two things; it provides a short circuit path for the surge current to go to either neutral or ground. Secondly, it clips off the surge voltage to a safe level.
- **After** a surge, the SPD resets itself to an open circuit.

This operation is illustrated with the following diagrams.



During the infancy of the hard wired suppressor industry, this description of operation was thought to hold true due to the assumption that suppressors would not operate when exposed to faults. However, surge protectors are non-discriminatory and cannot tell the difference between a surge voltage and a sustained over voltage caused by a distribution system anomaly. During a sustained over voltage, internal suppression elements conduct current, causing them to generate heat. This can result in fire or rupture depending on the severity. If a suppressor's internal protection circuit is not coordinated properly, unsafe operation could occur, possibly compromising other parts of the electrical system.

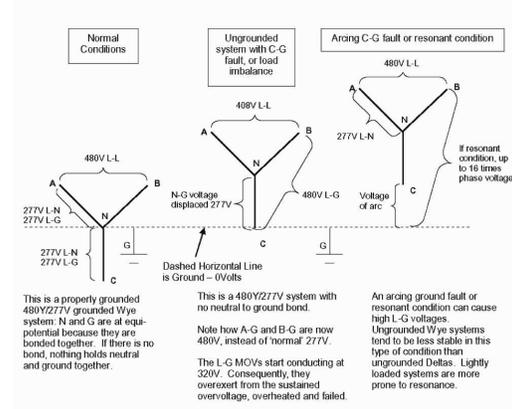
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Sustained over voltage in this context can be cycles, seconds, minutes; all of which are “sustained” relative to microsecond surges. This is sometimes labeled a temporary over voltage, but should not be confused with a transient over voltage. Evidence shows that the following electrical disturbances can cause surge protectors to see a sustained over voltage resulting in premature failure:

- Loss of secondary neutral; missing N-G bonding (system has no reference to ground, resulting in over voltages)
- Line to ground or line to line faults (system voltages skew due to fault)
- Misapplication (accidental 120V suppressor on 277V system)
- Poor voltage regulation (can raise voltage)
- Commingling (accidental contact with higher voltage circuits)
- Ferroresonance (This is a phenomenon characterized by sudden onset of very high sustained over voltages concurrent with high levels of harmonic distortion.)

Visual examples of sustained over voltages are shown below:



Making SPDs Safe

Beginning in the late 80's, the popularity of applying hard wired suppressors for facility protection skyrocketed. As the installed base grew so did the number of reports of unsafe SPD operations. Initially, when UL 1449 was first developed, it just addressed the integrity of SPD construction and installation.

In recent years, UL revised 1449 three times in efforts to shore up surge protector safety based on new scientific and field evidence. In each revision, new fault current testing was introduced. Manufacturers participate in this process and generally have multi-year compliance windows. The following summarizes what fault current tests were adopted for each revision:

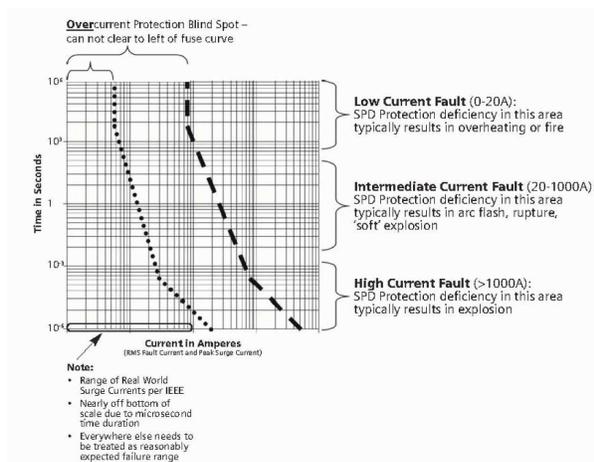
1998 — UL 1449 Second Edition – This introduced fault current testing for SPDs. Suppressors were subjected to low current 0.125A, 0.5A, 2.5A and 5A faults. High current withstand was demonstrated by the manufacturer selecting among test values of 5,000A, 10,000A or 25,000A, which became the SPDs Short Circuit Current Rating (SCCR). This corresponds to the Low and High Fault Current Testing depicted below.

2002 — NEC Article 285 was introduced to address SPD installations. Now SPDs were to be fault current tested as an entire device. The fault current rating of the internal fuse protection was no longer relied upon as evidence in the ability to clear faults safely. Once confirmed, a SPD is given a SCCR. Article section 285.6 requires SPDs to carry SCCRs that are

equal or greater than available fault current where they are to be installed. Consequently, UL 1449 was adjusted and increased fault current testing levels up to 200,000A. Manufacturers could again select fault current levels and demonstrate withstand capability. This SCCR was posted on each device, so inspectors could verify compliance to NEC 285.6. This corresponds to revised High Current Fault Testing depicted below.

2007 — UL 1449 Second Edition Revision (also known as Rev 2.5) – added intermediate fault current tests of 10A, 100A, 500A, and 1000A, and the 0.125A fault current test was deleted. The raised MCOV loophole which some suppliers adopted was closed with the new requirement that all suppression components must conduct during fault current testing.

2009 — UL 1449 3rd Edition, combines surge arrestors and TVSSs under one standard. Now surge arrestors are required to incorporate fault current protection controls similar to those utilized within TVSSs. Additionally, coordination is complicated for arrestors and TVSSs further by the adoption of In surge current performance testing.



What's Next?

Having compiled a large body of work concerning surge protective device safety, Underwriters Labora-

tories pursued and received an ANSI standard designation for UL 1449 3rd Edition. Part of this pursuit included harmonizing 1449 terminology utilized by other international surge suppression standards. Another point of harmonization was the adoption of international performance testing for discharge current and suppressed voltage. Those familiar with previous UL 1449 editions now need to learn new terminology and performance testing.

The following summarization is an effort to mapping previous UL 1449 terms and to ones found in the 3rd Edition.

Terminology

By combining surge arrestors and TVSS devices under the surge protective device umbrella, the 3rd edition task group adopted Type designations (1, 2, 3, & 4) classifying SPDs based upon their installation location within the electrical distribution system.

Type 1 — formally called Secondary Surge Arrestors, are permanently connected hard wired suppressors installed between the secondary of the service transformer and the line side of the service entrance disconnect overcurrent device as well as the load side, including watt-hour meter socket enclosures. This brings old-style Secondary Surge arrestors (SSA's) under UL 1449 and clarifies use for UL 96A Master label. Type 1 SPDs must include internal series overcurrent safety protective equipment – no external breakers or fuses are allowed. For UL 96 Master Label compliance Type 1 SPD must pass a discharge current (I_n) of 20kA.

Type 2 — formally known as hard-wired TVSS, Type 2 SPDs are defined as permanently connected SPDs intended for installation on the load side of the service entrance disconnect over current device and includes SPD's located at the branch panel. Also, these types can be tested with an external series overcurrent protective device. Nominal discharge current (I_n) testing includes less rigorous levels than those desiring Type 1 designations. These levels include - 3 kA, 5 kA, 10 kA or 20 kA.

Type 3 — are plug strip surge protectors. They are usually installed at a minimum of 10 meters (30 feet)

from the service entrance. An example is a cord connected, direct plug-in, receptacle type strip.

Type 4 (new category) — Component SPDs, including discrete components as well as component assemblies.

UL96A Lightning Protection Master Label Impact

Previously, UL 96A required surge suppressors evaluated as secondary arresters. There were issues associated with different regulation and administration. Secondary arresters now evolve into Type 1 SPDs, and UL 96A will accept Type 1 or Type 2 SPDs having 20kA In ratings (new rating, explanation follows).

Nominal Discharge Current Testing (In)

Since 1998, the only performance test listed in UL 1449 is the measured limited voltage test. As part of standards harmonization, the 3rd Edition task group adopted a new peak surge current performance test for surge protective devices.

Nominal Discharge current testing requires a SPD to be subjected to a predetermined peak value of surge current with a waveform shape of 8/20, selected by the manufacturer. They can choose between 10kA and 20kA for a Type 1 protector or 3kA, 5kA, 10kA, or 20kA for Type for Type 2 SPD. SPD passage is obtained if it remains functional after being subjected to 15 surges.

This test is significant because it introduces additional fault current coordination complexities not present in previous UL standards. This is evidenced by suppliers who previously re-designed products for UL 1449, 2nd Edition February 9, 2007 revision decided the expense to re-design for 3rd edition was too great and decided to get out of the market.

The upcoming UL 1449 3rd label will now list the devices In rating.

Clamp Voltage or Measured Limited Voltage Test

Since 1998, UL 1449, 2nd Edition, surge protectors have been clamp voltage tested to provide end users some means to gauge how well the suppressor will protect when subjected to IEEE type surges. This test subjected suppressors to the following procedures:

1. SPD is subjected a 6kV/500A, 8/20µs combination waveform, and the suppressed voltage reading is recorded.
2. Next, SPD is subjected to a duty cycle of 20 impulses (10 positive/10 negative) of a 6kV/3kA 8/20µs combination waveform
3. SPD is again tested using the 6kV/500A, 8/20µs combination waveform where a second suppressed voltage reading is recorded.
4. The average of the first and second reading is rounded up to one of UL's Suppressed Voltage Rating (SVR) categories 330V, 400V, 500V, etc....
5. All test measurements are obtained from 6" leads extending outside the SPD enclosure.

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