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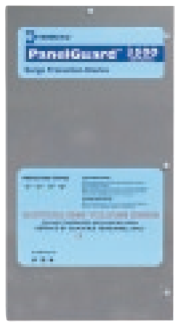
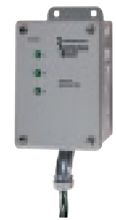
Strategies *for a* Staged Surge Suppression System

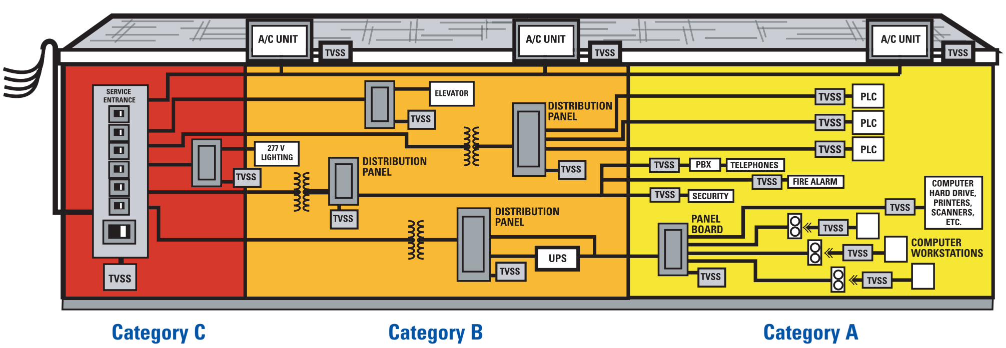




Strategies *for a* Staged Surge Suppression System

When evaluating TVSS (transient voltage surge suppression) designs it is easy to get caught up in the hype of comparing one brand's performance ratings to another. The #1 rule in marketing is to avoid comparisons with your competition. For whatever reason, smoke and mirrors still abound in this industry! Most consulting electrical engineers and facility managers agree that it is virtually impossible to compare one TVSS brand to another. Manufacturers talk about their "perceived strengths", with little regard to what is most important to their customers. This article will define these issues, explain how an effective staged suppression system is designed, and provide truly relevant performance factors for evaluation.

The #1 comparison criteria has always been clamping voltage. I recently overheard a manufacturer at a trade show claim that "my design is the best in the marketplace because we clamp lower than anyone else!". The prospective customer was a well-educated engineer with hundreds of high tech projects under his belt. It was hard to not interrupt, but I felt it was important to give the salesman the opportunity to present his viewpoint.



Combination Waves or Impulses			
Location Category	System Exposure	Voltage (Peak) 1.2 x 50 m sec.	Current (Peak) 8 x 20 m sec.
C3	High	20 kV	10 kA
C2	Medium	10 kV	5 kA
C1	Low	6 kV	3 kA
B3	High	6 kV	3 kA
B2	Medium	4 kV	2 kA
B1	Low	2 kV	1 kA

100 kHz Ringwaves			
Location Category	System Exposure	.05 m sec. 100 kHz Ringwave	
B3	High	6 kV	500 Amp
B2	Medium	4 kV	330 Amp
B1	Low	2 kV	170 Amp
A3	High	6 kV	200 Amp
A2	Medium	4 kV	170 Amp
A1	Low	2 kV	70 Amp

What is clamping voltage?

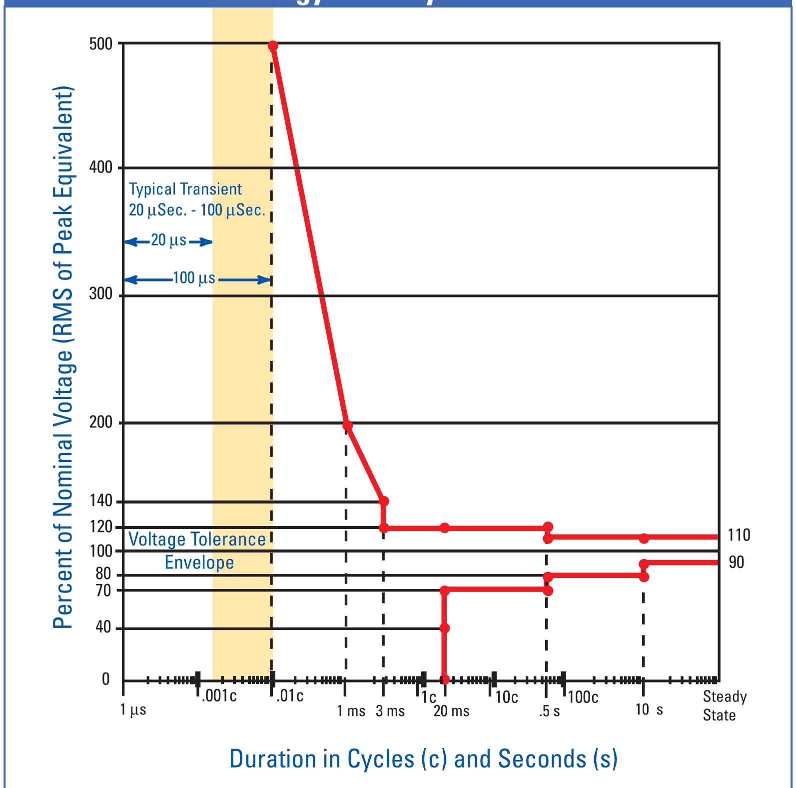
Clamping voltage is simply the amount of let-through that passes to the load after a transient has been shunted or suppressed. All TVSS components in the marketplace basically attenuate (suppress) a transient event in the same manner: they shunt the current and clamp the voltage. If you look at the most common suppression devices (metal oxide varistors, silicon avalanche diodes and gas tubes) they all clamp at a higher voltage at higher test currents.

ANSI/IEEE C62.41 has done a great job of defining typical transient current levels in today's facilities. The charts above summarize these waveforms. You can see a Category C3 event is characterized by a maximum of 20,000V @ 10,000 Amps (high exposure). As we move down into the building the event lessens to a Category B3 event (max. 6,000V @ 500 Amps–100 kHz Ringwave). Farther in at the wall outlet it is characterized by 6,000V @ 200 Amps–100 kHz Ringwave. As you travel it changes from an impulse-type event to a ringwave, due to the impedance of the wiring and transformers.

What clamp voltage is acceptable for modern loads?

CBEMA (Computer Business Equipment Manufacturer's Association) has developed a standard which shows what voltage they require for stable operation of typical computer and electronic equipment. The power parameters that were acceptable in the 1970s and 1980s when more robust linear power supplies were the norm are no longer acceptable. This new curve (below left) shows what levels of overvoltage and undervoltage or sags are acceptable for newer switch mode power supply designs, and where the trouble areas are.

ITI (CBEMA) Curve
Information Technology Industry Council



Published by: Information Technology Industry Council (ITI) 1250 Eye Street NW, Suite 200, Washington DC 20005 http://www.itic.org

You can see from the curve that most modern electronic equipment can withstand a transient of 20 microsecond duration equal to 5 times the voltage, or about 848 Volts peak on a 120 Vrms system. 120Vrms x 1.414 x 5 = 848 Volts.

For 277 Volt equipment the value would be higher: 277Vrms x 1.414 x 5 = 1,958 volts.

At first inspection, the level where most devices clamp would seem to be well within this clamping voltage. The typical 150 Volt MOV will turn on at 205 Vpeak (at a test current of 1 milliampere) and will clamp at the levels shown below. The waveforms below are from the ANSI/IEEE C62.41 standard:

Test Waveform	Voltage	Current	Clamp Voltage 20 mm 150 Volt MOV
Cat A1 Ringwave	2,000 Volts	70 Amps	304 Volts (peak)
Cat A2 Ringwave	4,000 Volts	130 Amps	328 Volts (peak)
Cat A3 Ringwave	6,000 Volts	200 Amps	376 Volts (peak)
Cat B1 Ringwave	2,000 Volts	170 Amps	322 Volts (peak)
Cat B2 Ringwave	4,000 Volts	330 Amps	336 Volts (peak)
Cat B3 Ringwave	6,000 Volts	500 Amps	368 Volts (peak)
UL test wave	6,000 Volts	500 Amp Impulse	352 Volts (peak)
Cat B1 Impulse	2,000 Volts	1,000 Amps	424 Volts (peak)
Cat B2 Impulse	4,000 Volts	2,000 Amps	472 Volts (peak)
Cat B3 Impulse	6,000 Volts	3,000 Amps	512 Volts (peak)

Since a metal oxide varistor is a "variable resistor" it clamps higher at higher surge currents (the clamp voltage increases when the surge current increases).

As you can see, for lower surge currents the MOV clamps within the acceptable range. As you flow more current you can see this clamp voltage increases dramatically.

You can see that the clamp voltage for a 20mm MOV at 6kV 3kA is well below the CBEMA maximum of 848 Volts.

The next most often compared parameter is Surge Current Capacity.

Estimating Lost Productivity

The first issue I discuss with potential clients is that they must define the actual cost of downtime (lost productivity and materials) in order to understand the benefit of TVSS equipment. For a semiconductor manufacturing plant it may be $2 Million dollars per hour. For a large bank processing center it may be revenues of $1 Million dollars per minute. For a fast food restaurant it may only be $500 per hour. System damage, disruption and upset, including lost productivity and lost raw materials, costs Fortune 1000 Companies an estimated $26 Billion dollars a year. In addition to the cost of downtime, you must add the cost of the replacing computers, hard drives, peripherals, lighting ballasts, variable speed drive electronic boards, and other sensitive equipment

What will it cost your company if your system goes down?

that would normally not need replacement. A semiconductor device would last indefinitely if it were not for three things: overcurrent, overvoltage, and the heat that is generated by the combination of those two occurrences. It is no secret why your VCR has a one year warranty and your lighting ballasts typically have a two year warranty. They are not designed to withstand common transient overvoltage events, which will occur hundreds, if not thousands of times a year. Without adequate protection your facility is unprotected from even the smallest events. If you can get your facility's power waveform to within CBEMA guidelines, then you will realize a tremendous return on your investment.

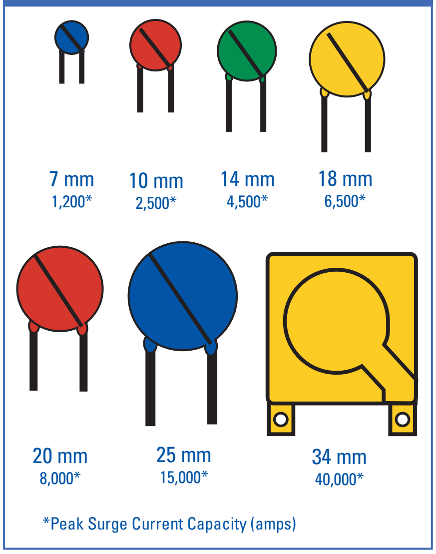
Maximizing Return On Investment

If your suppression system is for a 30,000 square foot manufacturing facility with annual revenues of $25 Million dollars ($100,000 a day) and you have two Service Entrances and 30 downstream panels your installed costs would be about $26,000. If it protects you from going down twice a year for four hours each time, then it would only take 3.12 months to pay for your investment.

100,000 per day in revenue / 8 hours per day = $12,500 per hour
2 occurrences of four hours each = 8 hours of downtime
8 hours @ $12,500 per hour = $100,000 in lost production per year
or $8,333 per month
$26,000 installed cost / $8,333 = 3.12 months to pay for the investment.

A 3 month payback is an excellent return on investment.

MOV Sizes



What is Surge Current Capacity?

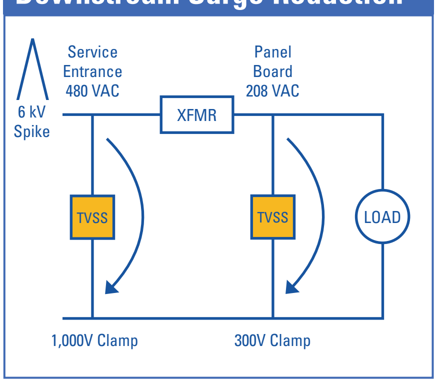
In general the larger the component (metal oxide varistor) the more surge current it can withstand, both on a one-time pulse basis and a repetitive basis. The chart at left shows common MOV sizes and single impulse capacities.

Most manufacturers parallel multiple components with some type of derating factor in order to give them larger surge current capacities. Since we want the device to last a minimum of five to ten years, (some manufacturers say their device is designed to last the lifetime of the building) and be able to take hit after hit without failing, we often see product surge current ratings of 100,000 to 200,000 amperes per mode which is 10 to 20 times the typical event. This makes good engineering practice since due to the nature of these devices they can only take so much current before they start to degrade or fail outright. NEMA defines failure of the device if the clamp voltage is beyond 10 % of the initial clamp voltage. As MOVs degrade the clamp voltage actually decreases due to less particle substrate between the metal oxide plates. So eventually the MOV will be degraded to the point that it is trying to clamp the normal sine wave and when it does it will typically go into a thermal runaway condition, short and then fail in an open state.

What is a Staged Suppression System?

If you install TVSS at the incoming switchboard as well as at downstream panelboards you get three benefits that may not be readily apparent.

Downstream Surge Reduction



1 First, the clamp voltage experienced at the load is lower than what any single device can do on its own.

This benefit is quite remarkable! Since the majority of the current with the event is shunted through the first device at the Service Entrance the second TVSS will knock down the event (reduce the peak voltage) even farther. Remember with less surge current to deal with the TVSS will clamp much lower. The result is a much lower clamp voltage for the sensitive electronics you are trying to protect.

2 Second, the reliability of the surge suppression system increases ten fold.

By specifying a two-stage suppression system (Service Entrance and downstream panelboard locations) the amount of surge current that the downstream panels are subjected to is greatly reduced. With less surge current comes less stress on each suppression component. An MOV can withstand a certain number of large impulses and a much greater number of small impulses. By limiting the events at the downstream panels to "small impulses" the overall reliability of the system is greatly increased.

More Expensive isn't Necessarily Better!

As with any product, the old adage "you get what you pay for" is still very true. In order to know you are specifying a reliable device, it pays to review the track record of the manufacturer. If they've only been manufacturing product for 3 years and offer a 10 year product warranty, you may want to take a closer look at their design. At last count there were 18 manufacturers in this business, with varying product claims and product characteristics.

The third benefit of a staged suppression system is that you can dramatically lower the total overall system cost. A Two-Stage System installation includes:

Step 1) Install the device at the Service Entrance.

Step 2) Install lower rated devices (smaller surge current rating) at the downstream panelboards. Since most facilities have 5 to 20 of these, it results in significant savings and virtually no sacrifice in performance.

Cost Comparison

Let's examine the typical costs if you only installed 80 kA per mode devices at the panelboards (single stage).

10 panels to protect = $1,200 x 10 = $12,000

If you employ a two-stage suppression system you have to add the cost of the Service Entrance Suppressor, but you can reduce the downstream devices to 40 kA per mode.

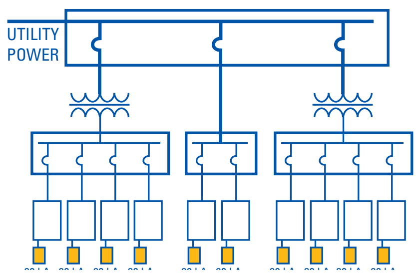
Qty (1) Service Entrance TVSS = $2,800 = $2,800

Qty (10) downstream TVSS = $600 x 10 = $6,000

Total system cost is now $8,800 (a 27% reduction!)

The Two-Stage approach will deliver a lower clamp voltage and increased reliability... maximizing your performance, increasing system reliability and lowering your direct costs.

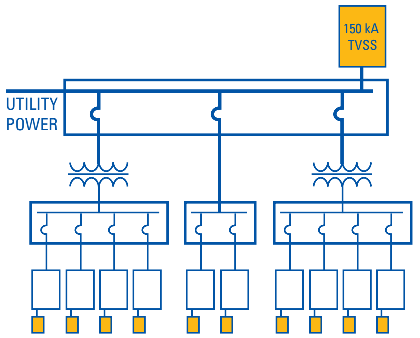
Single Stage System



Ten 80 kA units at $1,200 = $12,000

Total Investment = $12,000

Two-Stage System Benefits



One 150 kA unit at $2,800 = $2,800
Ten 40 kA units at $600 = $6,000

Total Investment = $8,800
(27% reduction!)

Questions you should ask...

to make sure you are getting a quality TVSS device

1. How long has the company been manufacturing TVSS systems?
2. Do they manufacture their own devices or are they simply brand labeling someone else's product?
3. Are the surge current ratings tested by an independent lab or are they merely theoretical?
4. Do they use 150 Volt rated components or lower rated components?
5. Does the device include overcurrent protection that is rated for the full surge current capacity of the device? Are the test results with the fusing in place?
6. Does the TVSS device include thermal protection that will disconnect the suppression components during a thermal runaway event?
7. Does the product warranty cover lightning events?
8. Does the warranty cover parts and labor, or parts only?

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