Understanding power supplies and inrush current

New inrush current limiting techniques increase the reliability and life expectancy of commercial, industrial, and medical power supplies.

In ac/dc power converters above a few watts, a large inrush current flows when the input capacitors are suddenly charged during the initial application of power. If unrestricted, this current can easily exceed 50 A at the peak of the ac cycle.

This high inrush current severely stresses the converter's fuse, input rectifiers and power switch. It can significantly reduce the reliability and life expectancy of the modules.

Universal power supplies are particularly subject to high inrush current, since their input capacitors must be large enough to handle the currents at line voltages as low as 110 Vac, but also able to handle high voltages of up to 240 Vac at turn on.

Designers of commercial, industrial, and medical systems must pay special attention to inrush current. In these environments, a power supply failure or a tripped circuit breaker can be inconvenient at best, and expensive or dangerous at worst.

Outdoor security systems designers must pay special attention to inrush current.

Supplies for outdoor use such as security systems are typically in remote, hard-to-reach locations (such as on high poles). Accessing the device to replace a power supply is usually inconvenient and expensive.

Industrial facilities such as manufacturing plants often have multiple supplies on a line, and the combined inrush current can trip a circuit breaker. The resulting unplanned downtime is extremely expensive – up to 30% - 40% of profits, according to a recent *Maintenance World* paper.[i]

The causes of large inrush current

A typical power supply (see figure 1) has lumped equivalent impedance **R1** from the common mode choke, bridge rectifier, line cord, and wiring. This is typically a few ohms.

C1 is used for EMI filtering and is usually around 0.1uF. It does not hold enough energy to present much of an inrush current problem.

C2 is the bulk storage capacitor, which can be many hundreds of microfarads. It is usually sized to meet a minimum hold up time and ripple current rating.

This figure shows that if the switch is closed near the top of the ac cycle, a large input current can occur, limited only by R1.

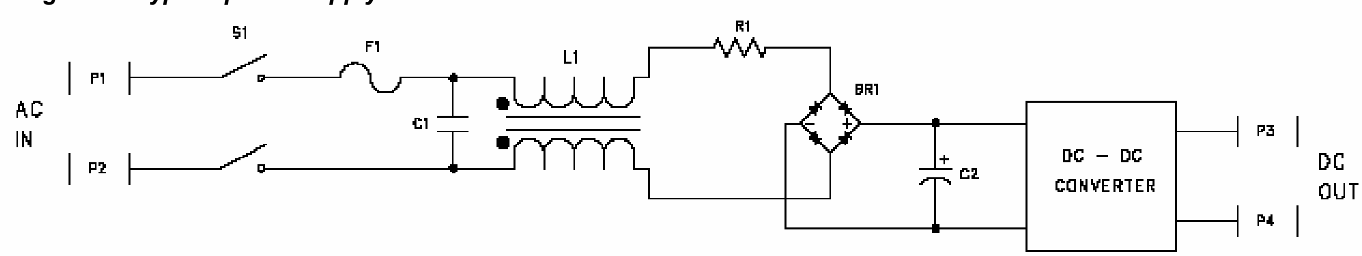
If the switch is closed at the top of the input line cycle, it is quite possible to get an inrush current spike of 50 A or more on a nominal 120 Vac line (170 V peak). In countries where the nominal line voltage is 240 Vac, the inrush current can exceed 100 A.

This large inrush current degrades the performance and lifetime of the power supply in a number of ways.

- The sparking of the switch contacts leads to premature switch failure. It can also cause the line circuit breaker to trip, especially if there are multiple power supplies on the same circuit.
- The current can thermally over-stress the input rectifiers, causing immediate power supply failure.
- High currents on the fuse cause heating, which can slowly degrade the fuse over time.

Power supply manufacturers use one of several inrush current limiting techniques to avoid these problems. The method used can tell the power supply buyer a great deal about the quality and reliability of the supply.

Figure 1 – typical power supply



Methods used to limit inrush current

- **Resistor in series with line**

For very small power supplies – a few watts at most – adding a resistor in series with the line is a simple and practical solution to limit the inrush current. The large resistance required to limit peak inrush current causes too great a loss in efficiency to be used in higher wattage power supplies.

- **NTC Resistor in series with line**

Many power supply manufacturers use a negative temperature coefficient (NTC) resistor in series with the line. An NTC resistor offers tens of ohms of resistance when cool, dropping to less than one ohm as its temperature increases. If the power supply is cool when turned on, the NTC provides good inrush current limiting. Its effect on efficiency is reduced as the power supply warms up.

However, this approach is not effective over large temperature extremes. A power supply used outdoors in the northern winter may never warm up enough for the NTC resistance to drop. Conversely, a supply in the hot summer sun will be very warm even with the power off, so that the warm NTC resistor will fail to provide adequate inrush current protection on startup.

An NTC resistor can also be problematic when a user turns the system off and then immediately switches it back on again. The capacitor voltage may drop, but the NTC resistor will not cool quickly enough to provide inrush current protection.

- **Electronic switch in parallel with resistor or NTC**

Placing a relay or electronic switch in parallel with either a resistor or NTC can offer high impedance only at startup. The supply manufacturer must ensure that the switch is turned on even at low line conditions so that the resistor does not burn up during brown-outs.

- **New: electronic switch in series with C2**

All three of the above techniques require a resistor with at least a 5 W power rating in order to charge C2 in a reasonable time without failing.

For example, a 25 Ohm resistor would be needed to limit the current to 15 amps peak at a high universal line of 265 Vac (375 V peak). The instantaneous power in this resistor would be over 5 kW.

A larger value resistor would have less peak power but would take longer to charge C2, resulting in the same dissipated energy. These high-wattage resistors are large and expensive, adding bulk and cost to the power module.

A new patent-pending technique from BEAR Power Supplies for inrush current limiting consists of an electronic switch in series with C2.

A control circuit uses zero-crossing techniques to monitor the AC line and turn on the power supply only when the input line is low. C2 will then charge in a quarter cycle, limited by the rise in voltage of the ac line.

This technique effectively limits the inrush current to about 8 A. It does not require high-wattage resistors and therefore results in smaller power modules. It is effective over a wide operating temperature (-40 to +70° C) since it does not employ an NTC resistor.

This new technique is most effective in supplies less than 500 Watts. At higher power, charging C2 in a quarter cycle still results in a fairly large inrush current. For these larger supplies, a switch in parallel with a resistor is recommended.

What to look for when purchasing a supply

Higher inrush current specifications equate to greater stress on the rectifier and lower reliability.

When looking at inrush current specs, consider the following:

- Is the inrush current rated as average or peak? Many companies specify the half-cycle average inrush current. The peak current is 40% larger.
- Is inrush current specified only at 120 Vac or 240 Vac? You must consider the inrush current over the real line voltage, which can be as high as 265 Vac in universal supplies.
- Is the inrush current limiting technique effective over your entire expected operating temperature range? This can be problematic when using an NTC resistor for inrush current limiting.

By understanding inrush current limiting techniques and their suitability for commercial, medical or industrial applications, you can improve the reliability and lifetime of your systems.

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[i] http://www.maintenanceworld.com/Articles/ibrahim/ process-monitoring-maintenance.htm