Establish Surge Current Capacity Levels:

Multiple Benefits for Today's Suppression Filter System Specifier

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As the transient voltage surge suppression industry progresses toward maturity, performance standards for surge suppression products are beginning to take shape. Regulatory agencies such as NEMA (National Electrical Manufacturers Association),Underwriters Laboratories (UL) and IEEE (Institute of Electrical and Electronics Engineers) are furthering the establishment of concise performance standards by publishing product parameters in a more uniform manner.

A one-performance criterion that has begun to gel is the single pulse surge current capacity. NEMA has provided a definition for single pulse surge current capacity that includes tested, rather than calculated, surge current values published per mode (L-N, L-G, N-G, etc.) Improved product technology and the desire of surge suppression manufacturers to provide offerings capable of surviving the most catastrophic surges have prompted single pulse surge current capacities per mode to climb higher and higher over the last several years. In response, a number of manufacturers of lower-rated surge suppression devices have questioned the benefit of high surge current capacity at high exposure service entrance locations as well as in lower exposure panel applications. This article details two primary reasons to conservatively rate single pulse surge current capacities in both service entrance and distribution system applications.

PART I: SERVICE ENTRANCE APPLICATIONS

At electrical service entrances, two separate issues must be addressed to ensure reliable protection: survivability of large ("catastrophic") transients and survivability of the much more frequent lower-magnitude transients that occur on a daily basis in most facilities.

Typically, a building's degree of large magnitude transient disturbance exposure is higher at service entrance than at any other location in the facility. It is an established fact that lightning is the most damaging of high exposure transients to threaten service entrances. The IEEE Emerald Book graph in Fig. 1 denotes the statistical probability of a single lightning stroke occurring above a specific current level and also illustrates the following probabilities and associated current.

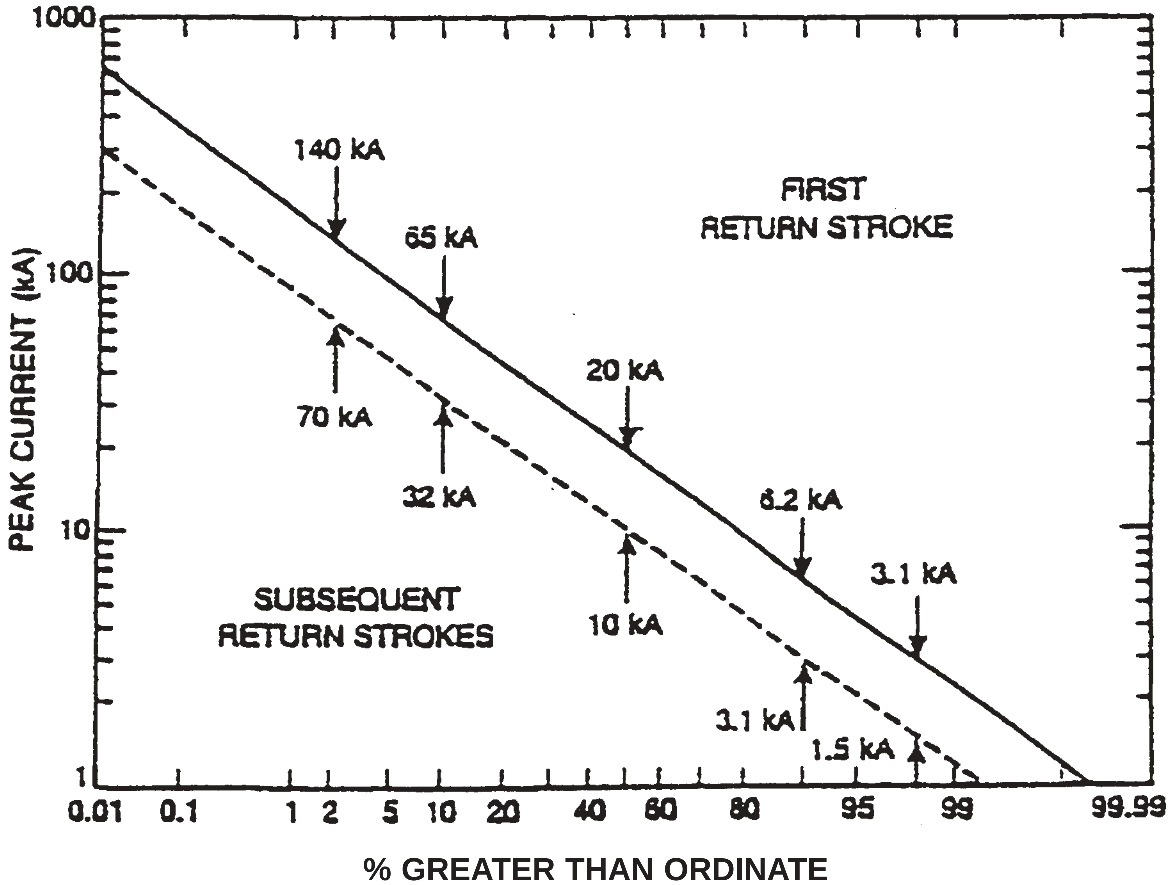

Fig. 1
Distribution of Lightning Stroke Current
(Reproduced from IEEE Std. 1100)

- •20% of primary strokes are greater than 40 KA in magnitude
- •10% of primary strokes are greater than 65 KA in magnitude
- •5% of primary strokes are greater than 100 KA in magnitude
- •2% of primary strokes are greater than 140 KA in magnitude
- •1% of primary strokes are greater than 180 KA in magnitude

Keep in mind that a single lightning strike is composed of multiple strokes. Each year, 100 million lightning flashes occur in the United States; 20% of those strikes hit the ground. Obviously, different geographic areas of the country experience a statistically higher number of lightning strikes than others; an area's isokraunic (frequency of lightning) rating is one of several factors involved in the probability of a specific facility incurring a damaging lightning episode.

SURVIVAL OF THE FITTEST

Regardless of building or utility integrity, a lightning strike that reaches the facility or travels very near the building or to nearby ground can force catastrophic lightning currents through the electrical distribution system. Lightning can produce potentially catastrophic surge current levels to a building's distribution system not only by directly striking the facility but also by striking an incoming utility feed, by reaching the surrounding earth or even by occurring cloud-to-cloud above a facility. With the very real chance of the facility being exposed to a direct or close-proximity lightning strike, today's service entrance surge suppression must be capable of surviving a large magnitude occurrence.

Often, suppression devices are specified into a building and installed under the auspices of ideal facility and utility distribution system conditions. With shining new grounding, recently connected bonds and unblemished utility integrity, the expected utility lightning strike magnitude conducted into the building is diminished. However, as the building and utility infrastructure age, facility electrical conditions may cease to be ideal. Common distribution system aging problems include building grounding increasing in impedance, N-G bonding with significant impedance or no N-G bonding at all and deteriorated utility conditions. All of these factors further increase an environment's susceptibility to higher current lightning transients.

Many budget-minded customers, anxious to cut corners on project price, have been snared by unscrupulous surge suppression manufacturers offering so-called "equal" high-exposure service entrance products that carry only a 50,000 amp single pulse surge current capacity rating. Since 19% of primary lightning strokes and 5% of secondary strokes are greater than 50,000 amps in magnitude, and since the role of surge suppression devices at service entrance is to protect sensitive loads before, during and after catastrophic transient episodes, these products do not offer complete or even adequate protection. The recommended minimum single pulse surge current capacity for surge suppression products in high-lightning locations is 150KA L-N, 150KA L-G and 100KA N-G.

A PENNY SAVED?

Today's cost-conscious purchasers would do well to remember that lightning strikes are comprised of multiple strokes. Surge suppression stressed to maximum capacity has a much greater potential for failure during the return strokes and therefore increases the chances of exposing critical electronics to residual lightning pulses. These same individuals (so anxious to shave a few dollars from a project) would be outraged if their personal insurance agent suggested coverage for only 80% of their homes or automobiles.

For geographical areas less prone to lightning, the minimum single pulse surge current capacity should be 125KA L-N, 100KA L-G and 100KA N-G. This level of suppression is sufficient to protect critical equipment from the highest probability of expected lightning magnitudes. As the lightning density increases or a facility's propensity to conduct lightning becomes greater (high-rise structures, overhead utility feeds, etc.), the single pulse surge current capacity should increase as well. A surge suppression device with a minimum rating per mode of 150KA L-N, 150KA L-G and 100KA N-G will provide protection from 99% of initial direct lightning strokes.

HIGHER SURGE CURRENT CAPACITY = HIGHER RELIABILITY

The second and possibly most critical factor for properly selecting surge suppression with sufficient single pulse surge current capacity is the relationship of surge current capacity to lower amplitude transient suppression reliability. The surge current/reliability correlation applies not only to service entrance protection that is constantly bombarded by less catastrophic transients: this relationship is also the foundation for reliability of lower exposure surge suppression within a facility distribution system. Although valid at all exposure levels, the surge current/reliability connection is best highlighted by studying a surge suppression device designed for branch panel application.

PART II: DISTRIBUTION SYSTEM APPLICATIONS

To explore the correlation of surge current and reliability, two metal oxide varistor-based (MOV) panelboard level surge suppression devices will be compared with single pulse surge current capacities as listed below:

	PRODUCT A	PRODUCT B
L-N	80,000A	40,000A
L-G	80,000A	40,000A
N-G	80,000A	40,000A

To simplify this example, only one mode of suppression utilizing a multitude of MOV components will be examined, but analysis will apply to all modes as well as to MOVs and silicon avalanche diodes.

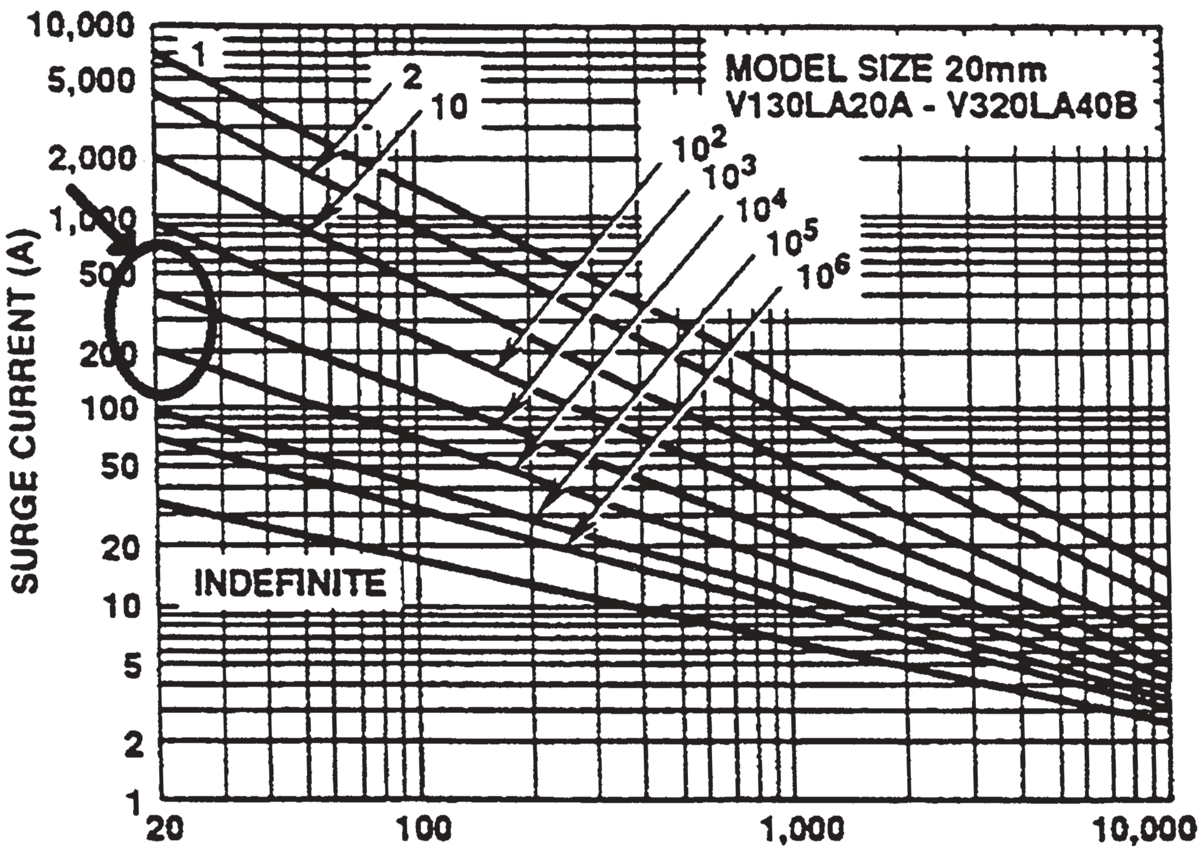

Fig. 2
MOV Manufacturer Component Data Graph

What is the probability of a medium-to-low exposure branch panelboard encountering an 80,000A transient? To create a real-world scenario, these branch panel suppressors will be exposed to more frequent lower level events. To keep calculations simple, a lower current magnitude transient of 2KA with an 8/20-usec standard transient current wave-form is used as a lower level transient magnitude. Long-term reliability of each device will be analyzed using the 2KA transient current and MOV manufacturer's component data. By reviewing the MOV data sheet, the relationship of current to life expectancy will be discerned. The same relational proportions to a device with multiple MOVs exposed to a 2KA impulse may then be easily determined.

EXPONENTIAL LIFE EXPECTANCY

The Harris 20mm MOV data graph in Fig. 2 provides information for a single MOV. The graph depicts Impulse Duration vs. Surge Current with each graph line representing expected pulse life. The area circled represents sample readings to be used for discussion. A 20 usec pulse (as read from the bottom axis) with a current magnitudes 400A (as read from the vertical axis) has a pulse life of 1000 (10E3) (as read from the intersecting line of the graph). Although the graph shows the response of a single 20mm MOV, keep in mind the Products A and B utilize a multitude of metal oxide varistors. The proportions of the basic relationship of a single MOV hold true for a multitude of current sharing MOVs.

Review of the graph reveals that a 20mm MOV pulsed with 20 usec 400 amp transients should be able to withstand 1000 pulses. Halving the current to 200 amps extends the MOV life from 1,000 hits to 10,000 hits. Similarly, halving the stress on a product utilizing multiple MOVs not only doubles product life expectancy but increases product life expectancy by a factor of 10 as illustrated in Fig. 2. As shown, halving the stress on MOVs not only doubles the life of the MOVs but increases the life by a factor of 10.

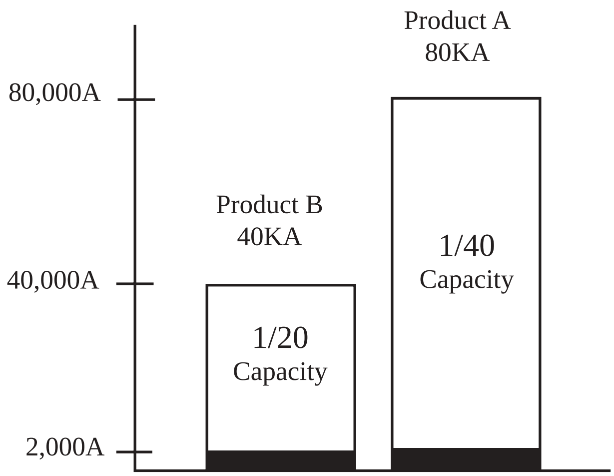

Fig. 3
Product A and Product B Surge Current

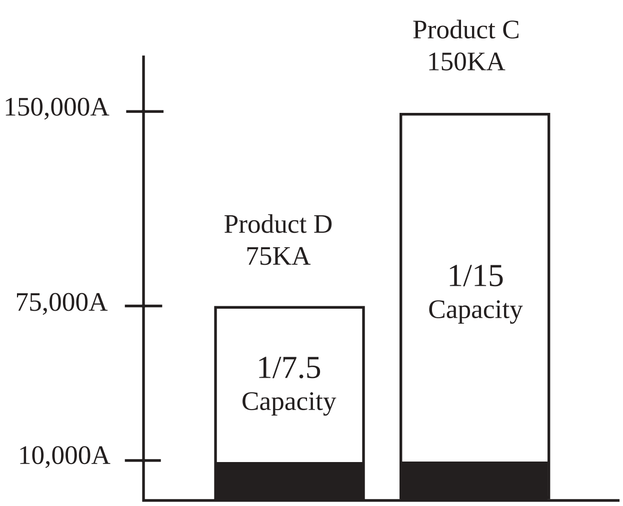

Fig. 4
Product C and Product D Surge Current

The single pulse surge current capacities of Products A and B are 80KA and 40KA respectively, and Fig. 3 illustrates these capacities along with a 2KA impulse indicating the fraction of each device's rated maximum. This graph shows that the 2KA transient is 1/20th of the single pulse surge current rating of Product B and 1/40th of the rated capacity of Product A. If the relationship between an MOV's number of pulses before failure and the surge current were linear, the life expectancy of Product A would be only twice that of Product B. However, surge suppression devices using non-linear solid state suppression such as MOVs or silicon avalanche diodes exhibit logarithmic impulse current vs. life expectancy relationships. Therefore, halving the current stress on the surge suppression provides a life expectancy extended by an exponential factor 10.

The principal for exponential improvement of life expectancy is applicable to service entrances as well. Rather than utilize two devices rated for 40KA and 80KA, service entrance surge suppression, Product C carries a surge current capacity of 150KA in any single mode, compared to Product D with 75KA. Instead of using a 2KA surge current to extrapolate the device's percent of capacity, a 10KA service entrance current magnitude is used to relate to utility power factor correction, utility transformer reactance or reclosure switching.

Fig. 4 shows the single pulse surge current capacities of service entrance Products C and D along with a 10KA impulse that depicts the fraction of each product's rated maximum. As does internal suppression, some service entrance products use only non-linear solid state suppression such as multiple MOVs or silicon avalanche diodes and therefore exhibit logarithmic impulse currents vs. life expectancy relationships. Once again, Product C will last 10 minutes longer than Product D.

In addition to halving the surge current handled by the MOVs to increase life expectancy, some manufacturers included an additional surge current path within the product. If Product C features a selenium cell that shares current with the MOVs and Product D relies solely on MOV technology, the component life expectancy of Product C will be further extended. In this situation, Product D is stressed to almost 1/8 of the MOV capacity while Product C implements MOV technology current sharing with a selenium cell. Should Product C contain MOV technology only, the current stress on the MOVs would be half that as encountered in Product D; therefore, Product C would have a life expectancy 10 times greater than that of Product D. Adding selenium and further reducing the current conducted by the MOVs will further exponentially extend the expected life of the device.

At service entrance, single pulse surge current capacity is both a measure of protection from catastrophic external transients and a measure of surge suppressor life expectancy when subjected to the daily bombardment of lower level external transients. Within a facility distribution system, the catastrophic transient is still present but less likely to be critical criteria. Instead, the single pulse surge current capacity internally applied suppression devices will directly correlate to the life expectancy of the suppressors. In both service entrance and distribution system applications, this is an exponential relationship rather than a line at one. Devices with higher surge current capacities last exponentially longer than lower rated devices.

HORSEPOWER

To compare surge capacity ratings, consider the wide range of horsepower available in today's automobiles. For many individuals, a major consideration in the purchase of a new car is the size of the motor under the hood. Although often more expensive, cars with greater horsepower maintain a higher resale value. Since driving a car faster than 65 mph is legally prohibited, why is higher horsepower desirable?

Horsepower has more performance benefits that top speed, such as quicker acceleration, less motor stress over the duration of the car's life and better responsiveness. Routine acceleration during city driving is less stressful on a higher horsepower motor than a smaller, lower rated engine. Similarly, a surge suppressor with greater surge current capacity lasts longer if the transient magnitude does not stress the capacity of the internal components. In other words, daily electrical transient activity will have less detrimental effect on a more powerful surge suppression device than on a less powerful one. And just as critical situations may call for an automobile driver to accelerate beyond the speed limit, surge suppression devices may call encounter extraordinary transient current magnitudes. Better to be equipped and be prepared than to face the results of a catastrophe that could have been prevented.

CONCLUSION

As detailed in this article, selection of proper single pulse surge current capacity hinges on two critical factors: exposure of the device to high magnitude transients and the desired reliability through lower magnitude transients. Single pulse surge current capacities relate not only to a product's ability to electrically function following severe transient episodes but are also directly related to the expected life of the product from low level transients as well. As the surge suppression industry continues to design increasingly higher capacity products, the greatest improvement will come in long term reliability. Meanwhile, specification of high-rated surge current capacity offerings provides the maximum available protection for today's sensitive loads.

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