

# Optimizing control panel design, construction

## Modern control panel wiring methods can reduce the costs of manufacturing and ownership.

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Global pressures and decreased time-to-market challenge manufacturers to embrace Lean concepts and use innovations to maximize their competitive effectiveness. Recent technology advancements intended to modernize conventional control panel wiring are transforming how panels are designed, built, commissioned, and maintained (see **Figure 1**).



**Figure 1. Recent control panel innovations offer significant improvements over conventional control panel wiring methods, which can reduce the costs of manufacturing and ownership**

Every year, the bar is raised on competitiveness. New technologies, innovations, and more effective manufacturing practices propel us to higher levels of productivity. The U.S. Bureau of Labor Statistics reported that labor productivity increased in 83% of the 86 manufacturing industries studied in 2010, with 57% of these industries posting productivity gains of 6.1% or more as opposed to 2009, when 40% of industries recorded productivity losses.

It is no surprise then that productivity is among the top five priorities for companies. The CEO Institute reports that the top five issues that keep CEOs awake at night include:

1. Improving productivity
2. Reducing costs
3. Achieving operational efficiency
4. Managing increasing competition
5. Achieving top line growth

So how do engineering managers translate these directives to drive productivity and competitiveness? Instilling a broader view of initiatives and looking at the total cost of ownership over the investment cycle—instead of the initial project cost—is crucial. Driving standardization and efficiency wherever possible also helps. Increasing productivity is no longer a voluntary objective; it is required for business survival because productivity gains help to insulate businesses from negative economic impacts.

But how can a company gain a competitive advantage? The primary factors in establishing and maintaining a first-mover advantage are decreasing time-to-market and getting early feedback from customers/end users on prototype designs.

For example, the U.S. automotive market is experiencing a growth period and is faced with the challenge of reducing time-to-market for new vehicle programs. What used to take 48 to 60 months from start of program to start of production is compressed to a 24- to 30-month cycle. In other words, machinery original equipment manufacturers (MOEMs) that used to have 40 to 60 weeks of lead time from contract to delivery are now challenged to deliver equipment in 20 to 30 weeks instead.



Powering Business Worldwide

## Increasing productivity

The first step for increasing productivity for control panel building operations is to understand how costs are allocated to design, engineering, material, assembly, documentation, quality control testing, and commissioning. Material costs can range from 35% to 65% while engineering, testing, and assembly costs make up the difference. Also, the costs for on-site installation and commissioning must be considered for system integration or turnkey operations.

Further, often-ignored, and hardly documented overhead costs are absorbed—although they may actually pertain to specific projects. Some of these costs relate to preengineering, preliminary designs, and/or post order service help or troubleshooting at a customer's request. Although considered good will, the time required increases the cost of doing business. Increasingly, MOEMs are discovering that including some level of machine- and control-panel diagnostics allows them to help customers troubleshoot systems themselves—with a little guidance via a conference call instead of making a costly site visit.

## Time, material savings mean cost savings

Many people say, "Time is money." However, material is too. When it comes to engineering, assembling, and testing control panels, reducing either time or materials (or both) can reduce costs significantly. Here are two examples that illustrate how reducing time and materials can also reduce costs.

In the time reduction example, the estimated time to wire motor starters, contactors, and pilot devices is 4 hours and 29 minutes. However, the estimate is only 41 minutes if a device-level wiring system is used—an 85% reduction in wiring time. Engineering and testing times were also reduced.

In the material reduction example, an installation that consisted of 1,600 motor starters would have required 7.83 miles of control wiring. However, by using a device-level wiring system, only 0.45 mile of flat cable was used. Calculating the material cost of each method using \$0.61/ft for flat cable and \$0.14 for #14 AWG, the device-level wiring system saved more than \$4,300. In addition, the calculated savings for wiring/assembly time was 22 man-days.

Another significant benefit is the device-level wiring network allowed the system to be installed and commissioned without having to ring out a multitude of control wiring connections. This type of control system can also connect electronic motor starters to the system, which allows motor current and other loads to be monitored without having to add current transformers or analog input cards to the PLC. This feature could enable a higher level of predictive data monitoring that was prohibitively expensive in the past.

### Time reduction example

Conventional	Device-level wiring system	Savings	
Wiring time	269 min	41 min	85%
Engineering time	115 min	35 min	70%
Testing time	46 min	4 min	90%

### Material cost example

Flat cable	Control wiring #14 AWG	
Length (in miles)	0.45	7.83
Length (in feet)	2,362.00	41,339.00
Cost per foot	\$0.61	\$0.14
Total cost	\$1,441.00	\$5787.00

## Finding cost-reduction opportunities

But what is to be done after the best component price is negotiated and the smallest footprint and enclosure size is established?

Further cost-reduction opportunities are limited by conventional hardwired control panels. With material costs a relative constant, the real opportunities for cost reduction exist in reducing control-panel engineering, testing, and assembly time. Perhaps creating a standardized layout or replacing hardwired pushbuttons with a touchscreen on a control network can minimize engineering time. For example, it is typically advantageous to use a touchscreen in designs with 10 or more pushbuttons. Additionally, even using spring-cage terminals instead of standard screw terminations can reduce wiring time by about 15%.

Using wiring harnesses can speed assembly time and help eliminate wiring errors. However, this approach is practical only when constructing significant quantities of the same control panel. Automating mundane tasks such as wire stripping and marking can improve quality and consistency while saving time. However, this approach also requires a significant amount of repetitive panels to justify the payback. Establishing point-to-point wiring practices among assemblers can also help reduce testing and/or troubleshooting time. While functional testing typically reduces the time required to check point-to-point wiring, when something goes wrong, it can still take an unpredictable—and possibly an inordinate—amount of time to locate and correct faults.

## Challenges with hardwired systems

Hardwired control panels continue to serve the automation/control industry very well. However, they present certain challenges because of the intensive labor required to:

- Cut individual control wires to the proper lengths
- Strip the insulation
- Add wire identification markers
- Add ferrules at the ends of wires

A simple control panel with a PLC and about 100 I/O points typically requires a wiring schedule or chart to instruct the assembler how to connect the PLC's I/O modules to the corresponding contactor, pushbutton terminals, sensors, or other field devices. When more than one panel is required, a wiring schedule is an efficient way to provide wiring instructions and to ensure consistency. However, it requires engineering time to create the wiring schedule. Also, with numerous wires in close proximity, wiring errors are likely. A wrong connection typically implies that there are multiple wiring errors.

More often, a detailed schematic diagram is used, which requires the assembler to interpret the diagram and keep track of all the wiring by highlighting each wired connection as it is physically wired. This is a tedious but essential practice that consumes time but minimizes the chance of not making a wired connection—which would be more troublesome to troubleshoot during the functional test stage.

When wiring is bundled to door-mounted devices, additional time is required to properly dress and bundle the wires in a way that does not restrict opening and closing the door, or does not damage the wiring bundle (see **Figure 2**). When wiring to small saddle-clamp-type connectors on pushbutton contact blocks, special steps must be taken to ensure that wires are inserted on the correct side of the saddle clamp, and to ensure proper electrical connections are made. Visibility and access become increasingly restrictive as component layout density grows or as pilot devices are added to the layout matrix.

Finally, after the panel is wired, last-minute engineering/design changes may be required. There may be control program modifications, or the customer may wish to add (or remove) components, features, or options. These changes must be accommodated before the control panels leave the shop.



**Figure 2. Additional control panel construction time is required when wiring is bundled to door-mounted devices because wires must not restrict opening and closing the door**

After the control panel is installed on-site, other challenges take over. Eventually, wiring duct covers may be removed to allow technicians to trace wires, control program modifications may be made, field devices may be installed requiring additional I/O wiring, or an added device/component may require wiring to be routed from the control power supply (see **Figure 3**).



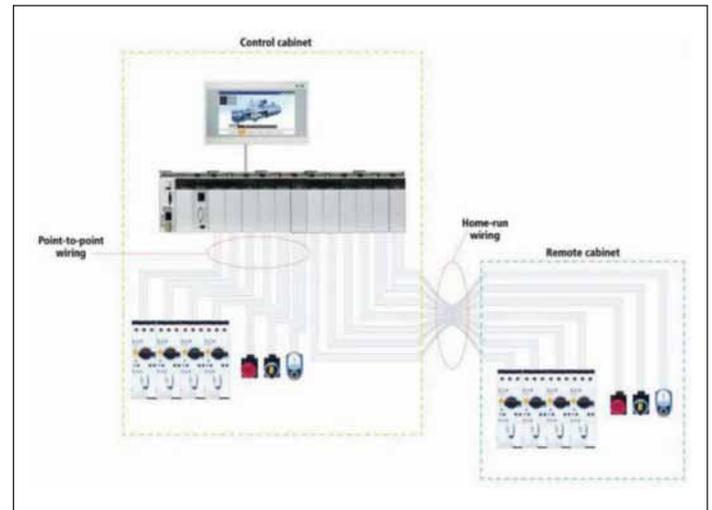
**Figure 3. Typically, control panels change over time to accommodate wire tracing, configuration/design modifications, the addition or removal of control or electrical components, or tapping into the control power supply**

Wiring, layout, and control program changes usually go undocumented. Typically, drawings are seldom updated and control scheme and programming changes are not recorded. However, depending on the business arrangement, the machine builder may still be responsible for the control panel, regardless of the ad hoc changes that may occur in the field.

## Improving control panel connection methods

How would reducing the number of point-to-point wires in a control cabinet affect productivity? Less wiring translates into less assembly time, fewer chances of making mistakes, less time required to check and test wiring connections, no time needed to create a wiring schedule, and more available control cabinet space.

Remember when the connections in the control panel were hardwired—before industrial control networks or fieldbuses (see **Figure 4**)? Remember when the wiring between control panels consisted of home-run wiring to the main controller and I/O modules? Fieldbuses and remote I/O eliminated home-run wiring, which marked a major productivity shift in on-site control wiring and system installations.



**Figure 4. Device-level wiring systems use smart modules that connect standard motor control components via flat cable to a gateway module, which connects to a standard fieldbus on the PLC's CPU**

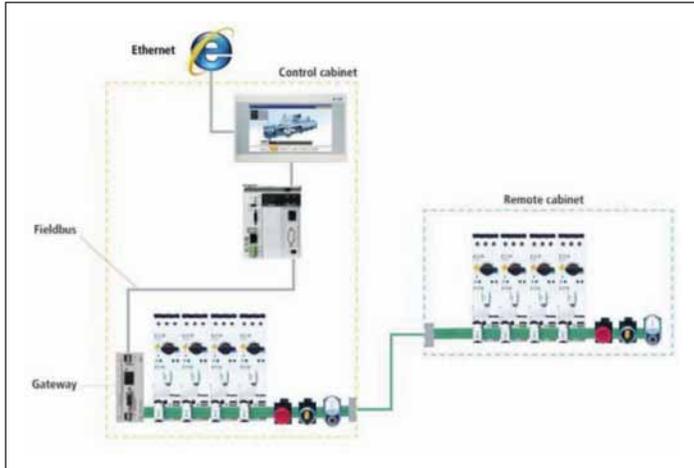
Although the various fieldbuses greatly improved system installation productivity, point-to-point wiring is still required within the cabinet to connect control components to I/O modules. While the elimination of home-run wiring to and from field devices has greatly improved productivity, that level of productivity has not been available for wiring within the control cabinet.

What if control components could be connected to the PLC's CPU without point-to-point wiring or without the need for some of the I/O wiring? What if I/O could be distributed to the component level using an approach that is economically feasible, is functionally equivalent to point-to-point wiring (or better), and is well suited for the dense arrangement of control components normally found in a control panel?

Consider a control panel wiring method that could:

- Connect standard motor-control components
- Eliminate most hardwiring
- Accelerate the engineering, assembly, testing, and commissioning processes
- Reduce control-cabinet space requirements
- Connect to industry-standard networks and fieldbuses

Device-level wiring systems that use smart modules, which attach to standard motor control components, such as contactors, motor starters, and other control circuit devices, are now available. These smart modules connect via flat cable to a gateway module, which connects to a standard fieldbus on the PLC's CPU (see **Figure 5**). Device-level wiring systems that incorporate a power supply can help eliminate most of the control wiring from the PLC's I/O modules to motor starters and control circuit devices. The I/O typically associated with controlling motor starters and control circuit devices can also be eliminated.



**Figure 5. Device-level wiring systems use flat multiconductor cables to connect components, replacing bulky wiring ducts found in conventionally wired control panels**

To understand the productivity, reliability, and economic advantages of using a smart-module-type device level wiring system, compare its advantages to those of a conventionally wired control panel. A wiring duct in a typical conventionally wired panel with numerous control wires can be replaced with a flat multiconductor cable that serially connects the components (see **Figure 6**). Many of the PLC's I/O modules have been eliminated, which increases available panel space. Saving panel space can significantly reduce material costs when stainless-steel enclosures are required. Panel assembly time is also significantly reduced, and testing time is virtually eliminated because there is only one flat cable to check. Diagnostic LEDs on the communication modules indicate network status, which further accelerates testing and commissioning.

From a maintenance perspective, a device-level wiring system has fewer connections that must be checked periodically for termination integrity. Dual-color LEDs on the wiring system's modules simplify troubleshooting. The modules also provide access to byte-level network signals to further aid diagnostic and troubleshooting efforts.

Because a single flat cable connects control components, field wiring modifications are less likely to occur. However, if and when they do, their presence is evident. This helps to protect the machine builder's intellectual property, and to preserve the original craftsmanship and quality of the completed panel.

Device-level wiring systems reduce engineering, design, assembly, and wiring time (see "Time, material savings mean cost savings"). They also simplify control connections, extend diagnostic capabilities to the device level, and increase the reliability, consistency, and flexibility of the control scheme.



**Figure 6. Device-level wiring systems use flat multiconductor cables to connect components, replacing bulky wiring ducts found in conventionally wired control panels**

## Control-panel connectivity— the next generation

Whether connecting to dedicated/discrete controllers or networks of PLCs, solutions that can improve control panel engineering, construction, testing, and commissioning are available now. At last, there is a device-level wiring system/network that optimizes control panel wiring the way fieldbuses revolutionized the industry nearly two decades ago. Device-level wiring systems enable engineers and designers to rethink traditional control panel layouts, allowing them to design modular, flexible, and compact control systems while providing advanced user diagnostics for commissioning and maintenance.

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