Grounding Practices for Automation Controls

ALAN REBECK
RO Associates
10701 Airport Drive
Hayden, ID 83835

Introduction

Whether lightning damage or lightning voltages induced between equipment cabinets as a result of multi-grounding causing mis-operation of computerized electronics, improper grounding can account for up to 40 percent of power-related problems including costly damage and downtime. In addition, transient overvoltages—a high voltage spike or impulse of very short duration—can account for another 40 percent if not adequately suppressed. Transient overvoltages can be produced by lightning, power companies switching feeders or capacitor banks, or load switching at customer facilities. These large voltages, lasting only a short period of time, are injected into power and data circuits causing equipment destruction and safety hazards.

Problems like these can be avoided by implementing a single-point grounding system, while following the National Electrical Code (NEC) when installing the safety ground and grounding electrode systems, and the use of a properly designed and selected surge suppressor.

Single-point grounding

The worst thing you could do for your equipment, as well as your safety, is to reference each equipment cabinet at your facility to the earth at different points. Because the earth is a very poor conductor, steady state and momentary voltage differences exist in the ground. If equipment cabinets have high-speed communication interfaces between them, and each one connects to the ground at different points, these voltage differences can cause equipment downtime, as well as pose a safety threat. Therefore, a single-point grounding system, where all references to the ground come to a single point in the facility before referencing the earth, is essential to any microprocessor-based installation.

In DC power operations this is done by using a master ground bar, such as a large piece of copper. In most AC installations, however, it's normally a question of referencing back to the original Neutral-Ground bond in the building or the secondary Neutral-Ground bond of an associated step-down or isolation transformer.

Whether it is an isolated ground, a neutral conductor, or a safety ground connected to an equipment cabinet—they all come to a single-point at the main distribution panel and then connect to the earth grounding system associated with the structure.

Lightning protection system ground

Both the NEC (NFPA 70) and the National Lightning Protection Code (NFPA 780) require a separate physical lightning protection (air terminal) earth ground electrode that must then be bonded to the main entrance grounding electrode system. The purpose of this is to direct the majority of current from a lightning discharge to a structure into the earth away from the building entrance grounding system, significantly reducing the lightning current into the building electrical grounding system. The required bonding of the two grounded systems maintains a reasonable degree of touch safety between the two grounding electrode systems during the lightning event.

Isolated ground

In addition to installing a single-point grounding system, the NEC allows an isolated ground— a term often misunderstood.

The computer industry has recognized for decades that metal conduit, which is allowed as a safety ground system for equipment cabinets by the NEC, often exhibits a great deal of electrical noise due to neutral-ground wire reversals, refrigeration and chilled water pump systems, etc. in buildings.

All sensitive electronic equipment utilize the safety grounding conductor as a logical reference as well as a means to trip circuit breakers during fault conditions. The isolated ground technique was developed and approved in the code a number of years ago as a means of establishing a "quiet ground" connection. Simply speaking, it means a sufficiently sized, insulated conductor, isolated from conduit and sub-panel enclosures (that touch conduit) and referencing the earth only at the building entrance Neutral-Ground bond or the secondary Neutral-Ground bond of a step-down or isolation transformer that is part of the associated electrical distribution for the equipment.

Grounding techniques

The NEC allows a single-point grounding system to be connected to the earth in seven different ways:

Rod and pipe electrodes. About 90 percent of all grounding electrode system installations are rod and pipe electrodes. Generally, this is comprised of an 8 to 10 foot stake driven into the earth that extends up and connects to the Neutral conductor in the main power distribution center. One of the problems associated with this type of system is that many facilities drive additional ground rods to clear up problems. The NEC requires that all earth ground references be directly bonded to the original Neutral-Ground bond at the building entrance. This is because if a person is touching one cabinet connected to an independent earth ground rod and something else connected to the main building ground system, those large voltage differences that can exist in the earth can harm that individual (especially during lightning events or fault conditions). Remember, the main reason for connecting an electrical distribution system to the earth is for touch safety.

In addition, driving extra rods (multiple grounding) can also cause equipment downtime because they can create ground loop currents circulating throughout the equipment cabinets between the different grounds. Instead, the ground should be cleaned up within the structure to a single point coming from each cabinet back to the main building ground point or the nearest Neutral-Ground bond at the secondary of an associated transformer. A common mistake is electricians wiring up additional connections to the earth with many amps of current running through equipment cabinets. Changes in this objectionable current create voltage spikes or transient overvoltages in the cabinets—any time you have a changing current in a wire you have spiking. It is legal to add another ground rod at a specific minimum distance and connect it to the original building entrance ground rod. It is illegal, however, to ground equipment cabinets out to separate earth grounding systems.

Ring ground. This system is comprised of a minimum #2 AWG, bare wire buried no less than 30-in. under the soil surrounding the building. The ring ground gives more of an equal-potential ground around the facility. It's almost always supplemented with earth ground rods. The problem with a ring ground is that many installers connect different equipment cabinets to different points around that ring. Large lightning voltages can exist in that wire due to the inductance in the wire, no matter how large that wire is. This leads to large voltage differences between the cabinets connected to different points on the ring. Instead, it should have one point coming up to a single point in the facility that all equipment cabinets are connected to.

Other legal grounding electrode systems include:

- *Concrete-encased electrode*— metal bars encased in concrete, buried in the earth
- *Grounded metal building frame*
- *Plate electrodes*—metal plates buried in the earth for a larger surface area
- *Supplemented metal underground water pipe*—although the code doesn't allow the use of an underground waterpipe by itself anymore, this can be used as a secondary or third connection to the earth
- *Underground local metal structures* (ex: gas piping).

Halo ground

A common mistake many facilities make is using a halo ground as a safety ground system. A ring of bare or insulated conductor is run around the ceiling of a shelter or equipment room and connected down in more than one location to a ring ground buried beneath the earth. Once again, if you connect the different equipment cabinets to different points around this halo ground they can be subjected to some of the same lightning equalization currents and voltage differences that can blow out communication interfaces between the cabinets. So, although a halo ground may be construed as a legal connection to the earth, it should only be used as a shield to block fields from getting into equipment cabinets such as radio frequency and lightning fields. If you chose to use this method, remember that you still need a master ground bar or common Neutral-Ground bond for all the equipment to connect to, only referencing the ring ground at one point.

Shield grounding

The other way equipment sustains disruption is through shields that are multi-grounded. Shields are typically constructed of aluminum-metal foil or mesh that wraps around twisted insulated wires—typically small 22-gauge in size—to block AC and high frequency fields. Low frequency power distributions that run in parallel can add noise or hum into low amplitude signal circuits, and high frequency fields can alter data if there are transmitters in the area. If the shield is grounded at more than one end, then unfortunately an equalizing AC current can exist on the shield because differing AC potentials in the soil, causing unwanted noise to be introduced into the signal circuit.