Understand surge protection techniques for low-power outdoor electronics

Growing demand for outdoor electronics puts renewed focus on protection techniques for lightning-induced surges

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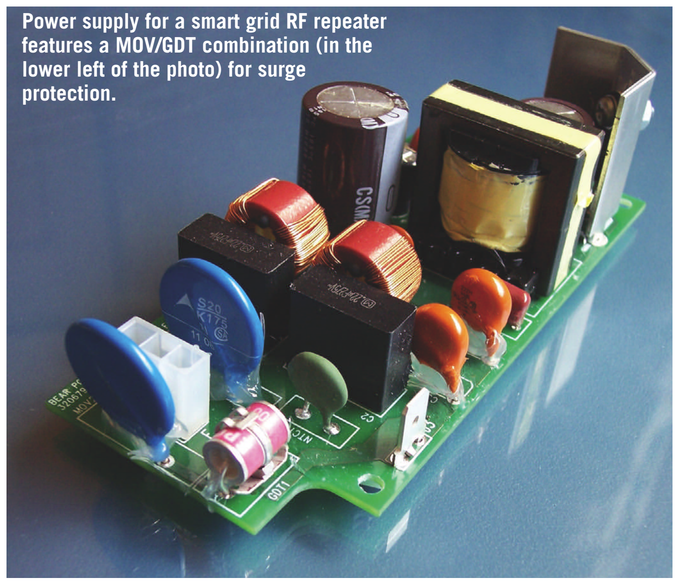

Power supply for a smart grid RF repeater features a MOV/GDT combination (in the lower left of the photo) for surge protection.

Low-power industrial electronics are increasingly found in outdoor applications. Growth drivers include the proliferation of video surveillance systems, adoption of LED lighting, build-out of the smart grid with devices such as pole-mounted RF repeaters, and deployment of a wide range of sensors and monitoring systems for equipment in clean energy, oil, gas and other industries.

The broad and growing range of applications means design engineers are increasingly likely to encounter design projects for equipment that works outdoors. For designers accustomed to creating indoor systems, this means learning new techniques for protecting equipment from lightning-induced surges.

Understanding threat categories

Surge protection standards are based on IEEE Standard C62.41.2, which outlines surge threat levels based on equipment location. Location Category A is inside a building and distant from the electrical service entrance. Category B is indoors on short branch lines closer to the service entrance. Category A and B locations are protected from lightning

Surge Waveform	Category A	Category B	Category C - Low exposure	Category C - High exposure
0.5 µs - 100 kHz ring wave	6 kV / 0.2 kA	6 kV / 0.5 kA	6 kV (optional, for cases where front-of-wave response may be a concern)	6 kV (optional, for cases where front-of-wave response may be a concern)
1.2/50 µs -8/20 µs combination wave high-energy surge	6 kV / 0.5 kA	6 kV / 3 kA	6 kV / 3 kA	10 kV / 10 kA (done as separate current and voltage tests)

Table 1 presents guidelines for developing design parameters and tests. Ideally you would consider both exposure levels and the source of surges. For instance, if the device will be used in areas with high lightning activity but little switching activity, give the combination wave more weight than the ring wave. If the devices will be used in a broad range of locations and types of exposure, design for the "typical" rather than the extreme unless life-support or similar stringent requirements apply. IEC 6100-4-5 and UL-1449 standards provide additional information about test requirements. Source: IEEE

surges by commercial surge protection devices (SPD) at the building service equipment panel, as well as by their distance from the source of the surge.

Location Category C covers the area from the line transformer outdoors and extending just into the building. This category is divided into "low exposure" and "high exposure" levels depending on a number of factors, including the type and amount of lightning exposure expected. This article will focus on Category C, low exposure.

Test wave recommendations

Lightning surge test recommendations presented in IEEE C62.41.2 include the 0.5 µs to 100 kHz ring wave and the 1.2/50 µs to 8/20 µs combination wave. The combination wave includes a short-circuit current (from direct flashes and near-flash effects) and an open-circuit voltage (from far flashes and near-flash effects).

The ring wave is a lower energy, higher frequency waveform. It is relatively easy to filter using line filters or standard transient voltage suppressors (transorbs). The combination waveform represents higher-energy surges and requires a different suppression approach.

Buy or design?

Commercial SPDs used at a building service entrance are typically DIN rail mounted and measure about 3x3 inches. In theory they may be used to protect individual Category C devices, but they are generally too large and expensive to incorporate into the enclosure for a remote monitor, smart grid RF repeater, surveillance camera or similar device. Therefore high-energy surge protection must be part of the system design for effective protection with the smallest size and lowest cost.

Types of surge protection devices

Surge protection devices can employ either clamping or crowbar techniques. A clamping device begins conducting when the voltage across it exceeds its rated level, and stops conducting (extinguishes) when the surge voltage drops below that threshold. Silicon avalanche diodes (commonly known as Transorbs) and metal oxide varistors (MOVs) are typical clamping devices.

A crowbar device begins conducting when the voltage across it exceeds a rated level, at which point the device impedance drops rapidly along with the voltage across it. Crowbar devices don't extinguish until current stops flowing, and therefore follow-on current due to the AC line will continue to flow long after the transient has passed. Because this follow-on current can significantly reduce the life of the device being protected, additional circuitry is used to release the current after one or more zero crossings. Gas Discharge Tubes (GDTs) are crowbar devices.

Protecting Category B & C equipment

For Category A equipment, a simple and common surge protection technique is to place a MOV across the line. MOVs offer excellent overall protection, with good energy and current handling capabilities. They have low let-through voltage (Figure 1) so very little of the leading edge of the transient above the DC breakdown voltage is let through before the device starts to conduct. This means there is little EFT coming through. They also stop conducting when the voltage across them drops below the breakdown voltage, meaning no follow-on current problems.

For suppressing high-energy transients experienced by Category B and C equip-

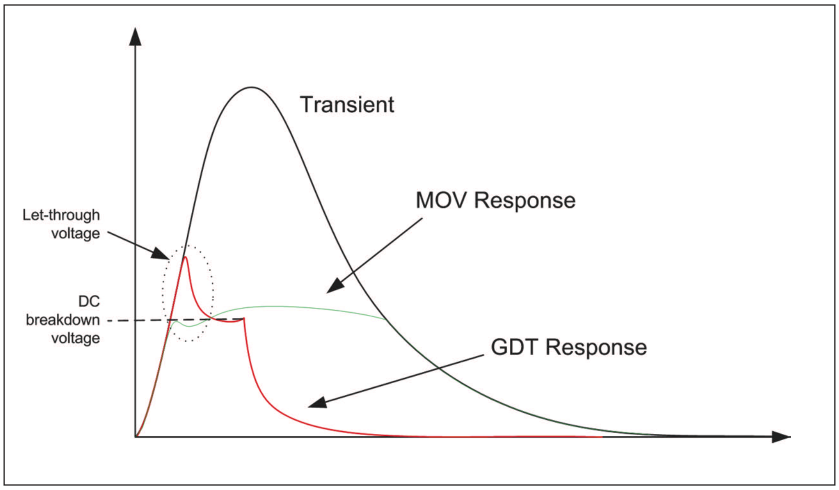

Figure 1. Let-through voltage for a MOV and GDT in response to a transient. Source: BEAR Power Supplies

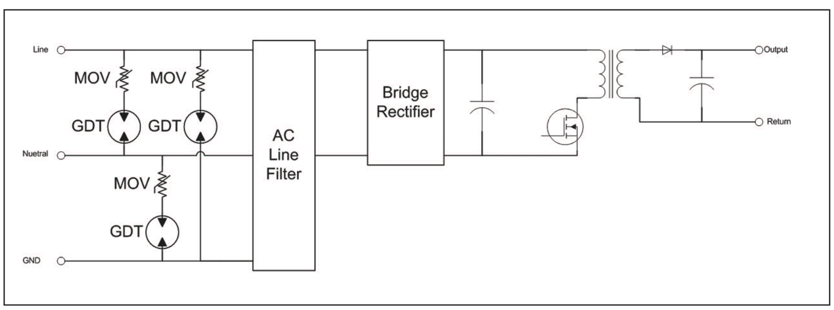

Figure 2. Combination protection circuit using MOVs and GDTs. Source: BEAR Power Supplies

ment, GDTs perform better than MOVs. However, GDTs have poor let-through voltage (Figure 1) and follow-on current characteristics. Therefore a good approach for Category C equipment is to combine a GDT in series with a MOV (Figure 2). The UL standard 1414 (6th edition) outlines the component requirements and provides examples of recognized combinations that are in compliance.

Using this combination allows the designer to choose a lower-voltage MOV than would be needed if the MOV alone were placed across the line. Lower-voltage MOVs offer the benefit of handling more current for a given energy rating. The MOV acts as a limiter for follow-on current to the GDT.

Silicon avalanche diodes can be used as secondary protection if needed. They are effective at handling fast transients and have no follow-on current after the transient has passed. They are generally not used as primary protection because of their lower energy handling capability.

Additional design considerations

Use the AC line filter to your advantage to separate primary and secondary protection. The filter will slow down and reduce the amplitude of the let-through voltage, and the secondary protection device can clamp it to the desired safe voltage.

Know the failure point of the device to be protected. Your surge protection should limit the energy to below that level, but not too far below. For example, if your device can take a low-energy 2-kV spike, you should clamp to 1.5 V kV rather than 1 kV. Over-designing the protection adds unnecessary costs.

Pay close attention to board layout. Avoid creating any path for a transient to cross the board. Be aware of instances such as mounting holes which may create unintended paths to ground. One technique is to provide a clean, short, low-inductance path to the AC line ground, and/or a single chassis ground mounting hole located near the AC input.

Surge protection lifetime

A MOV or GDT degrades each time it fires and will eventually fail, causing a short. Lifetime depends on the number and energy of the surges. Most manufacturers suggest replacing the device after 10 surges, but many monitoring devices are deployed in hard-to-reach locations and labor costs to replace or repair them are very high. Higher-rated components (for energy, current and lifetime specs) can add significantly to the system cost. By appropriately combining devices and using the line filter, you can provide long-lasting surge protection for Category C equipment while keeping design costs down.

For more information call BEAR Power Supplies at 1-800-551-2327 or email techinfo@bearpwr.com