Semiconductor Protection

Solid state devices have progressed through several generations of sophistication since their introduction in the 1940s. Fuse designs have changed to match solid state protection demands.

The protection task looks simple- choose a fuse of correct voltage and ampere rating which will protect a solid state device (diode, silicon-controlled rectifier, triac, etc.) through a wide range of overcurrents, yet carry normal rated loads without deterioration through a long life.

Solid state power devices operate at high current densities. Cooling is a prime consideration. The fuse should be cooled with the solid state device. Cycling conditions must be considered. The ability of solid state devices to switch high currents at high speed subjects fuses to thermal and mechanical stresses. Proper fuse selection is mandatory for long-term reliability.

Solid state devices have relatively short thermal time constants. An overcurrent which may not harm an electromechanical device can cause catastrophic failure of a solid state device.

Many solid state devices have an overcurrent withstand rating which is termed "I^2t for fusing". These values are found in most power semiconductor application handbooks.

Fuses intended for solid state device protection are rated in terms of total clearing I^2t. Fuses and devices are matched so that the total clearing I^2t of the fuse is less than the withstand I^2t for the device.

The published fuse total clearing I^2t values are derived from short-circuit test oscillograms of the fuse under controlled conditions. The end application can vary significantly from the tested conditions. The specifier must take these differences into account since they will affect fuse clearing I^2t.

For application guidelines, request the Mersen publication titled Power Semiconductor Fuse Application Guide, and the software program titled Select a Fuse for Power Electronics.

DC Circuit Protection

AC applications are more common than DC. This is why fuses are generally designed, tested and rated for AC. Fuses rated for AC are also capable of DC circuit interruption. The key question is how much DC voltage interrupting capability does an AC rated fuse have? There is no safe rule of thumb that will convert AC voltage rating to a DC voltage rating. Testing is required to determine the DC voltage rating of a fuse. This section covers AC fuses that have been tested for DC applications. Mersen is a leader in DC protection, offering a line of DC fuses. Contact Technical Services for further information.

DC Circuit Parameters

The degree of difficulty of interrupting a DC circuit is a function of the voltage, current and circuit time constant. The higher the voltage and time constant, the more difficult the interruption is for the fuse.

Time constant is defined as **t = L/R** where:

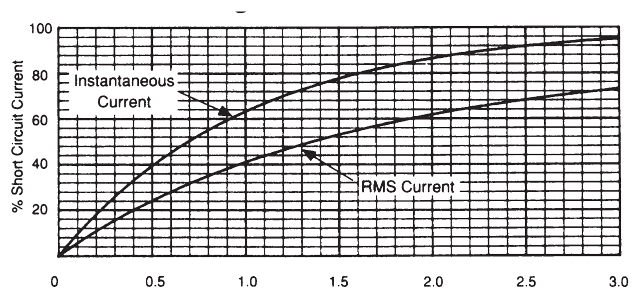
- **t** is time constant in seconds
- **L** is inductance in henrys
- **R** is resistance in ohms

If rated voltage is applied, 63% of rated current will be reached in one time constant.

DC Short Circuit

Graph A shows the relationship of current as a function of time during a DC short circuit.

Graph A- Current as a Function of Time During a DC Short Circuit



Time Constants (n)

Instantaneous Current (I inst) = Isc [I - e^{-n}]

RMS Current (I rms) = $Isc\sqrt{\frac{1 + 2e^{-n}}{n} - \frac{e^{-2n}}{2n} - \frac{1.5}{n}}$

Where Isc = short circuit current, n = number of time constants

Example

Given: Voltage = 600VDC
Circuit Resistance (R) = 0.1 ohm
Circuit Inductance (L) = 1.0 x 10-3 henry

Isc = $\frac{\text{600 Volts}}{\text{0.1 ohm}}$ = 6000 Amperes

t (time constant) = L/R = $\frac{\text{1.0 x 10-3 henry}}{\text{0.1 ohm}}$ = .01 second

In the example, if a short circuit occurs, the instantaneous current will rise to .63 x 6000 = 3780 amperes in .01 second (one time constant). In .05 second (5 time constants) the short-circuit current will reach its ultimate value of 6000 amperes.

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