

A large, stylized lightning bolt graphic in white and yellow, striking from the top left towards the bottom right, set against a dark red background on the left side of the slide.

**Advanced Protection Technologies**

**Presents:**

**Practical SPD Application for  
Lightning Professionals  
Regarding Changes in  
UL 1449 Third Edition and 2008 NEC**

**Performed by: Lou Farquhar, PE, CEM, GBE**



# This presentation summarizes our Feb 26, 2009 discussion at the ULPA/LPI Conference in New Orleans

**‘Regulatory Changes & What You Need to Know’ in First 19 slides**

**Simplifying Suggestions & Why:  
Slides 15-17**

**Theory & supporting info - slides 20-36**



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# Advanced Protection Technologies (APT)

- 24 Years Supplying Surge Protective Devices
- ISO 9001-2000 Quality Management System
- ISO 17025 evaluation by UL
- *Power Quality Assurance* magazine – PQ 50 Company
- Frost & Sullivan ranked APT – Leading Supplier of Three Phase Devices
- Market Engineering Customer Focus Awards
- Members of UL, IEEE, NEMA standards committees



FROST & SULLIVAN

Market Engineering Award Recipient

1999



# **Regulatory Changes Forcing Industry Changes**

**Collective Surge Industry has been working behind the scenes to simplify and coordinate regulatory activities**

**Coordinating UL 1449 Third Edition with 2008 NEC with NFPA 780, etc.**

**This is coming to fruition now**

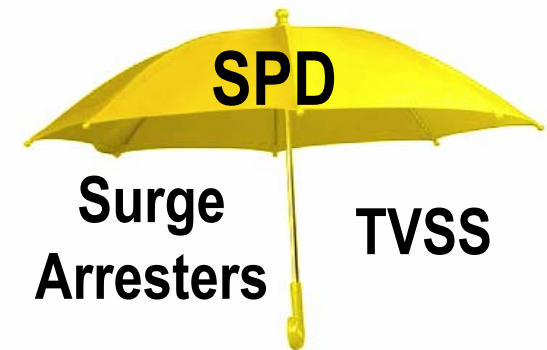


# UL 1449 THIRD Edition

Combines TVSS and Surge Arresters into one  
UL Standard, UL 1449 3rd Edition renamed:

***Surge Protective Devices (SPDs)***

Effective: Sept 29, 2009



- Coordinates with 2008 NEC
- New SPD Types: Types 1, 2, 3 & 4
- New Voltage Protection Ratings (VPRs) replace old-style Suppressed Voltage Ratings (SVRs)
- New I nominal ratings



# 2008 NEC

2008 NEC made substantial changes to:

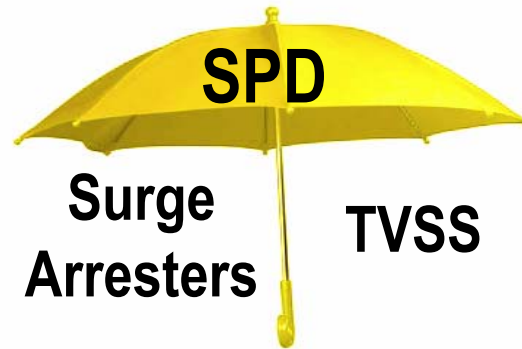
- Article 280 (Surge Arresters, over 1kV)
- Article 285 (SPDs, 1kV or less)

**Surge Arresters traditionally used in Lightning Protection are moved from Article 280 to Article 285.**

**Article 285 is effectively a mix of  
2005 NEC & UL 1449 THIRD Edition**



# UL 1449-3 & 2008 NEC Art 285



- **Surge Arrester SPDs now safety & performance tested**
- **Unaware of existing SA that meets 1449-3 & UL 96A**
- **≈99% of existing SA's become obsolete**
- **2008 NEC Art 285 changed based on 1449-3**
  - **Requires SCCR**
- **Major huge expensive big deal to surge manufacturers**
- **Bid Specifications become obsolete as product evaluation & ratings change**



# UL 1449-3 & 2008 NEC Art 285

**Background: Surge Arrestors and TVSS perform very similar surge suppression functions, but are handled differently by regulatory agencies.**

|                 | <u>NEC</u> | <u>UL eval</u> | <u>UL CCN</u> | <u>Safety test?</u> | <u>UL96A</u> | <u>Location</u> |
|-----------------|------------|----------------|---------------|---------------------|--------------|-----------------|
| Surge Arrestor: | Art. 280   | IEEE C62.11    | OWHX          | Not Really          | Yes          | Line Side/Any   |
| TVSS:           | Art. 285   | UL 1449        | XUHT          | Rigorous!           | ~No          | Load Side       |

**Solution corrected shortcomings and coincides with 2008 NEC, UL 96A (Master Label), NFPA 780 (Lightning Protection) and somewhat harmonize with worldwide surge nomenclature & standards**

**Should Tie Issues Together & Be Easier to Understand**



# UL 1449-3 & 2008 NEC Art 285

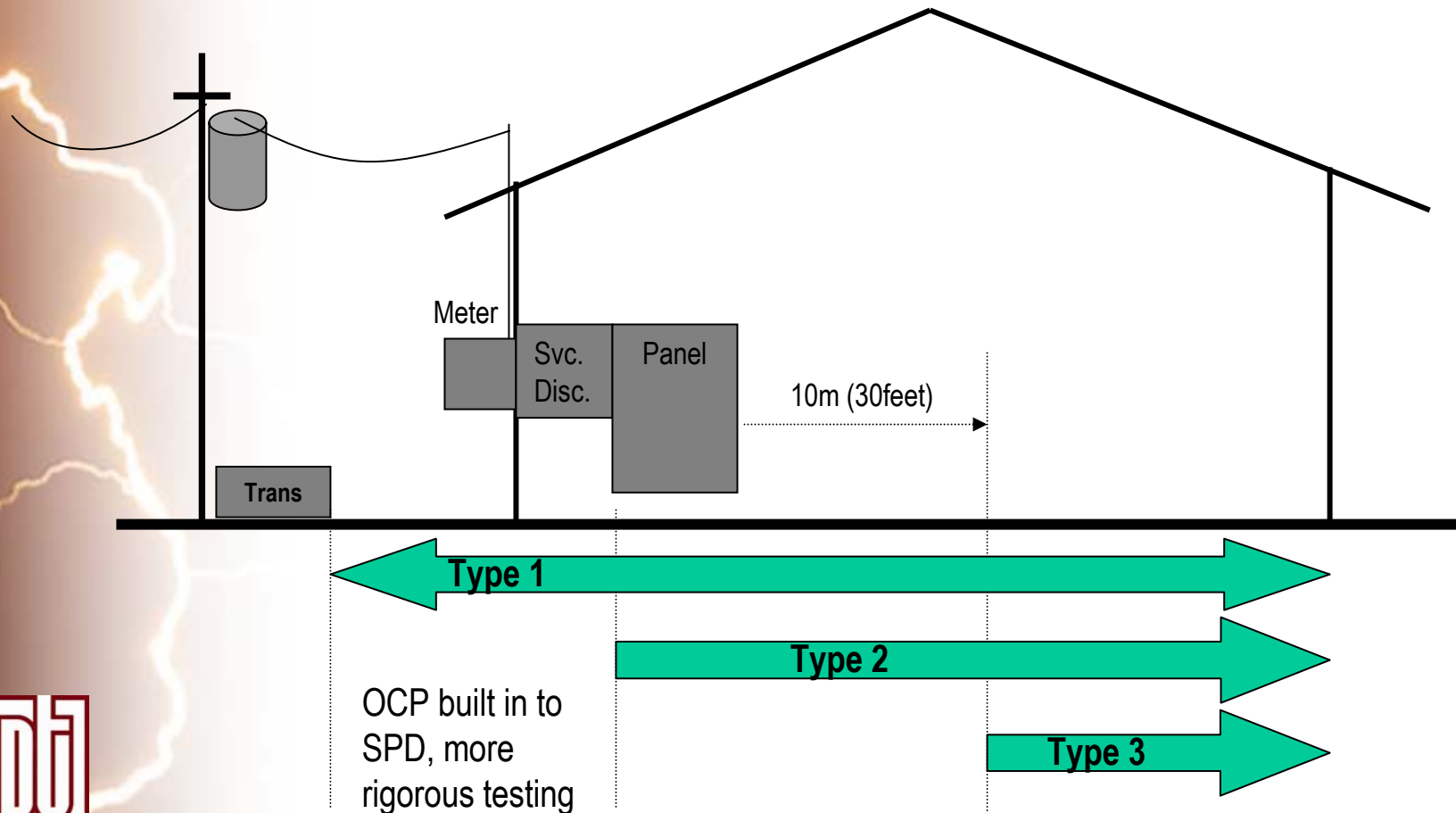
- Changing terms 'Surge Arrester' and 'TVSS' to **SPD**
- Creates Types 1, 2, 3 & 4 SPDs
  - **Type 1** – Installed on line or load side of Main OCP - similar to what you knew as SSA, except now includes rigorous safety testing. Includes all OCP & safety apparatus inside SPD
  - **Type 2** – Installed on load side of Main OCP - similar to what you know as hardwired TVSS. May require external OCP
  - **Type 3** – Point of Utilization – direct plug in - similar to what you know as surge strips - 10 meters from panel (rational based on being IEEE Cat. A location)
  - **Type 4** – surge suppression components, could be basic component or complete module. Type 4 components can be tested for Type 1, Type 2 or Type 3 applications.



# UL 1449-3 & 2008 NEC Art 285

## SPD Types: Types 1, 2, 3 & 4

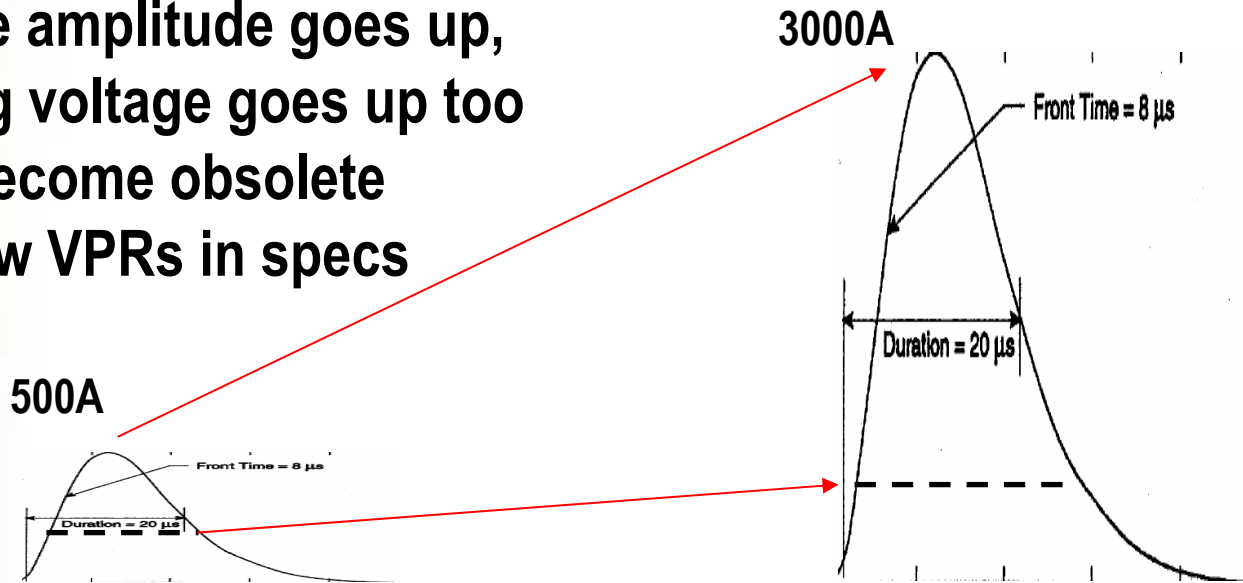
Based on Location within electrical distribution system  
(also coincides with ANSI/IEEE C62.41.2-2002 Categories C, B & A)



# UL 1449-3

## Performance Test Format Changed New Testing uses Six (6) Times More Energy

- As surge amplitude goes up, clamping voltage goes up too
- Specs become obsolete
- Need new VPRs in specs



Old – 6kV / 500A

Suppressed Voltage Ratings  
(SVR)

New – 6kV / 3,000A

Voltage Protection Ratings  
(VPR)



# UL 1449-3

- I nominal Testing – In - (Nominal Discharge Current)
- New Concept to USA – Originated from IEC 61643
  - Duty Cycle Testing
  - 15  $8 \times 20 \mu\text{s}$  surges through every mode of three samples used for VPR testing

Type 1 – 20kA or 10kA

Type 2 – 20kA, 10kA, 5kA or 3kA

Type 3 – 3kA

Type 4 – Based on intended usage as Types 1, 2 or 3



**UL 96A Master Label requires  
20kA In from Type 1 or Type 2 SPD**



# 2008 NEC Art 285

## ARTICLE 285 Surge-Protective Devices (SPDs), 1 kV or Less

### I. General

**285.1 Scope.** This article covers general requirements, installation requirements, and connection requirements for SPDs [surge arresters and transient voltage surge suppressors (TVSSs)] permanently installed on premises wiring systems 1 kV or less.

FPN No 1: Surge arresters less than 1 kV are also known as Type 1 SPDs.

FPN No 2: Transient voltage surge suppressors (TVSSs) are also known as Type 2 and Type 3 SPDs.

**285.3 Uses Not Permitted.** An SPD (surge arrester or TVSS) device shall not be installed in the following:

- (1) Circuits exceeding 1 kV
- (2) On ungrounded systems, impedance grounded systems, or corner grounded delta systems unless listed specifically for use on these systems.
- (3) Where the rating of the SPD (surge arrester or TVSS) is less than the maximum continuous phase-to-ground power frequency voltage available at the point of application

FPN: For further information on SPDs (TVSSs), see NEMA LS 1-1992, Standard for Low Voltage Surge Suppression Devices. The selection of a properly rated SPD (TVSS) is based on criteria such as maximum continuous operating voltage, the magnitude and duration of overvoltages at the suppressor location as affected by the phase-to-ground faults, system grounding techniques, and switching surges.

**285.4 Number Required.** Where used at a point on a circuit, the SPD (surge arrester or TVSS) shall be connected to each ungrounded conductor.

**285.5 Listing.** An SPD (surge arrester or TVSS) shall be a listed device.

**285.6 Short-Circuit Current Rating.** The SPD (surge arrester or TVSS) shall be marked with a short-circuit current rating and shall not be installed at a point on the system where the available fault current is in excess of that rating. This marking requirement shall not apply to receptacles.

### II. Installation

**285.11 Location.** SPDs (surge arresters or TVSSs) shall be permitted to be located indoors or outdoors and shall be made inaccessible to unqualified persons, unless listed for installation in accessible locations.

**285.12 Routing of Connections.** The conductors used to connect the SPD (surge arrester or TVSS) to the line or bus and to ground shall not be any longer than necessary and shall avoid bends.

### III. Connecting SPDs.

**285.21 Connection.** Where an SPD (surge arrester or TVSS) device is installed, it shall comply with 285.23 through 285.28.

**285.23 Type 1 SPDs (Surge Arresters).** Type 1 SPDs shall be installed in accordance with 285.23 (A) and (B).

**(A) Installation.** Type 1 SPDs (surge arresters) shall be installed as follows:

- (1) Type 1 SPDs (surge arresters) shall be permitted to be connected to the supply side of the service disconnect as permitted in 230.82 (4) or
- (2) Type 1 SPDs (surge arresters) shall be permitted to be connected as specified in 285.24.

**(B) At the Service.** When installed at services, the grounding conductor of a Type 1 SPD shall be connected to one of the following:

- (1) Grounded service conductor
- (2) Grounding electrode conductor
- (3) Grounding electrode for the service
- (4) Equipment grounding terminal in the service equipment

**285.24 Type 2 SPDs (TVSSs).** Type 2 SPDs (TVSSs) shall be installed in accordance with 285.24 (A) through (C).

**(A) Service-Supplied Building or Structure.** Type 2 SPDs (TVSSs) shall be connected anywhere on the load side of a service disconnect overcurrent device required in 230.91, unless installed in accordance with 230.82 (8).

**(B) Feeder-Supplied Building or Structure.** Type 2 SPDs (TVSSs) shall be connected at the building or structure anywhere on the load side of the first overcurrent device at the building or structure.

**(C) Separately Derived System.** The SPD (TVSS) shall be connected on the load side of the first overcurrent device in a separately derived system.

**285.25 Type 3 SPDs.** Type 3 SPDs (TVSSs) shall be permitted to be installed anywhere on the load side of branch-circuit overcurrent protection up to the equipment served, provided the connection is a minimum 10 m (30 ft) of conductor distance from the service or separately derived system disconnect.

**285.26 Conductor Size.** Line and grounding conductors shall not be smaller than 14 AWG copper or 12 AWG aluminum.

**285.27 Connection Between Conductors.** An SPD (surge arrester or TVSS) shall be permitted to be connected between any two conductors – ungrounded conductor(s), grounded conductor, grounding conductor. The grounded conductor and the grounding conductor shall be interconnected only by the normal operation of the SPD (surge arrester or TVSS) during a surge.

**285.28 Grounding Conductor Connections and Enclosures.** Except as indicated in this article, SPD grounding connections shall be made as specified in Article 250, Part III. Grounding conductors installed in metal enclosures shall comply with 250.64 (E).

# UL 1449-3 & 2008 NEC Art 285

## Summary:



- **UL 1449 3<sup>rd</sup> Edition new standard for SPDs**
- **Effective Sept 29, 2009**
- **New SPD Types: Types 1, 2, 3 & 4**
- **Performance tested - Voltage Protection Ratings (VPRs)**
- **New I nominal ratings**
- **Need 20kA In for UL 96A Master Label**
  - **We suggest using Type 1's because they definitely include OCP such that you do not have to add on your own**
- **Verify at [www.UL.com](http://www.UL.com) under CCN VZCA**
- **2008 NEC Article 285 for SPDs**
- **Need appropriate SCCR per 2008 NEC Art 285**



# Simplifying Suggestions:

(Why? on next slides)

- **Select UL Listed SPD having 'UL Mark'**
- **Select SPD with 20kA In rating**
- **Select high Short Circuit Current Rating (SCCR)**
- **Select low Voltage Protection Ratings (VPRs)**
- **Select Type 1 SPD**
- **Ensure short leads**
- **This does not have to be costly!**  
(There are basic SPD's meeting this)



# Suggestions & Why (2 of 3):

- **Select UL Listed SPD having 'UL Mark'**
  - 1.) Ensures UL 96A & NEC 285.5 compliance
  - 2.) Easy to verify at [www.UL.com](http://www.UL.com) under CCN VZCA
- **Select SPD with 20kA In rating**
  - 1.) Complies with UL 96A Master Label & NFPA 780 4.18.3.1.2
- **Select high Short Circuit Current Rating (SCCR)**
  - 1.) Comply with NEC 285.6
  - 2.) 100kA -200kA SCCR's almost always adequate
- **Select low Voltage Protection Ratings (VPRs)**
  - 1.) Provide better clamping performance (your computer would rather see less voltage than more – lower VPRs are better)
- **Ensure short leads**
  - 1.) Long leads hurt performance (cut off excess length)



# Suggestions & Why (3 of 3):

- **Select Type 1 SPD**

**Reason: Avoid installation & AHJ headaches because Type 1's can be installed 'anywhere'. Type 1's are more rigidly evaluated per UL & NEC for installation on *line* side of Main Disconnect. This means that internal overcurrent protection is included & tested within SPD and wires are tested too.**

- 1.) This can avoid supplemental breakers/fuses (extra cost)**
- 2.) This can avoid *wrong* breakers/fuses (extra liability)**
- 3.) Because wires are evaluated too, AHJ much more likely to flex where wire sizes might conflict (i.e., situation where system might call for #2 conductor and SPD has #10).**

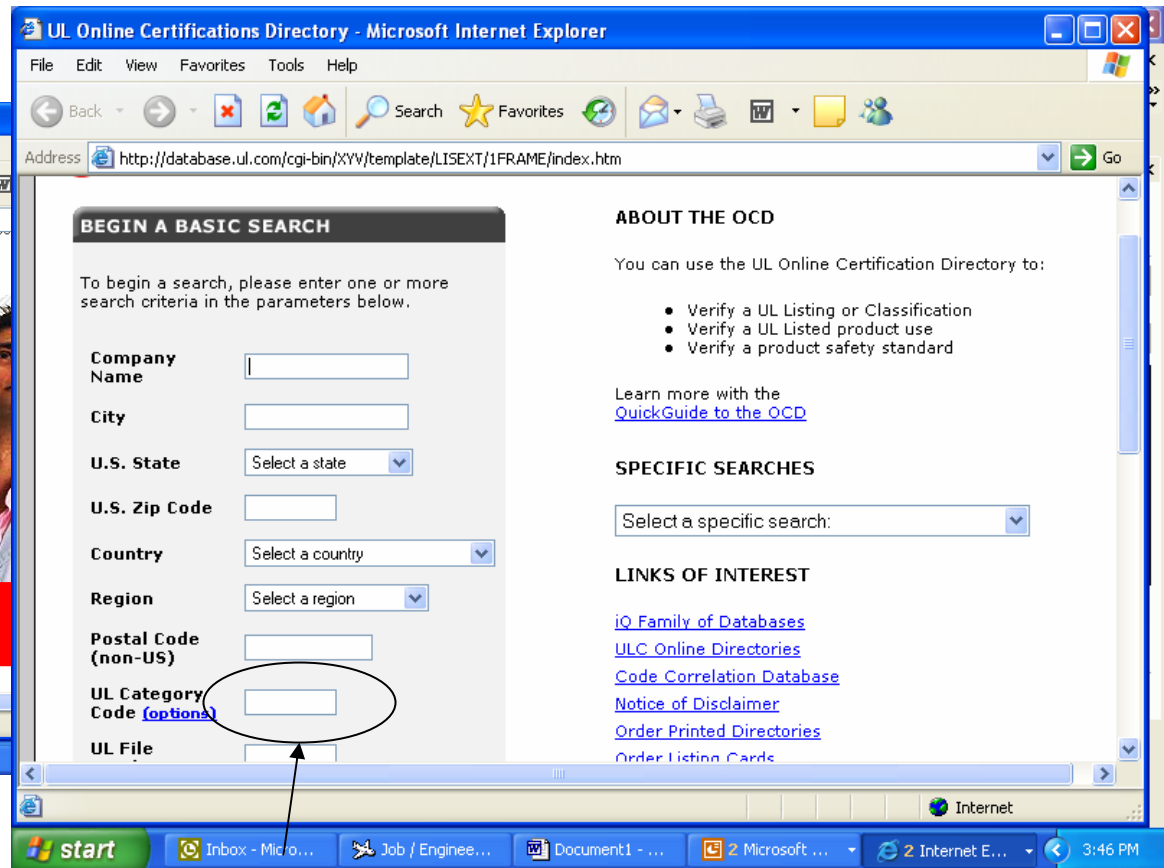
**(Type 2's with 20kA In's can work, but Type 1's avoid common problems at no extra cost.)**



# Verifying at www.UL.com



Click Certifications  
(lower left of webpage)



Category Code #'s:

XUHT for TVSS (<Oct 09)

OWHX for Arrestors (<Oct 09)

VZCA for SPDs



# **APT Here to Help: (800) 237-4567**

- Installation & Specification assistance
- Training
- Sounding Board for issues
- Competitive crosses or analysis
- General Help
- On-Line services via WebEx
- Etc.



# Theory & Supporting Info

**APT volunteers to help, explain, train, etc.**

**If questions, please contact at**

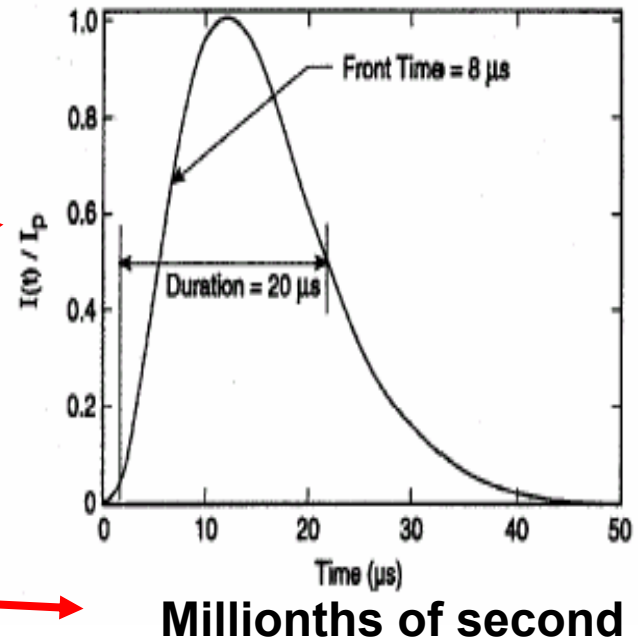
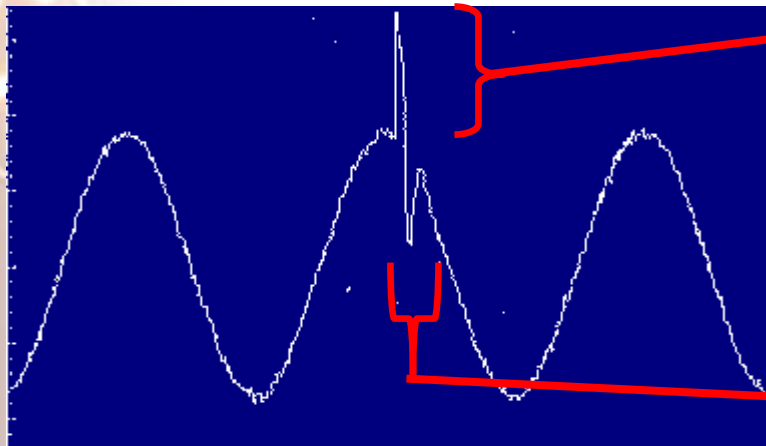
**(800) 237-4567**



# What Is a Surge/Transient?

- High amplitude, short duration overvoltage
- Can be positive or negative polarity

Transient Overvoltage – can be thousands of volts



# What Causes Surges/Transients?

- Lightning
- Switching any reactive load, either on or off
  - Any Inductor (cust. motor)
    - Internal disturbances
  - Any Capacitor (utility)
    - Utility operations
- Math:  $v(t) = \underline{3te^{-2t}} + 2t - 1$

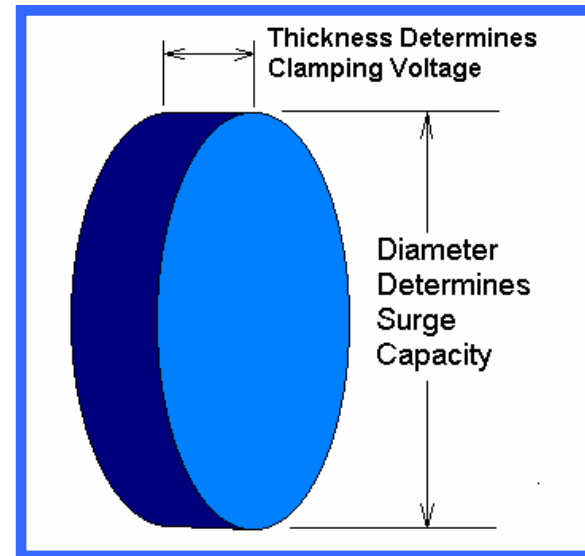
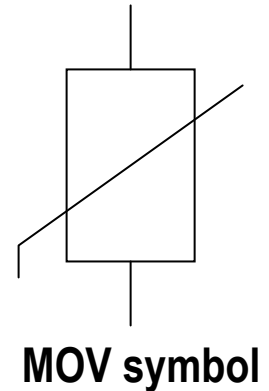


 **transient**



# Metal Oxide Varistor – MOV SPD Building Block

- Varistor - variable resistor
- Semiconductor; generally zinc oxide
- Connects parallel to load (not series)
- Thickness determines clamping voltage
- Diameter determines current capacity



# Inductance & Surges

- Wire's inductance at surge frequencies is good and bad
- Inductance of wire is about  $0.75\mu\text{H}/\text{m}$  (very low)
- Good because large surges cannot propagate far
  - Lightning generally effects very localized area, not large areas
- Bad because of effects on SPD installation
  - Long leads hurt SPD performance – Need Short SPD Leads
- Voltage across inductor defined as  $V = -L di/dt$ 
  - $di/dt$  becomes very large
  - let  $di = 10,000\text{A}$ ,  $dt = 8\mu\text{s}$ : 10 digit number!
  - $L$  is about  $0.75\mu\text{H}/\text{m}$
  - $V$  drop is  $9375\text{V}/\text{m}$



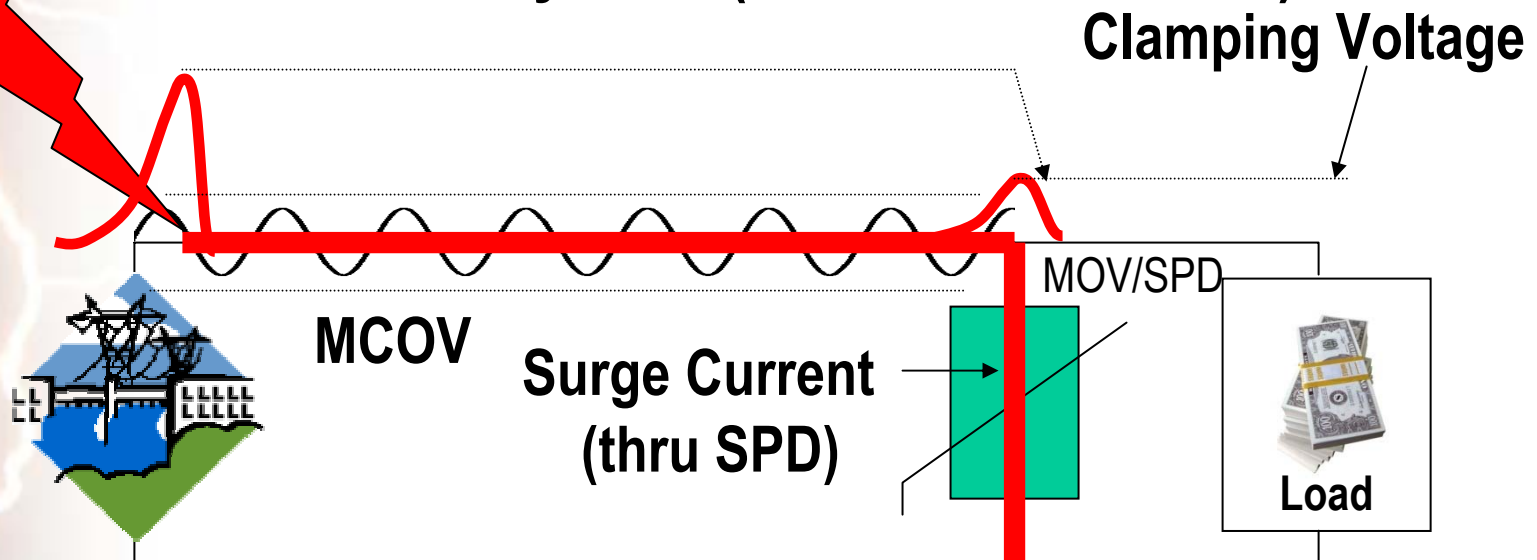
# SPD Connector Leads

- **Need short lead lengths!**
- **NEC 285.12: *“The conductors used to connect the SPD (surge arrestor or TVSS) to the line or bus and to ground shall not be any longer than necessary and shall avoid unnecessary bends”***
- **Industry typically states: Each foot of conductor adds  $\approx 100 - 170V$  to clamping voltage**
- **No Sharp bends or kinks**
- **No Wire Nuts!**
- **Right Hand Rule – can cancel inductive effects by bundling, tie-wrapping conductors together**



# SPD Terminology

- Clamping voltage, let-through voltage, suppressed voltage, measured limiting voltage (measured in  $V_{peak}$ )
- Surge current, peak-amp current, maximum current, (measured in  $A_{peak}$ )
- MCOV - Maximum Continuous Operating Voltage of the electrical system (measured in  $V_{rms}$ )



# SPD Terminology

- **Surge Current**
  - Normal operation - Current through MOV/TVSS while conducting a surge – tends to be momentary
- **Fault Current**
  - Failure condition - Current through MOV/TVSS when it has failed in a short-circuit condition – tends to be continuous
- **Two totally different currents**
- **A transient doesn't know if its entering 4,000A switchgear or a 100A panel.**
- **Fault current is based on the distribution system, not surge transient.**



# SPD/MOV Failures

- Industry Issues – Lot of UL & NEC action
- MOV is a sacrificial element - will protect load or die trying
- Failure caused by:

## ***Sustained* Overvoltage - TOV**

(Can be as few as 2-3 cycles)

Sequence: MOV protects, fails, fails short, follow-on/fault current causes MOV to catastrophically overheat

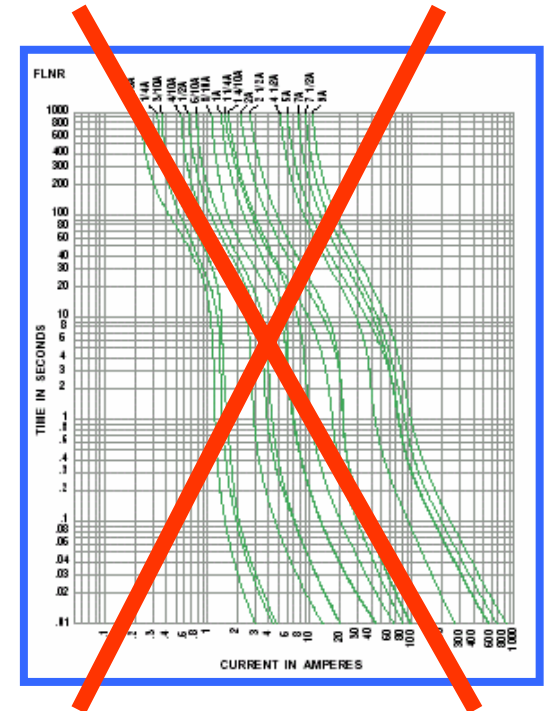
### Typical causes:

- Loss of neutral
- Loss of phase (ungr. wye-delta)
- Incorrect installation
  - 120V SPD on 277V system
  - Swap Phase with N or G
- Improper application
  - Ungrounded or impedance ground



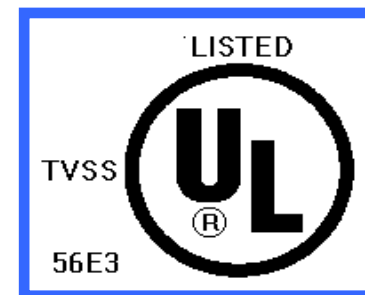
# MOV/SPD Failures

- MOVs are *Variable* Resistors
- MOVs fail short, but not necessarily *hard* short
- Failed MOV impedance can vary from  $\approx 200\Omega$  -  $0\Omega$ 
  - Depends on how & how hard MOV failed
- There are no MOV clearing curves
- Safety determined by testing, not calculations – many variables
- Realistically not practical to field-determine SPD overcurrent or thermal protection



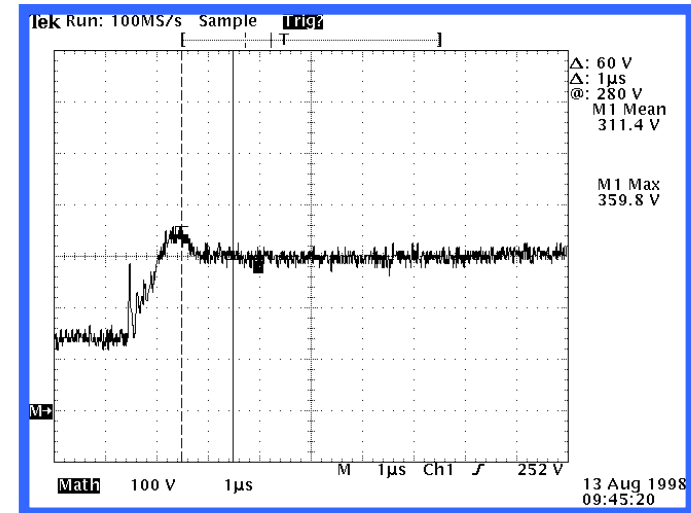
# UL 1449

- **UL 1449 is the industry safety standard**
- **End of life testing**
  - **Why? SPD/MOV failure**
- **Assigns Performance ratings for comparison**
- **UL 1449 Second Edition effective Aug 98**
- **UL 1449 Second Edition *Revision* adds Intermediate Fault Current testing, released and effective Feb 07**
- **UL 1449 *Third* Edition released & effective Sept 09**



# UL 1449 Performance Rating:

- Presently - Suppressed Voltage Ratings (SVR's)
- Clamp testing using 500A impulses
  - 24 impulse test series
  - Uses 6" lead lengths from outside of enclosure
- Directly comparable results
- Posted on every TVSS' UL label
- Discrete SVR categories of 330, 400, 500, 600, ....volts
- (This format changes in Sept 2009)



# UL 1449 Safety Testing

- **MOVs/SPDs have multiple failure scenarios (Any single failure mode test is inadequate)**
- **UL simulates various scenarios by:**
  - Testing at L-L voltage (i.e., 208V, 480V, 600V, etc.)
  - Controlling / limiting fault current (i.e., 1/8-200kA)
- **Fault Current tests in every mode `at:**
  - 0.5A, 2.5A, 5A, 10A, 100A, 500A, 1000A & SCCR
- **Tests are seven (7) hours or until temperature stabilizes or clears from circuit**
- **Cannot show any outward signs of failure**

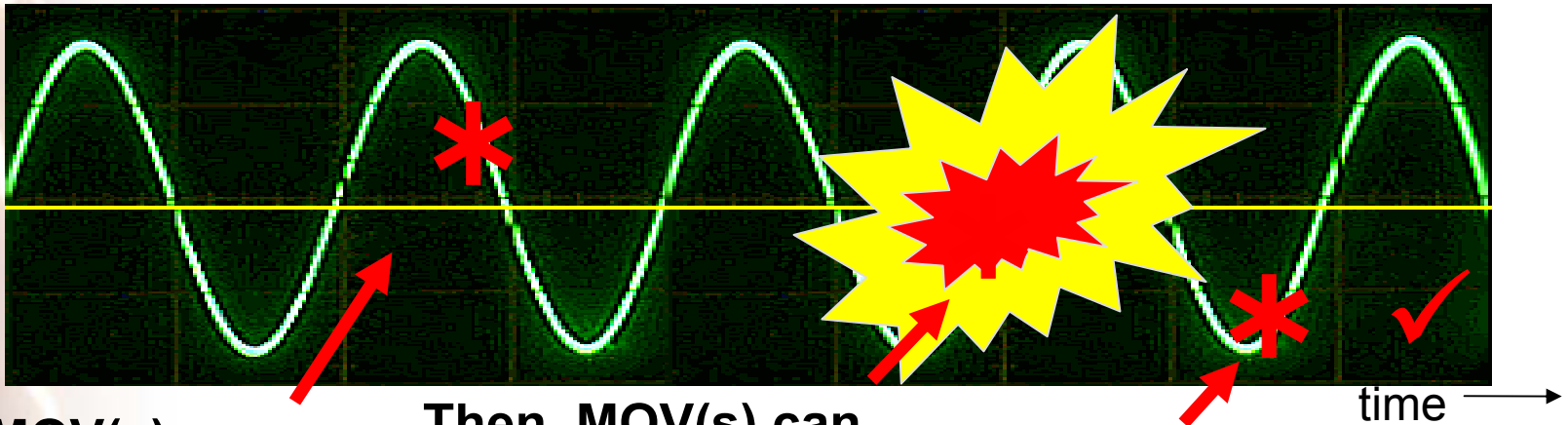


# 2008 NEC – Key Points

SCCR labeling consistent with location in distribution system:

**285.6 - “The SPD (surge arrester or TVSS) shall be marked with a short circuit current rating and shall not be installed at a point on the system where the available fault current is in excess of that rating. This marking requirement shall not apply to receptacles.”**

**Why fuse/breaker rating does *Not* determine SCCR:**



**MOV(s) can fail short here**

**Then, MOV(s) can overheat & rupture before OCP clears**

**Suppose Fuse clears after a few cycles**



# Verifying SCCRs

- Appropriate wording on UL label:

**“Suitable For Use on a Circuit  
Capable of Delivering Not More  
Than 200kA, 600 Volts Max.”**

**Appropriate wording in UL File:**

File E103120 Vol. 3 Sec. 11 Page 3 Issued: 08-08-99  
and Report

**ENGINEERING CONSIDERATIONS (NOT FOR FIELD REPRESENTATIVE'S USE)**

These transient voltage surge suppressors have been investigated with respect to electrical, fire and shock hazards only. In addition, they have been tested to verify that transient voltage surges are limited to maximum amplitudes specified by the manufacturer when subjected to a 1.2 by 50 us, 6 kV peak 8.0 by 20 us, 0.5 kA surge, and that they can withstand 2 impulses at 10 kA and continue normal operation. They are not intended to perform as a lightning arrestor. These devices are suitable for indoor use only unless otherwise specified. These devices have demonstrated containment when subjected to fault current of 200,000 A.

The effect of these suppressors on connected loads, the effect of the suppressor on harmonic distortion of the supply voltage and the adequacy of the suppression level to protect equipment from the damage from transient voltage surges have not been evaluated.

USL indicates these products have been evaluated to the Standard for Transient Voltage Surge Suppressors, UL 1449, Second Edition and the Standard for Electromagnetic Interference Filters, UL 1283, Fourth Edition.

CNL indicates these products have been evaluated to the applicable requirements of CSA C22.2, No. 8-M1986 - Canadian requirement for Electromagnetic Interference Filters (not evaluated as an EMI filter per CSA requirements), and Electrical Certification Notice No. 516.

impulses at 10 kA and continue normal operation. They are not intended to perform as a lightning arrestor. These devices are suitable for indoor use only unless otherwise specified. These devices have demonstrated containment when subjected to fault current of 200,000 A.

the effect of these suppressors on connected loads, the



# Grounding/Bonding TVSS/SPDs

- **Better Ground systems dissipate surge energy better. Lower ohmic readings are better than higher.**
- **Bonding Neutral and Ground together per the NEC ensures that the electrical system has a defined reference to ground**
  - **Missing N-G bonding jumpers are the #1 killer of TVSS/SPDs during new construction.**
- **Bonding different systems together ensures that all systems have the same reference to earth ground.**





**Thank you for your time**

