The Locomotive

Protecting Digital Control Equipment from Electrical Transient Damage

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[Editor’s Note: Since this article first appeared (The Locomotive Spring 1996), business and industry has become more dependent than ever on sophisticated electronics. This revised version is intended to help you improve the installation and protection of electronic control devices so they perform properly and are less likely to be damaged by electrical power problems.]

Expect New Exposures
Modern electronic control devices are frequently the most cost effective way to achieve real improvement in the performance of production machines and processes. New controls can add capability which was simply not available when equipment was originally designed or installed. Moreover, devices such as Computer Numerical Controls (CNC), Programmable Logic Controllers (PLC), as well as the various programmable motion controllers currently available for robotics applications offer unprecedented functionality and power, and are available at prices which deliver an attractive return on investment.

Unfortunately, many owners who make the decision to retrofit these control devices do not achieve the full benefit of the upgrade. One area in which this occurs is in the reliability of the machine or process when subjected to a real world electrical environment, complete with electrical transients which exist on virtually all wiring systems. If your electronics are not properly installed and protected from electrical transients, one or more of the following may occur:

- **Physical damage** to the electronics.
- **Processor resets**, leading to program interruption and/or (in the case of CNC devices) loss of machine position register information. This can lead to costly tool crashes.
- **Loss or corruption** of program or data.

What is a Transient?
There are several electrical transient phenomena which can threaten the smooth operation of computer based controls. These include:

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− Sag: decrease in line voltage lasting 1-30 cycles.
− Undervoltage or Brownout: sag of duration >30 cycles.
− Surge: increase in line voltage lasting 1-30 cycles.
− Overvoltage: surge of duration >30 cycles.
− Impulse: high frequency sub-cycle (less than 1 cycle) event having a steep rising or falling departure from the AC sine waveform. Also referred to as a spike.
− Outage: zero line voltage for at least 1 cycle.

While protection against electrical transients is usually built into control electronics, mistakes in installation can compromise the effectiveness of that protection. The purpose of this article is to point out some of the more common of these mistakes, and ways to avoid them.

Isolation and Grounding —The First Lines of Defense
We will discuss three topics in order. The last of these will be suppression. While suppression (or surge suppression) is frequently the first solution to be suggested, its benefit will be maximized only if isolation and grounding are properly done first.

It is assumed for the purposes of this discussion that the electrical portion of your installation complies with applicable electrical codes, including the National Electrical Code (National Fire Protection Association, NFPA – 70). If there is any doubt, your electrician should be able to make this determination for you.

Isolation
Isolation means keeping certain things separated. In the case of electrical and electronic devices, this is done to eliminate the imposition of electrical transients to the maximum extent possible. If transients can be eliminated by isolation, they will not need to be suppressed. Isolation measures include the following.

Conductors which carry higher voltages can adversely affect those carrying lower voltages which are in proximity, by electromagnetic coupling. These conductors should be separated physically and electrically to the greatest extent possible. The rules are:

− Don't run DC with AC.
− Run your wiring in grounded metallic conduit for maximum shielding effect.
− Don't run low level signals with AC or DC control and power wiring. It makes no difference that the signal wires are shielded, DON'T DO IT.
− If signal wires must cross AC or DC power wiring, cross at right angles to minimize electromagnetic coupling.
− Shield drain wires from shielded conductors should be connected to chassis ground at one end only.

Run Category I conductors with power conductors of up to 600 volts AC, observing requirements of local codes. Be sure to observe the requirements of Article 300 – 3 of the National Electrical Code which specifies that all conductors in the raceway be insulated to withstand the highest voltage present in the raceway.

Category II conductors must be properly shielded as appropriate, and routed in a separate raceway. If these conductors must cross power feed lines, they must do so at right angles. These conductors must be routed at least 1 foot from 120 VAC lines, 2 feet from 240 VAC lines, and 3 feet from 480 VAC lines. They must also be routed at least 3 feet from motors, generators, transformers, rectifiers, arc welders, induction furnaces, or microwave sources.

Category III conductors are to be routed external to all raceways, or in a separate raceway from any category II or III conductor.
Power Lines and Transformers

Power lines should be assumed to have transient voltages on them. In wiring an AC line to your electronics, employ devices which will isolate those electronics from the AC power line. Generally this will be a transformer. A transformer should be provided in the AC power connection to your electronics, even if no reduction in voltage is needed. It will be best if the transformer selected is an isolation transformer, designed especially to provide maximum isolation. If your installation is subject to severe voltage transients from the AC power line, (from variable speed motor drives, for example, or servo/spindle motor drive amplifiers), the double isolation technique illustrated here is strongly recommended.

Grounding

Proper grounding of electronics cannot be overemphasized. The manufacturer of the control electronics which you choose should include with the product complete installation instructions which include details for proper grounding. In general, a chassis ground terminal will be provided on the equipment which must be connected to ground. This is often found to be connected to the AC neutral wire. The problem is that, although the AC neutral is grounded, it is a part of the power circuit and can be subject to the same transients that are sought to be eliminated. As a general rule, grounds should be separately connected to a single grounding electrode driven into the earth as close as possible to the equipment. Again, this is a general rule, and the manufacturer’s instructions are to be followed in compliance with local codes.

Electronics should not be located in close proximity to power distribution conductors or devices. Make sure that the installation provides physical separation from high voltage wires and devices as recommended by the manufacturer.

Electronics should be located inside an enclosure made of a conducting material, and the enclosure should be grounded to provide the greatest degree of protection against radiated noise.
**Suppression**

In a shop environment, it should be assumed that there will be electrical transients and/or noise on the electrical distribution system and that they may be severe enough to affect electronics. Frequently, these are a result of the normal operation of motors which drive spindles and carriages associated with your tools. Low cost equipment is available which is very effective in reducing its severity. It is suggested that a tiered approach be employed in the electrical system as follows:

- **Suppress transients at the electrical service entry:** Have your electrician install surge suppression at the service entrance. The best place to intercept incoming power surges is at the building wall. This single device will provide primary protection to every susceptible device in your building. Remember, however, that many problems with transients originate within your own building, and for that reason it is wise to apply a second stage of suppression to every electrical panel that supplies AC to digital control equipment.

- **Suppress at the individual machine as well:** Place a surge suppressor in the AC connection to your new electronic controls. Install it according to the instructions provided by its manufacturer. Make sure that a proper ground is available for every such suppressor or else its function will be compromised or defeated.

- **Suppression at every other connection to your electronics:** This is frequently neglected in otherwise well protected installations. Remember that any wire which connects to your electronics can carry a destructive voltage surge. This includes any of the following: network connections of any kind; telephone modem connections; remote instrumentation lines.

**Remote Input/Output Lines**

Specially designed surge suppression devices are available to protect each type of connection.

**A Word about Sag and Brownout**

Remember that loss of power is a voltage transient. While it is not destructive in most cases by itself, it can have disastrous consequences for some electronic controls.

When a momentary reduction in AC line voltage occurs, the DC voltages upon which the microprocessor depends may fall to the point where data errors or a reset of the microprocessor can occur. In such a case, program or data memory will be lost or corrupted, including position data from connected motion axes. This can lead to a stoppage at best, and a tool crash or other dangerous events at worst.

Protection against voltage sag or brownout takes at least two forms:

- Make sure that your electrical supply is adequate. Have you added load which your distribution system cannot supply without unacceptable voltage reductions? This will require investigation by your electrician or power supplier. If inadequate supply is the problem, it must be corrected by adding capacity.

- Provide a power conditioner or uninterruptible power supply (UPS) designed to correct for momentary low voltage.
About the Author

Robert F. Weir, P.E., Director, Engineering, joined The Hartford Steam Boiler Inspection and Insurance Company in the Engineering Department in 1993. A graduate of the United States Naval Academy, he also holds an M.S. degree in Mechanical Engineering from Worcester Polytechnic Institute and is a graduate of Suffolk University Law School. He has more than 25 years of experience in utility and industrial plant and equipment, including an extensive background in steam boilers, turbines and industrial automation. In addition to his engineering credentials, he is admitted to the Bars of the Massachusetts Supreme Judicial Court, Federal Courts, including the U.S. Supreme Court. He is also a registered patent attorney.