Calculating Inrush Current Protection

Part and parcel of Electrical Safety Testing is Functional Testing, the powering ON/OFF of the device under test. The manufacturer needs to ensure the device functions safely under normal operating conditions and that it does so for its intended lifespan. Applying a high voltage to the device under test and measuring the resultant leakage current is the most common electrical safety test and provides valuable indication of dielectric strength and/or breakdown. Yet leakage current testing it is not as simple as applying the voltage and measuring the current. Inherent in leakage current testing is the troublesome characteristic of Inrush Current. Inrush current is the momentary surge in current when first applying line voltage to a mains powered device. The line impedance, input rectifier and equivalent series resistance are the only constraints to the amount of current the device draws.

More protection is needed in applications that encounter high inrush currents such as: High VA transformers, UPS's, ballasts, power supplies and laser systems. High current is desirable in certain applications such as a transformer which requires initially high amounts of current to magnetize itself. Also, some capacitors require high amounts of initial DC current to charge and the DC load draws this high surge of power from the AC mains. In other applications the surge of high current at initializing the mains voltage can damage the device or trip the circuit breaker.

Inrush Current Problems

Common problems that inrush current poses to electrical safety testing setups include:

- False Over-current Failures
  When monitoring the device under test's load current, the inrush current will be high for a short duration, causing the over-current protection for AC Sources and leakage testers to falsely trip out.

- Shortened component lifetimes
  High inrush currents repeatedly exceeding the ratings of components in the mains circuit can eventually lead to component failure. High currents that cause arcing can damage the contacts on relays and switches.

- Expensive over-specified equipment
  As a means to compensate for high inrush currents, some manufacturers unnecessarily over-spec the test equipment ratings, just as a means to be able to accommodate for the high inrush current. These methods will quickly drain the test equipment budget!

This application note will now look at protecting devices from high inrush currents and provides a method and considerations necessary in specifying the inrush protection needed for an example device.

Inrush Current Protectors

Inrush current protectors or NTC (Negative Temperature Coefficient) Limiters are used to limit the amount of current flow in a circuit. An NTC is a thermally sensitive resistor that has a high resistance at room temperature that decreases as the temperature increases. This behavior makes NTC's well suited for initially resisting current flow but then allowing the current to flow as the NTC increases in temperature due to the flow of current.

Specifying Inrush Protectors

The three most common problems in specifying inrush protectors are:

1. Specifying the initial resistance too low, allowing too much inrush current to pass through the circuit you are trying to protect.
2. Specifying the impedance of the inrush protector at full load current may be too high because the NTC does not reach full temperature. This can result in a voltage drop across the NTC, reducing the effective voltage across the input to the DUT.
3. Specifying the energy correctly. Knowing the minimum amount of energy the NTC must handle initially is necessary so that the NTC does not lose its protection capability and even burn up.

Example

Therefore, it is necessary to follow these steps when trying to select the appropriate inrush protector. Here is an example:

Step 1: Specify maximum peak voltage (V_{PEAK}) and peak allowable inrush current ($I_{PEAK\ MAX}$). These parameters are used to calculate the resistance required to correctly protect the circuit from over-current damage.

Voltage = 120Vrms
V_{PEAK} = 120Vrms x 1.414
$I_{PEAK\ MAX}$ = 10A (Maximum current allowed in circuit)

Calculate Resistance:

R_{COLD} = $V_{PEAK}/I_{PEAK\ MAX}$
= (120Vrms x 1.414)/10A
= 16.97Ohms

This is the minimum value of resistance required to initially protect the circuit from inrush current.

Step 2: Specify peak voltage (V_{PEAK}), peak current (I_{PEAK}), and time duration of inrush current. These parameters are used to calculate energy rating of the inrush protector. This is typically accomplished by attaching an oscilloscope to monitor the DUT voltage and current simultaneously.

Measured Using Scope:
V_{PEAK} = 169.7V peak
I_{PEAK} = 30A peak
Time = ½ Cycle at 60Hz = 8.3mS

Calculate Energy:
Energy = Vpeak x Ipeak x Time
= 169.7Vpeak x 30.0Apeak x 8.3mS
= 126.8 Joules

This is the minimum amount of energy the NTC will have to handle initially.

Step 3: Define the maximum steady state current (Isteady).
This parameter is required to make sure the NTC can handle the steady state current.

I_{STEADY} = 4 Amps

It's important to choose an NTC with a steady state current rating as close to this value as possible. Doing so will ensure that the NTC is operating at or as close as possible to its operating temperature, effectively producing the lowest voltage drop possible.

Step 4: Select an NTC with characteristics as closely as possible to the values determined steps 1, 2, and 3. Included herein are some suppliers of NTC inrush protectors:

Ametherm: www.ametherm.com
Newark Electronics: www.newarkinone.com
RTI Electronics: www.rtie.com

Per the example, we needed an inrush current protector with R_{COLD} = 16.97Ω minimum, Energy = 126.8 Joules minimum and I_{STEADY} = 4A. On the Ametherm website we located an NTC that could fill these requirements: P/N MS1530004 R=30Ω ±25%; E_{MAX}=135J; E_{FAIL} = 270J and I_{STEADY}= 4.2A. There are plenty others that could do the job as well.