Why you care: mixed cabinet electronics and power

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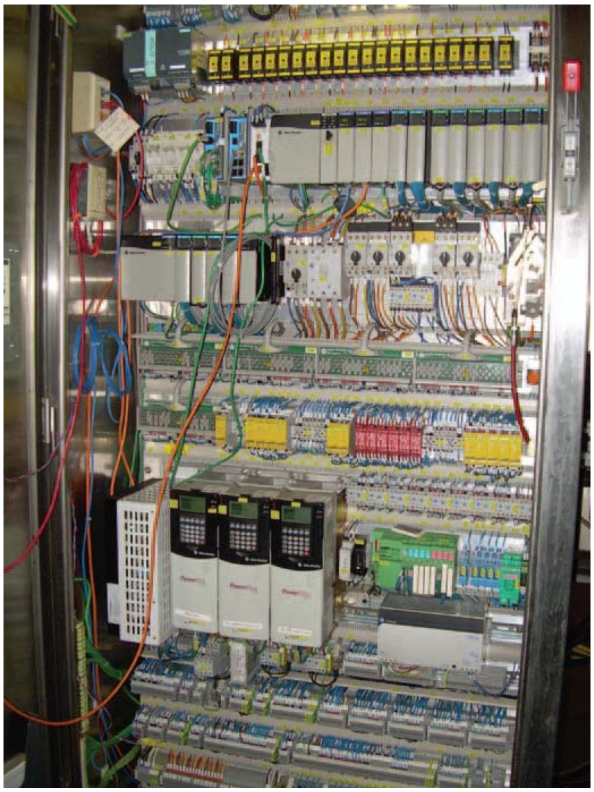

This automation cabinet contains power, control, and communication wiring. A 480-volt disconnect handle is at the upper right of the cabinet. PLCs near the top of the cabinet use 24-volt inputs and outputs to control a conveyor system while 480-volt VFDs near the cabinet bottom drive the conveyor motors.

Mixing higher voltage 480- volt three-phase cables in the same cabinet as lower voltage 24- or 120-volt control wiring and communication cabling can result in erratic operation or even complete failure of electronic equipment inside the cabinet. Knowing what is inside the cabinet before you open it, the specific wiring issues to look for once inside, what values to measure, and simple ways to correct problems can help alleviate many erratic and sometimes “mysterious” control and communication issues on the plant floor.

Cabinets on the plant floor are often designed as a central control point for automation and process control equipment. Inside the cabinet are the electronic programmable controllers (PLCs), variable frequency drives (VFDs), and their associated communication and control wiring.

Since the equipment being controlled in the facility is typically 480 volts, the 480-volt three-phase power must often be routed through the same cabinet as the electronic controls—an advantage for both troubleshooting and maintenance. You can use the same cabinet to observe the indicator lights on a programmable controller, measure three-phase voltage on a motor starter, or adjust the drive.

Safety first

Safety is always the first concern before opening a cabinet. As a technician or engineer begins work on electronic controls it is natural to maintain a narrow focus on the suspect low voltage equipment and controls and easily forget that work inside of a mixed voltage cabinet exposes workers to dangerous voltages and short-circuit currents. Before opening the cabinet door: **Know the voltage levels present.**

Industrial control panels are required to have durable and legible labels stating the rated voltage, number of phases, and the frequency of all supplies found in the cabinet. Older panels may not be marked. Many panels now have an arc-flash warning label on the panel door. Be aware that an arc-flash label usually provides the maximum voltage in the cabinet and does not address all supply voltages. In addition to any label, refer to electrical diagrams and vendor manuals, and even walk down systems if necessary to help determine voltage supplies to the cabinet.

It is generally best to stand to the side of the cabinet, if possible, to operate disconnects, release latches, and open doors—just in case something goes wrong. Once the cabinet door is open, make a visual inspection for any obvious abnormalities or the smell of burnt insulation. Refer to the appropriate wiring and control circuit diagrams to identify components and terminal strips.

Minimizing electromagnetic interference

As a part of the visual inspection notice how wiring enters the cabinet. 480-volt power conductors and low

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voltage control wiring will generally be brought in through separate conduits.

Running such conductors in separate conduits in the field helps to minimize the possibility of electromagnetic interference. If power conductors are too close to control wiring and electronic components, whether in the field or in the cabinet, you can expect erratic operation of equipment. (See “How power cables cause problems in mixed cabinets” for more information.)

How power cables cause problems in mixed cabinets

As current flows through a conductor a magnetic field is produced in a circular path around the conductor. As the alternating current flow reverses direction the original magnetic field will collapse and a magnetic field will build in the opposite direction around the power conductor. This entire process will occur 60 times every second in 60 hertz alternating current circuits.

If another conductor is within the effects of this changing magnetic field, the three requirements for electromagnetic induction will have been met:

- An electromagnetic field is present (created by current flow in the power conductor).
- A conductor is present within the magnetic field (low voltage control wiring).
- Relative motion occurs between the conductor and the magnetic field. (The magnetic field is constantly building, collapsing, and reversing direction.)

As a result, voltage is created or “induced” into the control wiring—hence the term electromagnetic induction. The abnormal voltage and current flow created in the control wiring is referred to as electromagnetic interference, or EMI. The EMI can produce enough voltage for a PLC or VFD to “see” a false signal. Or, the voltage on the control wiring can be distorted by the EMI and electronic equipment supplied by the control wiring will not operate properly.

To reduce the effects of electromagnetic interference, power conductors should not be in close proximity to control and communication wiring. There is no standard distance definition for “close proximity.” You must use reasonable judgment. Keep power and control conductors in separate wiring trays inside the cabinet. If for some reason it is necessary for power conductors and control wires to cross over each other, ensure that they cross at a ninety-degree angle to reduce the effects of electromagnetic interference.

Separation of power and control circuitry

Part of the visual inspection must ensure adequate separation of power and control circuitry.

To help differentiate between control and power circuits, notice the conductor sizes and color-coding schemes in use. Control circuit wiring is typically 16 AWG or 18 AWG. Power conductors will generally be no smaller than 12 AWG and are often considerably larger. Grounded conductors are white, gray, or have three continuous white stripes on any color insulation except green, blue, or orange. Control circuit wires that are white with a blue stripe are the grounded conductor for a dc control circuit. Any control wire that is orange, or white with an orange stripe, is an ungrounded conductor that remains energized after the main supply disconnect is switched to off. Additionally, red insulation indicates an ungrounded conductor in an ac control circuit and blue insulation indicates the ungrounded conductor in dc control circuits. Conductors that enter the cabinet as part of a multi-conductor cable can have different color schemes. Refer to wiring diagrams as needed.

The ungrounded three-phase power conductors entering the cabinet have no color-coding restrictions. Typically, brown, orange, and yellow are used for 480-volt phases A, B, and C, respectively. Black, red, and blue are used for 208-volt or 240-volt phases A, B, and C, respectively.

In summary, when it comes to identifying and separating wires: Use caution, know what color-coding schemes are used inside your cabinet, and if in doubt, measure with a digital multimeter to verify voltage levels at various terminals.

Low voltage instrumentation wiring

Usually either a “twisted pair” of conductors or a “shielded cable” helps minimize the effects of electromagnetic interference in low voltage instrumentation wiring. In a twisted pair, one conductor twists around another with the number of twists per inch specified. A shielded cable is a twisted pair cable with a braided or foil covering running the entire length of the conductors; it also has a thermoplastic jacket for physical protection.

Twisted pair wires help minimize the effects of induction and should remain twisted until their termination. The braid or foil covering over a twisted pair helps prevent voltages from being induced into the control wire. This braid or foil must be connected to ground at only one end. A drain wire runs the length of the shielded cable just underneath the foil so it is the contact for the entire length of the cable. The drain wire, if present, is terminated to ground. The drain wire “drains off” to ground any stray voltages induced into the cable.

If a control circuit is grounded at more than just one point, control issues are almost sure to occur. For example, if the drain wire is connected to earth at each end of the cable, or if the cable jacket is accidentally scraped off at some point and the foil contacts grounded metal, a "ground loop" will result. Unwanted current will now flow through the drain wire and foil between the two points that are grounded (the ground loop) due to the difference in potential between the separated grounds. When inspecting cabinets make sure that any insulation placed over the ungrounded end of shielded cables is in place and that the drain wire or any foil is not accidentally contacting metal in the cabinet.

Taking voltage measurements

Once you correct any abnormalities found during the visual inspection, take voltage measurements to ensure there is no electromagnetic interference from power conductors. Use a properly rated digital multimeter to measure and record voltage levels. Input voltage to electronic equipment such as PLCs and VFDs is generally specified as plus or minus 10 % of the rated voltage. Measure voltage to each input and output field device. Be especially wary if any significant voltage is present where it should be absent. This may be an indication of induction from power conductors, creating low control circuit voltages. Quite often the source of this problem is in the field routing of conductors and can require considerable troubleshooting to locate the problem. Since the voltage induced into the control circuit wiring will vary as the current flow varies through the power conductor, control circuit voltage necessary to use a recording digital multimeter, such as the Fluke 289 True-rms Industrial Logging Multimeter, to identify these variances.

Fluke 289 True-rms Industrial Logging Multimeter.

Tightness of control wiring terminations

Check for tightness of control wiring terminations. Any effects of electromagnetic induction that the controls may normally have been able to handle will be exacerbated at a loose termination point and electronic inputs can be affected. Occasionally wires come loose from their pressure connector, usually due to improper installation. Check each individual wire at its termination point to ensure it is secure in its connector or under its terminal screw. Tighten all terminal screws.

Proper inspection and maintenance of power and control wiring minimizes electronically controlled equipment performance issues. Loose control wiring and terminal screws, improper grounding techniques, and routing of power and electronic conductors too close together are among some of the most common, yet hard to find, causes of improper equipment operation. Knowing what is in your cabinets, making proper inspections, and interpreting control voltage readings will help many of those mysterious equipment problems disappear.

Inspection checklist for cabinets containing both control and power circuits

1. Determine voltage levels inside cabinet before opening enclosure door.
2. Follow all electrical safe work practices including proper use of PPE and establishment of approach boundaries.
3. Stand to side if possible when opening cabinet door.
4. Perform visual inspection of wiring and components for any obvious abnormalities.
5. Observe color-coding schemes and differentiate between control and power conductors.
6. Verify adequate separation of power and control conductors.
7. Verify any power and control wiring crosses each other does so at ninety degrees angle.
8. Measure voltage levels to power supplies of electronic equipment and verify within manufacturers' ratings.
9. Measure voltage of field input and output devices and verify within specification.
10. Check integrity of all control terminations and tighten terminal screws.

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