EFFECTS OF WIRE LEAD LENGTH ON VOLTAGE PROTECTION RATING

SURGE PROTECTION NOTE 8

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INTRODUCTION

Proper installation of Surge Protective Devices (SPDs) is very important to maximize the performance of these devices. Device performance is normally defined by a set of ratings for the device determined by testing of a nationally recognized test laboratory. One such performance rating that is affected by installation is the Voltage Protection Rating (VPR). VPR gives the user an idea of what voltage levels their equipment will be exposed to in the event there is a surge on the electrical system. This technical paper will examine proper installation practices and the effects of excessive lead length on surge protective devices.

TERMS

- **SPD:** Surge Protective Device
- **VPR:** Voltage Protection Rating

VOLTAGE PROTECTION RATING

The UL 1449 standard 4th edition defines the requirements for testing to determine a device's Voltage Protection Rating. Each device is subjected to three "shots" of a 6kV and 3kA combination waveform (Figure 1). The resulting voltage that is allowed to pass the SPD in the circuit is recorded and an average of the three shots is calculated. This average value is then compared to values table 79.1 in the standard and assigned the appropriate minimum voltage protection rating. For example, if the average of three shots is 539V, the voltage protection rating is 600V. Voltage protection ratings are important as they define the protection level for a very high overvoltage event with its corresponding current. The VPR should be at a value that is something less than five times the rated voltage

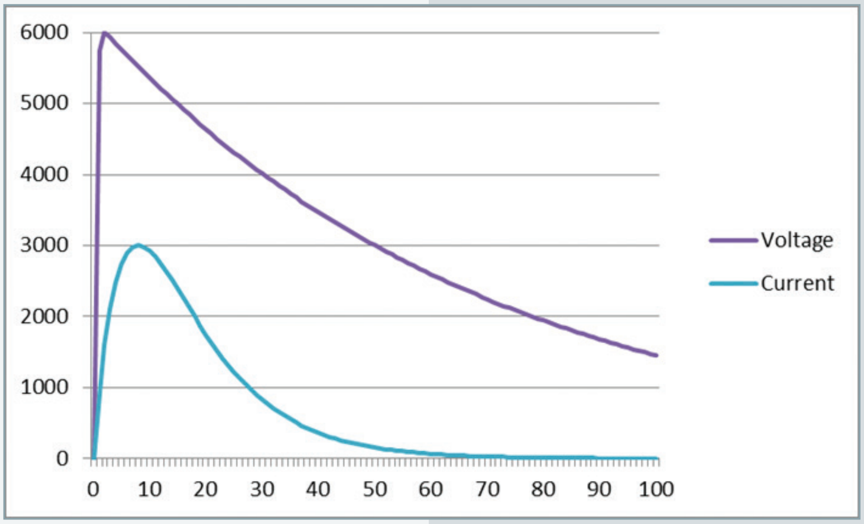

Figure 1: Combination Wave

in order to be effective at protecting downstream electronics from overvoltage. The main reason for a five times limitation is the Information Technology Industry Council's (ITIC) voltage tolerance curve which describes the tolerance region for electronic devices (Figure 2). This curve was originally created for 120V systems, but can be useful to predict power quality effects on industrial power system equipment as well. The beginning point on the curve is 500% voltage for 0.01 cycles. Considering that voltage surges are short time events, typically shorter in duration than 0.01 cycles, it can be inferred that events beyond 500% voltage will cause damage to equipment.

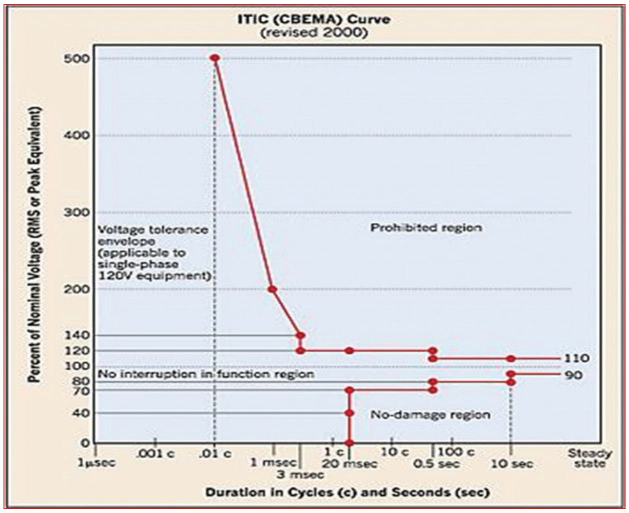

Figure 2: ITIC (CBEMA) curve

WIRE LENGTH EFFECT ON CLAMPING VOLTAGE

Since surges are fast transient events, the response of the circuit is different than that of the nominal AC voltage at 50 or 60Hz. The rapid change in voltage appears to the circuit as a high frequency signal and at higher frequencies AC circuits have more impedance. The main cause of this is the inductance of the circuit. Simply adding more wire to a circuit adds more inductance and thus higher impedance to the high frequency surge event. Longer lead lengths of SPDs will increase the clamping voltage and reduce their performance in protecting downstream loads. Standard UL VPR testing is performed with 6 inches of lead length. For most

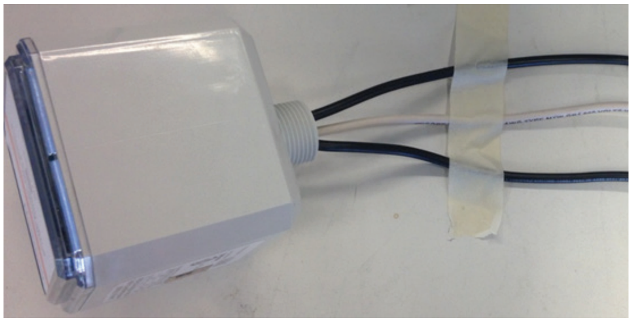

Figure 3: Wire Leads Separated by ~25mm

applications, this wire lead length is not practical for field installation. Testing was performed to determine wire lead length effects in three different installation conditions. The first test simulates poor installation in which the leads are separated by approximately 25mm (See Figure 1). Table 1 shows testing results of this test from two different samples with various lengths of wire lead.

Conductor Length	Sample 1 L-N Test Result VPR=600	Sample 1 L-L Test Result VPR=1000	Sample 2 L-N Test Result VPR=700	Sample 2 L-N Test Result VPR=1000
36"	1200	1800	1200	1500
33"	1000	1500	1200	1500
30"	1200	1500	1000	1500
27"	900	1500	1000	1200
24"	900	1500	900	1200
21"	900	1200	800	1200
18"	800	1200	800	1200
15"	800	1200	800	1000
12"	700	1000	700	1000
9"	700	1000	700	1000
6"	600	900	600	900
3"	600	900	600	900

Table 1: VPR for different lead lengths, straight wire, separated by ~25mm.

In examining the results, we can see that the devices performance rapidly deteriorates for cable lengths greater than 6". Sample 1 performs to UL spec only up to 6" for the L-N mode and 12" for the L-L mode. Sample 2 performs to UL spec up to 12" for L-N and up to 15" for the L-L mode. In addition, increased wire lengths beyond 36 inches will further increase the VPR of the SPD system.

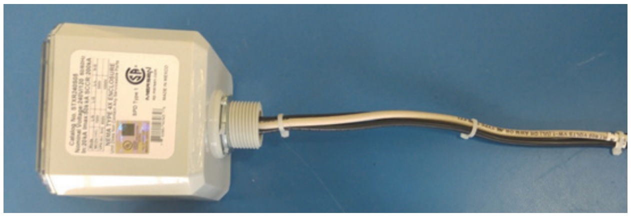

Figure 4: straight tie wrapped cable

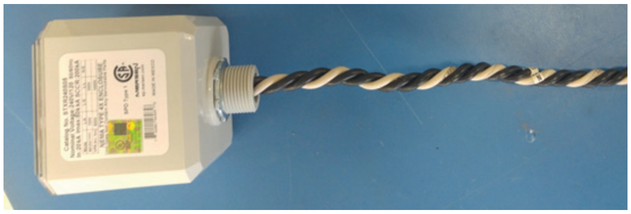

Figure 5: Twisted Cable

Conductor Length	Sample 1 L-N Test Result VPR=600	Sample 1 L-L Test Result VPR=1000	Sample 2 L-N Test Result VPR=700	Sample 2 L-N Test Result VPR=1000
36"	800	1200	800	1200
33"	700	1200	800	1200
30"	700	1200	800	1200
27"	700	1200	800	1200
24"	700	1000	800	1200
21"	700	1000	700	1000
18"	600	1000	700	1000
15"	600	1000	700	1000
12"	600	900	700	1000
9"	600	900	700	1000
6"	500	900	600	900
3"	500	900	600	900

Table 2: VPR for different lead lengths, straight wire, tie-wrapped

Conductor Length	Sample 1 L-N Test Result VPR=600	Sample 1 L-L Test Result VPR=1000	Sample 2 L-N Test Result VPR=700	Sample 2 L-N Test Result VPR=1000
36"	700	1000	800	1200
33"	700	1000	800	1200
30"	700	1000	800	1200
27"	700	1000	800	1200
24"	600	1000	800	1200
21"	600	1000	700	1000
18"	600	900	700	1000
15"	600	900	700	1000
12"	600	900	700	1000
9"	500	900	700	1000
6"	500	900	600	900
3"	500	900	600	900

Table 3: Twisted wire VPR results

For the second test, the leads were tie-wrapped together (Figure 4). Tie-wrapping the conductors allow some cancellation of the electric field to occur which will reduce the circuit inductance. The results of the second test are given in table 2.

In examining these results, we can see that for Sample 1, the device performs at or better than the rated VPR up to 18” for the L-N mode and up to 24” in the L-L mode. SPD installations with leads greater than these lengths would not be as effective at protecting equipment downstream. In contrast, shorter wire leads reduce the effective VPR, which provides better protection. As indicated in green at the table above, the lengths indicated would perform better than the UL test.

BENDS IN WIRING

The examples in tables 1 and 2 show results for straight wire. When wires are run with sharp bends, the inductance will increase and thus increase the VPR. Sharp bends imitate a wire loop, which is more inductive than a straight run. Should bends be required, they should not exceed recommended bend radii to keep added inductance to a minimum.

REDUCING INDUCTANCE IN WIRE LEADS

Inductance in wire leads can be reduced by adding a tight twist to the leads (Figure 5). This twist will allow magnetic fields created by the current flow to cancel and reduce the effective inductance. Table 3 shows the third set of tests performed with twisted cable.

With the wire leads twisted, the standard VPR rating is held up to 24 inches in the L-N mode and all the way to 36 inches in the L-L mode for sample 1. For sample 2, the standard VPR rating is held up to 21” for both modes. This allows for longer cable runs with little ill effects to the VPR rating of equipment. Note that each device performs one class better than the UL rating for normal 6 inch cable runs. Again, this is true for straight wire only. Bends in the cable would reduce some of the positive gains.

RECOMMENDATIONS

All SPDs should be installed as close to the service entrance or protected equipment as possible. Cable and conduit runs should be as straight as possible to avoid adding inductive impedance to the circuit. If bends are required, they should not exceed normal bend radii and should not be looped. At a minimum, the leads should be tie-wrapped together to allow the device to perform at its UL certified protection rating. Where runs exceed 6", the cable should be twisted to negate the effects of cable inductance on performance.

SURGE PROTECTION PRODUCTS FROM MERSEN

TPMOV®

Mersen's patented TPMOV (Thermally Protected Metal Oxide Varistor) eliminates common destructive failure modes associated with standard MOVs. Comprised of a voltage clamping device and a disconnecting apparatus that monitors the status of the metal oxide disk inside the TPMOV, the device is securely disconnected in the event of an overvoltage by an arc shield. Upon failure, the TPMOV is also equipped with a visual pin indicator as well as a normally open microswitch providing remote indication, if applicable.

TPMOV

Surge-Trap® NEMA Type 1 SPDs

Mersen's Surge-Trap NEMA Type 1 SPD line includes six surge protection products designed and manufactured by Mersen with the latest materials, layouts, and components, including the industry-leading TPMOV Technology. All are NEMA devices for ANSI/UL 1449 Type 1 and 2 applications, indoor and outdoor use, and provide UL96A lightning protection plus a variety of other features and benefits to meet clients' needs. To aid partners offering Mersen products, the company designed an intuitive cataloging system and partner portal that makes it easy to compare features and quickly find the right product for customers. For more information regarding Mersen's surge protection products, visit: ep-us.mersen.com/surge-trap.

Surge-Trap® NEMA Type 1 SPDs

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ADDITIONAL RESOURCES

Surge Protection Note 1: Introduction to Specifying Surge Protection

Surge Protection Note 2: Surge-Trap® and the Different kA Ratings

These and other Tech Topics are available on ep.mersen.com.

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