Maximizing Parallel Connected Surge Protector Performance

MTi Engineering Department

The performance of a parallel connected hard wire surge protective device is strongly dependant on the way in which it is connected to the electrical system. There are two basic wiring practices that can be used to maximize the benefit provided by a parallel connected surge protective device; minimizing lead length and minimizing wire bends.

Minimizing the lead length is by far the most beneficial in maximizing the effectiveness of the surge protective device. The surge protector employs voltage sensitive elements that will conduct once a certain voltage is present. When the surge protector conducts, it will draw significant current through the leads that connect it to the electrical system. This current can be tens of thousands of amperes in magnitude. The current flow creates a voltage across the surge protector connection leads from not only the copper losses (I^2R) but more significantly from the inductive losses ($L*dI/dt$) in obedience of Ohm's Law ($v = iz$ where $z = R + X_L$ and $X_L = 2\pi fL$). The reason that the inductance has a significant effect is due to the high frequencies that are encountered in surges. Power frequency is 60Hz, where as a laboratory surge generator will create a test surge of approximately 16,600Hz. This is considered to be a typical switching transient frequency at which to test surge protectors. The much higher frequency results in substantially higher voltage drop across the surge protector connection leads during a surge event. The voltage across the connecting leads adds to the voltage across the surge protector to create a higher voltage at the connection point on the electrical system. The longer the connection leads, the more surge voltage will be "let through" to the electrical equipment.

Another way to improve the performance of the surge protector is to minimize the number of tight bends in the connection leads. This effect is small when compared to shortening the lead length, however it does improve the overall performance. Tight 90 degree bends create a difference in electric field intensity along the bend with the highest field intensities located at the inside of the bend. The connecting leads obey Microscopic Ohm's Law ,$J=\sigma E$ (where J=conduction current density, σ = conductivity and E = electric field intensity). The higher electric field intensity at the inside of the bend will cause a higher current density there as well. The higher current density causes a higher power density resulting in excessive heating (therefore voltage drop) around the bend. This is especially noticeable at high frequencies due to the low skin depth penetration that essentially makes the wire smaller, which in turn further increases the power density and voltage drop at the bend.

A hard wired surge protector was exposed to incrementally higher surges and the resulting let-through voltages were measured. The same surge protector was tested with three different connection strategies; using long connection leads with no tight bends, using long connection leads with several tight bends and using short connection leads having no tight bends. The testing was performed to illustrate the phenomena discussed earlier. The surge protector performed best when the connection leads were short and without tight bends (See Figure 1).

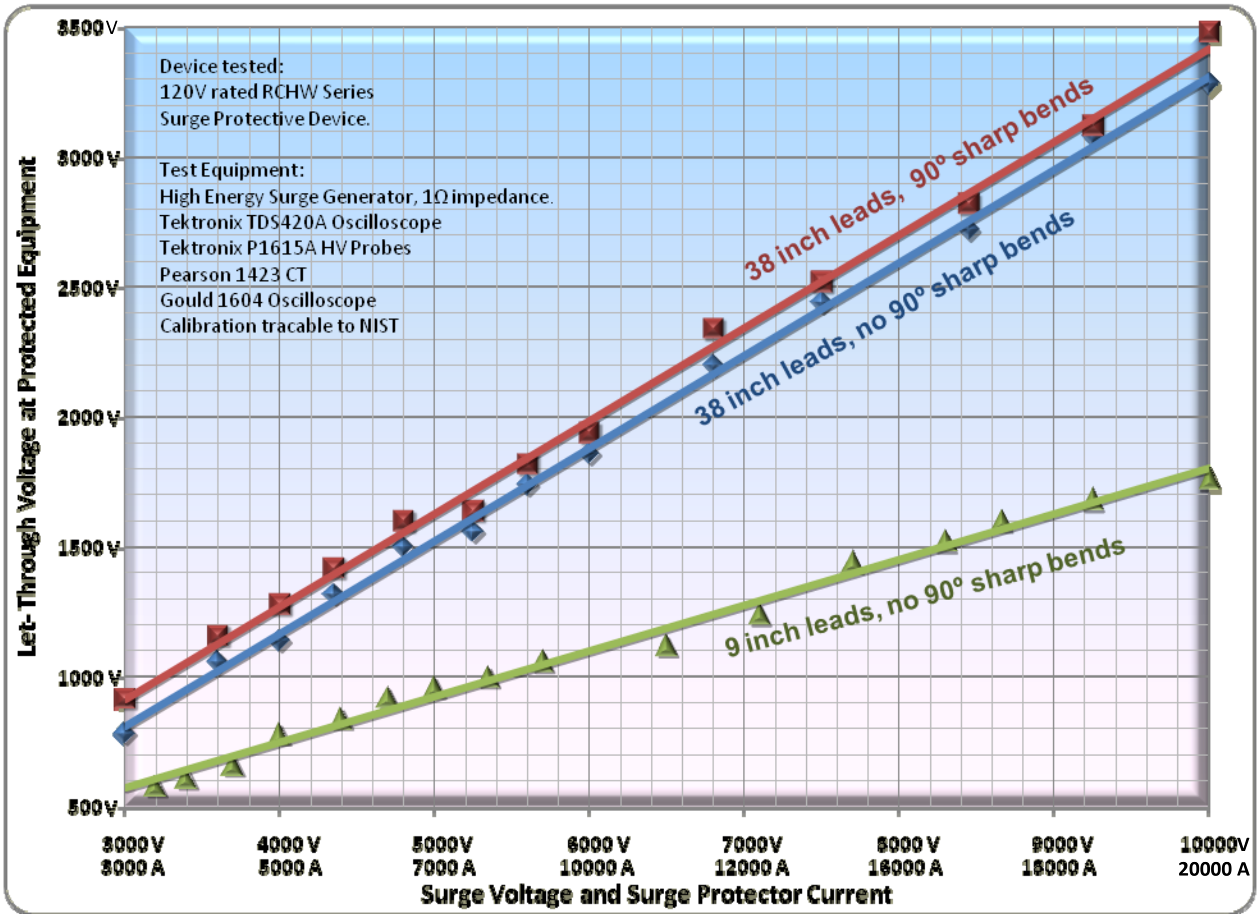

Figure 1

Plot of let-through voltage with respect to surge impulse with varying configurations

Notes:

The above plot shows the negative effects of excess lead length and routing the leads with sharp bends. Figure 1 shows the test results of a 120V rated product. Other voltage rated products as well as products with varying surge current ratings will perform similarly. Excessive numbers of sharp bends (14) were used to better show the effect on surge performance. Better surge performance equates to lower let-through voltage at a given surge event. The same mode was used for all testing. The above plot is not intended to represent the performance of all parallel connected surge protective devices, rather it is intended to illustrate the concepts of the wiring methodology.