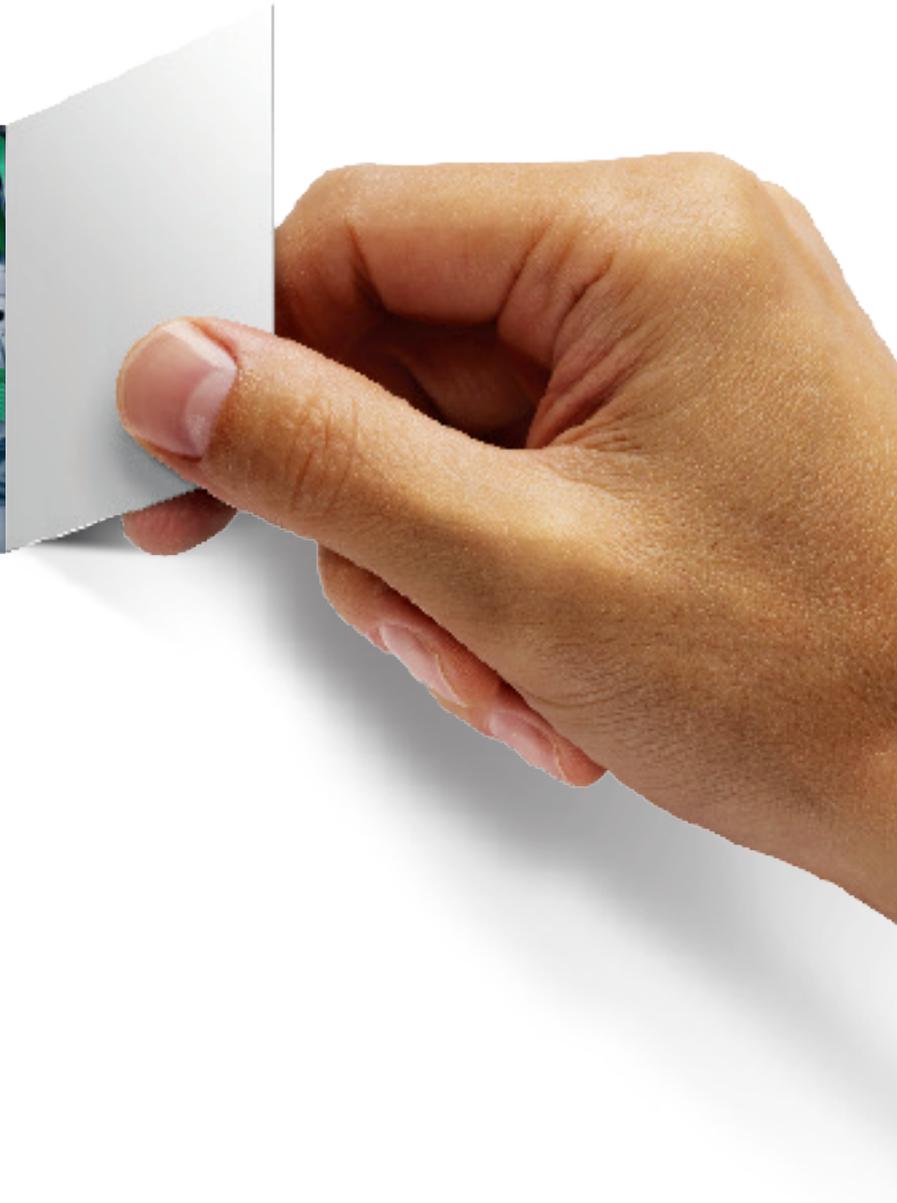


Is conventional wiring out dated? Is intelligent wiring the future? Build it in.



Dipl. Ing. Heribert Einwag
1st Edition

EATON

Powering Business Worldwide



Is conventional wiring outdated?

Facing intense economic and competitive pressures is nothing new for machine builders. With increasingly squeezed margins and shorter delivery lead times, machine builders are taking advantage of every opportunity to maximize manufacturing speed and efficiency value.

Industrial fieldbus systems have replaced conventional field wiring in all modern applications, simply because they offer decisive benefits: they save money and time, they are much easier to design, offer more flexible functionality through individual parameterization and they also aid the rapid location and diagnosis of faults. Now the same benefits are available for more simple devices, traditionally controlled via individual wiring within panels or even outside when they are installed in the periphery. In this paper Heribert Einwag, Product Manager at Eaton, asks: what possible reason can there be for sticking to conventional wiring?

Inside a modern control panel, typical components found may include a PLC (programmable logic controller) or a smart relay and a combination of motor starters, variable speed drives, soft starters, pushbuttons, indicator lamps, and maybe even an HMI (human machine interface) display – linking all of these components together is a mass of control wiring. However, they present certain challenges because of the intensive labour required to measure, cut and strip the wires, crimp the ferrules on and add wire markers at both ends. Additionally, extra space is needed to install the necessary I/O cards and provide cable ducts that contain all needed control wires. This hinders the manufacturer to realize smaller control cabinets, which are highly desirable today from customers who demand that the total application design is smarter.

Opportunities for cost reductions

Material costs, which include the devices and wires, are a relative constant; it would therefore be logical to focus on reducing the control-panel engineering, testing, and assembly time – as time is money. Engineering time could be cut, for example, by adopting a standardized layout or replacing the pilot devices with a touchscreen display. By replacing standard screw terminals with cage clamp terminal blocks (screw-less), wiring time would be also reduced.

Assembly time can be speeded up by using a wiring harness with the added benefit of minimizing wiring effort and errors. In addition, automating repeated tasks such as wire stripping and marking can improve quality and consistency, as well as save time. Both approaches are especially beneficial to machine builders that build a standard line of machines that integrate the same control panel.

Establishing good point-to-point wiring practices among assemblers, by using a wiring diagram as opposed to schematic wiring for instance, can also help reduce testing and/or troubleshooting time. Point-to-point testing is laborious and tedious. While functional testing typically reduces the time required to check the wiring, when something goes wrong, it can take a long time to locate and fix the faults.



Point to point wiring is very costly and error-prone

Conventionally wired systems – the challenges

To guide the assembler how to connect the PLC's I/O modules to the corresponding contactors, pushbutton terminals, sensors, or other field devices, even for a relatively simple control panel, typically requires a wiring schedule or chart. It can take a lot of engineering time to draw up a wiring schedule but it does ensure wiring consistency if more than one panel is required. Nevertheless, with an abundance of wires in close proximity with each other, wiring errors are likely.

To minimize the chances of not making a wired connection, a detailed schematic diagram is frequently used; the assembler still has to interpret the diagram and usually keeps track of all the wiring by highlighting each wired connection as it is physically wired – this is a tedious yet essential practice that takes time but avoids problems occurring during the functional test stage.

When wiring is bundled to pilot devices on the door for example, additional time is required to properly dress and tidy up the wires in a way that does not restrict opening and closing of the door, or cause damage to the wiring bundle itself.

Once the panel is wired, there still may be last-minute changes required, if the customer for example wishes to add components, features or options. These changes must be accommodated before the control panels leave the machine builder's factory.

Even when the control panel is installed on-site, other challenges may take over; technicians may make control program modifications or install additional field devices, requiring additional I/O wiring, or an added device/component may require wiring to be routed from the control power supply.

Wiring, layout, and control program changes can go undocumented. However, depending on the business arrangement, the machine builder may still be responsible for the control panel, regardless of the changes that may occur in the field.

Improving control panel connectivity

Before industrial control networks or fieldbuses, remember when the wiring between control panels consisted of long wiring runs to the main controller and I/O modules? Fieldbuses and remote I/O eliminated these long runs, which marked a major productivity shift in on-site control wiring and system installations. The remaining wiring between the remote I/O system and the connected switchgear has been reduced significantly.

With a fieldbus, multiple field devices can be connected to a single cable, so the number of cables between the control panel and the devices is reduced dramatically. Fieldbus technology of one kind or another has been in widespread use for well over a decade and produces big savings in plant installation time and costs. Yet inside control panels, ordinary wiring – directly comparable to the old-style field wiring – continues to be used. But why?

Part of the answer is that, because field wiring runs are long and costly to install, the potential savings associated with the elimination of conventional field wiring were greater than those associated with the elimination of conventional panel wiring. That made fieldbus systems attractive for outside-the-panel applications even when the technology was comparatively expensive and complicated to use.

A first reaction might well be to think about adapting an existing fieldbus system for in-panel use. In practice, this is already being

done for complex devices such as soft starters, variable speed drives and touch panels. However, for simple switchgear devices, this technology is not yet being used. The reason being that the costs involved to connect to a fieldbus system are high and, in most cases, the full functionality is unnecessary.

A much better approach is an intelligent wiring and communication system that sits under the fieldbus, which has been developed specifically with in-panel applications in mind and is also capable to connect devices outside of the cabinet.

Consider a control panel wiring method that could connect standard motor-control components, eliminate most hardwiring, accelerate the engineering, assembly, testing, and commissioning processes and reduce control-cabinet space requirements, while connecting to industry-standard networks and fieldbuses.



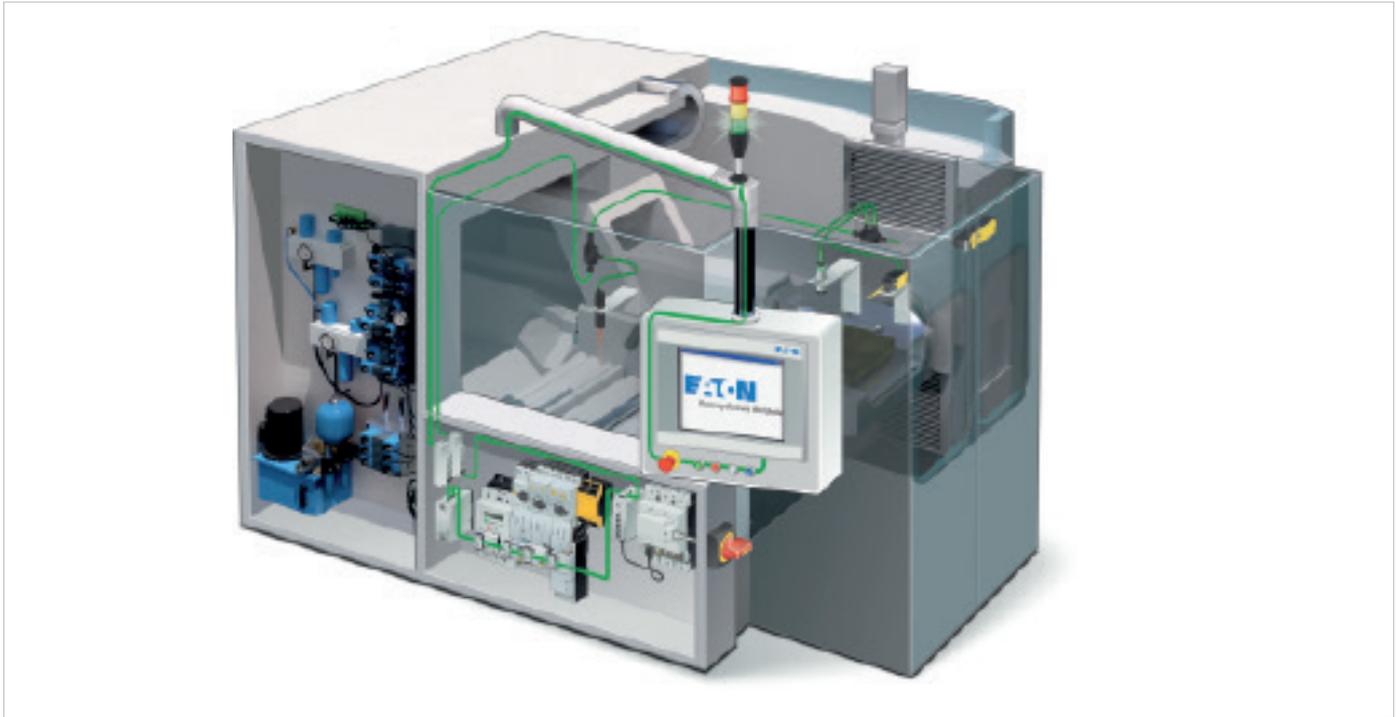
SmartWire-DT simplifies the wiring significantly and reduces hugely the needed space in the control panel.

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 a flat multi-conductor cable to a gateway module, which connects to a standard fieldbus on the PLC's CPU. 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, up to now, installed I/O typically associated with controlling motor starters and control circuit devices can also be eliminated.

Panel assembly time can also be significantly reduced, and testing time will be virtually eliminated because there is only one flat cable to check. Diagnostic indicators on the communication modules could show network status, which would further accelerate testing and commissioning time.

From a maintenance perspective, a device-level wiring system has fewer connections so the regular checks for termination integrity would be quicker. Smart modules not only provide digital information but also analogue or more sophisticated information to further aid diagnostic and troubleshooting efforts.

When an integrated wiring system connects control components, field wiring modifications and manipulations of the original panel



SmartWire-DT allows very flexible machine design inside and outside the cabinet and reduces the time required for wiring, testing and commissioning by up to 85%.

setup require know-how and are self-evident immediately. They are therefore less likely to occur, which helps protect the machine builder's intellectual property and preserve the original craftsmanship and quality of the completed panel.

Building a smart controlled machine

Device-level wiring systems reduce engineering, design, assembly, and wiring time. They also simplify control connections, extend diagnostic capabilities to the device level, and increase the reliability, consistency and flexibility of the control scheme. Moreover, they save space in the control cabinet, because the number of cable ducts and I/O modules can be notably reduced.

All of the features described, and many more, are embodied in Eaton's SmartWire-DT intelligent wiring and communication system. This not only provides a convenient and cost-effective alternative to conventional panel wiring – with wiring cost reductions of up to 85 percent easily possible, along with panel space savings of 40 percent – it also offers a wide range of advanced features.

By considering real-world examples of how and why this device-level wiring system has been incorporated in various installations and industries, machine builders may better understand its true value.

Baking Machines: Constant product quality is a critical factor for success in all baked goods, which is why smart production processes are being heavily adopted. When automating the control of bowl tippers, simple and failsafe design were also key to promote functional and worker safety. By adopting a device-level wiring system, complex and error-prone point-to-point wiring was no longer necessary and the size of the switch cabinet was reduced by more than 50 percent. Fault diagnostics and troubleshooting were simplified and didn't require specialist personnel. Further benefits were the ability to offer customers enhanced operator

security and protection, while follow-up costs for commissioning, repair and maintenance of the machine on the plant were negligible. This installation is also a proof point that the technology is not only worthwhile for large installations it can also add real value and benefit for small applications such as the bowl tippers.

Industrial Washers: If it's not broken, don't change it – this is not the case for a manufacturer of industrial washers who had been using control systems with conventional panel and field wiring for many years, however, as each machine became more complex, so too did the wiring. It was also becoming increasingly difficult for the machine builder to accommodate upgrades or enhancements. After adopting a device-level wiring system, immediate benefits were realised; a panel that had previously taken four hours to wire could be completed in 40 minutes – a six-fold time saving – with virtually no possibility of wiring errors. Other benefits for the machine builder included a simplified design process for the control system due to standardised components being used. The machine builder was also able to offer its customers added value; with comprehensive machine monitoring and logging functions, machine users can instantly check, for example, how many cleaning cycles have been carried out over a given period or how often the filters had needed cleaning. Diagnostic facilities, in the event of a machine stoppage, for example, provide users with accurate information about the reason for the stoppage and comprehensive guidance on how to fix the problem.

Filling & Packaging: The requirements placed on packaging machines are constantly changing – for the machine builder, this means that the system design needs to be highly flexible as well as reliable. In the global environment, a customer in North America may specify a different PLC to a customer in Europe, for example. By using a device-level wiring system, the majority of the machine can be pre-wired so that it is independent of the final PLC and fieldbus system used by the customer. At time of sales, the machine builder would therefore only need to select the correct gateway to connect to the corresponding fieldbus; by standardising the core wiring of its packaging machines, the machine builder is

able to shorten its delivery lead times while offering more flexibility to its customers.

Food Processing: For the control, drives and automation of a potato sorting plant a automation specialist was tasked to get the plant up and running in time for the harvest season, during which an exceptionally large quantity of potatoes have to be processed in a short amount of time. The project involved 250 drives, which were required for conveyor belts, pumps, fans and machines. Based on experience, the engineer estimated that at least 32 km of cable would have to be laid for the entire plant, with at least an additional 1 km cable for the conventional cross wiring within the switchboards. On using a device-level wiring system the wiring required was reduced to an eighth of what it would have been.

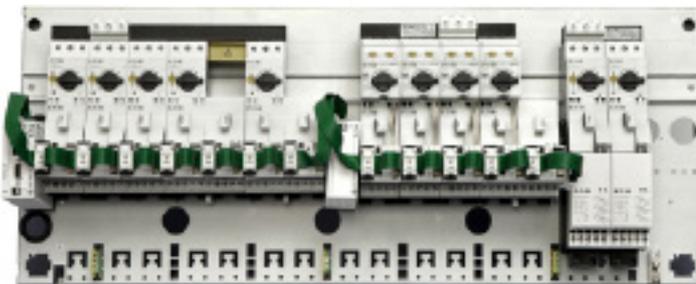
The cross wiring was reduced from 1 km to 50 metres, and the cabling required for the control circuit devices on the machines

reduce by approximately 40 percent. Due to the high level of data transparency, time for troubleshooting for faults was also reduced. Instead of the two weeks commissioning a similar installation, it took 1.5 days. The end results for the company was implementing this complex project from start to finish in just four months with enormous reductions in wiring runs, which enabled them to meet the customer's tight deadline and save a significant amount wiring cost.

From these real-world proof points, it is clear that by changing from a conventional point-to-point wiring system to a device-level wiring system can provide machine builders and end users with advantages that have not been traditionally considered. It is an enabler to develop new solutions that help increase productivity, reduce engineering and installation costs, as well as optimize maintenance.

What is distributed control?

Distributed control allows parts of the automated system to be decentralized and dispersed throughout the system. This means that certain portions of the system are controlled by separate controllers located close to the area of direct control. This allows multiple different form factors for a wide variety of application requirements. Further, by spreading the I/O data across the application as appropriate (either in-cabinet or on-machine), machine builders are able to reduce their automation and control footprint by reducing the number of necessary components.

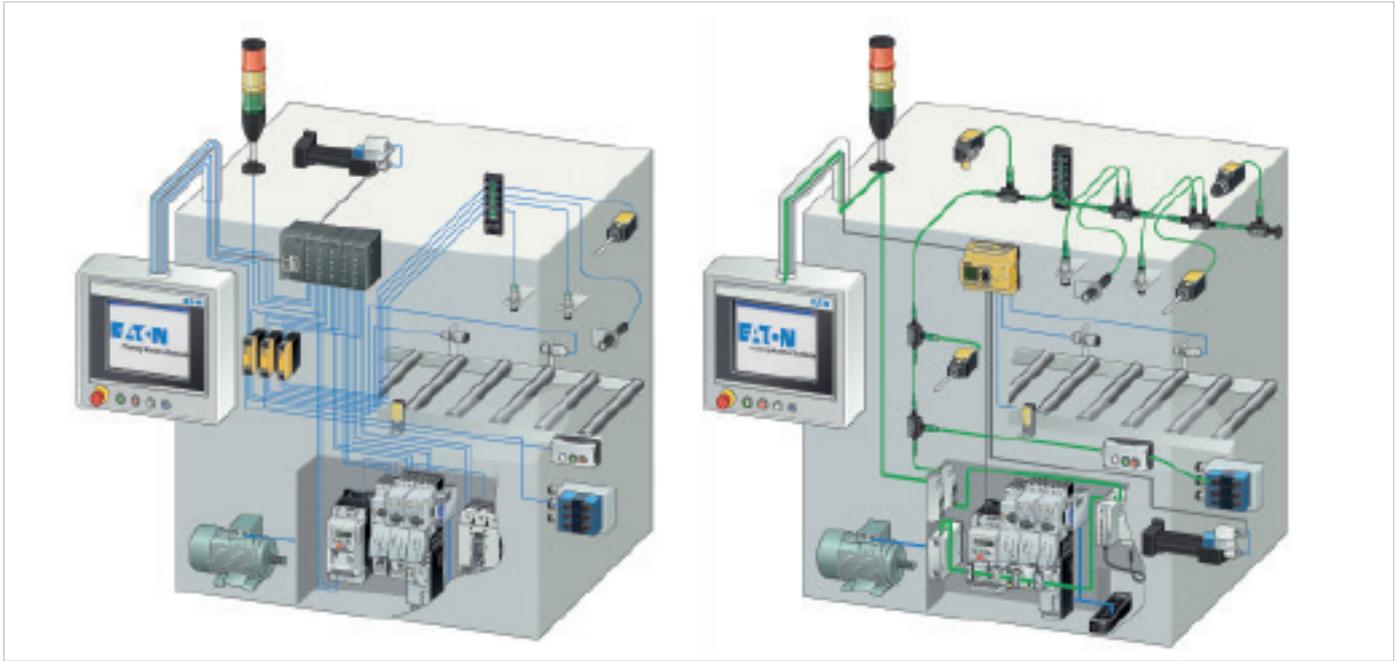


Distributed control enables users to implement a flexible modular design with the exact amount of I/O expansion to be added when necessary, providing an inherent scalability for fast, cost-effective updates for future expansion. Distributed intelligence reduces any additional load on the PLC, and also allows the system to

accommodate future functional requirements by enabling expansion while using the same PLC to control automated applications. This means users can enrich their systems by expanding the size and functional capabilities, and still standardize on PLC systems.

During off-loading, some of the control functions from the main processor (either PLC or PC-control) to the distributed I/O modules, which are located either on-machine or in-cabinet, reduce network traffic. This occurs because through the distributed I/O, the main processor does not need to make requests of the remote I/O for status of inputs or to initiate an output. The distributed I/O system with control/programmable functionality can handle certain tasks, relegating communications to supervisory or status data to the main processor.

By enabling remote I/O configurations, machine builders can achieve high-level connectivity with only a few I/O points required, even in widespread areas, providing a cost-effective control solution for diverse industries and applications. In large facilities, where extensive monitoring and control is necessary, it is not practical or cost-effective to have a controller at each site. This would require a tedious and expensive installation process that would require each I/O point to be hardwired with cable running over long distances. For example, remote I/O systems can be used in acquiring data from remote plant or facility locations. Information such as cycle times, counts, duration, or events can be sent back to the PLC for maintenance and management reporting. Additionally, hardwiring increases the likelihood of errors, such as mis-wiring, which can require excessive downtime to correct.



Complex and error-prone point-to-point wiring is no longer necessary. All devices in machine can be connected to the SmartWire-DT cable using simple plug-in connectors.

Open the door to Industry 4.0

The focus of Industry 4.0 discussions is often on topics such as networking and big data but developments at device level should not be ignored. If 'Smart Factory' concepts are to be realized successfully, simple components such as switches and control units in devices and systems need to be converted into communication-enabled smart devices in a cost-effective manner.

In the smart factory of the future, the product being manufactured will itself tell the machines how, where and by whom it is to be made, machines will independently communicate information concerning their detailed "state of health" and components will proactively report the optimum time for maintenance or repair work. In order for this to work, parts, machines, components, employees, controls and ERP systems must all be able to exchange data with one another.

This requires the capture and evaluation of relevant information relating to the components installed in the machine or system. There is therefore a need not only for suitable sensor technology, but also for the transmission and analysis of data. There are already many complex devices with their own electronics in existence today that fulfil these requirements. However, a large number of components, such as buttons, signal units, switching devices and the sensors and actuators installed in the field, are not yet networked to a large extent, but are linked to the controller via complex control wiring. As a result, the breakdown or malfunction of these devices or the connected components can cause major problems.

If the devices themselves do not provide any data, additional components must be designed and installed in order to capture the data – along with the effort, space and cost this entails. The goal should be to upgrade the devices themselves, to provide information and to realize the transfer of data via a cost-effective and powerful communication medium.

This is already possible using modern-day technology – an application specific integrated circuit (ASIC) can be used to convert small devices, such as switches, buttons or sensors, into intelligent communication-enabled 'smart' devices. Taking an electronic motor starter (EMS) enabled with this technology as an example, the benefits become clear: without the additional effort and costs of external components, the 'smart' EMS is able to provide information about the present current and the load condition of the connected motor. This enables early detection and correction of faults, ensuring trouble-free operation. Data about the installed device type or set overload current allows correct installation to be verified. In this way, condition-based maintenance can be realized simply and cost-effectively in the context of Industry 4.0.

Connection of the system to important fieldbuses is vital and is already available. Should a uniform communication standard be defined for the smart factory of the future, perhaps involving the transition to WLAN technology, for example, then only the communication layer will need to be replaced in order to ensure continued access to the data in the smart devices.

Time and material savings translate to cost savings

Remember that 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.

Taking a car body conveyor system as an example, which needed to be integrated seamlessly into the plant automation structure. The project used over 1,600 motor starters supported by contactors and pilots devices in multiple door cabinets. Conventional wiring solutions were ultimately rejected, since they would have required a large amount of installation effort and only offered a low level of flexibility for plant modifications. In addition, the project design, installation and commissioning would be too time consuming, even when using remote I/O modules. The project therefore used a device-level wiring solution in order to fully meet the customer's time, budget and flexibility expectations.

In terms of time reduction; the estimated time to hardwire the motor starters, contactors, and pilot devices was 4 hours and 29 minutes. However, the device-level wiring system took just 41 minutes to complete – an 85 percent reduction in wiring time. Engineering and testing times were also reduced.

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

In terms of material reduction; for an installation that consists of 1,600 motor starters, it was estimated that approximately 12.5 km of control wiring would be required. However, by using a device-level wiring system, it took only 0.7 km of flat ribbon cable. Calculating the material cost of each method using 1.75 €/m for flat cable and 0.40 €/m for 14 AWG (2.08 mm²), the device-level wiring system saved more than 3,700 €. In addition, the installation time was reduced by 22 man-days.

Material Costs

	Control Wiring	Flat Cable
Length (km)	12.5	0.7
Length (m)	12,500	700
Cost per m (€/m)	0.40	1.75
Total Cost (€)	5,000	1,225

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

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Eaton Industries GmbH
Hein-Moeller-Str. 7-11
D-53115 Bonn/Germany

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