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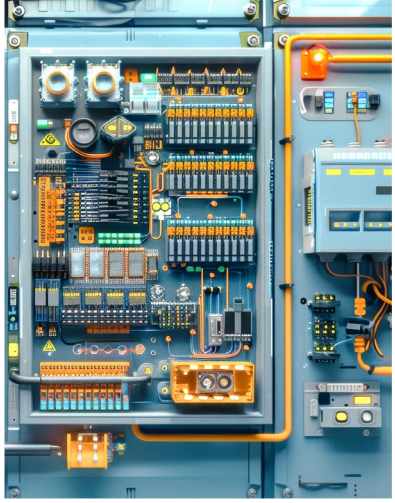

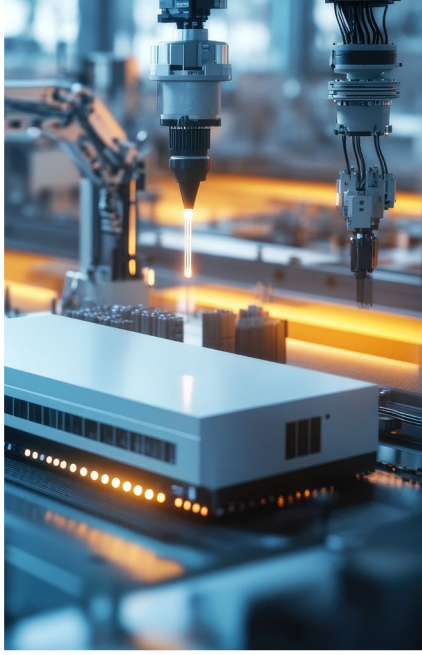

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Editor’s note

Welcome to the DigiKey *eMagazine Volume 21 – Exploring the Control Cabinet.*

In any industrial automation application, whether on the manufacturing floor or in an industrial kitchen, there is a control cabinet. This cabinet is vital to the operation of any automated process. Blending machine and process, the cabinet drives efficiency and precision.

Opening the door to an industrial control cabinet is like stepping into the nerve center of modern industry. Inside, you'll find a meticulously organized array of devices, each playing a crucial role in the system's functionality. From the programmable logic controllers (PLCs) that act as the brain of the operation to the human-machine interfaces (HMIs) that provide real-time insights, every element is designed to work in harmony.

Exploring the industrial control cabinet reveals the sophisticated balance between technology and engineering, showcasing the advancements that drive innovation in industrial settings. These advancements allow us to drive smarter machines, reduce waste, increase efficiency and productivity while maintaining a high level of accuracy and quality.

In this magazine, we will dive into topics such as speed drives and frequency drives, DIN rail power, cybersecurity, de-energizing circuits, terminal blocks and industrial interconnect, thermal regulation, and more.

We hope you find this collection of articles helpful and can spark new ideas to innovate more in the world of industrial automation.

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Cabinet safety – A paramount consideration in any industrial application

PANDUIT™

In industrial environments, electrical cabinets remain one of the most dangerous points of contact for workers. Even when the power is shut off, residual voltage or partial disconnect switch failures can leave components energized. Each year, hundreds of arc flash events and electrical injuries occur because someone assumed the cabinet was safe to open.

Workers must verify the absence of voltage before accessing electrical enclosures. However, traditional methods using handheld test instruments are complex and time-consuming. Even permanent tools like voltage indicators and test portals can fall short when it comes to confirming true de-energization.

That's where absence of voltage testers (AVTs) come in. These systems automate the verification process, giving workers a clear indication—without opening the enclosure—whether it is truly de-energized. This article explores the risks associated with conventional verification methods, and how Panduit's VeriSafe AVT addresses their shortcomings.

The problem with traditional methods

Industrial workers rely on a variety of tools to assess electrical safety, but not all are designed—or approved—for verifying the absence of voltage. Among the most commonly used are voltage indicators and test portals. While both offer some insight into the electrical status of equipment, they each carry limitations that can compromise safety when used for absence of voltage verification.

Voltage indicators are simple, permanently mounted devices that illuminate when voltage is present, typically between 40V and 1000V. While they offer a quick visual warning, they are fundamentally limited when it comes to confirming de-energization. A non-illuminated indicator doesn't necessarily mean the system is safe; LED or fuse failures, poor installation, or open circuits can all produce a false negative. Additionally, since these devices route line voltage directly to the enclosure door, they introduce a potential shock hazard when a worker is troubleshooting with the door open. OSHA has stated that voltage indicators should not be used to verify de-energization.

Test portals offer another option. These devices allow technicians to connect a handheld tester to measure voltage without opening the cabinet. While helpful for troubleshooting, test portals are not well-suited to confirming a safe-to-open condition. They cannot verify that the internal leads are properly connected at the time of testing and are vulnerable to fusing issues. Either condition could show a zero-voltage reading when voltage is actually present. Like indicators, test portals can also route hazardous voltage to the door, exposing workers to additional risk.

Neither voltage indicators, nor test portals satisfy NFPA 70E's requirements for absence of voltage verification. According to Article 120.5(7), proper verification must include testing each phase both phase-to-phase and phase-to-ground, using an adequately rated instrument. Exception 1 allows for permanently mounted test devices, but only if they meet strict criteria. Devices must be UL 1436 listed, test all phases, and perform self-verification using a known voltage source before and after testing. Both voltage indicators and test portals do not fulfil these conditions.

While OSHA does not define detailed performance requirements for voltage testing tools, it recognizes NFPA 70E as the benchmark for electrical safety. By that standard, absence of voltage testers are the only permanently mounted device currently aligned with both best practices and regulatory expectations.

Introducing absence of voltage testers

Absence of Voltage Testers offer a streamlined, automated approach to verifying that electrical equipment is de-energized before access. Unlike voltage indicators

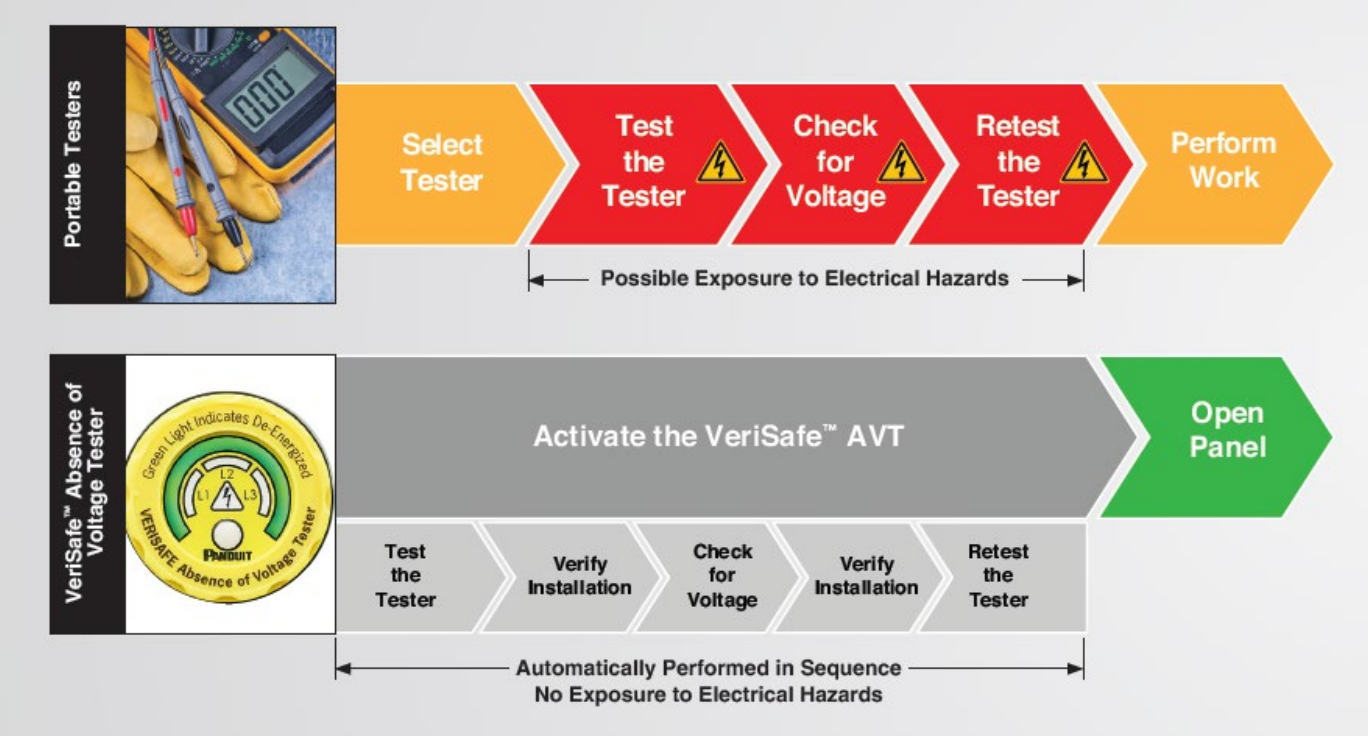
or test portals, which either show the presence of voltage or allow indirect measurement, AVTs are dedicated safety devices built to verify that no voltage is present inside an enclosure.

The core advantage of AVTs is that they automate a process that would otherwise require multiple steps and tools. At the push of a button, the system initiates an internal sequence: it checks that the tester itself is functioning, verifies that sensor leads are properly connected, tests each phase both phase-to-phase and phase-to-ground, and uses a known voltage source before and after each test to verify the tester is functioning correctly. If all criteria are satisfied, a visual indication is provided to confirm that the absence of voltage has been verified. This automation reduces the chance of human error and eliminates the need to open the cabinet for initial testing.

Industrial electrical manufacturer Panduit offers their VeriSafe Absence of Voltage Tester as one such solution. Once installed, it allows a qualified worker to initiate the test sequence from outside the enclosure. By automating each verification step and providing a clear green-light indication when the system is de-energized, VeriSafe helps support safety without requiring handheld testers or direct exposure to conductors.

The hardware behind Panduit's VeriSafe AVT

The VeriSafe AVT is designed around a modular architecture that separates operator interaction from high-voltage components,



Comparison of testing methods. (Image source: Panduit.)

helping reduce risk during electrical maintenance. The system is engineered for testing three-phase circuits up to 600V.

At the center of the system is the indicator module, which mounts externally in a standard 30mm knockout and provides clear visual cues with red, yellow, and green LEDs to guide workers through each phase of testing. This interface removes the need to open the cabinet during initial verification, keeping personnel safely distanced from energized conductors.

Inside the enclosure, the isolation module acts as a safeguard. It ensures that hazardous voltage remains contained, and includes output contacts for integration with alarms or other safety systems. Connecting the modules is a replaceable cable assembly with right-angle connectors, which save space. The sensor leads—two per phase—can be installed on either side of the disconnect and are kept physically separated to ensure accurate connection to the circuit under test.

Each AVT system is tested to NEMA 4X, IP66, and IP67 standards, offering protection against dust, water, and corrosion. Versions rated for Class I, Division 2 and Zone 2 hazardous locations are available, making VeriSafe suitable for demanding industrial applications.

The system includes a long-life industrial battery that can be accessed from the front panel and is easily replaceable without tools.

Additional features include built-in overcurrent protection, which eliminates the need for external fusing and prevents failure modes common in older testing approaches.

Real-world case study: grounding failure

A case study involving a 480V three-phase system highlights the difference that a fail-safe device can make. In this scenario, a disconnect switch had partially failed, leaving one phase live while the other two were open. Compounding the danger, the ground leads had not been properly terminated. To a worker preparing to access the panel, the system appeared de-energized.

Standard test portals and voltage indicators gave false readings, showing no voltage across any phase. Had a worker relied solely on these tools, they would have opened the enclosure while one conductor remained energized, risking shock, arc flash, or equipment damage.

Panduit's VeriSafe AVT detected that the sensor leads were not properly grounded and halted the test sequence, indicating that the installation could not be verified. This fail-safe response prevented a potentially dangerous incident, underscoring the value of automated absence of voltage verification.

Conclusion

Electrical cabinet safety begins well before a door is opened. Even with power shut off, residual voltage or equipment failures can leave components energized, posing serious risks to workers who assume the system is safe.

Traditional tools like voltage indicators and test portals are not equipped to verify the absence of voltage. These methods can produce false negatives, fail to detect installation errors, and do not meet the standards outlined in NFPA 70E or UL 1436.

Panduit's VeriSafe AVT addresses this gap by automating the verification process and ensuring the test itself can be trusted. By detecting faults, performing self-checks, and isolating hazardous voltage, the system eliminates many of the failure modes associated with other testing methods—and helps set a higher standard for electrical safety.

To learn more, visit VeriSafe ATV.

The benefits of upgrading to stainless steel

The electrical and control cabinets in industrial environments are constantly subjected to physical stress, humidity, water exposure, particulate matter, and corrosive chemicals. Despite protective coatings, the traditional enclosures degrade over time, compromising their ability to protect the internal electrical systems.

This degradation has a significant impact—it reduces system reliability, increases the risk of electrical faults that may be hazardous to floor operators, and drives up the maintenance and replacement costs. In industries where exposure to harsh chemicals is unavoidable, it is crucial to select a more durable alternative.

One such alternative is stainless steel. With its high resistance to corrosion, better mechanical strength, and reduced maintenance needs, stainless steel has become the material of choice for industrial enclosures. It delivers a robust solution needed for control cabinets in challenging conditions, where conventional options often fail to meet performance standards.

This article explores the strategic reasons for upgrading to stainless steel enclosures, showcasing examples from Hammond Manufacturing.

Material advantage of stainless steel

Understanding the material advantages of stainless steel is crucial for selecting the right grade for a specific application.

In comparison to carbon steel, stainless steel has additional alloying elements—chromium, molybdenum, and nickel—that improve its corrosion resistance. When exposed to oxidizing agents, such as saltwater or chemicals, chromium forms a protective layer of chromium oxide that shields the surface from further corrosion.

One of the most practical advantages of stainless steel is its low maintenance. Traditional enclosures require periodic inspections, repainting, and replacement due to rusting. By contrast, stainless steel enclosures resist rust and chemical damage over extended periods, reducing operational downtime.

The clean aesthetics of stainless steel make it an ideal choice for the food and beverage, pharmaceutical, and water treatment industries. Its smooth and non-porous structure allows for easy cleaning even in environments where frequent hosing or chemical washdowns are required.

In outdoor or extreme temperature applications, such as rooftop HVAC units and remote utility stations, stainless steel maintains its structural integrity. The material protects control cabinets through its resistance to UV exposure and temperature fluctuations, ensuring long-term performance.

Stainless steel grades and composition

There are more than 150 grades of stainless steel, each with varying combinations of alloy elements. According to ASTM A941, stainless steel must have a minimum chromium content of 10.5% and a maximum carbon content of 1.20%. Additional elements, such as nickel and molybdenum, influence properties like corrosion resistance and tensile strength.

Two of the most widely used stainless steel grades in industrial applications are 304 and 316:

- *304 stainless steel* (18% chromium and 8% nickel) is the most common. It offers standard corrosion resistance, strength, and ease of maintenance, making it suitable for general industrial use.
- *316 stainless steel* (16% chromium, 10% nickel, and molybdenum) is the second most popular in sales volume. It provides superior corrosion resistance to chlorides, acids, and alkalis. It is suitable for environments like food processing, medical

equipment, coastal facilities, and locations with high salt concentrations and aggressive cleaning agents.

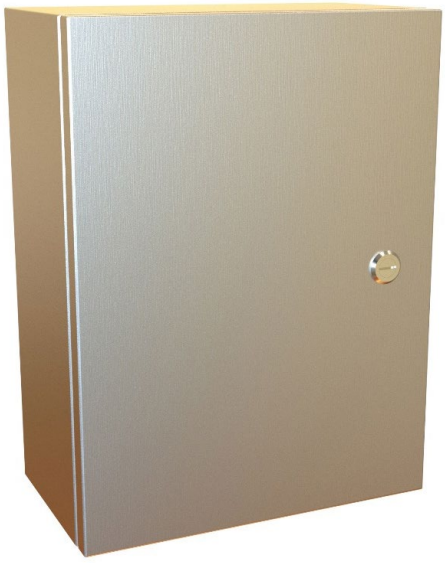


Figure 1: Stainless steel enclosures from Hammond's EN4SDSS series. Feature fully welded seams for structural integrity. (Image source: Hammond Manufacturing)

Stainless steel enclosures

The Hammond Manufacturing EN4SDSS series (Figure 1) is an example of a stainless steel wall-mount enclosure. It demonstrates advantages for rugged industrial environments. Available in 14-gauge for larger sizes and 16-gauge for smaller sizes, this series comes in 304 and 316L stainless steel grades. The latter is suitable for the harsh environments of the food and chemical industries.

All the external hardware—hinges, latches, and pins—is made from stainless steel to prevent rust. Unlike spot-welded cabinets that allow water ingress through seam cracks, the EN4SDSS enclosures feature fully welded seams for enhanced structural integrity, protecting against water and dust.

These enclosures offer design flexibility, with removable and interchangeable doors for ease of modification and reconfiguration. Also, the door alignment guide on 36" wide models prevent misalignment and assists in proper closure of the enclosures.

In terms of protection ratings and standards, the EN4SDSS series complies with NEMA Type 3R, 4, 4X, 12, and 13, which indicate protection against wind, dust, rain, sleet, ice formation, and corrosion. The enclosure is also compliant with UL 508A Type 3R, 4, 4X, and 12, as well as CSA Type 3R, 4, 4X, and 12.

These enclosures are available in a wide range of sizes, with widths from 12 inches (305 mm) to 72 inches (1829 mm), heights from 12 inches (305 mm) to 36 inches (914 mm), and depths from 6 inches (152 mm) to 12 inches (305 mm).

Additionally, Hammond Manufacturing offers the EJSS (Eclipse Junior Stainless Steel) series (Figure 2) as a stainless steel enclosure solution for wall-mount applications. They are designed for use in junction boxes and electrical wiring applications within compact installations.

Figure 2: Stainless steel enclosures from Hammond's EJSS series. Made of natural stainless steel with a smooth brushed finish. (Image source: Hammond Manufacturing)

These enclosures house components in high-moisture environments or corrosive conditions. Similar to the previously discussed Eclipse enclosures, the EJSS series also complies with the NEMA standards.

In enclosures exceeding 4" x 4" dimensions, a galvanized steel inner panel is incorporated as standard. The panel provides a

practical mounting surface for internal electrical components, including DIN rails and terminal blocks. The design features a welded mounting bracket integrated into the back of the enclosure, providing ease of installation on walls and panels.

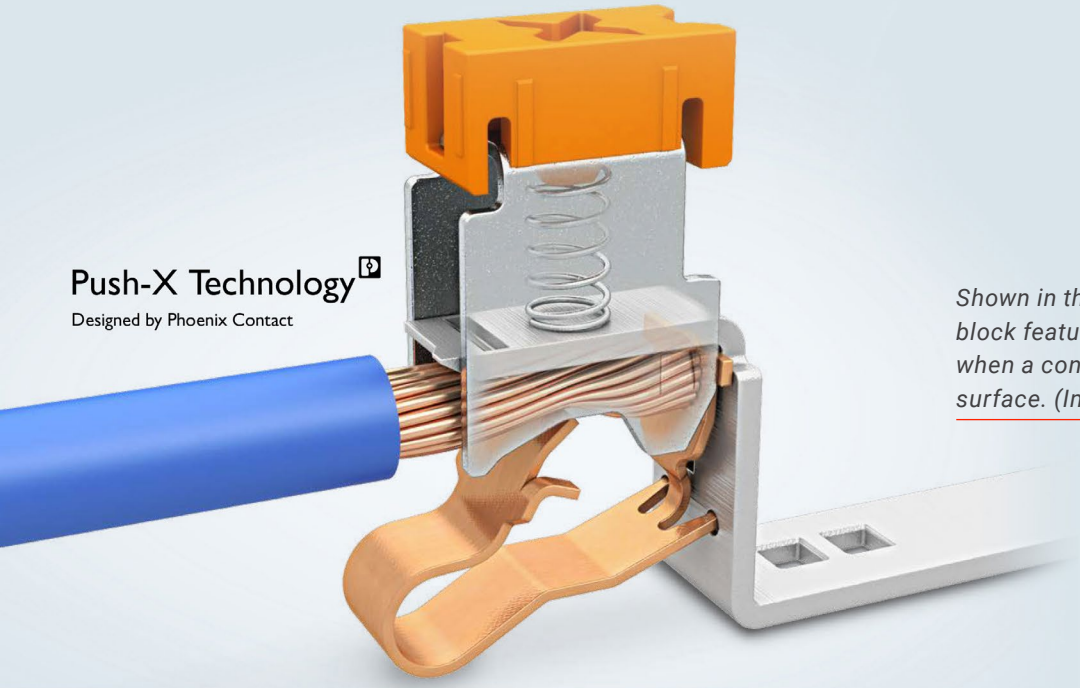
Conclusion

As industrial operations become increasingly complex, there is a growing need for robust equipment enclosures to support the electrical and electronic control systems. The enclosures must deliver long-term protection and reliability against extreme industrial conditions of humidity, temperature, dust, water, and other corrosive elements.

Solutions offered by Hammond Manufacturing through the EN4SDSS and EJSS series address this need with better corrosion resistance and rugged construction. Making this strategic decision to upgrade to a stainless steel enclosure will reduce operational risks and extend the enclosure's life. This will lower the total cost of ownership even if the initial investment is higher.

For industries that demand performance, hygiene, and durability, stainless steel is more than an option, but a necessity.

Saving time with tool-free wiring



Shown in the closed position, a Push-X terminal block features a contact spring that engages when a conductor presses against its release surface. (Image courtesy: Phoenix Contact.)

After years in the field, few things test an electrician's patience like a stubborn terminal block. You're crammed into a control cabinet, fumbling with a screwdriver while trying not to overtighten a screw that may already be on its last thread. Strip the wire just a bit too long and you're dealing with exposed copper. Do it too short and you risk a poor contact.

These frustrations aren't new. Traditional screw-type terminal blocks have long been the industry standard, but their limitations are well known. Mechanical stress and vibration can cause wires to loosen over time, even if the connection felt solid when installed. Screws introduce another layer of risk: overtightening can damage conductors, while under-tightening leaves room for dangerous arcing or overheating. Inconsistent insulation stripping only compounds the problem. With loose connections generating heat, insulation can degrade over time, increasing the likelihood of fire hazards.

Installation itself can be a chore. Every wire demands a tool, and reaching terminal screws within confined spaces can seriously challenge an electrician's

dexterity. For high-density applications, the difficulty isn't just in connecting wires—it's about managing space and routing in an environment that may already feel like a game of electrical Tetris.

Electrical components manufacturer Phoenix Contact's Push-X terminal blocks offer a smart alternative to the headaches of screw-type terminals. Designed for tool-free installation, Push-X enables direct wiring of all conductor types—including stranded styles—without the need for ferrules. That means installers can leave the screwdriver behind and rely on a single tool: a wire stripper. Once stripped, the conductor is simply inserted into the terminal. This approach not only speeds up installation but also reduces the variability introduced by torque tools, while offering a more reliable connection in tight or complex spaces.

A closer look at the Push-X design

At the core of Push-X technology is a pre-tensioned contact spring that activates as soon as a conductor is inserted. With a simple, tool-free motion, the wire taps the release surface inside the clamping chamber, triggering the spring to snap closed and lock the wire into place. This mechanism works regardless of wire type—whether it's rigid, stranded, or flexible, with or without ferrule.

In many ways, Push-X solves the most common frustrations associated with screw-type terminal blocks. For starters, the contact spring applies a consistent, factory-calibrated force to each wire, completely removing the guesswork involved in tightening screws. This ensures repeatable, high-quality connections regardless of the installer's hand strength or angle of approach—important in panels where space constraints make ideal positioning nearly impossible. There's no risk of crushing a conductor with too much torque or leaving it vulnerable to vibration by keeping it too loose. Once engaged, the spring holds the conductor securely over time, even in high-vibration environments.

Push-X is designed to accommodate small wires—down to 0.5 mm² (20 AWG) for rigid and 1.5 mm² (14 AWG) for flexible conductors—demonstrating the minimal force required to trigger the contact spring. Even fine-stranded wires trigger the mechanism easily, a major step forward from earlier push-in designs that required ferrules or extra force.

Conductor release is just as simple. An orange pusher marked with an "X" pops up when a wire is inserted, signaling that the connection has been made. Pressing it down again both releases the wire and resets the spring, so the block is immediately ready for the next conductor.

Push-X also gives installers more flexibility in how they route and terminate wires within dense control cabinets. Because the terminal block opens automatically at the factory, users don't need to preload the mechanism or pry it open themselves—wiring is a one-step process. The lateral entry design reduces the bending radius of conductors, which helps preserve wire markings and makes it easier to manage cable routing. These terminal blocks serve to close the gap in the PTV and PTPOWER lateral spring-cage terminals range.

The XTV series is the first to incorporate Push-X technology, and its thoughtful features extend beyond the clamping mechanism itself. Available in 6, 10, and 16 mm² versions, the series supports conductor sizes up to 25 mm² (4 AWG) and includes feed-through blocks as well as 3- and 4-conductor variants. These multi-conductor models reduce the number of terminal blocks required on a DIN rail, freeing up panel space and simplifying wiring layouts.

Color-coding and labeling further facilitate installation. Alongside the standard gray versions, the XTV series includes green-yellow protective conductor blocks to align with the color of protective earth cables. Each block is also labeled with a QR code, giving installers instant access to documentation, datasheets, and installation guides in multiple languages.

Push-X terminal blocks have also been tested extensively by Phoenix Contact. Despite the low insertion force required to engage the spring, the design resists accidental triggering. Drop tests and simulated shipping conditions confirm that the mechanism won't prematurely activate from vibration or impact.

The XTV series handles up to 76 A at 1000 V (IEC) and 75 A at 1000 V (UL). It is also compatible with Phoenix Contact's broader CLIPLINE complete terminal block system, allowing integrators to use common accessories such as bridges and switching jumpers across multiple product lines.

In its factory setting, the pusher is depressed. The orange pusher pops up when the contact spring engages a conductor. (Image courtesy: Phoenix Contact.)

Applications of Push-X Technology

Push-X terminal blocks are designed for a range of control and distribution tasks across industries. In factory and building automation, they help simplify dense wiring inside control panels and distribution boxes. The tool-free connection method is useful in settings where space is limited and installation times are tight, such as during equipment upgrades or panel retrofits.

Process industries like water treatment and food production often involve environments with vibration or regular maintenance

Push-X terminal blocks come in three sizes and are available in 2, 3, and 4-conductor variants. (Image courtesy: Phoenix Contact.)

schedules. Here, a secure, low-maintenance terminal connection can reduce the need for rework. Push-X also has a role in energy infrastructure—particularly in renewable systems and transportation—where field wiring conditions vary and consistent connections must hold up over time.

From signal wiring in marshaling panels to power distribution in data centers and conductor management in automotive systems, Push-X supports faster wiring while keeping the process straightforward.

Conclusion

For electricians used to wrestling with terminal screws within cramped enclosures, Push-X offers a welcome shift. Just strip the wire and push it in; no torque tools or second-guessing required. Push-X's preloaded spring grips a wide range of wire types and sizes, whether you're using ferrules or not. And when it's time to make a change, a tap of the pusher releases the conductor and resets the terminal for the next job. When wiring dozens—or hundreds—of conductors, these advantages translate into meaningful time savings, fewer wiring mistakes and a lower risk of accidental electrocution.

By rethinking a task that's long been more tedious than it should be, Push-X makes wiring in the panel a little less frustrating, and a lot more efficient.

To learn more, visit Push-X Terminal Blocks.

Surge protection in industrial control cabinets

By Abhishek Jadhav for DigiKey

Control cabinets serve as the powerhouse of any industrial facility, housing programmable logic controllers (PLCs), communication devices, sensors, variable frequency drives, and human-machine interface panels. As these components become more compact and complex, their susceptibility to damage from transient overvoltage increases.

These transient overvoltages are short-duration (typically milliseconds), high-magnitude voltage peaks with fast-rising edges, capable of reaching up to 6,000 volts even on a low-voltage consumer network. When a voltage surge exceeds the specific dielectric strength of the devices, it can affect the entire electrical system. It leads to short circuits, equipment damage, fire hazards, and even complete failure of facility operations.

The primary causes for these transient overvoltages include lightning strikes, switching operations, and electrostatic discharge. Among these, lightning strikes are the most common source of power surges. Even indirect effects of a lightning strike can induce a surge voltage. The electromagnetic field created by the lightning current generates resistive and inductive coupling, which can potentially cause severe equipment malfunctions or permanent damage.

Industries must integrate surge protection devices and strategies to safeguard electrical and electronic equipment within control cabinets. These devices detect and divert impulse current and transient overvoltages away from sensitive systems, ensuring

that only the required power levels reach critical components. Such protection also helps prevent costly downtime and equipment replacement.

This article explores the fundamentals of surge protection devices and design challenges, followed by examples from Littelfuse and Phoenix Contact.

How does surge protection work?

Surge protection devices (SPDs) operate in a high impedance state, functioning as an open circuit. In this state, they maintain electrical isolation between the active conductors and ground, ensuring no connected equipment is affected.

However, during transient overvoltage, SPDs switch within nanoseconds to a low-impedance state. This closed-circuit condition allows them to divert excess current to ground, thereby limiting the surge voltage and discharging the associated surge current.

Surge voltages can occur between active conductors (normal mode) or between active and protective conductors (common mode). To protect electrical components, SPDs are typically placed in parallel—either between phase conductors or between phase and ground potential—depending on the surge path, as shown in Figure 1.

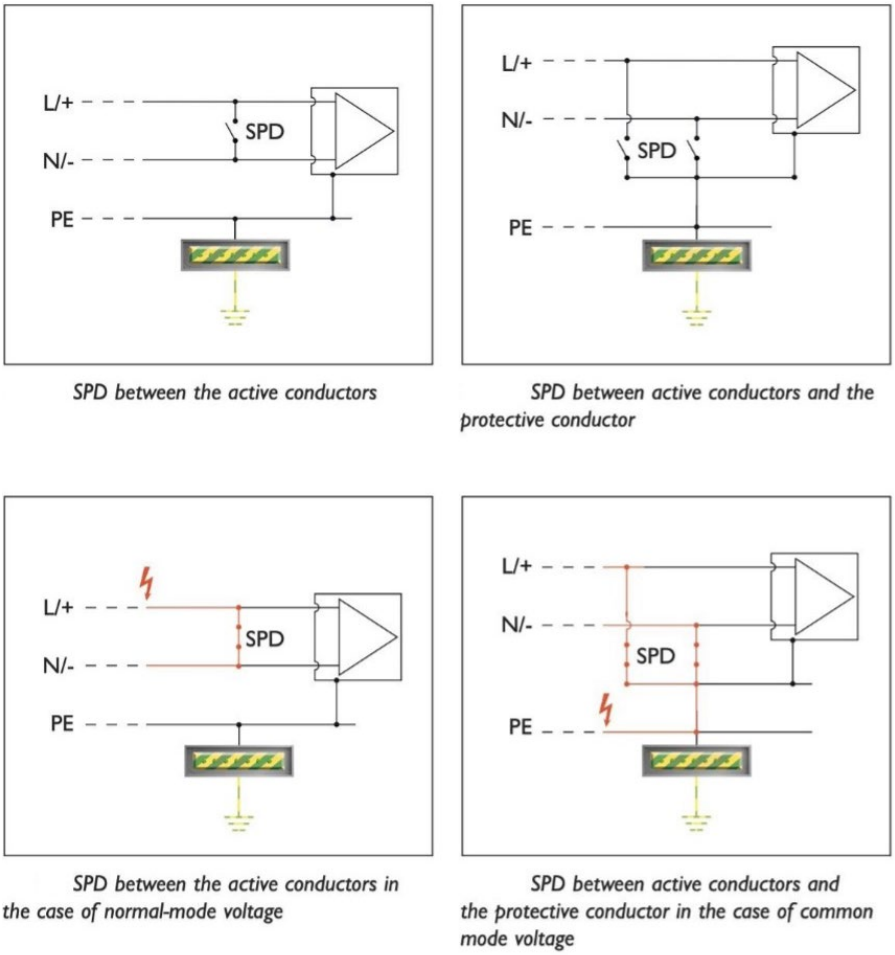


Figure 1: Parallel installation of SPDs for both normal and common mode surge protection. (Image source: Phoenix Contact)

Nonlinear components inside an SPD

This dynamic behavior of an SPD is enabled by the presence of at least one nonlinear component within its design. These components conduct electricity only when the voltage across them exceeds a defined threshold. Common types include metal oxide varistors (MOVs), avalanche breakdown diodes (ABDs), and gas discharge tubes (GDTs).

Among these, MOVs are the most widely used in AC power circuits. Their surge current rating depends on their cross-sectional area and composition. The larger the cross-sectional area, the higher the surge current rating of the device. MOVs are made of zinc oxide grains mixed with other additives. These grains form a network of semiconductor junctions at their boundaries, which act as diodes, allowing current to pass only during overvoltage events.

Under normal conditions, MOVs remain in a high-resistance state. When a surge occurs and the voltage crosses a threshold, their resistance drops, enabling them to shunt the surge current to ground. After the event, they automatically return to their high-resistance state.

Design challenges with SPDs

While SPDs are designed to absorb high-energy transients, repeated exposure to smaller overvoltages on the power distribution system can lead to premature aging and device failure. This occurs when the maximum continuous operating voltage (MCOV) rating is too close to the system's nominal operating voltage, making the SPD vulnerable to routine voltage fluctuations.

To resolve this issue, it is recommended that the MCOV of the device be at least 115% of the nominal system voltage, ensuring the device is unaffected by normal voltage variations in the power distribution system.

In some cases, the current magnitude exceeds several hundred thousand amperes. To evaluate the performance of an SPD, the primary benchmark is the nominal discharge current rating, which demonstrates the device's ability to withstand repetitive current surges without damage or degradation.

Examples of industrial surge protection devices

Surge protection in an industrial setting involves a strategic approach with different types of SPDs installed at various points in the electrical distribution system to reduce surge energy. According to UL 1449, SPDs are classified by installation location:

- Type 1 devices: Installed very close to the service disconnect. They are designed for the line side of the main overcurrent protective device but can also be used on the load side.
- Type 2 devices: Located downstream of the service disconnect, protecting against residual surges from external events.
- Type 3 devices: Placed close to the load, offering localized protection for sensitive electronics.

Littelfuse offers the SPDN-A series of SPDs that are intended for installation at the sub-distribution board downstream from the main panels to protect the branch circuits and connected equipment. For example, the SPDN-A480-3D (Figure 2), has a nominal voltage of 480 V and is capable of continuously withstanding up to 550 V without degradation.

The device features line-to-neutral, line-to-ground, and neutral-to-ground protection, along with the ability to suppress electromagnetic and radio frequency interference. This SPD is designed using multiple MOVs in a layered structure, enabling a compact design.

Figure 2. Littelfuse's SPDN-A480-3D surge protection device with an MCOV rating of 550 V in a 3-phase delta configuration (Image source: Littelfuse).

Figure 3. The Phoenix Contact 2907916 PLT-SEC Series Type 3 surge protection device with a nominal voltage rating of 24 V AC/DC (Image source: Phoenix Contact).

Figure 3 shows the Phoenix Contact 2907916 PLT-SEC Series Type 3 SPD that can be placed near sensitive electrical components, such as programmable logic controllers (PLCs) or control units. It is suitable for final-stage protection against residual surges that pass through upstream protection.

Additionally, it includes a DIN rail-mounted base and a plug-in protection module and is rated for 24 V AC/DC low-voltage, single-phase circuits. Its remote signaling contact ratings are 250 VAC / 125 VDC, 0.5 A for remote alerts or panel indicators.

Conclusion

As industrial control systems become increasingly complex, integration of surge protection devices has become essential. By clamping transient overvoltages, SPDs protect the electronic and electrical components housed within control cabinets.

Selecting the correct SPD is vital for meeting the specific requirements of an industrial facility. Key factors in this selection process include the MCOV and the nominal discharge current. A layered protection strategy, utilizing UL Type 2 and Type 3 devices, is crucial for enhancing the resilience of industrial operations.

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Using a unified cybersecure platform to support comprehensive industry 4.0 connectivity

By Jeff Shepard
Contributed By DigiKey's North American Editors

A unified and cybersecure Industry 4.0 deployment requires multiple levels of connectivity. The first level of connectivity starts on the factory floor with the control of individual devices, including machines and robots, sensors, and traceability solutions. The second level of connectivity extends to mid-level automation with human-machine interfaces (HMIs) and machine-to-machine communication. The highest level of connectivity links with the company's information technology (IT) and operations technology (OT) systems to coordinate overall logistics and maximize efficiency and productivity.

Satisfying diverse connectivity needs requires an automation platform that supports multiple open protocols like EtherCAT, Safety over EtherCAT (also called FailSafe over EtherCAT or FSoE), EtherNet Industrial Protocol (EtherNet/IP), common industrial protocol (CIP) Safety, and IO-Link for connecting machines, machine controls, sensors, vision systems, safety devices, and HMIs.

The Open Platform Communications Unified Architecture (OPC UA) protocol is needed to support data consolidation, sharing, and secure visibility across the enterprise. Finally, a software platform is required that integrates configuration, programming, simulation, and monitoring with an intuitive interface, allowing engineers to manage process control, motion, safety, vision, and robotics in one system.

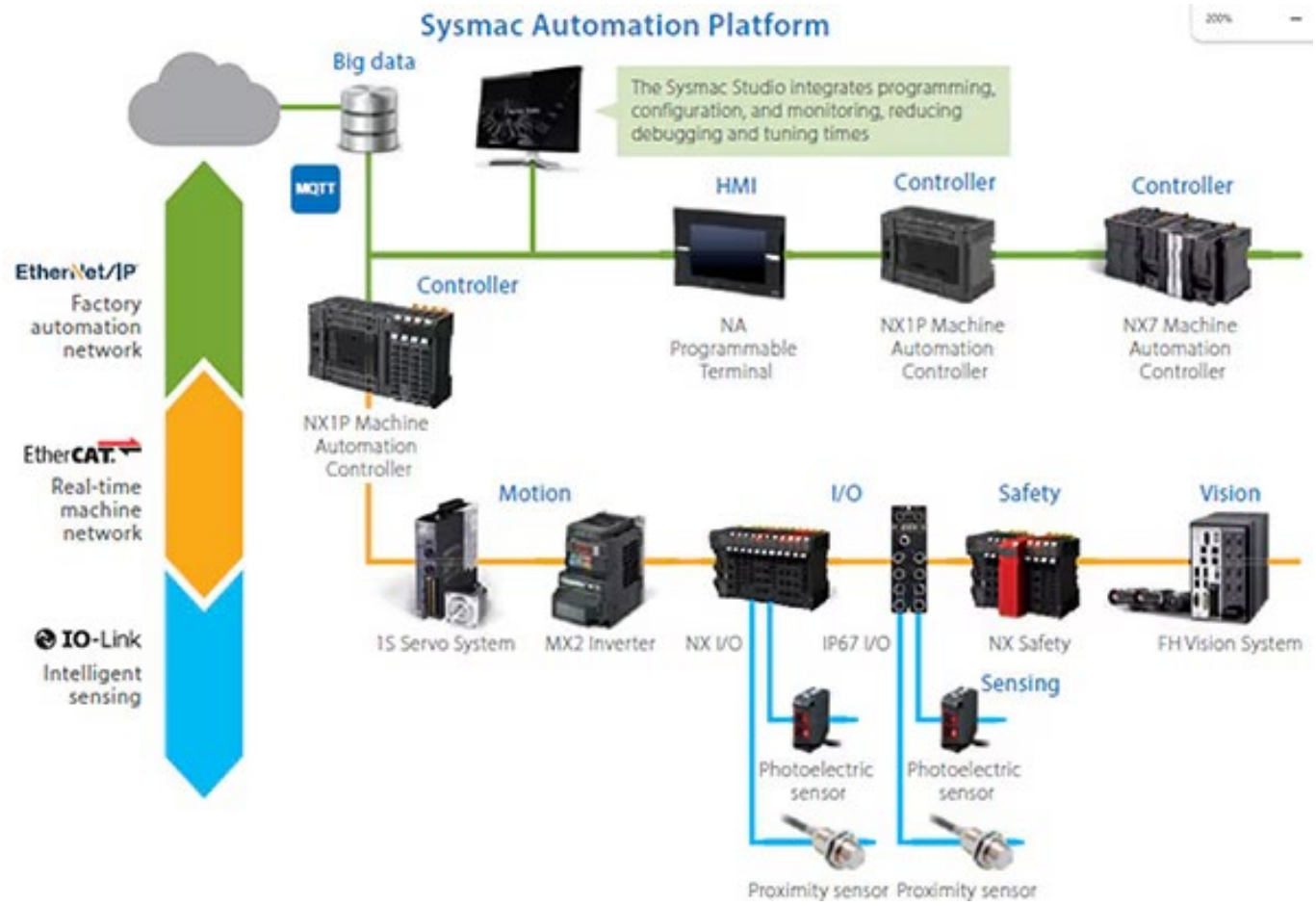


Figure 1: Levels of connectivity used in Industry 4.0 automation systems from IO-Link on the factory floor to MQTT and OPC UA reaching higher-level enterprise systems and the cloud. (Image source: Omron Automation)

This article first presents a diagram of the levels of connectivity in Industry 4.0 automation systems (Figure 1). It then uses product examples from Omron Automation to move through the various levels of automation from IO-Link and intelligent sensing to EtherCAT for vision systems and real-time machine control, EtherNet/IP for factory automation networks, and how OPC UA links the factory to higher-level enterprise networks and the cloud using Message Queuing Telemetry Transport (MQTT) and other standard protocols. It closes with a look at how Omron's Sysmac Studio software ties it together.

Safety, sensors, and servos

At the automation network level closest to the factory floor, sensors, safety controllers, motor drives, and servos are found and have specific connectivity requirements. IO-Link supports intelligent sensing, and EtherCAT links the various motion, I/O, safety, and vision subsystems into a real-time machine network.

I/O units

It takes a wide range of I/O units to support the diversity of sensors in Industry 4.0 factories. Omron's Sysmac NX I/O Units include over 120 models and support a wide range of protocols, including IO-Link for connecting to sensors and EtherCAT and EtherNet/IP for linking with motion, safety, vision, and other controllers. These I/O units also support FSoE and CIP Safety protocols.

Safety controllers

Safety is a crucial consideration when working with factory automation. Omron offers the NX Integrated Safety Controllers that support robust safety systems that meet PLe according to EN 13849-1 and SIL3 according to IEC 61508, including FSoE connectivity. In addition, EtherNet/IP coupler units like the NX-EIC202 can link NX Integrated Safety Controllers with an EtherNet/IP multivendor network, the NX-series I/O Units, and other safety units.

The safety CPU can control up to 128 safety I/O units. The safety units can be used with any combination of standard NX I/O units. Further increasing deployment speed and flexibility, safety programs can be standardized and reused efficiently using program organization units (POUs) defined in IEC 61131 for design and operation.

AI-based vision

Artificial intelligence (AI) based automated vision systems can boost productivity across a wide array of Industry 4.0 applications like robot guidance, code reading and verification, color inspection, counting, defect identification, optical character recognition (OCR), and optical character verification (OCV), and presence/absence detection.

Developing and deploying AI-based vision systems can be a complex and time-consuming activity. Omron's FH series includes the hardware and software needed to implement various AI-based vision applications quickly.

For example, the model FH-2050 can support two cameras. Additionally, like other models in the FH series, it boasts a wide range of connectivity options, including EtherCAT, EtherNet/IP, Ethernet TCP/IP, PROFINET, serial RS-232C, and universal serial bus (USB), enabling it to fit into many locations in Industry 4.0 factories seamlessly.

In the case of mass customization, a hallmark of Industry 4.0 production lines, automated visual inspection can be challenging to implement. Until recently, experienced human inspectors were required to identify product defects. Today, AI has reached a level of capability where it can recognize object features and defects, ranging from blemishes to scratches, as well as human inspectors. In addition, AI can include machine learning to support continuous improvement and adaptation to new requirements.

Servos

Servos and drives are an integral part of Industry 4.0 factories. Omron's 1S servo technology supports units from 50 W to 15 kW. For example, model R88D-1SN15H-ECT is a 1.5 kW servo drive rated for 200 to 240 Vac single and three-phase input power. It's compatible with the R88M-1L1K530T-BS2 servo, rated for 1.5 kW and 3,000 revolutions per minute (rpm) with 4.77 Newton-meters (Nm) of torque. Like all 1S servos, this unit features:

- High-resolution multi-turn 23-bit encoder
- Direct motor brake control with an embedded relay
- Built-in safety functions
  - Hardwired safe torque off that meets PLe according to EN ISO 13849-1 and SIL3 according to IEC 61508

- FSoE safe torque off that meets PLd according to EN ISO 13849-1 and SIL2 according to IEC 61508

Both the hardwired and FSoE safe torque off meet EN61800-5-2(STO). A hardwired solution can bring the line to a standstill by cutting main power. FSoE supports more nuanced responses and can send a Safe Operating Stop command, only slowing the motors in the affected area. FSoE can also send a Safe Stop command, stopping the motors when needed.

Machine controllers

Machine controllers like the NX1P2 series from Omron can fulfill two functions. They can be used to directly control various servos and other machines on the EtherCAT level of real-time machine control, and they can provide a link up to the EtherNet/IP factory automation level.

These controllers support integrated sequence and motion control and connect to up to eight controlled axes using EtherCAT (Figure 2). They also feature EtherCAT control network support and EtherNet/IP connectivity for linking to factory automation controllers. They have slots for two option boards providing expanded connectivity, including serial communications and analog I/Os. These controllers fully conform with IEC 61131-3 programming standards to simplify and speed commissioning.

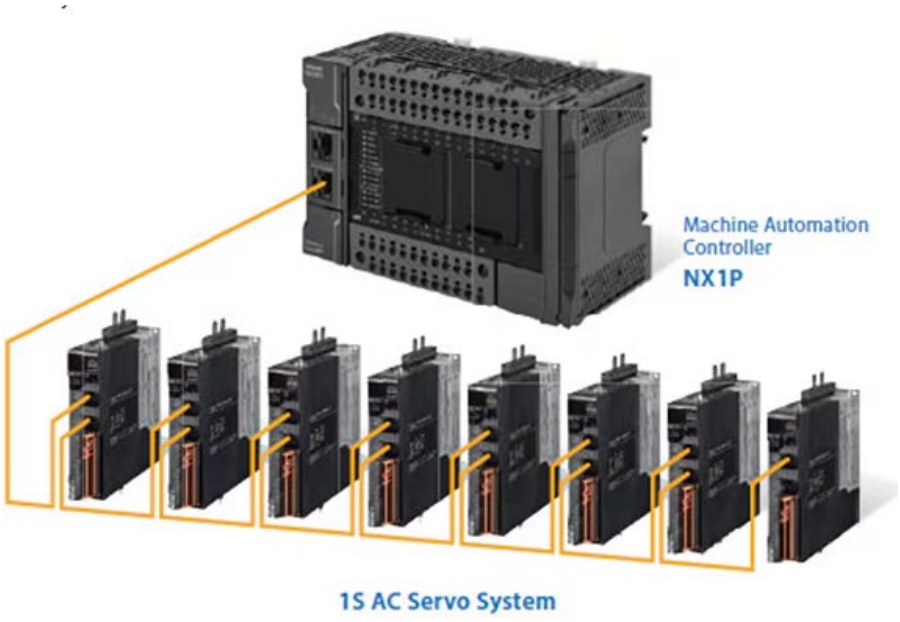


Figure 2: NX1P controllers can use EtherCAT connectivity to support up to eight axes of motion, like eight 1S AC servo drives. (Image source: Omron Automation)

Omron's NX1P is an essential all-in-one controller that can manage advanced motion, vision, safety I/O, networking, and IoT connectivity. For more complex machine control applications that can benefit from up to 254 CIP safety connections, up to 62 axes of motion, 256 EtherCAT nodes, 1 Gbps EtherNet/IP ports, and OPC UA, network designers can turn to the Sysmac NX502 controllers.

Advanced machine control

The NX502 controllers are suited for use at the EtherCAT and EtherNet/IP network levels, and they include MQTT, OPC UA, and structured query language (SQL) capability for connecting to the company's IT and OT systems and the cloud.

NX502 controllers have slots for up to four EtherNet/IP (EIP) expansion cards with data Transfer rates up to 1 Gigabit per second (Gbps). Each EIP card creates a

subnet, increasing the number of machines that can be controlled and segmenting the machine-level network from the database network and the factory-level network. Network segmentation also reduced cyber-attack risk by limiting access to the different subnets.

These controllers sit at the apex of the network architecture and support a variety of control, information, and safety functions, including (Figure 3):

- Control
  - Up to 32 axes of motion with 250 µs cycle time
  - Servo control with up to 64 axes
  - 80 MB program storage
  - 260 MB variable storage
- Information
  - OPC UA provides secure connectivity for manufacturing execution systems (MES) and enterprise resource planning (ERP) systems
  - SQL functionality supports fast and reliable direct access to databases and communication of production data
  - MQTT supports direct connection to the cloud and secure data collection
  - Up to 10 x 1 Gbps EtherNet/IP ports for high-speed, high-capacity communications with expansion unit
- Safety
  - Up to 8 CIP Safety networks for network modularization and safety control across production lines
  - Up to 254 FSoE connections for high speed and high-reliability safety in large production lines

Figure 3: NX502 controllers (center) can combine all the functions needed to implement Industry 4.0 automation networks. (Image source: Omron Automation)

Human-machine interface

The NA series advanced programmable terminal/HMI provides operators and network engineers reliable and convenient access to Sysmac automation devices and networks. These wide-screen terminals have two Ethernet ports supporting simultaneous access to a control device and maintenance activities. They are programmable, making it simple to implement custom user interfaces.

These HMIs are available in sizes of 7”, 9”, 12”, and 15” to fit a wide range of application needs. The 12” and 15” models have 1,280 x 800 pixels, while the 7” and 9” models have 800 x 480 pixels. Operators wearing gloves can use their resistive touch screen, which can be made waterproof if needed. The function keys can be programmed to simplify user interactions (Figure 4).

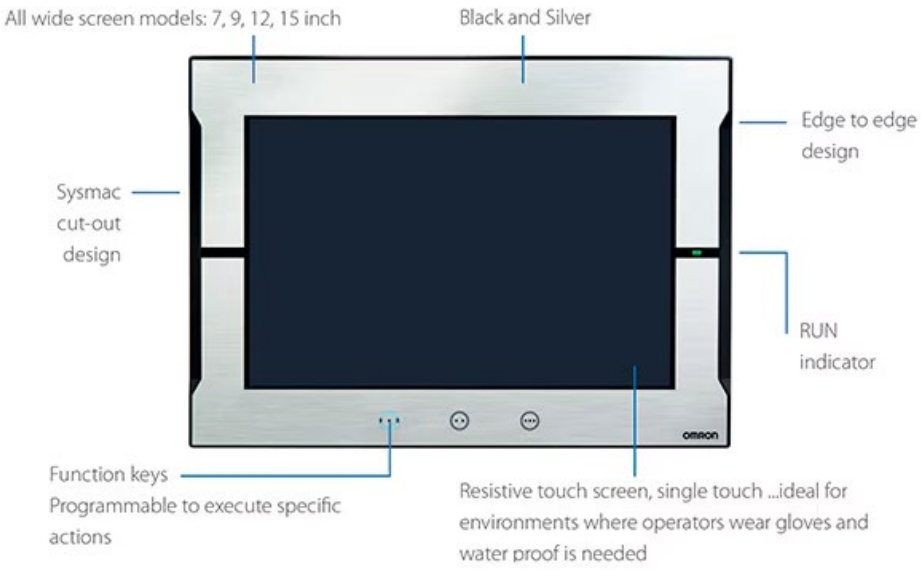


Figure 4: These programmable HMIs feature two Ethernet ports and can be made waterproof. (Image source: Omron Automation)

Cybersecure software

Sysmac Studio includes comprehensive and cybersecure software tools for designing, verifying, and operating industrial networks. It enables network designers to integrate logic, motion and drives, robotics, safety, visualization, sensing, and information technologies. Some key capabilities during design and verification include (Figure 5):

Figure 5: Sysmac Studio software provides comprehensive support for designing, verifying, and operating Industry 4.0 automation networks. (Image source: Omron Automation)

- **Automatic programming** based on truth tables with input, output, and stop conditions of safety devices
- **User-defined function block** (FB) to support help files to describe input and output conditions and program functionality; can have different security levels to protect them from unauthorized changes
- **Offline simulation** performed on a separate computer without connecting actual hardware
- **Online functional** testing of integrated safety functions; test results can be output as a report

Sysmac Studio software also supports ongoing operations and maintenance. Downtime is minimized using an SD memory card containing logging settings and safety data logging. This data enables network technicians to efficiently determine the cause of an unexpected system stoppage and take appropriate preventative and corrective measures.

The safety unit restores an automatic configuration restart to reduce maintenance:

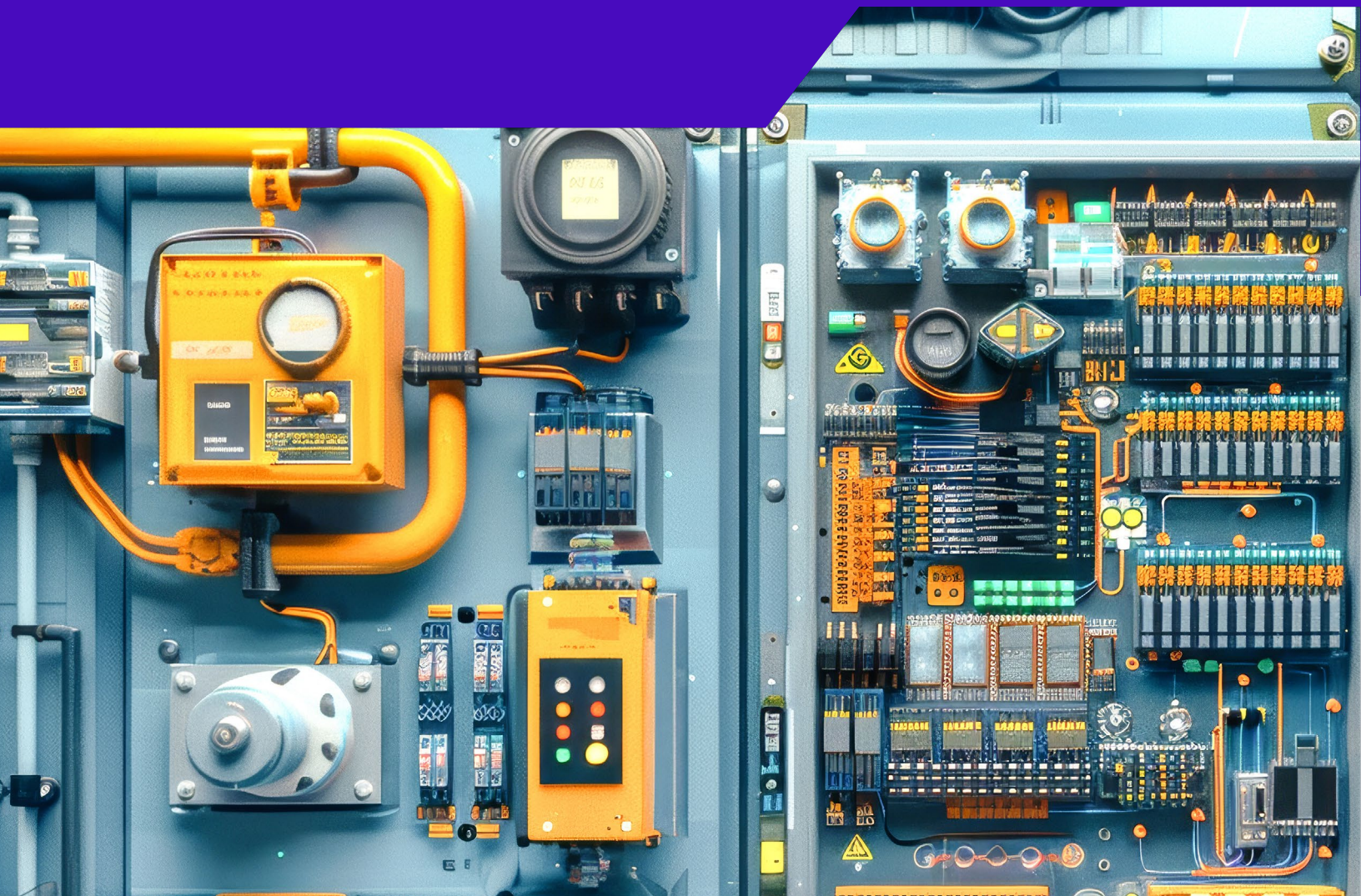
- Restore programs and settings are stored on an SD card in the safety unit. When a safety controller unit is replaced, the stored programs and settings can be quickly copied to the new unit.
- When a safety I/O unit is replaced, automatic configuration restart automatically downloads the setting data into the new unit.

Conclusion

Sysmac automation devices and software from Omron support the complete connectivity needs for Industry 4.0 factory automation networks. Their capabilities extend from IO-Link for connecting to sensors and EtherCAT and EtherNet/IP for linking with motion, safety, vision, and other controllers. They include support for FSoE and CIP Safety protocols. Powerful controllers and software that use OPC UA, SQL, and MQTT are available to link the factory network to the company's IT and OT systems as well as the cloud.

How smart motor controls can maximize resilience and uptime

By Jeff Shepard
Contributed By DigiKey's North American Editors



Smart motor controls are needed that can maximize resilience and uptime of machinery in the next generation of Industry 4.0 manufacturing, metals and basic materials processing, mineral extraction and mining, and critical infrastructure like drinking water and wastewater plants.

The motor controls in these applications must be able to control and protect motors between 75 horsepower (HP) and 700 HP. Comprehensive protection, including overload protection, ground fault protection, and phase imbalance protection, is needed to support resilient operation.

They should also include self-diagnostics for contact wear and coil over/under voltage detection with visible indicators to support predictive maintenance and have modular designs for faster servicing to maximize uptime. Compliance with National Electrical Code (NEC), UL, and International Electrotechnical Commission (IEC) short circuit current rating (SCCR) is needed to ensure electrical equipment can withstand high currents without damage and that it's safe.

These motor controls must also comply with IEC 60947-4-1, which covers the safety of electromechanical contactors and starters, including motor protective switching devices (MPSD), instantaneous-only motor protective switching devices (IMPSD), and actuators of contactor relays.

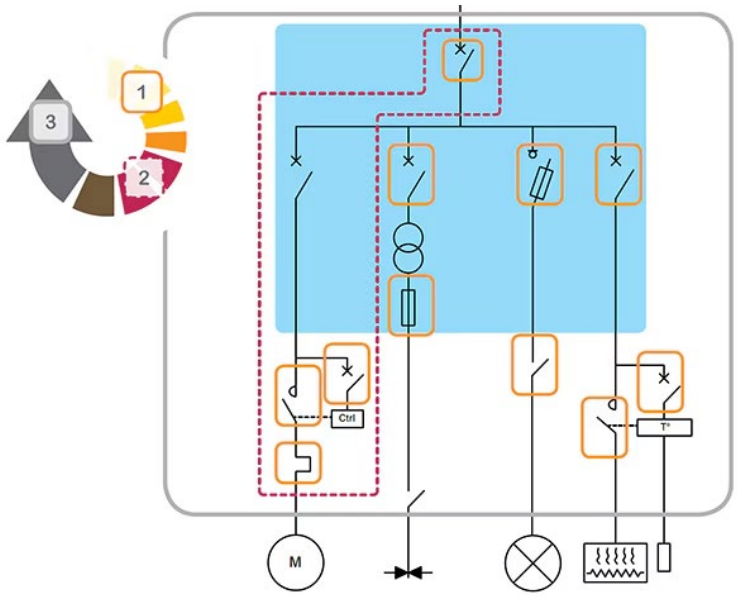


Figure 1: SCCR calculations begin with individual component ratings (yellow boxes), move up to determine the SCCR of branch circuits (red dashed box), and then consider the SCCR needs of the completed control panel (grey rectangle). (Image source: Schneider Electric)

This article begins with an overview of SCCR requirements. It then takes a deep dive into a recently developed family of smart motor controls from Schneider Electric, including modular contactors and overload relays detailing the operation of the protective functions and how self-diagnostics is implemented.

It looks at how those overload relays meet the requirements of IEC 60947-4-1 and presents how the modular design speeds preventative maintenance. It closes by looking at how two contactors can be used to assemble a reversing assembly, enabling bidirectional control of AC motors.

The SCCR is an essential characteristic when specifying a control panel that contributes to overall dependability. It's used when sizing power components like contractors and conductors. IEC 60947-4-1 details three phases for calculating the SCCR (Figure 1):

1. Identify the SCCR of each protection and/or control component and each block and element in the distribution system.

2. Determine the SCCR of each branch circuit. Based on the values of the components in the circuit.
3. Determine the SCCR of the complete control panel. Based on the values of the circuits.

TeSys Giga Contactors

TeSys Giga contactors are available with ratings from 115 to 900 amps (A) in both 3-pole (3P) and 4-pole (4P) configurations. They have SCCRs rated up to 100 kiloamps (kA) and 480 volts (V), with the specifics for various protection devices and ratings listed in a table on the side of the contactor. Additionally, the 4P contactors show the AC-3 and HP motor ratings. These contactors are available for two load categories:

- AC-1 – This applies to AC loads where the power factor is more than 0.95. These are primarily non-inductive or slightly inductive loads, such as resistive loads. Breaking the arc results in minimal arcing and contact wear.
- AC-3 – This applies to squirrel cage motors with breaking during normal running of the motor. On closing, there's an inrush current of up to seven times the rated full load current of the motor. On opening, the contactor breaks the motor's rated full load current.

TeSys Giga contactors can be supplied by an alternating current (AC) or direct current (DC) control voltage and have built-in surge suppressors. There are two versions of contactors, standard and advanced. Standard contactors are designed for general usage. Examples include:

- LC1G1154LSEN, 4P for AC-1 loads. Rated for 250 A with a 200-500 V AC/DC wide-band coil
- LC1G225KUEN, 3P for AC-3 loads. Rated for 225 A with a 100-250 V AC/DC coil

Advanced TeSys Giga contactors have additional features like a greater selection of coil voltages, lower coil power consumption, a programmable logic controller (PLC) input, and a cable design that enables maintenance without removing cables or busbar connections.

Advanced models are also compatible with the optional Remote Wear Diagnosis (RWD) module discussed in the next section. Examples of advanced contactors include:

- LC1G115BEEA, 3P for AC-3 loads. Rated for 115 A with a 24-48 V AC/DC coil
- LC1G800EHEA 3P for AC-3 loads. Rated for 800 A with a 48-130 V AC/DC coil

All TeSys Giga contactors include a Diagnosis LED on the front panel for quickly evaluating fault conditions (Figure 4).

Figure 2: Typical TeSys Giga contactor showing the Diagnosis LED in the top center of the unit. (Image source: DigiKey)

TeSys Giga contactors have several integrated diagnostic functions to improve reliability and support preventative maintenance, including:

Contact Wear Diagnosis and RWD

Contacts experience wear every time they break the current in the power circuit. A contact failure results in loss of motor control. The contact wear algorithm in TeSys

Giga controllers continuously calculates the remaining service life of the contacts. When the remaining life is below 15%, an alert is issued, enabling preventative maintenance to be scheduled:

- A local alert is visible on the Diagnosis LED on the front of the contactor.
- An optional RWD module can be used with advanced contactors.

Control Voltage Diagnosis

The control voltage monitors for undervoltage and overvoltage conditions. The diagnosis indication is remotely available on units with part numbers ending in LSEMC using an optional remote device management (RDM) module. An undervoltage is defined as a supply voltage below 80% of the minimum specification, and an overvoltage is defined as greater than 110% of maximum.

Internal Functioning Diagnosis

Continuous blinking of the Diagnosis LED indicates any internal malfunction of the control circuitry.

Motor protective switching devices

Smart motor controls like TeSys Giga contactors are an important part of Industry 4.0 installations. The use of MPSDs is also an important consideration to ensure maximum productivity and availability.

In IEC 60947-4-1, MPSD refers to a device designed with a delay to protect a motor from overload conditions. A second type of device, an IMPSD, is a specific type of MPSD that trips immediately upon detecting an overload. IMPSDs are not usually associated with AC motor protection.

Depending on the application, motor starting can take a few seconds or several tens of seconds. The MPSD must be specified to meet the application requirements for safety while avoiding nuisance tripping.

To satisfy specific application needs, IEC 60947-4-1 defines several classes of overload relays. The trip class indicates the maximum amount of time it takes for the relay to open when there is an overload.

	1.05 x Ir	1.2 x Ir	1.5 x Ir	7.2 x Ir
Class	Time to trip from a cold start			
10A	>2 hrs	<2 hrs	<2 min	2 s < to < 10 s
20	>2 hrs	<2 hrs	<2 min	2 s < to < 10 s
20	>2 hrs	<2 hrs	<2 min	2 s < to < 20 s
30	>2 hrs	<2 hrs	<2 min	2 s < to < 30 s

Table 1: Examples of thermal overload relay classes based on rated current (Ir). (Table source: Schneider Electric)

There are also differences between North American and IEC trip classes. For example, class 10 is a North American trip class that trips the overload within 4-10 seconds of detecting 600% of the overload current setting. Class 10A is an IEC trip class that trips the overload within 2-10 seconds of detecting 720% of the overload current setting (Table 1).

Trip classes 10A and 10 are suited for normal-duty motors. Class 20 is recommended for heavy-duty motors to avoid nuisance tripping. Class 30 is used with a very long starting motor.

TeSys giga overload relays

TeSys Giga thermal overload relays are highly flexible and designed for use with AC motors. Settings for ground fault protection, phase imbalance protection, and trip class

Figure 3: The front panel of TeSys Giga overload relays includes status LEDs and protection adjustments. (Image source: DigiKey)

(5, 10, 20, and 30) are configurable on the front panel. The front panel also includes alarm and status LEDs. They have wide adjustable thermal overload protection ranges that enable four overlapping models to handle applications from 28 A to 630 A (Figure 3):

- LR9G115, adjustable from 28 to 115 A
- LR9G225, adjustable from 57 to 225 A
- LR9G500, adjustable from 125 to 500 A
- LR9G630, adjustable from 160 to 630 A

Thermal overloads

Thermal overload protection is used with single-phase and three-phase asynchronous motors. The current level for thermal overload protection can be adjusted based on the model of the overload relay being employed. In addition, the trip class and associated delay are adjustable. Thermal overload protection can be set for automatic or manual resetting.

Phase loss

Phase loss protection is used to protect three-phase asynchronous motors from overheating. The overload relay continuously monitors the current in each phase. When the current value in one of the phases is lower than 0.1 of the rated current (Ir), and the current value in another phase is greater than 0.8 Ir, the overload relay triggers within 4 ±1 seconds. Phase loss protection cannot be disabled and must be reset manually.

Phase imbalances

Phase imbalances cause overheating of an asynchronous motor. Common causes include:

- Long main supply line
- Defective contact on the incomer switch
- Imbalanced network

When the imbalance ratio exceeds 40%, the overload relay triggers in 5 ±1 seconds. Phase imbalance protection must be reset manually.

Ground faults

Ground-fault protection is used to protect three-phase asynchronous motors. A ground fault occurs when the insulation on the load circuit becomes ineffective due to vibration, moisture, or other factors. The overload relay monitors the ground current (Ig). When the Ig exceeds more than 10% of Ir, the relay trips in 1 ±0.2 seconds. Ground fault protection must be reset manually.

Modularity

The modular design of TeSys Giga contactors can be especially useful if excessive contact wear is experienced or if an overload or other abnormal operating

conditions damage the controller. Control modules can also be replaced to adapt to different coil voltages, and the switching module can be switched out to replace worn-out poles.

A cable memory function can be implemented with an optional kit to facilitate rapid maintenance. Once installed, the control or switching module can be replaced quickly without removing the cables.

Going in reverse

Reversing contactors are used to change the direction of rotation of AC motors in applications like conveyors, elevators, and packaging lines. They work by reversing the polarity of the connections, causing the motor to rotate in the opposite direction.

A reversing contactor can be made using two mechanically interlocked standard contactors. The interlock prevents the contactors from turning on simultaneously (Figure 6).

For example, the following components can be used to build a reversing contactor rated for 200 HP at 460 V with a 100-250 V AC/DC coil (Figure 6):

- LC1G265KUEN, TeSys Giga motor controller, two required
- DZ2FJ6, contactor lug kit
- LA9G3612, spreaders
- LA9G3761, reverser bars
- LA9G970, mechanical interlock

Summary

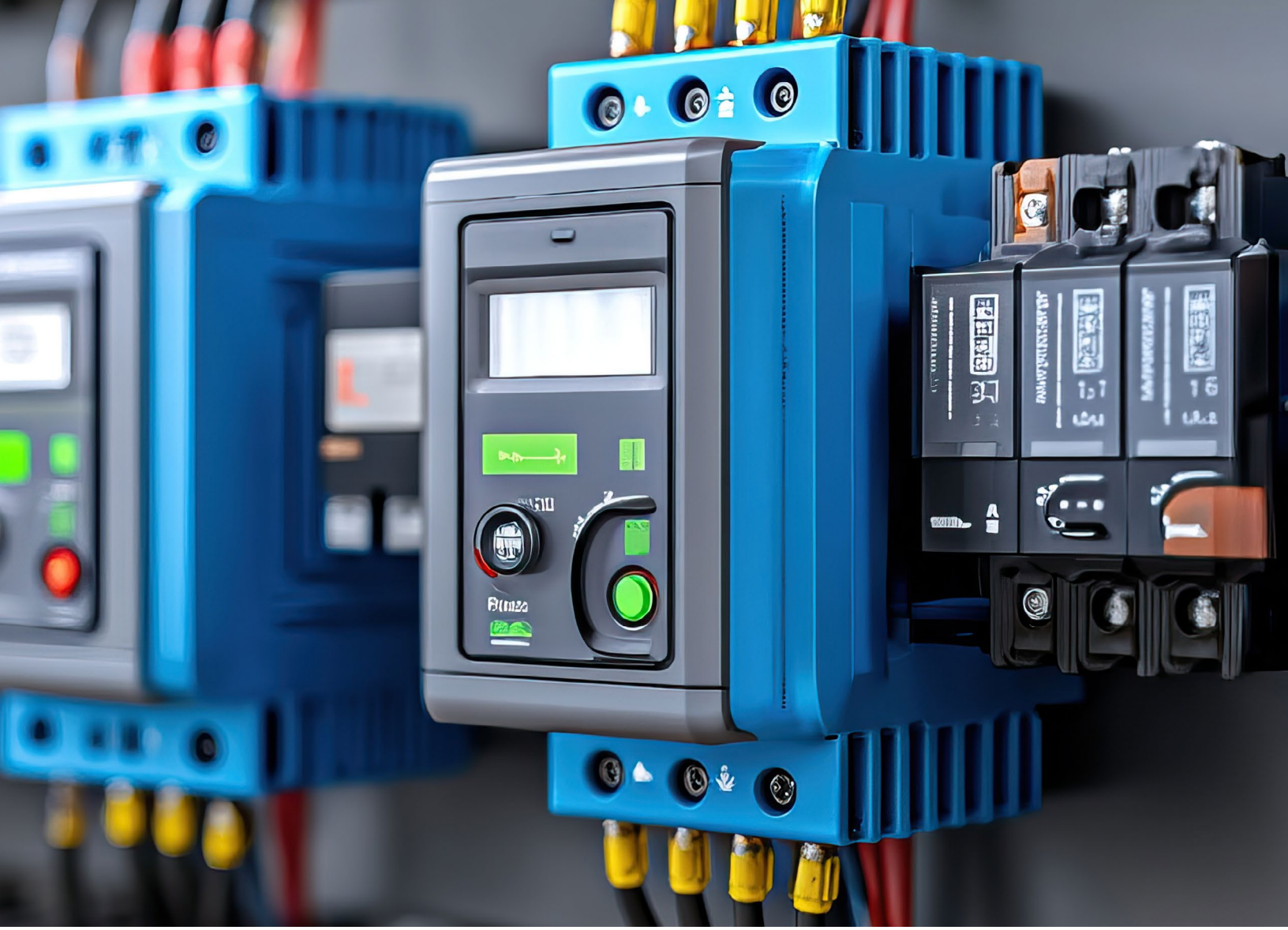
TeSys Giga contactors and overload relays are highly versatile devices that can maximize resilience and uptime in a wide range of applications. The contactors have ratings from 115 to 900 A in 3P and 4P configurations. They have SCCRs up to 100 kA 480 V, and their modular design speeds maintenance.

The programmable overload relays have wide operating current ranges, enabling a small number of devices to satisfy the needs of many applications. Finally, bidirectional motion control can be realized by connecting two TeSys Giga contactors with a mechanical interlock system.

Figure 4: Two TeSys Giga contactors interlocked to form a reversing contactor for AC motors. (Image source: Schneider Electric)

Using temperature controllers and micro PLCs to speed small-scale automation projects

By Jeff Shepard
Contributed By DigiKey's North American Editors



Heat. It's important in many industrial processes like packaging sealing machines, plastic molding operations, solder reflow ovens, semiconductor processing, etc. Each process has specific needs for temperature levels and control precision.

Automation helps achieve maximum productivity and sustainability in Industry 4.0 operations. Small machines and heat processing are no exceptions. But not all circumstances call for large, comprehensive solutions.

Many applications can experience enhanced performance with relatively simple dedicated temperature controllers and small programmable logic controllers (PLCs).

Machine designers can choose from a range of options for simple automation projects, including heater controllers for single- and three-phase power environments, heater controllers with a range of sophisticated control algorithms, and PLCs optimized for small to medium-sized automation environments. Some small machines work in relative isolation, while others can benefit from connectivity to the larger operation.

This article presents a review of power controllers and heater controller options, including hardware and software considerations. It closes with a glance at system integration issues related to sensor technologies for measuring temperature and PLCs optimized for small to medium-sized machines and presents exemplary products from Omron.

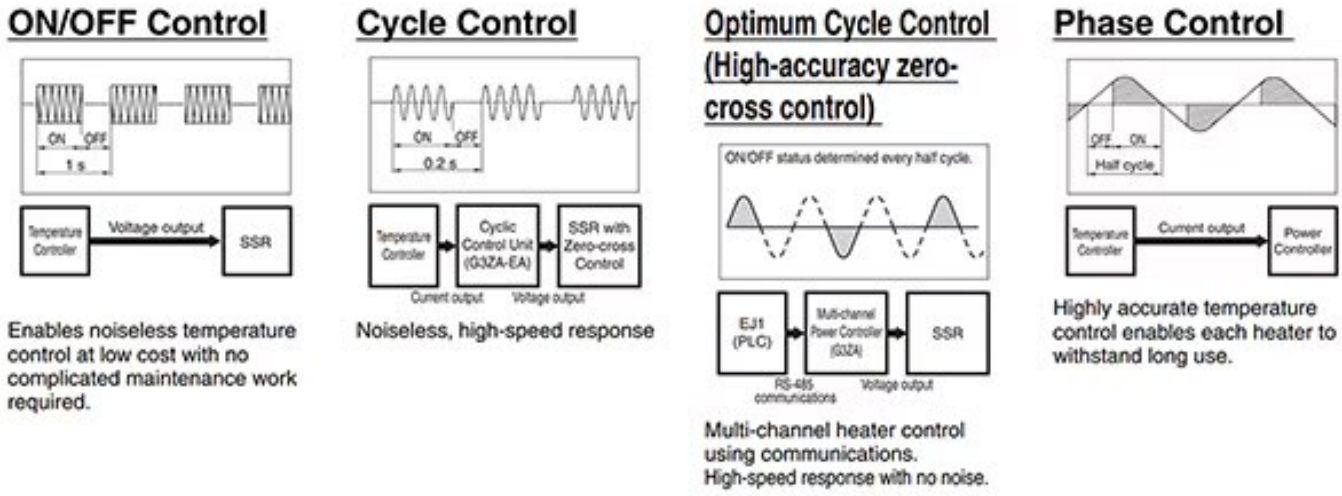


Figure 1: Power switching options for industrial heater control. (Image source: Omron)

From curing materials like thermo-set resins and adhesives to producing food and beverage products, industrial processes often require temperature control to maintain efficiency and ensure quality. Industrial heaters are necessary, but temperature controllers are the key.

There's more than one way to control the temperature of industrial heaters. The system's operating priorities determine the approach selected. Simple voltage control can be used when operating costs are the primary consideration and less precise temperature control is tolerable.

By regulating the voltage powering the heating element, the power consumption of the heater can be controlled, and the heat output can vary. Changes in voltage can be implemented quickly, producing corresponding temperature changes, but with a lag that varies with system design. Reducing the voltage will reduce energy costs and lower the temperature. Still, the reaction time for temperature reductions can be too long for many processes, and it can be difficult to control the temperature precisely.

Beyond basic voltage control

For many applications, basic voltage control is inadequate. In those cases, designers can use on/off control, cycle control, optimum cycle control, or phase control (Figure 1). Each of those techniques presents a different set of performance characteristics:

- Phase control provides the best controllability response with good solution size and cost, plus acceptable noise performance for most applications.
- Cycle control provides good controllability response, solution size and cost, and excellent noise performance. In "optimum" cycle control, the switching status is determined for every half-cycle.
- On/off control using solid state relays (SSRs) provides good controllability response with the smallest solution size, reasonable cost, and excellent noise performance.

Implementing phase control and optimum cycle control

Omron offers designers several options for implementing on/off control, phase control, or optimum cycle control, including the model G3PW-A245EU-S, that's rated for operating voltages from 100 V_{AC} to 240 V_{AC}; other models are available for operation from 400 V_{AC} to 480 V_{AC}.

These controllers include heater burnout detection for increased system uptime. An RS-485 communication port is used to set variables and monitor load current.

The G3PW controllers support total runtime monitoring and are suited for use with constant resistance and variable resistance loads.

Multi-channel power controllers

The G3ZA multi-channel power controller series adds three-phase optimum cycle control to support three-phase heaters. When used with zero-cross SSRs, it supports low-noise power operation. One controller can control up to 8 SSRs. In addition, a soft-start function is available for lamp heaters (Figure 2).

Figure 2: G3ZA multi-channel power controllers support three-phase optimum cycle control. (Image source: Omron)

Three-phase optimum cycle control has been added for three-phase heaters. The model G3ZA-4H203-FLK-UTU is rated for operation from 100 V_{AC} to 240 V_{AC} and includes RS-484 connectivity. Other models are available for operation from 400 V_{AC} to 480 V_{AC}.

Temperature controllers for system integration

Temperature controllers like the EJ1N-TC4A-QQ can connect to power controllers like the G3ZA series of multi-channel controllers. They have inputs for temperature sensors as well as connections for the system PLC. The input unit can handle thermocouples, platinum resistance temperature detectors (RTDs), and analog inputs.

Functionality includes auto-tuning (AT) that can help implement proportional-integral-digital (PID) control. Self-tuning can be used to determine the PID constants using the step response method manually. Up to 16 temperature controllers can be connected using a single DeviceNet communication hub.

Thermo management software

EJ1N temperature controllers can benefit from using the EST2-2C-MV4 thermo support software package. This software enables editing and batch downloading parameters from a personal computer, speeding configuration and commissioning.

It also supports trend monitoring from up to 31 controllers. Parameters that can be monitored include process values (PVs), system values (SVs), manipulated values (MVs), PID parameters, and alarm on/off status.

Supported logic operations include setting inputs from external inputs (event inputs) or temperature status, sending values to external control or auxiliary outputs, and changing the operating state with on/off delays.

Improved PID

PID control can be highly useful for temperature control applications. Power controllers like the G3ZA series of multi-channel controllers with fast-switching SSRs, together with temperature controllers using PID algorithms, can provide the fine-grained control needed to maintain the required temperature tolerances.

Basic PID control involves a tradeoff between rapidly achieving the SV of operation with a measurable amount of overshoot or minimizing overshoot but with a slower ramp-up to the SV. In addition, there's a tradeoff between achieving the SV and responding to disturbances in the actual PV as measured by a sensor. Better response to PV changes is often associated with poor SV ramp-up performance.

To address those performance tradeoffs, Omron has developed an enhanced PID algorithm called 2-PID, or two degrees of freedom PID. The factory PID presets are suited for most heating applications and support responses with minimal overshooting. However, with 2-PID, designers can set the reaction speed to changes in the SV, and the controller automatically tunes the PID algorithm to provide an optimized response to disturbances in PV (Figure 3).

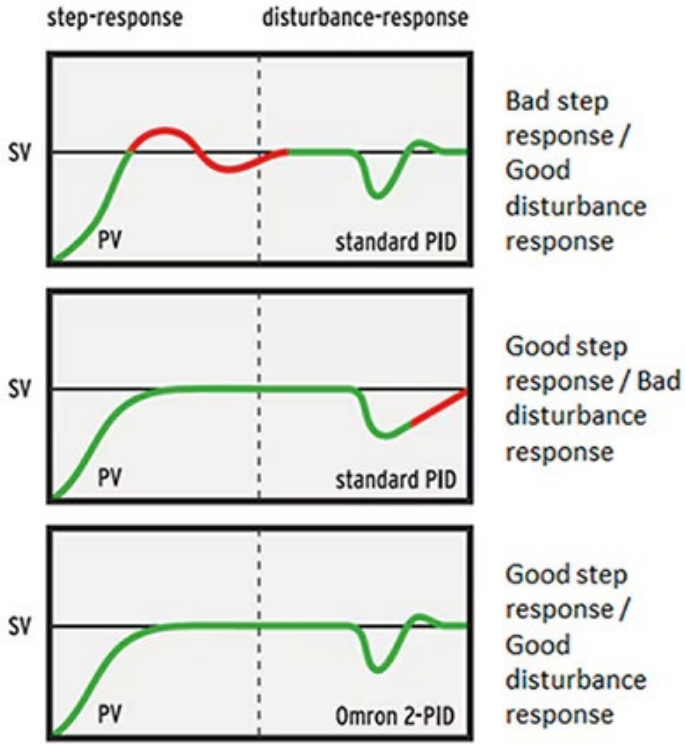


Figure 3: Omron 2-PID temperature control (bottom graph) combines good disturbance response (right side) with good step response (left side). (Image source: Omron)

2-PID control is included in Omron's E5CC temperature controllers, like the E5CC-QX3A5M-003. These controllers can also implement basic on/off control for less demanding applications.

The large white PV display shows the PV and the smaller green SV display shows the desired value (Figure 4). The optional CX-Thermo management software supports fast programming. For simple applications, these controllers can implement timer functions and basic logic operations with the intervention of a PLC.

The RS-485 interface supports Modbus communication or Omron's proprietary CompoWay/F. These controllers accept a variety of inputs, including:

- 12 types of thermocouples
- PT100 or JPt100 RTDs
- 4 to 20 mA or 0 to 20 mA current inputs
- 1 to 5 V, 0 to 5 V, or 0 to 10 V voltage inputs

Figure 4: E5CC temperature controllers clearly display PV and SV values. (Image source: DigiKey)

Adaptive PID for disruption suppression

The NX-TC Adaptive Temperature Controllers take PID control to the next level and can adapt to real-time operating conditions. Adaptive control enables self-optimization of control settings due to process changes. In addition, these controllers include built-in functions for packaging sealing applications and water-cooled plastic extruders. For simple applications, basic on/off control can be implemented.

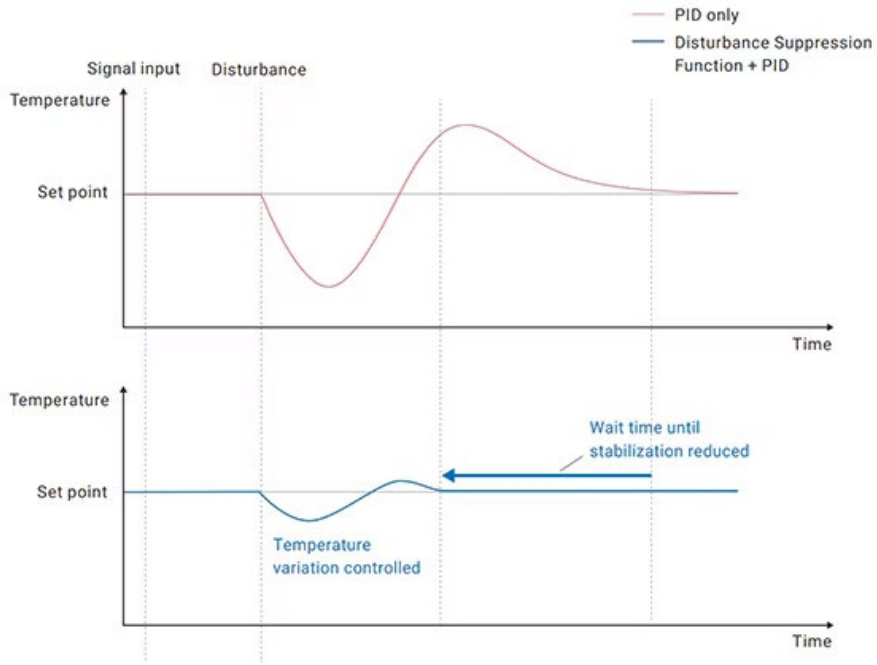


Figure 5: DSF-enhanced PID control can reduce the wait time for temperature stabilization by up to 80 percent. (Image source: Omron)

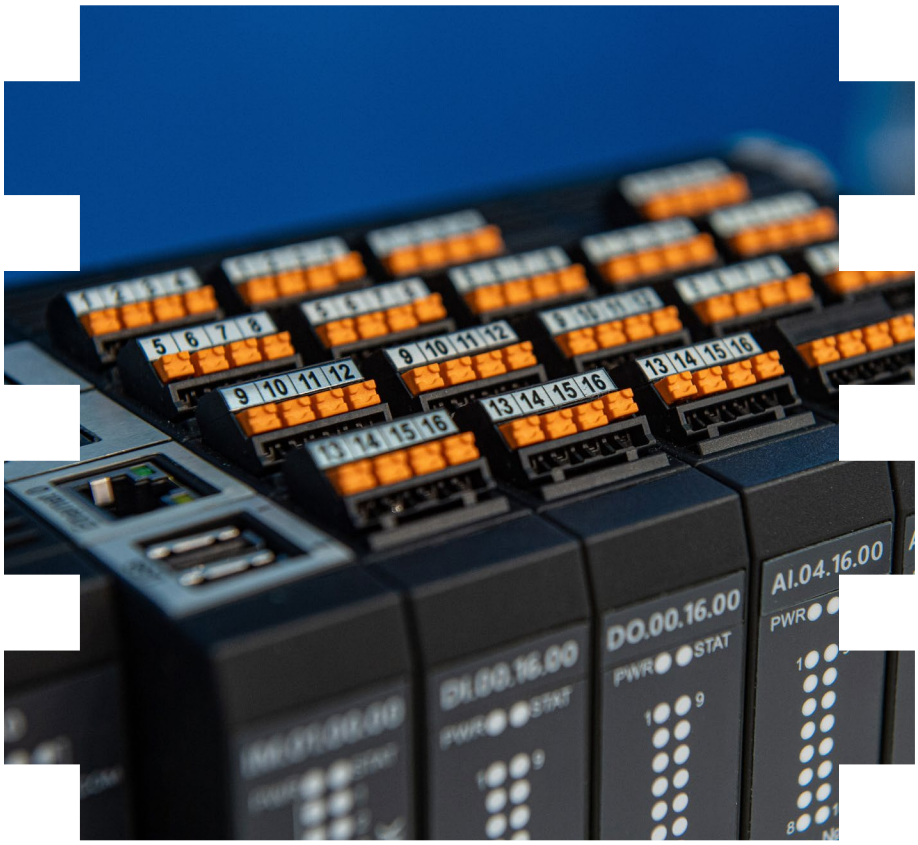
The disturbance suppression function (DSF) works in conjunction with the PID control to suppress temperature drops caused by routine and anticipated disturbances in applications like:

- Deposition equipment where the chamber temperature falls when gas is injected or material is added or removed through an open door
- Wafer probers when current is applied to the wafer, resulting in an increase in temperature
- Molding systems where the mold temperature drops when resin is injected

DSF automatically suppresses positive and negative temperature excursions caused by foreseeable events. DSF is initiated by trigger signals prior to the disturbance and adds to or subtracts from the MV. This autotuning adjusts the feed forward (FF) MV, FF operation time, and FF waiting time and can shorten the time for achieving temperature stabilization by up to 80 percent (Figure 5).

NX-TC units like the 2-channel NX-TC2405 designed for driving SSRs are optimized for scalability. Designers can use Omron's Sysmac studio for programming control of multiple heating circuits or locations when implementing multistage heating/cooling processes.

In addition to DSF PID, these controllers support on/off control and include a heater burnout error detection function. They include EtherNet/IP and EtherCAT for network connectivity and can accept a variety of thermocouple or RTD sensor inputs.



You can't optimize what you don't measure

Power-switching designs, temperature controllers, and thermo management software can't deliver optimal performance in an information vacuum. Temperature sensors provide the operational data that enables controllers and software to do their jobs. There's a wide array of temperature sensor technologies available to designers, including:

- Thermistors function as temperature-sensitive resistors. They typically have repeatability and stability of about ±0.1°C. Model E52-THE5A-0/100C has an operating temperature range of -50°C to 300°C.
- A Type K temperature sensor is a thermocouple containing chromel and alumel conductors. They can be configured as immersion sensors, surface sensors, or other styles. Model E52-CA1GTY 2M has an operating temperature range of 0°C to 300°C.
- RTD sensors are highly accurate, and their immunity to electrical noise makes them suitable for harsh industrial environments. The E52-P6DY 1M platinum pt100 RTD sensor is rated for operation from -50°C to 250°C.
- Non-contact infrared (IR) sensors like the ES1-LW100-N can measure temperatures of a 35 mm diameter target area at a distance of 1,000 mm. It's specified for temperatures up to 1,000°C.

Tying it together into a system

Designers of small- to medium-sized machines with up to 320 I/

Os can turn to CPE2 Series PLCs from Omron. The communication capabilities of these small PLCs support machine-to-machine (M2M) data transfers and integration into the Industrial Internet of Things (IIoT).

With an operating temperature range of -20°C to +60°C, CPE2 PLCs are suited for various industrial applications like packaging and sealing machines, filling and capping machines, metal or plastic machining tools, plastic molding machines, and small part assembly. Model CP2E-N30DR-D has 18 inputs and 12 outputs and can operate from 100 to 240 V_{AC} or 24 V_{DC} power. It can be paired with the NB7W-TW01B 7" color touchscreen HMI for a complete system solution (Figure 6).

Figure 6: Omron CP2E-N30DR-D controller and NB7W-TW01B 7" color touchscreen HMI. (Image source: Omron)

Conclusion

Managing heat is an essential aspect of many industrial processes. That requires selecting and integrating power controllers and heater controllers with optimized algorithms. Temperature sensors are another important piece of the heat management puzzle. Finally, designers can turn to small PLCs to support M2M communication and integration into the IIoT.

How the simple DIN rail solves for modularity, flexibility, & convenience in industrial systems

By Bill Schweber
Contributed By DigiKey's North American Editors

While engineers often use a standard 19 inch rack enclosure for their larger, multi-instrument test installations, this configuration is often not a good fit for industrial and laboratory situations. Instead, an arrangement is needed that can handle units of very different sizes, form factors, and interconnections; provide full and easy access from one side (the front); enable sufficient cooling and filtering for the often hot and dusty environment; support neat cable dressing with full labeling; and provide for physical protection and user safety where needed.

An alternative that meets these requirements and is better suited to the diverse needs of industrial installations is the DIN rail mounting system standard. This is a very widely used arrangement for mounting, accessing, and protecting the broad array, form factor, and size of electronic units needed by the application. It supports modules ranging from basic power supplies through advanced sensor interfaces to programmable logic controllers (PLCs), with thousands of DIN-compatible products available from hundreds of vendors. It is designed for flexibility and ease of installation, connection, and access in industrial and other installations.

This article looks at this worldwide metric-based mounting system, and using sample solutions, shows how designers can take advantage of its attributes and versatility.

Basics of the DIN rail

Exactly what is the “DIN rail”? It’s a mounting rail for electronic modules that can be used for power supplies as well as many other functions—such as circuit breakers, programmable logic controllers, proportional-integral-derivative (PID) controllers, loop transmitters and receivers, motor drives, relays, and metering units, to cite a few—all of which are available with DIN rail mounting capability (Figure 1).

The acronym "DIN" derives from the specifications published by Germany's DIN—Deutsches Institut für Normung, or German Institute of Standards—which have since been adopted as European (EN) and international (IEC) standards. The DIN rail standard was initiated in the late 1950s and the same standard has also been adopted by the North American Electrical Manufacturers Association (NEMA).

DIN rails are made from cold rolled carbon steel sheet, aluminum, or polycarbonate, with various plating and finishes for corrosion resistance where needed. Different materials also have different short-circuit and fault current ratings, a consideration in some settings.

Figure 1: The DIN rail handles a diverse array of module sizes and functions, including power supplies, transducer I/O, and communications interfaces at low to high point counts; it is well suited to a neat, organized, and labeled cable arrangement and dressing. (Image source: VPEL)

The DIN rail is widely used as an open standard mounting arrangement. Users of this rail are not committed or tied to any single vendor or group, as hundreds of vendors offer thousands of DIN rail products.

There are three standard DIN rail configurations, with the most widely used by far being the 35 millimeter (mm) wide IEC/EN 60715 version, commonly called the "top hat" rail profile (Figure 2). It is also called the TS35 rail in the United States, although the DIN name is used more often. The predecessor of the "top hat" version is the asymmetric G profile, generally used to hold heavier, higher power components; there is also a C profile.

Originally designated as DIN EN 50022, and subsequently standardized as IEC IEC/EN 60715, the standard calls out both 7.5 mm and 15 mm deep versions. The modules that the rail supports are mounted side by side in any arrangement or configuration that the user prefers for the application; users are unrestricted and can put the power supply at the left, right, or center to supply the loads, doing whatever works best in the situation.

DIN rails are available in standard lengths such as one

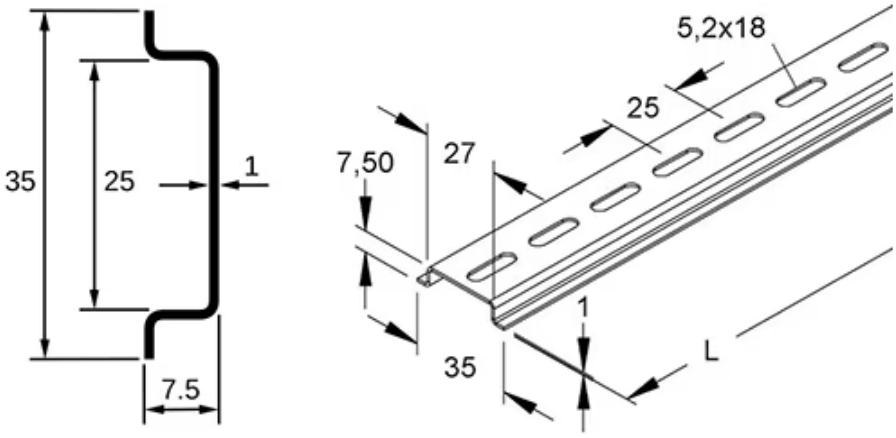


Figure 2: The basic profile of the EN 60715 7.5 mm DIN rail is shown on the left. More detailed dimensions of the "top hat" rail as well as standard panel attachment perforations are shown on the right. (Image sources: Wikipedia (left), elektrotools.de (right))

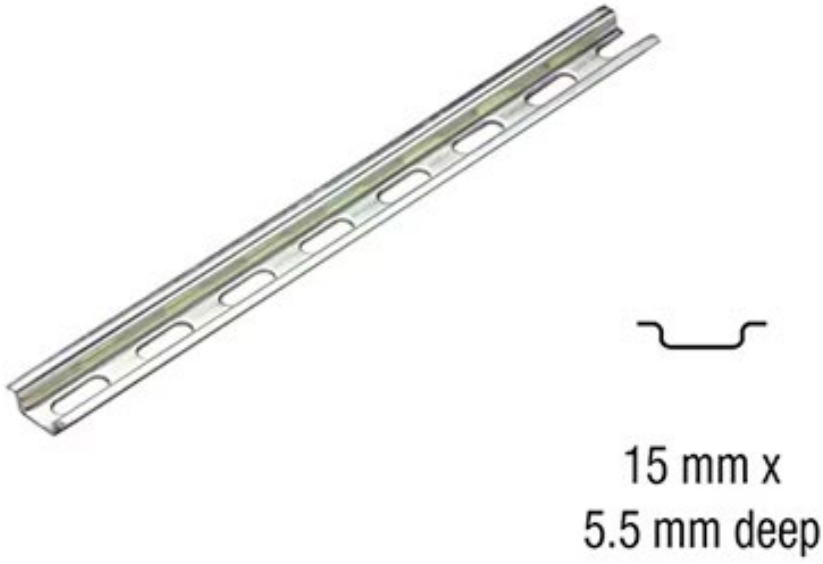


Figure 3: The CA601/S DIN rail from Altech Corporation is available in a wide range of lengths and material options. (Image source: Altech Corporation)

and two meters or can be custom cut to any desired length which is useful for unique projects. The standard also defines for, but does not mandate, standard cutout slots (called perforations) for ease of attachment to a panel. For example, Altech Corporation offers its CA601/S "top hat" rail measuring 15 mm deep (Figure 3). The rail is available in zinc plated steel, stainless steel, and aluminum in lengths of one and two meters, as well as custom lengths.

The rail plus its modules are usually mounted in a rack or equipment cabinet for physical integrity and safety. However, it can also be mounted to a wall or other horizontal surface if it makes more sense in a specific application for visibility and physical access. Vendors also offer a wide array of interconnection terminal blocks, brackets, clips, and other items that facilitate DIN rail use. Also, if perforations are not required, there are options available without them.

Note that the DIN rail is just that: a mounting rail and not an interconnection bus, although the rail may provide a chassis grounding connection. The various units mounted via the rail are then interconnected with discrete cables. While this may seem to be less convenient and more work than a standard "plug in the cards" backplane bus, it is actually a benefit in many industrial applications.

This is because there is no bus to limit or define the voltage, current, type (AC or DC), or total amount of power that can be supplied to the various modules. Further, a defined bus—which has its well-known benefits in embedded systems—would constrain the type and number of highly diverse data channels needed, such as having dozens of analog 4-20 milliamp (mA) loops together with Ethernet data paths, to cite two "extremes" of signal speed and type.

The DIN rail has been especially beneficial for power supplies with their wide array of voltage/current ratings and corresponding size and power ratings differences. It offers flexibility and possibilities for all parties: supply vendors, specifiers, and users. Some power supplies and other modules (such as PLCs) are designed specifically for DIN rail, but many can serve both rail and non-rail applications with the addition of a simple, low-cost mounting kit.

This is an advantage for supply and module vendors, as it allows offering the same unit in multiple end product form factors; doing so reduces the number of distinct units that need to be built and stocked, thus simplifying the repair and replacement supply chain and shortening repair and upgrade time.

The DIN rail does not define the I/O cable routing for the modules which it holds. However, DIN rail devices such as PLCs, sensor/actuator interfaces and loops, and other interconnection modules generally have inputs located on the top and outputs on the bottom. Again, since the DIN rail is only a mounting rail, it can accommodate specialized situations where the common arrangement is impractical or undesired.

Available modules: a wide assortment

Every project has a power supply, and DIN rail supplies are available covering AC and DC inputs with outputs that span low, moderate, and high AC and DC voltages at various power levels. For example, the DRC-5V10W1AZ from Delta Electronics is a basic, single output, fully enclosed AC/DC converter delivering 5 volts at up to 1.5 amperes (A) for a total of 7.5 watts from a package measuring 91 x 56 x 18 mm (Figure 4).

This universal input supply operates on voltages ranging from 90 to 264 volts AC, and features Class II, double isolation, so no

earth connection is required. The unit delivers full power up to 55°C without derating over the entire input voltage span. Efficiency is better than 78% with a 115 volt AC input and it includes the full list of protection features including overvoltage, overcurrent, and over-temperature protection.

Figure 4: The DRC-5V10W1AZ from Delta Electronics is a double isolated, low-power AC/DC DIN rail power converter, delivering 7.5 watts from a package measuring 91 x 56 x 18 mm. (Image source: Delta Electronics)

PLCs are widely used in industrial and process control, so there's a wide selection of DIN mountable units on the market. One interesting approach is provided by the CP2E-N14DR-D series (Figure 5) from OMRON Automation and Safety. The CP2E Series Micro Pro is a compact and versatile controller designed for efficient data collection and seamless Machine to Machine (M2M) communication.

Ideal for a wide range of industrial applications, it comes in three models to suit varying control needs: the CP2E-N Network Model with Ethernet connectivity and advanced 4-axis positioning, the CP2E-S Standard Model with axis control capabilities, and the CP2EE Essential Model for basic control tasks.

The CP2E-N model stands out with two built-in Ethernet ports featuring switching functionality, up to three serial ports for open device connectivity, and a four-axis positioning function with linear interpolation.

Figure 5: The CP2E series from Omron Safety and Automation (Image source: OMRON Automation and Safety)

All models offer battery-free operation for reduced maintenance, intuitive programming with function blocks and structured text, and reliable performance in harsh environments with an operating temperature range of -20 to 60 °C. LED indicators on I/O terminals further enhance usability by enabling quick and easy troubleshooting.

Power and dissipation issues

Thermal issues must be assessed when using the DIN rail, especially when using it in cabinets or other enclosures. Since the DIN rail standard does not define a maximum power level or the physical arrangement of multiple power

supplies (if any), it's important to look at both the total heat load and the distribution of the heat sources.

The former can be checked fairly simply by looking at the supply's rating, as the maximum heat generated (watts) cannot exceed that value. Next, the ambient temperature is factored into the analysis. However, the unconstrained arrangement of the various modules on the DIN rail means that a higher dissipation module (typically a power supply, but not necessarily) might be situated adjacent to a heat-sensitive module, so the thermal floor plan must be checked as well.

Engineering is largely about trade-offs and standards, and no solution or format is "perfect" for every application. Despite its flexibility, the DIN rail approach is not the "universal" answer to using larger, heavier units such as power supplies. In practice, the DIN rail is suitable for dissipation up to about 1000 W in a closed, rack width enclosure, unless substantial forced air or active cooling is available. If larger supplies are used, they are sometimes mounted "off rail" due to their weight and size, but there also are many rail-compatible ones for relatively higher power ratings.

Also, the DIN rail and its supplies may not be a good choice when the power supply or other modules need to have multiple user readouts for parameters such as voltage and current, indicators for various status and fault conditions such as power good or overload, or I/O status and alarms. This is because DIN modules tend to be narrow with more use of depth than width, thus limiting the availability of front panel space for user readouts.

Modules with more indicators and readouts are available, but they are generally wider and take up more of the rail real estate. Fortunately, the flexibility and non-bus nature of the DIN rail allows for an easy solution to this problem by simply using two (or more) rails, with one mounted below the other and linked by cabling as needed.

Conclusion

The DIN rail mounting system standard offers flexibility and ease of use for designers, vendors, and buyers of industrial systems and industrial system modules. It supports modules ranging from basic power supplies through advanced sensor interfaces to PLCs, with thousands of DIN-compatible products available from hundreds of vendors.

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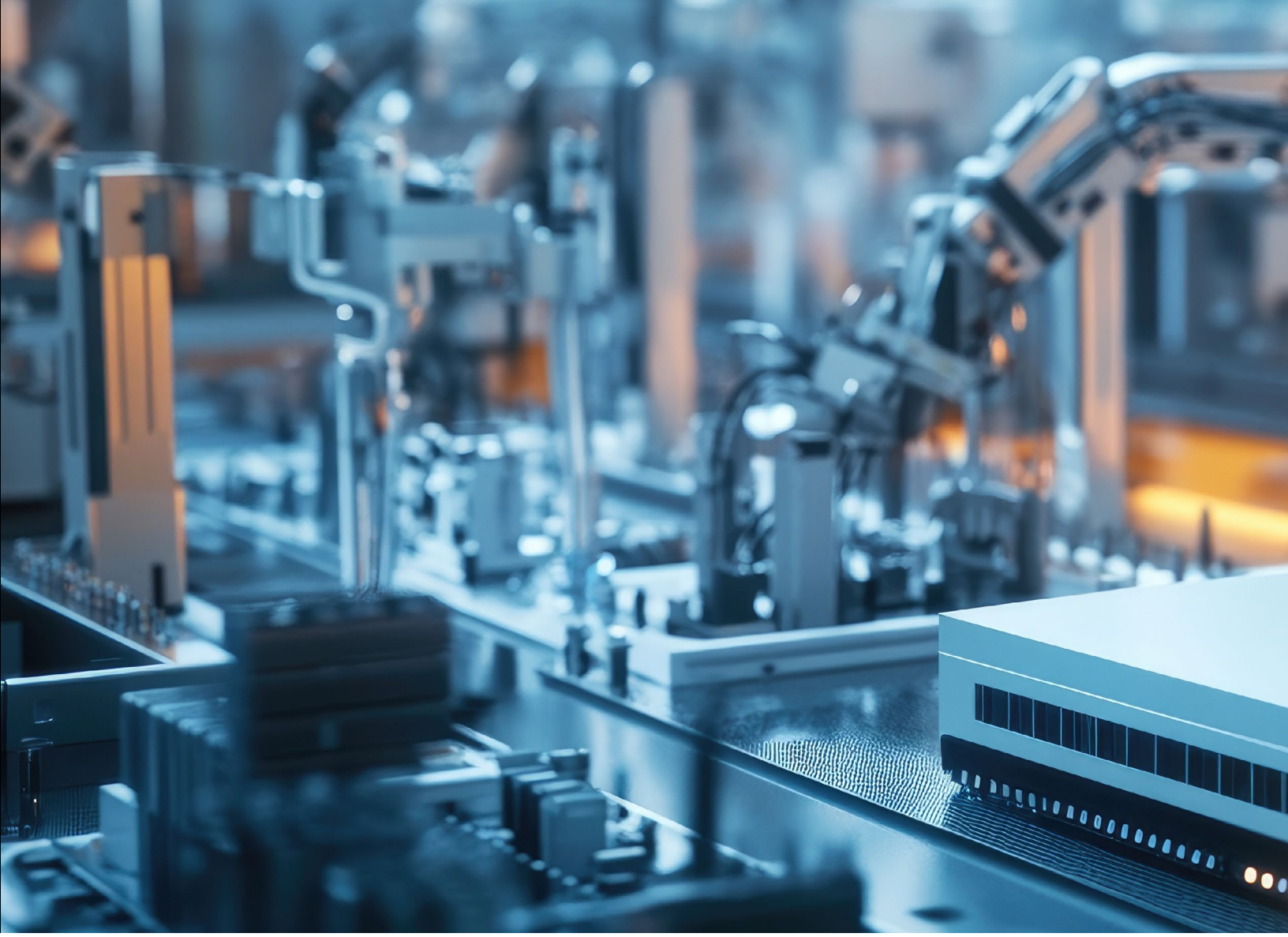
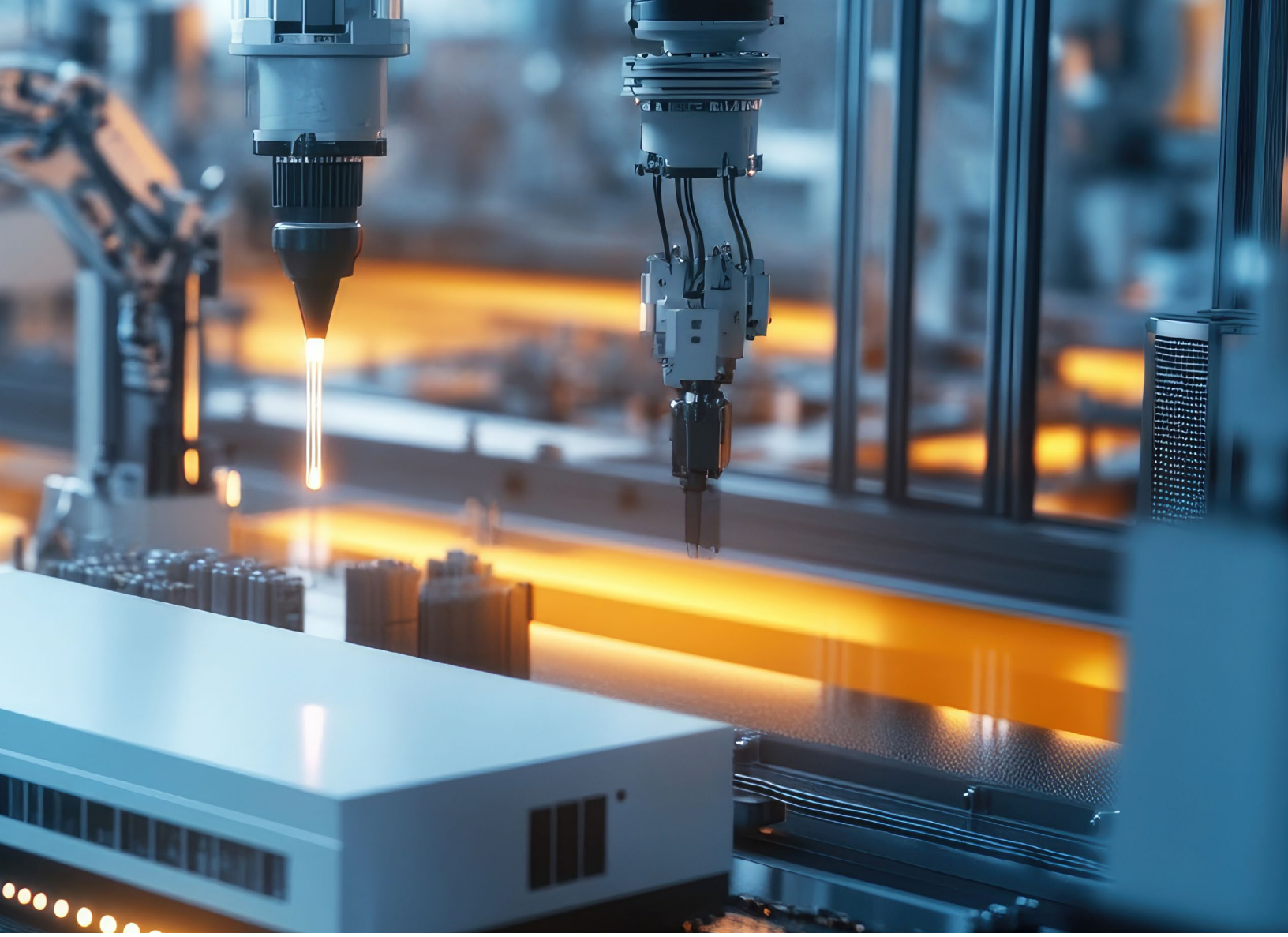


How to quickly design and deploy IIoT-ready machines

By Jeff Shepard
Contributed By DigiKey's North American Editors



Rapidly designing and deploying machines ready for integration into the Industrial Internet of Things (IIoT) is challenging. IIoT-enabled machines must support fast commissioning of machine-to-machine, machine-to-plant, and machine-to-cloud communication and coordination.

That demands a comprehensive solution. It needs to include a complete array of control, interface, and communication modules. Scalability is a must. It should support simplified installation for rapid deployment. Finally, it must easily integrate into a multi-vendor environment to support legacy equipment.

The reward is greater operational efficiency across all levels of the organization and throughout the machines' lifecycles.

This article reviews how the motor control options from Schneider Electric provide designers with end-to-end automation solutions. It presents the features and benefits of Altistart soft starters, Altivar drives, Modicon Ethernet switches and programmable logic controllers (PLCs), Harmony control relays, and PowerPacT circuit breakers.

It then details how the TeSys island system elements support comprehensive solutions and integrates easily with Rockwell Studio 5000 and Siemens TIA Portal environments to support legacy machines and closes by

looking at how Schneider Electric's EcoStruxure Machine Expert software speeds development, configuring, and commissioning of IIoT ready machines.

Motion is a basic characteristic of industrial machines. It is implemented in various ways, from simple motion profiles in systems like pumps, conveyors, and cranes to complex motion profiles in process and assembly operations and robotics.

Machines with simple motion profiles can benefit from the features found in soft starters like the Altistart soft starter family. Altistart soft starters support the following:

- Controlled acceleration that reduces mechanical shocks that can increase wear and tear and lead to increased maintenance needs and machine downtime
- Limiting inrush currents to reduce energy use
- Protecting motors from power surges that can happen during startup, improving motor lifetimes
- Higher reliability by detecting faults such as a blocked motor, underload, or incorrect earthing and sending an alert to machine operators

Basic machines that don't need high starting torque can turn to the ATS01 series soft starters. Activating the BOOST logic input enables the application of a voltage boost equal to 100% of the nominal motor voltage for 200 milliseconds (ms) to overcome initial mechanical friction in the system. The programmed voltage ramp-up begins following the boost.

The model ATS01N232RT is for soft starting and stopping three-phase asynchronous motors up to 15 kilowatts (kW) (20 horsepower (hp)) with acceleration and deceleration times from 1 to 10 seconds. It's optimized for simple belt-driven applications like pumps, compressors, and fans operating from 440 V_{AC} to 480 V_{AC}. Controls are on the front panel to set the start time, initial voltage, and stop time for installation and commissioning.

Designers of more demanding process and infrastructure machines like mixers, crushers, and conveyors can turn to the Altivar ATS480 series of soft starters. While simpler soft starters employ voltage ramps, the ATS480 soft starters use a softer torque ramp and can implement a braking function.

The model ATS480C11Y operates with voltages from 208 V_{AC} to 690 V_{AC} (Figure 1). Depending on motor voltage, it can be used with motors from 22 to 90 kW (25 to 100 hp). It has a Modbus serial communication port with an RJ45 connector. Optional communication cards are available for Profibus, PROFINET, Modbus TCP/EtherNet/IP, and CANopen.

Figure 1: This Altivar Soft Starter is designed for use with asynchronous motors from 22 to 90 kW. (Image source: DigiKey)

Driving more advanced machines

Complex motion profiles in advanced machines can be supported using variable frequency drives (VFDs) like the Altivar 320 family with units rated from 0.18 to 15 kW (0.25 to 20 hp) for applications like material handling, packaging,

textiles, hoisting, mechanical actuators, and material working. The ATV320U75M3C is rated for 7.5 kW and operates from a supply voltage of 200 V_{AC} to 240 V_{AC}.

To speed up configuration and commissioning, these drives feature 150 functions and are standard and customizable configurations. There are dedicated functions for applications like material handling, textiles, hoisting, and mechanical actuators.

Altivar 320 VFDs can provide high-performance control of asynchronous and permanent magnet motors, including torque and speed accuracy at very low speeds and dynamic motion with flux vector control without a sensor. When used with three-phase synchronous and asynchronous motors, these VFDs feature:

- Support of high-speed motors
- Static speed accuracy for open-loop synchronous motors
- Flexible system integration options, including Ethernet, CANopen, Profibus, EtherCAT, DeviceNet, and more
- Integrated safety functions that comply with functional safety standards
- Formats like compact and book drives with degrees of protection from IP20 to IP66 support integration into different types of cabinets (Figure 2)

Figure 2: Altivar 320 VFDs are available in various form factors to simplify installation and maximize space utilization in equipment cabinets. (Image source: DigiKey)

High-performance multi-axis machines

Modicon Ethernet switches and programmable logic controllers (PLCs) can support high-performance designs from a single independent axis to high-performance synchronized multi-axis machines requiring high-speed and precise positioning and movements like robotics.

These IIoT native edge controllers can connect directly to the cloud using Message Queuing Telemetry Transport (MQTT), Open Platform Communications Unified Architecture (OPC UA) server and client, and Transport Layer Security (TLS) encryption and have embedded safety and cybersecurity functions. The dual Ethernet port can support Ethernet/IP and Modbus TCP protocols. There are also RS232 and RS485 ports, a USB port, and a slot for an SD card.

TM262L controllers are for logic control of multiple input/output arrangements, including four fast digital inputs and four fast digital outputs. The model TM262L10MESE8T has an execution speed of 5 nanoseconds (ns) per instruction. The dual-core processor efficiently manages parallel applications and communication (Figure 3).

Figure 3: This Modicon M262 PLC supplies IIoT-ready machine-to-cloud and machine-to-plant Ethernet connectivity. (Image source: DigiKey)

The TM4 bus on the Modicon M262 family supports up to 3 communication expansion modules. Profibus DP (TM4PDPS1) and Ethernet (TM4ES4) expansion modules can be used in various combinations to a maximum of three modules.

Nixing abnormalities

Sometimes, machines, including IIoT-ready machines, must be protected from abnormal conditions. That's where Harmony Control Relays come in. They can monitor both electrical and mechanical conditions and identify abnormalities related to current, voltage, phase, frequency, speed, temperature, pump control, and even liquid level.

Quick and accurate identification of abnormalities can increase uptime and reduce the need for unscheduled maintenance in applications like pumping, water processing, hoists and lifts, packaging systems, and textile machines. Harmony Control Relays are available with a wide range of functions to suit specific application needs.

Model RMNF22TB30 is a three-phase relay with integrated near-field communications (NFC). It can monitor seven parameters: phase loss, phase sequence, asymmetry, undervoltage, overvoltage, under-frequency, and over-frequency. Using the NFC app, designers can use AND, OR, and NOT logic to form custom monitoring combinations for the two individually configurable relay outputs.

For simpler machines that only need overvoltage monitoring, designers can turn to the RM22UA21MR (Figure 4). This

Figure 4: Single-phase overvoltage control relay with a switching capacity of 2 kVA. (Image source: DigiKey)

single-phase control relay includes a selectable memory function and an integral LED indicating control status. The screw trimmers enable simple and precise threshold settings, and it provides automatic shutdown management and fault information for quick fault identification and troubleshooting.

Basic protection

Applications that can benefit from more basic protection can turn to PowerPacT Circuit Breakers rated from 15 to 125 A and available with one-, two-, three-, and four-poles. These thermal magnetic circuit breakers have positive contact indication and deliver isolation in compliance with IEC/EN60947-1 and IEC/EN60947-2 standards for "low-voltage switchgear and control gear."

Model BJL16020 is a 20 A single-pole unit with a rated operational voltage of 240 V_{AC} 50/60 Hz according to UL 489. Its continuous current rating is 80% of the maximum rating, and it is rated "service breaking" according to IEC 60947-2 (Figure 5). The VisiTrip LED readout makes it easier to see which circuit breaker has tripped in the enclosure or panel. It also has a QR code to access information, including the instruction manual, part numbers, and CAD drawings.

Figure 5: Circuit breakers like this offer positive contact indication and meet the isolation requirements of IEC/EN60947. (Image source: DigiKey)

Integrated fieldbus nodes

TeSys is a digitized IIoT-connected load management solution that acts as an integrated node in a Fieldbus network and includes the modules needed to implement an IIoT-ready machine. It's based on multifunctional devices and avatars for industrial applications with loads up to 80 amps and can speed design, wiring, and commissioning times.

A bus coupler like the TPRBCEIP is the core module that provides internal communication with the TeSys island modules via ribbon cables. It's also the connection point between a TeSys island and an external automation system using EtherNet/IP or Modbus TCP communication. An embedded web server supports diagnostics and maintenance. It includes one RJ45 service port over Ethernet, a micro SD card port, and a port for the internal bus interconnecting the modules of the island. A typical configuration includes (Figure 6):

A. Bus coupler

B. Analog input / output module

C. Digital input / output module

D. Voltage interface module

E. Standard starters

F. Safety integrity level (SIL) starter

G. SIL interface module

H. Power interface module

Exemplary TeSys island modules include:

- LC1DT406BL 40 A, 4-pole, normally open, TeSys Deca contactor with IEC60335-1 compliance for industrial and HVAC systems

- LC1G115EHEN 150 A (75 kW at 440 V_{AC}), 3-pole, normally open, TeSys Giga contactor, designed for use in demanding applications with operating rates of up to 600 cycles per hour and operating temperature up to +60°C
- TPRDG4X2 digital I/O module with four digital inputs and two digital outputs can manage motors and other electrical loads up to 65 A (37 kW, 40 hp). All adjustments and settings are digitized, and no mechanical dials or dip switches
- TeSys island Communicating Motor Starters rated up to 40 hp (80 A at 480 V). These SIL starters meet the requirements of IEC 61508, IEC 62061, and ISO 13849-1 and support PL d, and SIL 2

TeSys island also supports comprehensive solutions and integrates easily with Rockwell Studio 5000 and Siemens TIA Portal environments to support legacy machines.

Putting it all together

When it's time to build the completed machine, designers can turn to the EcoStruxure Machine Expert. This software solution supports development, configuration, commissioning, operation, and maintenance of IIoT-ready machines.

EcoStruxure Machine Expert can handle all the latest IIoT machine building blocks, including Modicon M262 PLCs and the TeSys Island digital load management system. It's

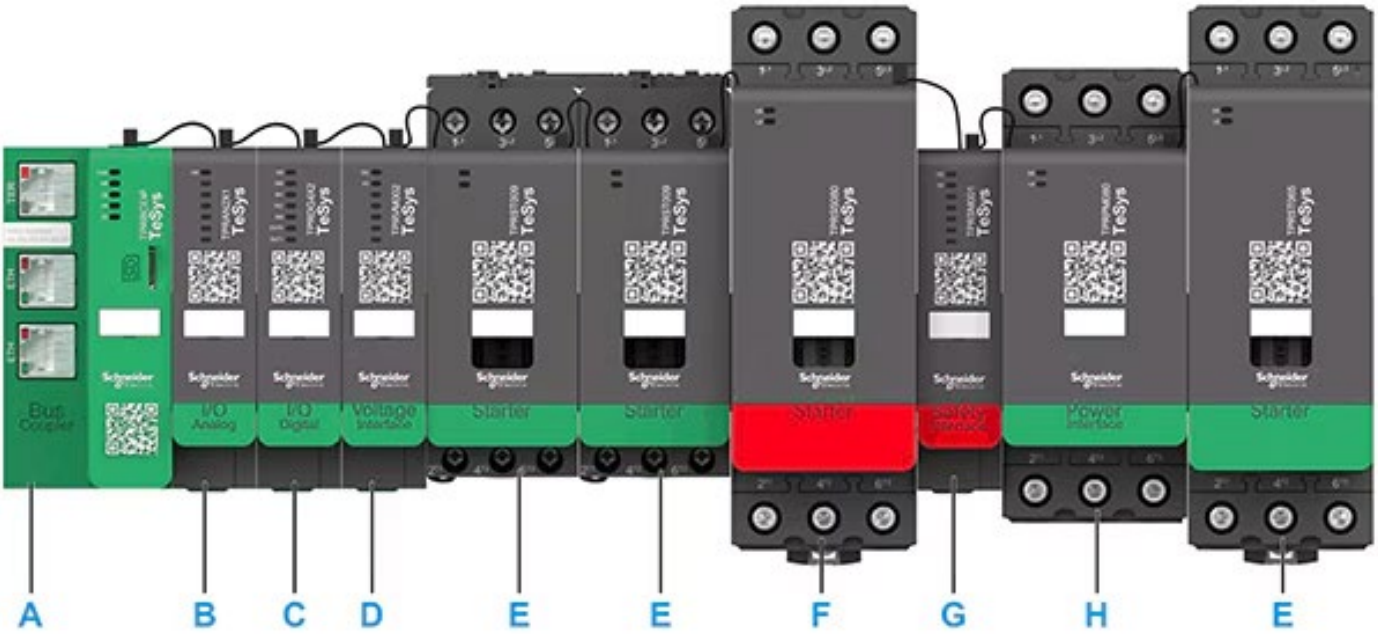


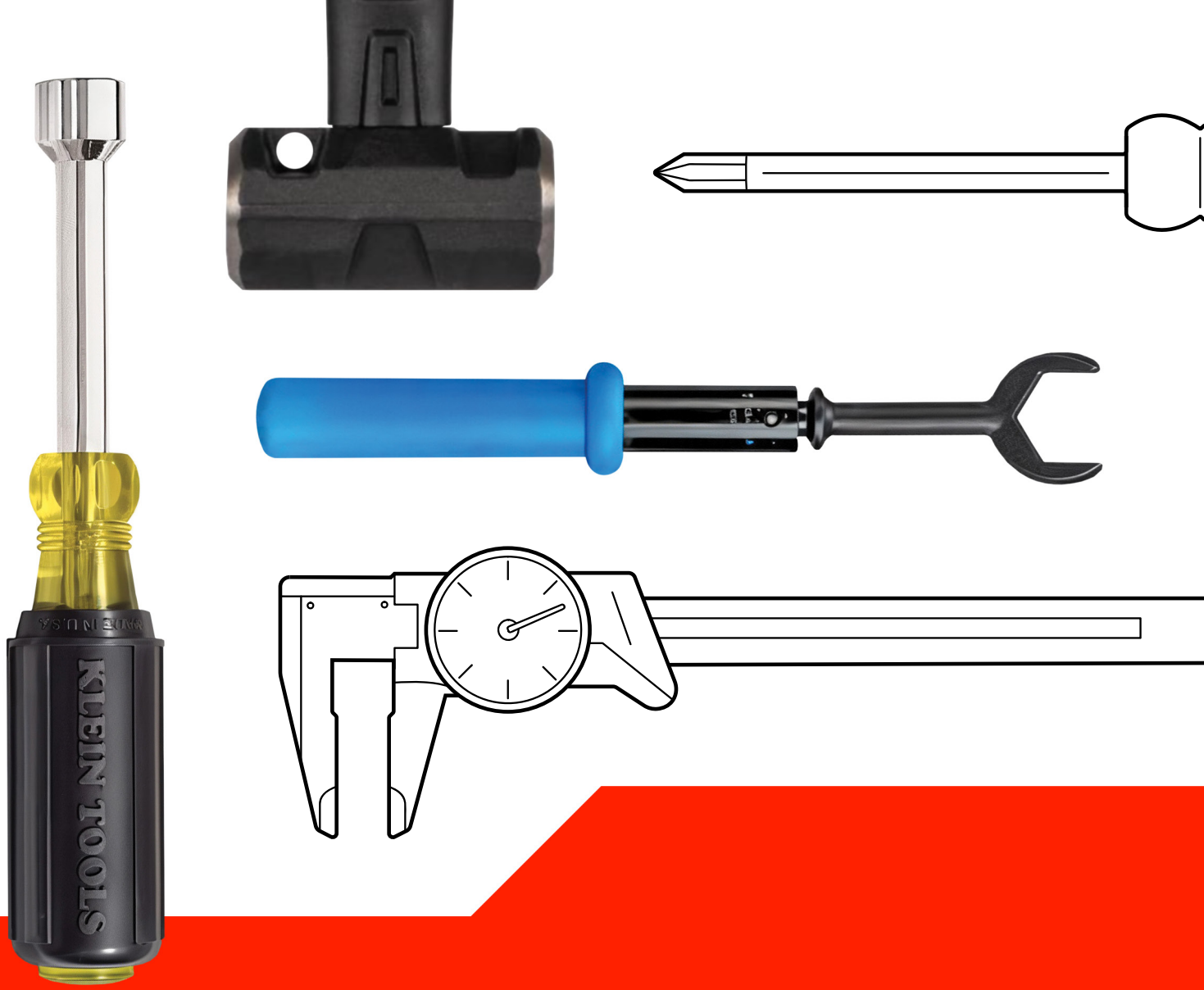
Figure 6: The combined units in the TeSys island act as a single node in a Fieldbus network. (Image source: Schneider Electric)

designed to deliver machines optimized for safety, reliability, efficiency, connectivity, and sustainability. It leverages the IIoT with mobility, sensing, cloud, analytics, and cybersecurity solutions to accomplish that complex task.

tasks. Schneider Electric supplies machine designers with a comprehensive suite of devices and software tools for IIoT-enabled machines that deliver improved operational efficiency across all levels of the organization and throughout the machines' lifecycles.

Conclusion

IIoT-enabled machines are an important aspect of Industry 4.0 operations. Designing, commissioning, and integrating those machines are complex



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