TECH BRIEF

Littelfuse Varistors (Connection and Terminology)

TERMS AND DESCRIPTIONS	SYMBOL
Clamping Voltage Peak voltage across the varistor measured under conditions of a specified peak V_C pulse current and specified waveform. NOTE: Peak voltage and peak currents are not necessarily coincidental in time.	V_C
Rated Peak Single Pulse Transient Currents (Varistor). Maximum peak current which may be applied for a single 8/20µs impulse, with rated line voltage also applied, without causing device failure.	I_{TM}
Lifetime Rated Pulse Currents (Varistor). Derated values of I_{TM} for impulse durations exceeding that of an 8/20µs waveshape, and for multiple pulses which may be applied over device rated lifetime.	-
Rated RMS Voltage (Varistor). Maximum continuous sinusoidal RMS voltage which may be applied.	$V_{M(AC)}$
Rated DC Voltage (Varistor). Maximum continuous DC voltage which may be applied.	$V_{M(DC)}$
DC Standby Current (Varistor). Varistor current measured at rated voltage, $V_{M(DC)}$	I_D
For certain applications, some of the following terms may be useful.	
Nominal Varistor Voltage. Voltage across the varistor measured at a specified pulsed DC current, $I_{N(DC)}$, of specific duration. $I_{N(DC)}$ of speci c duration. $I_{N(DC)}$ is specified by the varistor manufacturer.	$V_{N(DC)}$
Peak Nominal Varistor Voltage. Voltage across the varistor measured at a specified peak AC current, $I_{N(AC)}$, of specific duration. $I_{N(AC)}$ is speci ed by the varistor manufacturer.	$V_{N(AC)}$
Rated Recurrent Peak Voltage (Varistor). Maximum recurrent peak voltage which may be applied for a speci ed duty cycle and waveform.	V_{PM}
Rated Single Pulse Transient Energy (Varistor). Energy which may be dissipated for a single impulse of maximum rated current at a specified waveshape, with rated RMS voltage or rated DC voltage also applied, without causing device failure.	W_{TM}
Rated Transient Average Power Dissipation (Varistor). Maximum average power which may be dissipated due to a group of pulses occurring within a specified isolated time period, without causing device failure.	$P_{T(AV)M}$
Varistor Voltage. Voltage across the varistor measured at a given current, I_X.	V_X
Voltage Clamping Ratio (Varistor). A figure of merit measure of the varistor clamping effectiveness as defined by the symbols $V_C/V_{M(AC)}$, $V_C/V_{M(DC)}$.	$\frac{V_C}{V_{PM}}$
Nonlinear Exponent. A measure of varistor nonlinearity between two given operating currents, I_1 and I_2, as described by I = kV where k is a device constant, $I_1 \leq I \leq I_2$, and $\alpha_{12} = \frac{\log I_2/I_1}{\log V_2/V_1}$	α
Dynamic Impedance (Varistor). A measure of small signal impedance at a given operating point as defined by: $Z_X = \frac{dV_X}{dI_X}$	Z_X
Resistance (Varistor). Static resistance of the varistor at a given operating point as defined by: $R_X = \frac{V_X}{I_X}$	R_X
Capacitance (Varistor). Capacitance between the two terminals of the varistor measured at C specified frequency and bias.	C
AC Standby Power (Varistor). Varistor AC power dissipation measured at rated RMS voltage $V_{M(AC)}$	P_D
Voltage Overshoot (Varistor). The excess voltage above the clamping voltage of the device for a given current that occurs when current waves of less than 8µs virtual front duration are applied. This value may be expressed as a % of the clamping voltage (V_C) for an 8/20 current wave.	V_{OS}
Response Time (Varistor). The time between the point at which the wave exceeds the clamping voltage level (V_C) and the peak of the voltage overshoot. For the purpose of this definition, clamping voltage as defined with an 8/20µs current waveform of the same peak current amplitude as the waveform used for this response time.	-
Overshoot Duration (Varistor). The time between the point voltage level (V_C) and the point at which the voltage overshoot has decayed to 50% of its peak. For the purpose of this definition, clamping voltage is defined with an 8/20µs current waveform of the same peak current amplitude as the waveform used for this overshoot duration.	-

Littelfuse®
Circuit Protection Specialists

Varistor Terminology

The following tabulation defines the terminology used in varistor specifications. Existing standards have been followed wherever possible.

Definitions (IEEE Standard C62.33)

A characteristic is an inherent and measurable property of a device. Such a property may be electrical, mechanical, or thermal, and can be expressed as a value for stated conditions.

A rating is a value which establishes either a limiting capability or a limiting condition (either maximum or minimum) for operation of a device. It is determined for specified values of environment and operation. The ratings indicate a level of stress which may be applied to the device without causing degradation or failure. Varistor symbols are defined on the linear V-I graph illustrated in Figure 1.

Test Waveform

At high current and energy levels, varistor characteristics are measured, of necessity, with an impulse waveform. Shown in Figure 2 is the ANSI Standard C62.1 waveshape, an exponentially decaying waveform representative of lightning surges and the discharge of stored energy in reactive circuits.

The 8/20μs current wave (8μs rise and 20μs to 50% decay of peak value) is used as a standard, based on industry practices, for the characteristics and ratings described.

One exception is the energy rating (W_{TM}), where a longer waveform of 10/1000μs is used. This condition is more representative of the high energy surges usually experienced from inductive discharge of motors and transformers. Varistors are

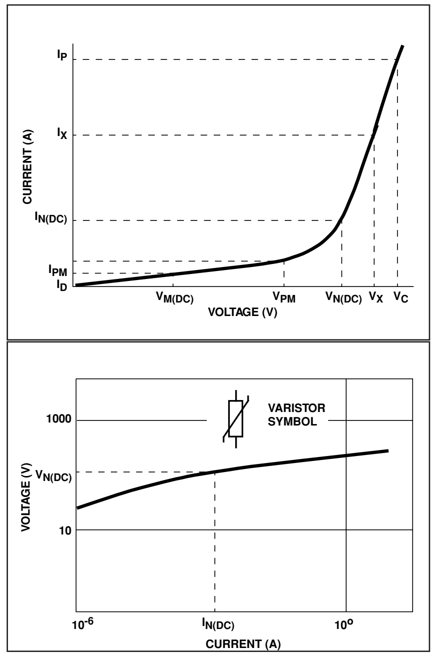

Figure 1. I-V Graph illustrating symbols and definitions

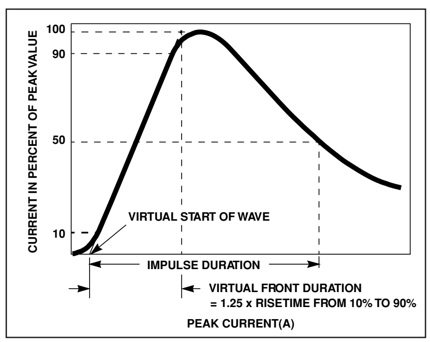

Figure 2. Definition of Pulse Current Waveform

rated for a maximum pulse energy surge that results in a varistor voltage (V_N) shift of less than ±10% from initial value.

How to Connect a Littelfuse Varistor

Transient suppressors can be exposed to high currents for short durations in the nanoseconds to millisecond time frame.

Littelfuse Varistors are connected in parallel to the load, and any voltage drop in the leads to the varistor will reduce its effectiveness. Best results are obtained by using short leads that are close together to reduce induced voltages and a low ohmic resistance to reduce I • R drops.

Electrical Connections

Single Phase

This is the most complete protection one can select, but in many cases only Varistor 1 or Varistor 1 and 2 are selected.

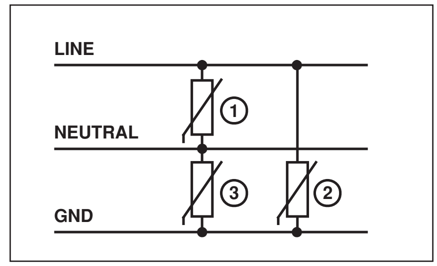

Figure 3a. Single phase electrical connection

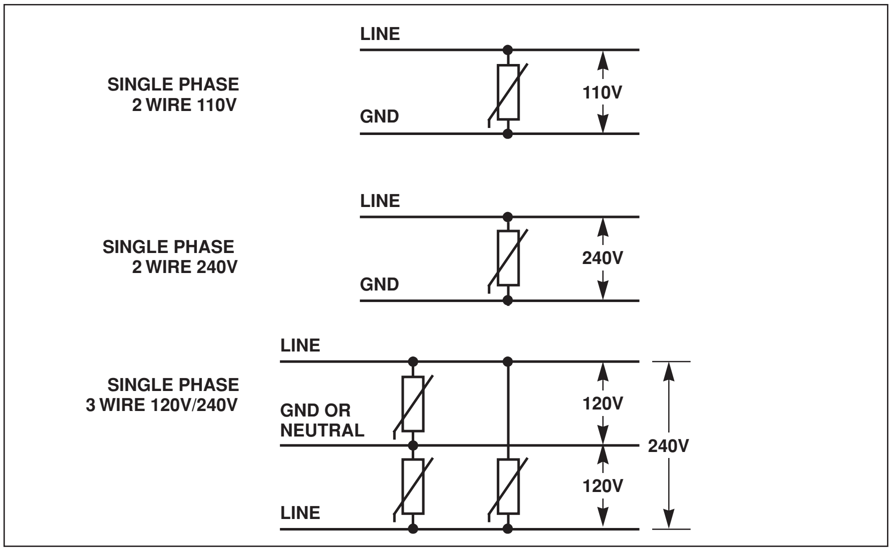

Figure 4. More single phase electrical connections

Three Phase

For higher voltages use the same connections, but select varistors for the appropriate voltage rating.

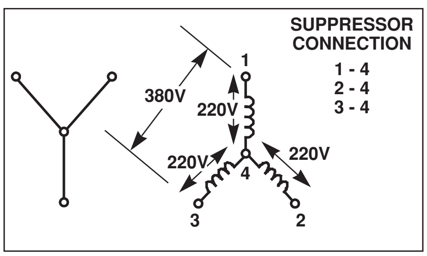

Figure 5a. 3-Phase 220V/380V, underground electrical connection

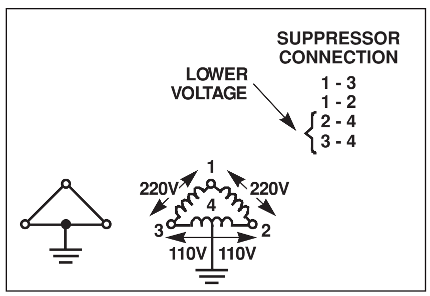

Figure 5d. 3-Phase 220V electrical connection

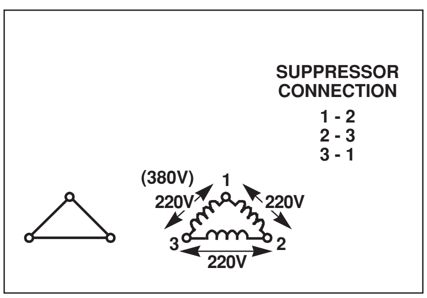

Figure 5b. 3 Phase 220V or 380V, ungrounded electrical connection

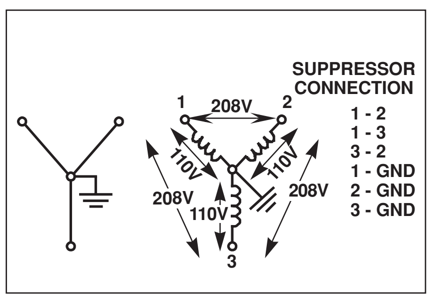

Figure 5e. 3-Phase 120V/208V, 4-Wire electrical connection

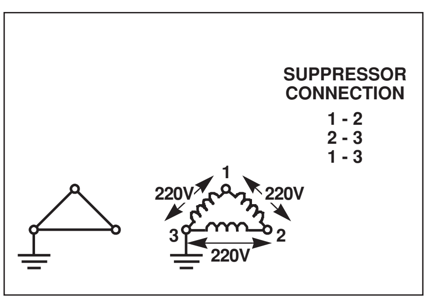

Figure 5c. 3 Phase 220V, 1 Phase ground electrical connection

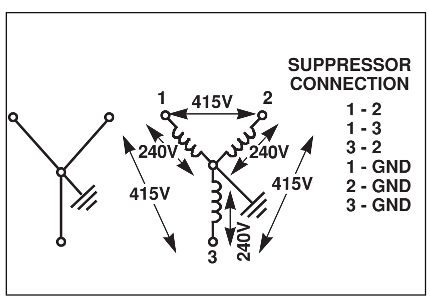

Figure 5f. 3-Phase 240V/415V electrical connection

DC Applications

DC applications require connection between plus and minus or plus and ground and minus and ground.

For example, if a transient towards ground exists on all 3 phases (common mode transients) only transient suppressors connected phase to ground would absorb energy. Transient suppressors connected phase to phase would not be effective.

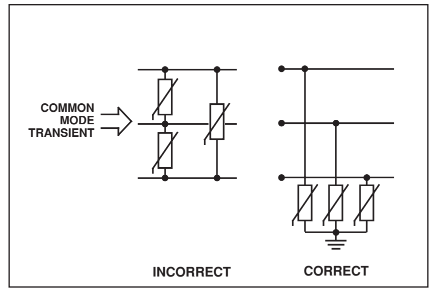

Figure 6. Common mode transient and correct solution

On the other hand if a differential mode of transient (phase to phase) exists then transient suppressors connected phase to phase would be the correct solution.

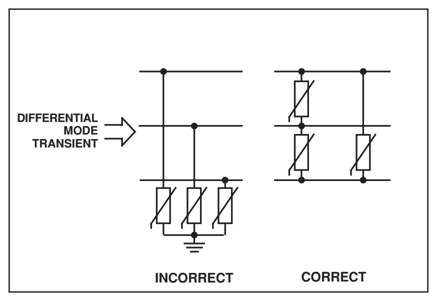

Figure 7. Differential mode transient and correct solution

This is just a selection of some of the more important variations in connecting transient suppressors.

The logical approach is to connect the transient suppressor between the points of the potential difference created by the transient. The suppressor will then equalize or reduce these potentials to lower and harmless levels.

References

For Littelfuse documents available on the web, see http://www.littelfuse.com/

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