SURGE RECEPTACLES AND DOWNSTREAM PROTECTION

By Jason Crossman B.Sc EET, Killark Product Manager, Wiring Products Hubbell Canada LP

Electrical surges are one of the most common problems plaguing a society that has become increasingly dependent on electronics as a way of life.

When considering the level of investment and dependence that is placed on modern electronics, it seems ludicrous not to offer these devices some form of protection from electrical disturbances.

State-of-the-art audio and video equipment as well as personal computers have infiltrated most homes and there is a need to protect all of this equipment from the dangers of electrical surges.

Surges, in one form or another, exist in all electrical systems. While some surges originate from lightning, the majority of surges originate inside the facility. What does this mean to the average person? Portable welders, power tools or just about anything with a motor can generate surges in the electrical system. Simple day-to-day use of these machines may be subjecting sensitive electronics to repeat surge events. Although these surges will generally not cause direct failure of a component, there is an ongoing assault that if left unchecked, they can cause premature failure of your equipment. Circuitry in microchips, transformer windings and printed circuit boards can all fall prey to the elusive repeated surge event. Electric motors found in the home are very robust and require little in the way of surge protection themselves, but these same motors create magnetic fields while they are operational. At the precise moment that power to the motor is turned off, a magnetic field begins to collapse and can introduce a surge into the electrical system. Sensitive electronic devices in the home are now susceptible to being hit by that surge.

As soon as an electrical component is plugged into any outlet, it is placed directly in harms way. In fact, as long as the device remains plugged in it continues to be at risk. It is important to remember that the equipment does not need to be running to be at risk, just simply plugged into the electrical system. This is where the term point-of-use protection originates. While there are many levels of protection available, point-of-use offers substantial protection for minimal expense. Much like every other facet of life though, you get what you pay for. Inexpensive versions of surge receptacles will undoubtedly offer minimal protection and a false sense of security. Metal Oxide Varistors (MOVs) offer excellent protection against the typical internal surge event. During normal operation the MOVs of a surge receptacle lie dormant due to an extremely high internal resistance. When a surge condition begins, the increase in voltage begins to turn on the MOV, which alters the internal resistance to a very low value. Like water, current takes the path of least resistance. In the MOV, the path of least resistance is directed to ground, away from your sensitive equipment. After the surge event subsides, the MOV returns to the normal state of high resistance.

Anyone familiar with Ground Fault Circuit Interrupters will know that installing a GFCI receptacle as the first in the circuit will offer ground fault protection to all of the receptacles downstream. Surge receptacles do not work the same way. Simply identifying the first receptacle in the circuit and replacing it with a surge receptacle does not offer immunity to all of the receptacles that are fed downstream. While it is true that any moderate surge that originates from the main panel, or that is induced into the wiring prior to the surge receptacle will be shunted to ground, it does not offer adequate equipment protection from a surge that originates from one of the standard receptacles downstream. The reasons for this are many, but are due primarily to reactance and wire resistance. Reactance is an AC circuit phenomenon that affects the natural resistance and inductance of the wiring. Reactance further complicates surge protection because of the frequency dependent nature of the reactance quantity. Since a surge is much higher in frequency than the standard 60Hz, electrical signal reactance becomes a factor. It can be illustrated by the equations below. As frequency (f) is increased, reactance is increased.

Reactance, $X_L = \omega L$

where $\omega = 2\pi f$

L = inductance in Henries

L for typical solid core #14 AWG:

$$L = 2(l)\left(\ln\left(\frac{2(l)}{r}\right) - 1\right)10^{-7}$$

Where l = length of conductor

r = conductor radius

Using a length of 1 foot (300mm) and the radius of 0.815mm for #14 AWG,

$$L = 2(300)\left(\ln\left(\frac{2(300)}{0.815}\right) - 1\right)10^{-7}$$

$= 336.089\ \mu H$ at 300mm (1 foot)

Solving for 10 feet of wire

L = 4.742 mH/10 feet

Based on f = 60Hz and L = 4.742mH

$$X_L = 2\pi(60)(4.742)(10^{-3}) = 1.788\,\Omega$$

Substituting a frequency, f, of 20kHz to simulate higher surge frequencies.

$$X_L = 2\pi(20000)(4.742)(10^{-3}) = 595.947\,\Omega$$

This increase in reactance becomes critical when devices downstream of the surge receptacle introduce surges. Consider a home that has four receptacles in the same room that are on the same circuit. If only the first receptacle in the circuit is replaced with a surge ver-

sion, all four receptacles will be protected from reasonable surges originating from outside of that room. However, if the third receptacle is used with a heavy power tool, a surge could be introduced into the wiring through that standard receptacle. The single surge receptacle will offer little to no protection for any equipment plugged into the second or fourth receptacle. When the surge originates from outside the room, it must directly pass the MOVs in the surge receptacle before it can reach any other standard receptacles. When the surge comes the other way, there are many paths. A typical resistance value for electronic equipment is usually less than 50 Ohms. When that value is placed in a parallel connection with the larger resistive/reactive value of the wiring, the television plugged into the second receptacle or the stereo equipment plugged into the fourth receptacle may take the surge. Physical wire resistance combined with reactance can make equipment appear as the path of least resistance resulting in electronic equipment taking the hit.

The terminology of downstream protection or bi-directional protection can be misleading. There are many factors to consider when using these terms. Downstream is generally a reference to protecting equipment downstream from a surge that originates upstream of the surge protection device. Bi-directional protection is possible to a certain extent when the distance between receptacles is kept to a minimum. However, in typical wiring the receptacle spacing is far enough apart that if there is to be any sensitive equipment powered from that circuit, there should be a surge receptacle directly at the point-of-use. Consider the graphical representations on this page:

The graphs illustrate the natural logarithmic function of reactance and the incremental reactive quantity as a function of wire length.

At a distance of only 2 feet the reactance value is already at 100 Ohms based on a 20kHz surge event. This is where point-of-use protection becomes critical. It is not realistic to believe that potential surge generating equipment will never be connected to the same circuit the electronics are on, or that a single receptacle can be expected to protect all equipment. Modern Metal Oxide Varistor manufacturing is capable of producing an MOV that will last for many years under normal conditions. When a surge receptacle fails, it is probably not defective, but rather it is a good indication of just how many surge events are present and of what magnitude. If a surge receptacle fails prematurely, then an evaluation of the entire facility should be conducted. Under normal conditions of internally generated surges, a surge receptacle should offer trouble-free protection for years. It is neither necessary, nor feasible to replace all receptacles with surge protective receptacles when all that is required is an evaluation of which outlets in the facility are used for electronic equipment.

Based on the cost of equipment, if it prevents one trip to the repair shop or it extends the life of the component, the surge device has more than paid for itself.