

EATON

New Technology for Control Panel Design

Developments in connection technology continue to simplify the design and wiring that go into industrial control panels.

By Richard Chung

Ever since the first control panels were installed on the floor of industrial plants, there have been attempts to reduce the amount of wiring and effort that goes into connecting industrial processes and machines to their controls. Decades ago, programmable logic controllers (PLCs) began replacing the numerous control relays, and their associated wiring, used to sequence machine operations. Then industrial networks distributing the input/output (I/O) modules closer to the process inputs and actuators emerged to eliminate the need for lengthy runs of discrete wires between the PLC controller and distributed I/O modules.

These undertakings continue today. Advances in technology now permit use of rapid connection techniques such as insulation displacement connectors. Communication bus technology has evolved over the years to include specialized protocols and formats that are optimized for roles in industrial sensing and control. More recently, industrial bus technology has evolved to a point where it can take over some kinds of discrete cabinet wiring in an economical way. Specifically, it is now quicker to run bus lines to individual control panel components such as indicators, displays, and switches than to make their connections with discrete point-to-point wiring.

The Design of Control Panels

A control panel is the central nervous system of modern industrial processes and production lines. As such, it may be useful to review how the contents of the panel typically get defined. The control panel is one of the entities specified after engineers have determined the sensors, actuators, and controls that the given process or production line at hand will require. The process of defining controls generally includes determining the physical location and capacity of remote I/O; the necessary specifications for the sensors involved; and operating characteristics of motor starters, contactors, and drives powering the actuators.

With this information in hand, panel designers can begin estimating the footprint required by the controls running the process. In laying out a panel, designers must plan not only for the existing controls and other panel components but also must allow for changes in the production line or process that could result in the addition of more control points later on, or the removal of some I/O if parts of the line become inactive due to changes in the product lineup.

Panel design also involves connection styles that often depend on industry preferences. Some industries, for example, demand ring lugs on specific kinds of controls. However, screw-type connections are the most widely used connection style today. Estimates are that 15% to 18% of control cabinets use spring-cage-type terminations that eliminate the need for screw connections. Insulation displacement connections also account for about 5% of the terminations within control cabinets. Both spring-cage and insulation displacement connections are more resistant to loosening caused by vibration and are more widely adopted by industry since most OEM panels are subject to vibration during transportation to the end customer.

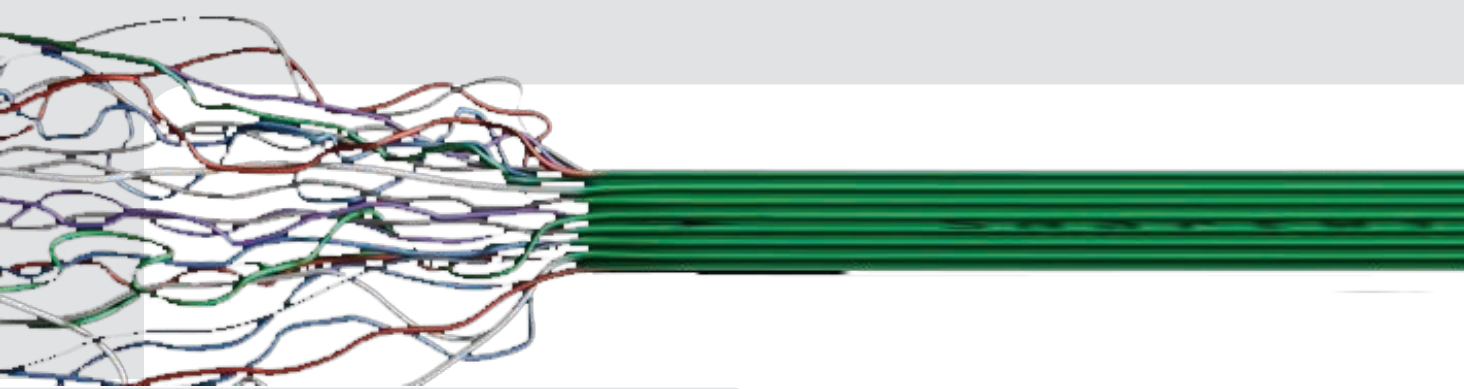
Panel designers size the cabinet based on the components' footprint, space for wiring ducts, heat dissipation needs, and space for future



Instead of using traditional point-to-point wiring connections in control panels, a new panel wiring solution from Eaton replaces the myriad of wires with a single cable that connects motor control components to manufacturers' PLCs. This solution reduces time required for wiring, testing, and commissioning by up to 85%.

expansion. Cabinet materials can vary depending on factors that include the UL enclosure type rating, whether the cabinet must be stainless steel of a specific gauge, special panel finishing, and so forth. Similarly, the cost of the cabinet itself depends on these factors as well as use of a particular style of door, latching method, and other factors related to cabinet hardware and mounting.

Panel designers also lay out components with regard to such practices as spelled out in NFPA 79 and UL 508A standards for industrial machinery panels in the United States and defined in IEC standards such as IEC 60204 safety standard for European industrial equipment. These documents dictate factors such as color coding of ground and bond wires, factors for E-stop selection, minimum clearance between conductors operating at specified voltages, connections for main disconnect



The Eaton panel wiring solution is engineered to reduce panel wiring complexity and assembly labor time, speed the start-up commissioning processes, and provide extensive run-time diagnostics.

switches with door-mounted rotary handles, and numerous other practicalities associated with components mounted in panels.

It is important to note that UL 508A applies only to what are called industrial machinery panels. These are found in such areas as metalworking machine tools, injection molding machinery, woodworking machinery, assembly machines, and material handling machines. UL 508A does not apply in panels for applications not classified as industrial machines. These include pumps, HVAC, fans, wastewater treatment, portable machines, and supervisory control and data acquisition (SCADA) panels for oil and gas plants.

There are also standard practices for control panels that are not spelled out in standards. For example, panels that contain operator controls and displays are generally mounted at the eye level of the operator. Where several panels mount in a row, panel doors are typically all configured to open in the same direction.

Where a panel mounts near a room entrance/exit, its door is typically configured so it does not block the exit in an emergency (such as an arc flash).

These standards effectively ensure that, among other things, panels have internal dimensions big enough to guarantee safe operation given the number of conductors they handle and power levels they control. However, the practicalities of industrial plants are often such that floor space available for control panels comes at a premium. So designers are generally pressured to minimize the panel footprint while simultaneously meeting safety requirements and ensuring that any rewiring associated with future control changes can take place with minimum effort. Space becomes a premium for floor-mounted control cabinets as well as control panels that have to be mounted on OEM machines.

Control panels typically undergo a detailed panel checkout procedure once they are fabricated. This generally includes basic tests such as a power-up and verification of the short-circuit current rating (SCCR) of the panel, a hot verification of all PLC output points as well as continuity checks and ground-fault checks of all high-voltage circuits. Technicians normally check torque on terminal blocks and verify nameplates and wire tags. It is also common practice to check circuit functions by running I/O simulations and exercising the operator interface.

A Need to Simplify

The need to rapidly commission a control panel and simplify any ensuing panel changes poses a conundrum for today's panel designers. Despite advances over the years that have reduced the amount of discrete wiring associated with each I/O point, space



constraints result in panels having wiring ducts that are full to overflowing.

The panel testing that takes place as part of commissioning can be as simple as ringing out each wire with a continuity test, in the case of one-of-a-kind type cabinets. Panel builders making multiple identical units often devise test fixtures and simulation programs that can put panels through their paces.

But it goes without saying that this sort of wiring verification and checkout can be time-consuming. This is particularly true of industrial panels that serve automated processes incorporating dozens of sensors and actuators. Standard practice dictates that each wire be tagged, checked for continuity, and verified against schematics. This is a laborious task for technicians during the commissioning of lines and retrofits.

Better Productivity

Several techniques have emerged that both simplify panel wiring tasks and reduce the time needed to make alterations in the field. These schemes can also incorporate jumper bars for power connections between modules that eliminate the need to provide discrete power connections to panel components.

A point to keep in mind is that connections to conventional rail blocks use discrete wires and still must be made one at a time. Technicians must strip each wire for connection, and connections are made via a screw-down or a spring-loaded clamp.

In recent decades, fieldbus networks have increasingly reduced wiring loads run between controls and far-flung resources such as sensors and actuators. In particular, industrial versions of Ethernet are now widely used in factories and plants. This is partly due to the development of hardened versions of both the Ethernet hardware layer—including connectors,

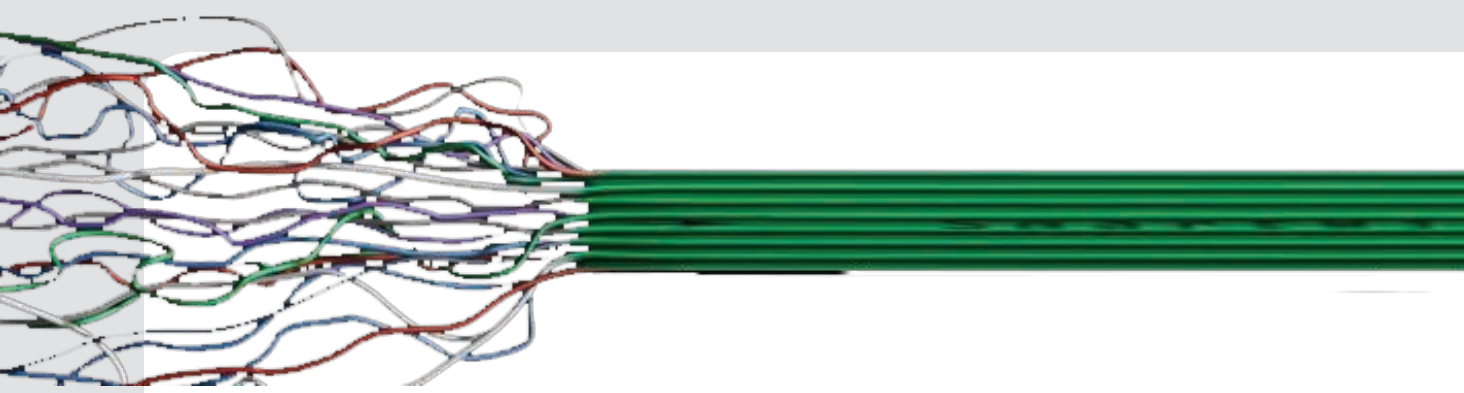
cables, and switches—and the software layer. Though Ethernet started out as a relatively slow protocol running over an unshielded twisted pair of wires, it now can handle speeds of up to 1,000 Mb/sec over long distances.

Ethernet, though, has come to refer to a collection of standards. There is no single Ethernet standard covering industrial automation. The situation is often explained using the Open Systems Interconnection (OSI) stack, wherein Ethernet forms the bottom two layers—physical and data link. Most industrial versions of Ethernet use software handling the upper layers as well as media access control hardware modifications that enable real-time performance. In that regard, EtherNet/IP™, PROFINET, EtherCAT®, POWERLINK, and others are based on the original 802.3 standard. There are several groups that handle standards for a particular protocol including the Open DeviceNet Vendors Association (ODVA) for EtherNet/IP.

Ethernet protocols for industrial uses are often categorized by their real-time performance: non-real-time, real-time, and hard real-time. Real-time types minimize cycle times and prioritize data packets through various software techniques. Hard real-time protocols, such as EtherCAT and PROFINET isochronous, use custom hardware and special switches to implement real-time response.

There is no special hardware or software needed to build an EtherNet/IP device. This lets other protocols such as Modbus® TCP that use standard unmodified Ethernet coexist in the same device. EtherNet/IP is basically an adaptation of the common industrial protocol (CIP) to the Transmission Control Protocol/Internet Protocol (TCP/IP) suite of standards for networking.

CIP is used by DeviceNet™ and ControlNet™ protocols. DeviceNet, ControlNet, and a few other



similar schemes are often called device-level protocols because they handle networking among factory-floor devices such as sensors and actuators for the purpose of data collection, peer-to-peer interlocking, real-time I/O, drive and motion control, and safety.

Other device-level protocols include the Process Field Bus Decentralized Peripherals (PROFIBUS DP) and Controller Area Network Open (CANopen®). Both are protocols used to operate sensors and actuators via a centralized controller in factory automation applications. PROFIBUS DP can use three different physical protocols: a serial RS-485 link with twisted-pair cables in a bus topology, optical transmission via fiber optics for distances up to 15 km, and Manchester Bus Powered (MBP) transmission. In the latter case, data and power feed through the same cable.

DeviceNet is perhaps the most widely used device-level protocol and is overseen by ODVA. Its networking principles are based on CANopen. In the OSI protocol stack, DeviceNet's layers one and two are from CAN. Layers three and four are specific to DeviceNet and are defined so that devices following the protocol connect to the network rather than directly to controllers, a fact that simplifies installation and maintenance issues. Layers five through seven use the CIP protocol. CIP networks use the same library of predefined functions, a fact that makes it easy for different vendors to have DeviceNet equipment that works with other brands.

The DeviceNet communication scheme includes features such as self-diagnosis of faults and a means of prioritizing messages. It defines master and slave devices that permit

network operations such as noting time-out errors when expected messages do not appear on schedule, or shutting down when devices added to the network have addresses duplicating that of a device already connected.

A point to note about DeviceNet and similar device-level buses, however, is that they were created to simplify wiring associated with sensors and actuators widely dispersed throughout production lines. Generally speaking, a variety of factors would make it impractical to use them as a means of reducing the wiring load inside the control cabinet itself. For example, even the smallest cables specified for DeviceNet runs tend to be too beefy for use in the cramped quarters inside cabinets. Devices on a DeviceNet also must be given a physical address, usually set with DIP switches, through a process that would be cumbersome if applied to the numerous controls and operator interface devices that make up a typical control cabinet.

Conclusion

Control panel and industrial connection technology continues to advance. In addition, there has been a movement among standards organizations to harmonize worldwide standards that apply to the deployment of industrial equipment, including control panels. No doubt there will be developments in this area that affect the increasingly distributed processing architectures that are used to reduce plant wiring and speed the process of commissioning and retrofitting controls. Innovative approaches like the SmartWire-DT™ system (see *The SmartWire-DT System: Reducing Complexity in Control Panels*) are reducing the effort involved in commissioning the next generation of machines and control panels. ■



Improving Productivity Through Innovative Panel Wiring Solutions

In Europe, the SmartWire-DT™ system has been available for several years. Companies such as Zwergenwiese Naturkost GmbH and mts Perforator GmbH, both in Germany, are among the firms that have implemented the system.

Zwergenwiese makes vegetarian sandwich spreads from certified organic ingredients. Its bottling process requires a constant supply of empty jars for continuous production. The company developed an automatic empty jar de-palletizer in which it used a SmartWire-DT connection and communication system to reduce the extensive mounting and wiring that would normally be required.

The SmartWire-DT system in the control cabinet connects motor starters, pushbutton actuators, and indicator lights. Specifically, Eaton XT combination motor controllers and M22 pilot devices were directly connected to the SmartWire-DT network; DS6 solid state controllers and M-Max Series variable frequency drives were integrated as part of the SmartWire-DT network using SmartWire-DT digital I/O modules and standard M22 potentiometers.

The starting point of the system is a SmartWire-DT gateway, which establishes the connection to the system's PLC fieldbus. Zwergenwiese incorporated the SmartWire-DT system on a CANopen® fieldbus controlled by an Eaton PLC with an Eaton XV Series operator interface.

In all, the company installed 10 floor-standing control cabinets to automate the production process, the de-palletizer stations, and the facility HVAC controls. Each of the two de-palletizer control cabinets contained more than 60 XT combination motor controllers. Zwergenwiese estimated that conventional wiring would have required 40% to 50% more cabinet space.

In another application, mts Perforator designed a new control console for its underground tunneling machines using the SmartWire-DT system and M22 pilot devices. Micro tunneling machine systems locate the control house on the surface with electrical umbilical cables running to the tunnel boring machine beneath the surface.

Use of the SmartWire-DT system reduces the frequency of faults such as loose connections and miswired terminations, thanks to the use of flat cable and the specialized connectors. Each SmartWire-DT enabled device includes a status LED that helps to reduce commissioning time and troubleshooting in the field. In addition, nodes on the SmartWire-DT network are automatically assigned addresses on the gateway—in the order that nodes are connected—with the push of a button.

The system also takes advantage of time monitoring and a watchdog timeout feature that references an

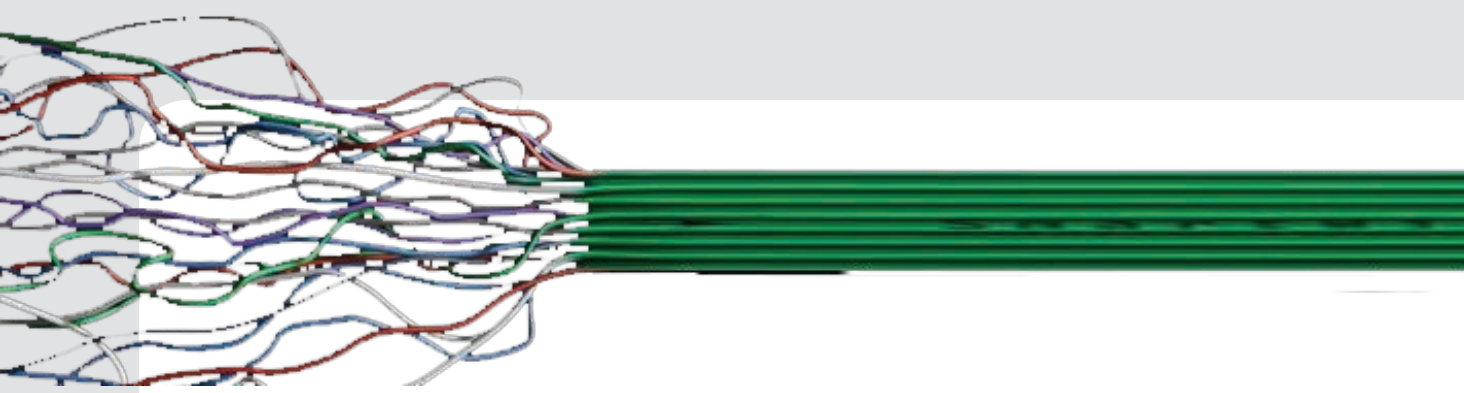


The SWD-Assist software supports users in the planning, engineering, and commissioning of a SmartWire-DT network.

established target configuration. This safeguards the integrity of the control scheme.

The SmartWire-DT system has a maximum network length of 2,000 feet, which can be extended to pushbutton control stations outside of the control cabinet, and can connect up to 99 nodes per gateway. The software program SWD-Assist enables the layout, planning, and system configuration of a SmartWire-DT network.

These features were among the reasons mts Perforator used the SmartWire-DT network in the tunneling control station. According to mts Perforator, the use of the SmartWire-DT system reduced engineering and wiring costs. More importantly, it helped protect against wiring changes, a key factor in the warranty of the tunneling machines. ■



The SmartWire-DT System: Reducing Complexity in Control Panels

The SmartWire-DT™ system is a line bus embedded control and wiring system that helps speed the deployment and design of OEM machine panels. It is the first system that is practical for turning discrete control panel components into network-addressable elements that can be polled, monitored, and controlled through a gateway controller.

One feature of the SmartWire-DT system is its quick connection technique: it uses crimp-on insulation displacement connectors working with eight-wire flat cable. The cable is connected inline between control panel elements and effectively buses them together. This method effectively eliminates the point-to-point wiring that would be otherwise needed.

Components can be directly connected to the system using a smart module and include selector switches, pushbuttons, indicating lights, contactors, and motor starters. Each module contains an embedded processor and gets its own unique address. The address is assigned during the auto-configuration process by the SmartWire-DT gateway, which manages the system. The automatic addressing eliminates the need for a technician to set an address via DIP switches or separately program each module. Up to 99 modules or nodes can be connected to each gateway in a SmartWire-DT system.

Controls and components located outside the panel can also use the SmartWire-DT

system because the system can work over distances of up to 2,000 feet. In this case, the flat cable in the cabinet must transition to a round cable that can run between the main control cabinets and remote cabinets that include SmartWire-DT devices and SmartWire-DT I/O modules. There are also machine-mount pushbutton stations that connect directly to the SmartWire-DT system. It also checks the status of components on its network via a scan taking place every 10 and 15 msec. It uses industry-standard RS-485 line driver technology as its physical layer, which has proven to be reliable, noise-immune, and able to withstand harsh environments.

The SmartWire-DT system uses a gateway to establish a connection to standard programmable logic controller (PLC) fieldbuses, including EtherNet/IP™, Modbus® TCP, PROFIBUS DP and CANopen®. The SmartWire-DT system can also handle certain tasks that might otherwise be relegated to device-level control buses. Thus, it can reduce traffic and congestion in such automation networks. Further, each SmartWire-DT device has status indicators that the gateway can poll to test and verify the integrity of the system.

The SmartWire-DT bus also provides two power-line levels: one just for supplying power to the control panel modules, 15 volts (V) direct current (DC), and a separate 24 V DC line for powering the contactor coils.

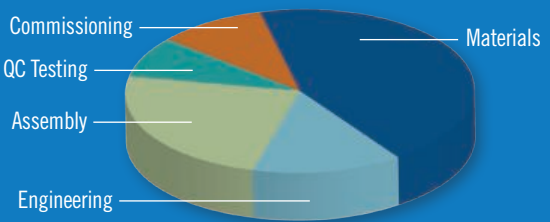


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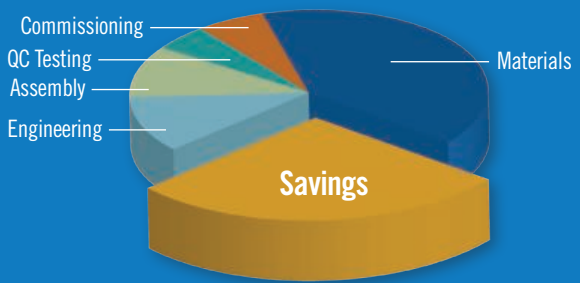


After

Conventional Control Panel



SmartWire-DT Control Panel



A configuration software program called SWD-Assist is available as a free download to help machine builders plan the layout and detail network logistics such as additional powerfeed modules, terminating resistors, and any required flat-to-round cable adapters. The free software runs on computers compatible with the Microsoft® Windows operating system. SWD-Assist lets machine builders plan and

configure the SmartWire-DT network with simple click-and-drag commands.

An auto-completion wizard simplifies the use of SWD-Assist and generates the required bill-of-materials and data files for the gateway modules. ■