Smart Manufacturing | Volume 17

We get technical

DigiKey




contents

Editor's note

Welcome to the Smart Manufacturing eMagazine Volume 17, where we delve into the rapidly evolving world of industrial automation and the technologies shaping the future of manufacturing. In this issue, we explore a range of solutions designed to enhance productivity, safety, and sustainability across industries.

We'll explore smart motor controls that maximize resilience and uptime, and how miniature safety laser scanners are revolutionizing safety while boosting productivity. We will also dive into how small and medium enterprises (SMEs) can harness the power of the industrial metaverse to explore and deploy robotic solutions with agility.

As always, we bring you practical insights into the selection and optimization of key equipment, from maximizing the impact of variable frequency drives (VFDs) and variable speed drives (VSDs) to key considerations when choosing industrial automation equipment. We also shine a spotlight on OEMs in the food and beverage sector, offering solutions for efficient motion that drive operational success.

Lastly, we look ahead at how new IO-Link masters are bridging the gap between cloud connectivity and local control, enabling manufacturers to achieve a balanced approach to Industry 4.0.

We hope these articles provide valuable insights and inspire you to consider how these innovations can help unlock the full potential of your operations.

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.

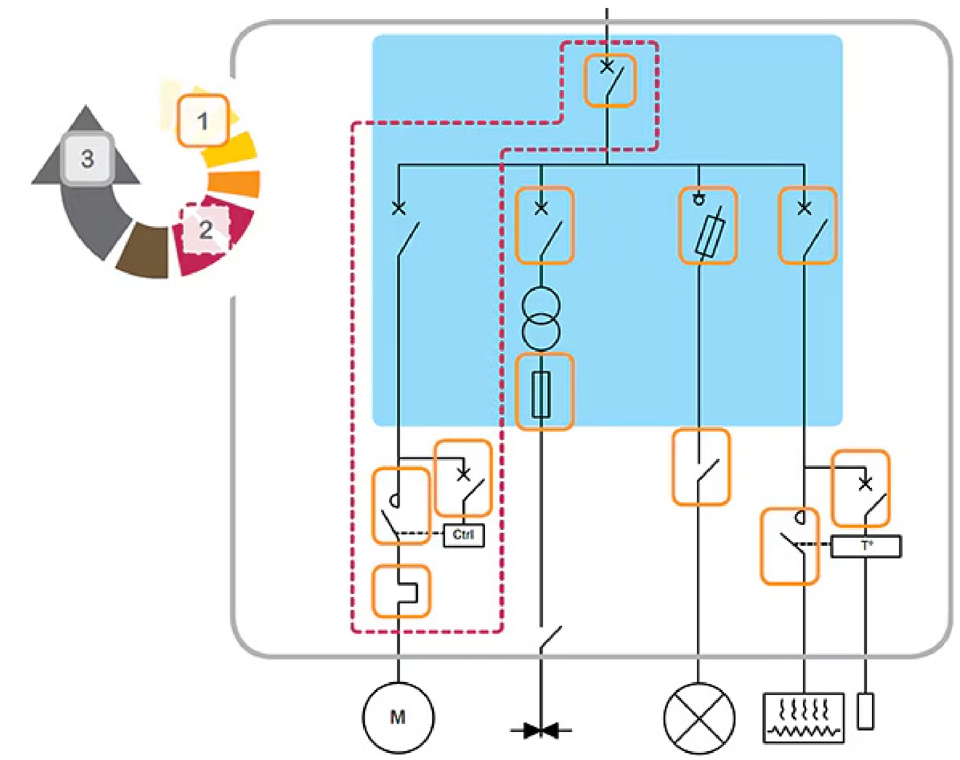


Figure 1: SCCR calculations begin with individual component ratings (yellow boxes), move up to determine the SCCR of branch circuits (red dashed box), and then consider the SCCR needs of the completed control panel (grey rectangle). (Image source: Schneider Electric)

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

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

for use with AC motors. Settings for ground fault protection, phase imbalance protection, and trip class (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)

How miniature safety laser scanners can maximize protection and productivity

By Jeff Shepard
Contributed By DigiKey's North American Editors

The increasing complexity of Industry 4.0 factory and logistics automation requires new approaches to system design that simultaneously maximize safety and productivity.

The flexible nature of Industry 4.0 operations means that the placement and extent of hazardous operations can change occasionally, and safety systems must adapt quickly. A reconfigurable, programmable, and flexible safety system is needed.

The ability to establish warning zones to alert workers approaching a hazardous area before they get too close can be a big plus. It prevents workers from accidentally entering the hazardous area, tripping a safety device, and turning off a machine. That enhances uptime and productivity.

This article begins with a brief review of international standards for safety mats and safety laser scanners, then moves on to comparing application considerations for safety mats and safety laser scanners, looking at factors like contact versus non-contact operation, warning field protection, and adjustability.

It closes by presenting examples of miniature safety laser scanners from SICK and how they meet the requirements of several applications, along with installation and configuration options, including how the scanners are easily replaced if they become damaged.

Key safety performance standards include International Electrotechnical Commission (IEC) 61508, "Functional Safety of Electrical/Electronic/Programmable Electronic Safety-related Systems (E/E/PE, or E/E/PES)," International Organization for Standardization (ISO) 13849, "Safety of machinery — Safety-related parts of control systems," and IEC 61496, "Safety of machinery — Electrosensitive protective equipment."

Safety mats and safety laser scanners meet various parts of those standards. For example, IEC 61508 defines a series of safety integrity levels (SILs). Safety laser scanners meet SIL 2 requirements. So do some, but not all, safety mats. Some safety mats only meet the requirements of SIL 1, which is an order of magnitude less stringent than SIL 2.

SIL 1 safety devices are intended for use with low-risk applications where the consequences of a failure are not severe, like basic machine guarding, non-critical processes, and simple alarms. SIL 2 safety devices are designed to mitigate risks that could result in serious injuries or significant environmental damage, but not necessarily catastrophic events.

Using similar concepts to SILs, ISO 13849 defines performance levels (PLs). Safety mats typically qualify for a PLc certification, while safety laser scanners must qualify for the tougher PLd certification. Some safety mat installations can also meet PLd performance requirements.

To become certified, a safety laser scanner must meet SIL 2, PLd, and IEC 61496-3, specifically covering active optoelectronic protective devices responsive to diffuse reflection (AOPDDR, or laser scanners). The implications of the various safety certifications for safety mats and safety laser scanners are important, but they are just the start when maximizing protection and productivity.

More to consider

Properly specified safety mats and safety laser scanners can both meet the IEC and ISO safety requirements. But that's not the end of the story; there's more to consider in Industry 4.0 factory and logistics automation applications.

A safety mat is a matrix of mechanical switches. When a weight, like a person stepping on the mat, closes one or more of

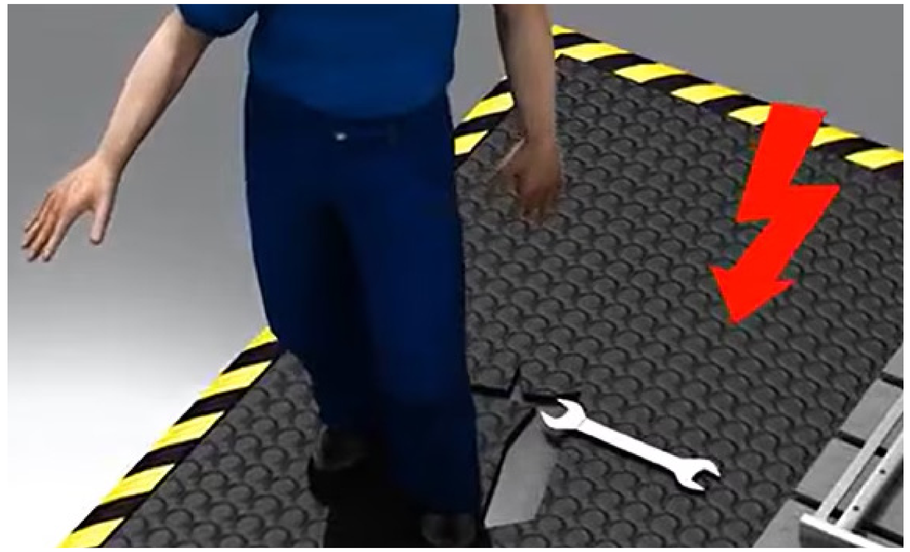


Figure 1: Safety mat operation requires physical contact and can be compromised by accidents and environmental hazards. (Image source: SICK)

the switches, it sends a signal to the mat controller that stops the operation of the protected system.

The mechanical nature of safety mats can be a cause for concern. First, for the mat to operate, there must be direct contact with a person walking across the mat. Second, the mats are subjected to wear and (sometimes literally) tear. People can drop heavy and/or sharp tools on the mat, damaging it (Figure 1). Or a forklift may drive across the mat and damage it. Environmental factors like spills of corrosive materials can also compromise the mat.

Adjustability

Safety mats are inherently fixed installations and are not adjustable. There are different sizes and mat configurations for specific installation requirements. That can present challenges in Industry 4.0 factories and logistics operations that are subject to reconfiguration as process demands change.

Making changes to safety mat-based systems can require the acquisition of a new mat, extending the time needed for the changeover to become operational. That can negatively impact machine availability and overall productivity.

One way to minimize the impact is to keep various replacement safety mat sizes on hand. That can speed changeovers and the replacement of mats that become damaged. But it's also expensive. It can also require keeping a variety of safety mat controllers on hand since not all mats are compatible with all controllers.

These issues can be addressed by using safety laser scanners. Safety laser scanners are not based on mechanical switches; they are electronic devices that can be adjusted for various application needs.

Safety laser scanners are a non-contact technology that use an infrared (IR) laser to scan the surroundings in two dimensions. They emit short pulses of IR light. If a pulse of light strikes an object, it's reflected to the scanner. The distance to the object can be determined with a high degree of accuracy based on the time interval between the moment of transmission and the time the reflected light returns.

The ability to determine the distance to obstacles enables safety laser scanners to establish a series of warning and protective fields based on the nearness of an object. Some safety laser scanners can have dozens of defined fields. That can be useful for applications like navigation for an autonomous mobile robot.

The S300 Mini Standard safety laser scanners from SICK are optimized for safety applications that need three defined fields — a protective field and two warning fields — to be active simultaneously. Their compact dimensions of 102 x 116 x 105

Figure 2: Size comparison of the S30 Mini Standard safety laser scanner and a soda can. (Image source: SICK)

millimeters (mm) (w x h x d) make them suitable for applications like robotic work cells and automatic guided vehicles (AGVs) (Figure 2).

S300 Mini Standard scanners have a 270° scan angle to cover a wide area and a selectable resolution for hand, leg, or body detection. These scanners support warning field ranges up to 8 m and are available with three maximum protective field ranges:

- One meter, model 1058000
- Two meters, model 1050932
- Three meters, model 1056430

Dynamic environments

Dynamic environments, where the layout or operational conditions change or where AGVs move around, can benefit from configurable safety laser scanners. The detection zones can be modified as needed to suit changing protection needs.

Setting multiple warning fields can be especially useful for preventing people from getting too close and shutting down a machine. The warning signal devices can include a simple flashing light if the first warning field is breached and a warning siren or horn if the second warning field is entered. There are specific rules for calculating the size of protection fields.

Safety distance calculations

ISO Standard 13855, "Safety of machinery – Positioning of safeguards with respect to the approach of the human body , includes guidelines for calculating the minimum safe distance required to stop a machine when a person approaches it. ISO 13855 applies to several types of safety devices, including safety laser scanners, safety light curtains, pressure-sensitive devices, safety mats and floors, and more.

It can be useful when calculating the size of safety fields for safety laser scanners (Figure 3). A common formula for calculating the safe distance, S, is S = (K × (TM + TS)) + ZG + ZR + CRO, where:

- K = Approach speed (1,600 mm/s, defined in ISO 13855)
- TM = Stopping time of the machine or system
- TS = Response time of the safety laser scanner and the downstream controller
- ZG = General supplement = 100 mm
- ZR = Supplement for reflection-related measurement errors
- CRO = Supplement to prevent reaching over

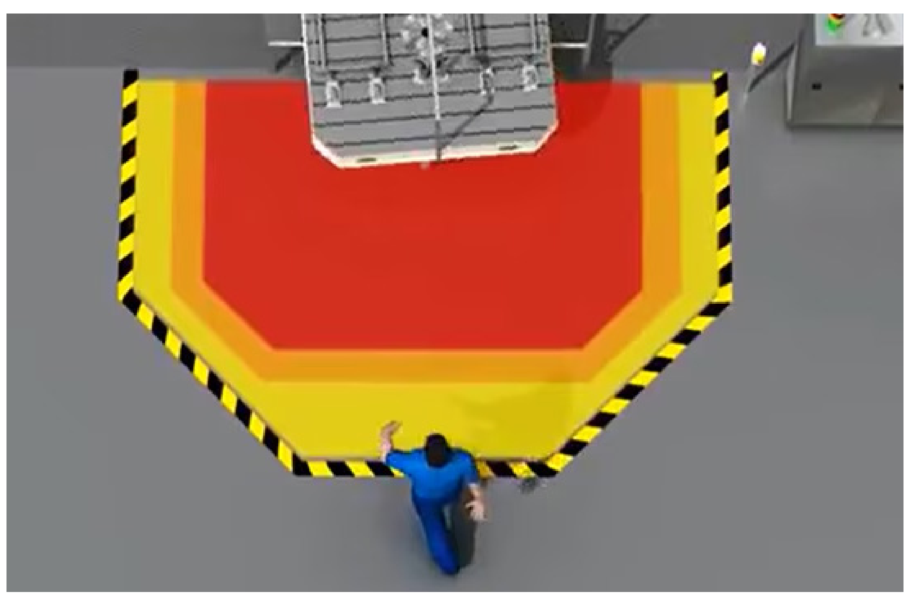


Figure 3: ISO 13855 guidelines can be used to calculate the sizes of safety fields (red) for safety laser scanners like the S300 Mini Standard. (Image source: SICK)

Automated guided vehicles

Automated guided vehicles (AGVs) move items quickly and efficiently without human intervention in Industry 4.0 factories, warehouses, and distribution centers. In some AGVs, switching strips or bumpers are used to detect obstacles. That can limit the speed of travel for the AGV, and the strips or bumpers can experience physical damage, requiring replacement and taking the AGV out of operation for a period.

To maintain safety, flexibility, and maximum availability, AGVs can replace switching strips and bumpers as the primary safety devices, and they can include a laser safety scanner to detect obstacles and safely stop. The small size of the S300 Mini facilitates integration, even in the smallest AGVs (Figure 4).

Using two safety laser scanners can provide an expanded protected area. If the scanners are mounted on the front corners of the AGV, the protected area extends to the front and both sides of the vehicle. Suppose the scanners are mounted diagonally opposite each other on the front and rear of the vehicle. In that case, the protected area will surround all sides of the AGV, enabling safe movement in both directions.

Configuration, installation, and maintenance

Configuration and diagnostic software (CDS) from SICK can be used to define protective and warning fields using a PC or laptop. The software includes an intuitive interface for application design and implementation. The

Figure 4: The compact size of S300 Mini Standard safety laser scanners enables them to be mounted on small AGVs. (Image source: SICK)

software also calculates and saves all configuration and diagnostic data for quick commissioning and/or efficient troubleshooting. Configuration and diagnostics can be implemented during commissioning or maintenance.

SICK also offers a choice of mounting kits for physically attaching the S300 Mini safety laser scanners. Kit 1a, model 2034324, is the basic mounting bracket without a protective cover for the optics, and kit 1b, model 2034325, includes optics protection (Figure 5). In addition, supplemental mounting brackets, including kit 2, model 2039302, and kit 3, model 2039303, can be added to align the scanners in two planes. The maximum adjustment angle is ±11° in both planes.

The mounting kits also support quick replacement of damaged scanner heads. The replacement scanner head attaches to the system plug, which is permanently mounted on the machine. The replacement head immediately downloads the configuration data from the system plug and assumes the programmed safety tasks, no reprogramming or manual downloading of configuration data. It's a plug-and-play process that minimizes machine downtime.

Summary

S300 Mini Standard safety laser scanners provide a robust alternative to safety mats in Industry 4.0 factories, warehouses, and distribution centers that simultaneously maximize safety and productivity. They meet IEC 61508, ISO 13849, and IEC 61496 safety standards and are suitable for fixed installations and mobile platforms like AGVs. Finally, S300 Mini Standard safety laser scanners support flexible and rapid configuration, installation, and maintenance.

Figure 5: Mounting kit 1b includes optics cover protection. (Image source: SICK)

How SMEs can use an industrial metaverse to explore and deploy robotic solutions rapidly

By Jeff Shepard
Contributed By DigiKey's North American Editors

Robots and collaborative robots (cobots) are on the leading edge of factory automation technologies. Digital twins and virtual reality (VR) are on the leading edge of design and development tools. Combined, they can be leveraged to create an industrial metaverse that delivers higher productivity faster, even for small- to medium-sized enterprises (SMEs).

Designers at SMEs can benefit from a simple and intuitive interface that combines a digital twin, a highly detailed virtual model of a physical object like a delta, linear, or multi-axis robot, and a 3-dimensional (3D) VR environment to enable direct execution and checking of the robot's movement sequences.

Using these features supports fine-tuning and optimization of the automation system even without any physical hardware and enables rapid exploration of multiple solution possibilities.

This article first reviews the distinction between a mathematical, data-described digital twin and a visual digital twin (VR twin) and how both are needed to create the industrial metaverse. It then presents a robot control system and related software from Igus that can be used to simulate a robot on a 3D interface (visual digital twin) without using any physical hardware, along with compatible delta, linear, and multi-axis robots that can be used to realize the optimized solution.

Digital twins and VR are complementary technologies using different visualization forms, interactions, and hardware. Digital twins are data-based models of physical objects, systems, or processes. They are designed to be used over the entire lifecycle of the item being modeled from initial conception to decommissioning and recycling.

VR is an immersive, visually based technology that also uses digital models. In a VR environment, it's possible to simulate the relationships and interactions between objects, like a robot performing a task. So, while both technologies can be used for design and simulation, digital twin technology is focused on overall lifecycle considerations, and VR focuses on interactions between physical objects.

A metaverse combines digital twins and VR into a purpose-built virtual environment that supports real-time interactions between the digital objects and people. It's often associated with gaming but is increasingly applied to business and industrial activities.

Welcome to the iguverse

Igus has developed the iguverse metaverse to support engineering interactions in industrial environments, such as developing and deploying robotic systems. The iguverse can be implemented through Igus Robot Control (iRC) software. This free and license-free application enables users to control various types of robots, including delta robots, cobots (robot arms), and gantry robots.

It provides users with a 3D interface and over 100 sample programs. System requirements to implement iRC include a PC (minimum of an Intel i5 CPU) with Windows 10 or 11 (64-Bit) with 500 MB of free disk space and Ethernet or wireless networking connectivity.

The software's core is a 3D digital twin of the robot being programmed. An example of this is a three-axis linear gantry robot like model DLE-RG-0001-AC-500-500-100 with a workspace of 500 x 500 x 100 mm or a two-axis xy actuator like model DLE-LG-0012-AC-800-500 with an 800 x 500 mm workspace (Figure 1). Designers can define movements with a few mouse clicks and use the 3D model to ensure the required movements are feasible, even before purchasing the robot.

In addition to the iRC software, the robot controller is a key element in the iguverse development environment. For example, the model IRC-LG12-02000 is for 48 V motors, has seven inputs and seven outputs, and has a 10 m cable for connecting to the robot. The IRC controllers include motor drive modules for various sizes of bipolar stepper motors and are available configurable or preconfigured.

It also has several interfaces for system integration, including:

- Programmable logic controller (PLC) interface for control via the digital inputs and outputs, especially for easy starting and stopping of programs via a PLC or pushbutton
- Modbus TCP interface for control via a PLC or PC
- Common Robotic Interface (CRI) Ethernet for control and configuration using a PLC or PC
- Robot Operating System (ROS) interface for operating the robot using ROS
- Interface for object detection cameras
- Cloud interface for remotely monitoring the robot's state

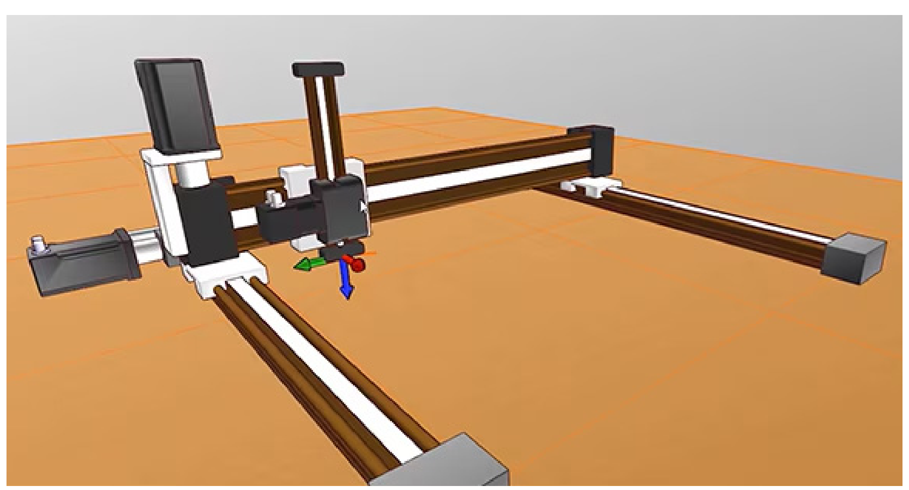


Figure 1: Example of a 3D VR digital twin of a three-axis gantry robot in the iguverse. (Image source: Igus)

Supported kinematics

A variety of kinematics (basic motions) that define the controlled movement of the robot are supported in the iguverse. In addition to the preconfigured kinematics, up to three more kinematically independent axes can be configured in IRC. Preconfigured kinematics include:

- 2-axis and 3-axes delta robots
- Gantry robots,
  - 2-axis (X and Y axis)
  - 2-axis (Y and Z axis)
  - 3-axis (X, Y, and Z axis)
- Robot arms (cobots),
  - 3-axis (axis 1, 2, 3)
  - 3-axis (axis 2, 3, 4)
  - 4-axis (axis 1, 2, 3, 4)
  - 4-axis (axis 2, 3, 4, 5)
  - 5-axis (axis 1 to 5)
  - 6-axis (axis 1 to 6)
- 4-axis SCARA robot

Easy programming for low-cost automation

Igus robots and the IRC are designed to support low-cost automation. That would not be possible without an easy-to-use programming interface.

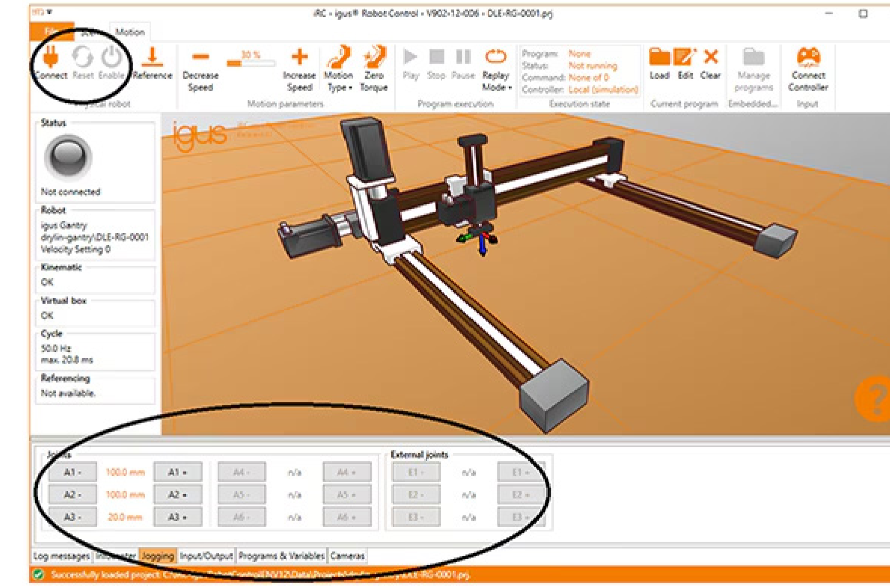


Figure 2: The "Jogging" tab (bottom left) in the iguverse immersive development environment can be used to enter motion profiles. (Image source: Igus)

A 3-button mouse or a gamepad can move and position a robot in the iguverse. With the IRC software, a user can freely move all axes of the digital twin in the 3D interface. A teach-in function supports the development of robot control software, even without a physical robot being connected.

To implement teach-in, the user manually moves the virtual robot to the required position and defines how it moves there. The process is repeated until the complete motion profile has been created. The tool center in the IRC software allows users to add matching end effectors, like grippers, easily and automatically adjusts the tool center point on the robot. In addition, a connection to a higher-level industrial control system can be added.

The process begins by activating the robot using the "connect," "reset," and "enable" buttons as needed in the interface. The status LED on the IRC should become green, and the status should indicate "No Error." The motion profile can now be entered using the "Jogging" tab (Figure 2).

Gantry robots

Gantry robots, like those included in the preceding examples of the iguverse, consist of two base X-axes, a Y-axis, and an optional Z-axis. The Y-axis is attached to the two parallel X-axes and moves back and forth in two-dimensional space. The optional Z-axis supports a third dimension of movement.

Gantry robots from Igus have self-lubricating plastic liners that slide and roll smoother and quieter than traditional ball-bearing-based designs. The new design is lighter weight, corrosion-resistant, and maintenance-free, which are important qualities for SMEs. Also crucial for SMEs, these robots cost up to 40% less than traditional gantry robots, providing a quicker return on investment (ROI).

These robots are suited for two classes of applications: low speeds with high loads or high speeds with low loads. Representative applications include packaging, pick and place, labeling, material handling, and assembly operations.

They are offered in a range of sizes. Available accessories include couplings, end effectors, and motor flanges. Examples of medium-sized gantry robots include:

- DLE-FG-0006-AC-650-650 is a two-dimensional flat gantry with a 650 x 650 mm workspace. This robot can handle payloads up to 8 kg and has a dynamic rate of up to 20 picks per minute.
- DLE-RG-0012-AC-800-800-500 is a three-dimensional gantry with an 800 x 800 x 500 mm workspace. It can handle payloads up to 10 kg with a dynamic rate of up to 20 picks per minute.

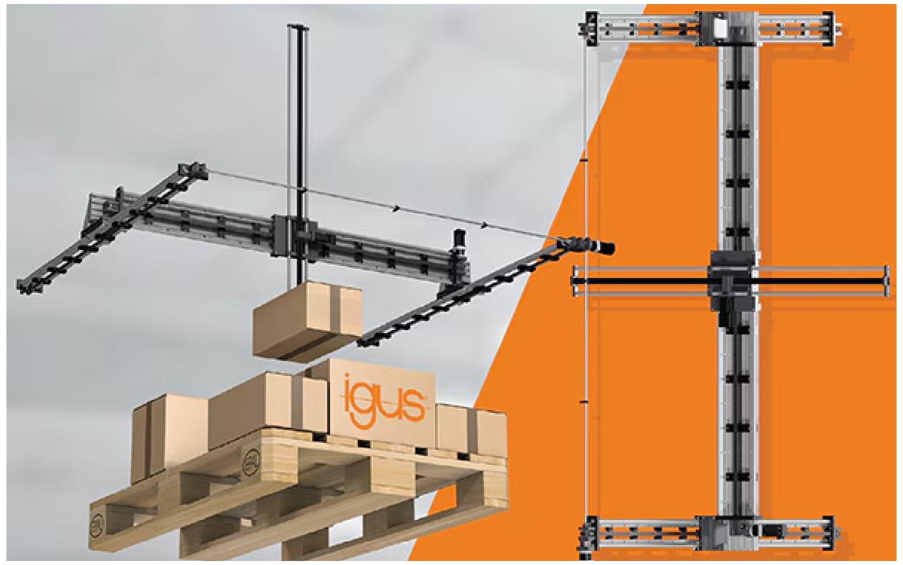


Figure 3: Palletizing is a common and important activity in manufacturing and logistics operations and can be automated using a gantry robot. (Image source: Igus)

Palletizing prowess

Palletizing products for shipment is an everyday activity in manufacturing and logistics operations. The newest and largest member of the iguverse is the XXL large gantry robot with a working space of 2,000 x 2,000 x 1,500 mm, well-suited for palletizing applications up to 10 kg. Custom designs with working spaces up to 6,000 x 6,000 x 1,500 mm are available.

These gantry robots can pick parts weighing up to 10 kg, transport them at a speed of up to 500 mm/s, and place them on a pallet with a repeatability of 0.8 mm (Figure 3). The Igus palletizing robot solution costs up to 60% less than comparable systems.

Delta robots

Like gantry robots, delta robots are available with two or three axes. Delta robots have a dome-shaped work envelope mounted above the workspace. They have exceptionally high speeds and are often used for material handling and parts placement. Examples of Igus' delta robots include:

- RBTX-IGUS-0047 is a three-axis design with a workspace diameter of 660 mm. It has an accuracy of ±0.5 mm, a maximum payload of 5 kg, a maximum speed of 0.7 m/s, and can perform up to 30 picks per minute. (Figure 4).
- RBTX-IGUS-0059 is a 2-axis design with a workspace diameter of 700 mm. It also has an accuracy of ±0.5 mm. Its maximum payload is 5 kg, its maximum speed is 2 m/s, and it can perform up to 50 picks per minute.


Figure 4: Example of a three-axis delta robot next to an Igus iRC (left). (Image source: DigiKey)


Figure 5: Articulated arm cobots with 4 DOF (left) and 6 DOF (right). (Image source: Igus)

Articulated arm cobots

The iguverse also supports articulated arm cobots. Cobots can have from two to 10 or more axes, also called degrees of freedom (DOF). They generally have large work envelopes and can perform complex tasks in collaboration with a person. Igus model REBEL-6DOF-02 has 6 DOF and model REBEL-4DOF-02 has 4 DOF. Both have an accuracy of ±1 mm, a nominal working range of 400 mm and can perform a minimum of 7 picks per minute with a linear speed of 200 mm/s.

The 6 DOF model has a maximum payload of 2 kg and a maximum reach of 664 mm. The 4 DOF model has a maximum payload of 3 kg and a maximum reach of 495 mm (Figure 5).

Summary

The iguverse immersive industrial metaverse combines digital twins and VR to provide tools that enable rapid development and deployment of robotic solutions. It's free, license-free, and designed to run locally on a PC without a cloud connection. It can be used to develop and test robotic solutions without a robot being present.

It supports a wide range of kinematics in delta robots, gantry robots, robot arms (cobots), and SCARA robots. The IRC includes an array of interfaces to support automation and operational needs, including PLC interface, Modbus TCP/IP, CRI Ethernet, ROS interface, an interface for object detection cameras, and a Cloud interface. The iguverse, the iRC, and related robots from Igus have been optimized to support the low-cost automation needs of SMEs.

What support products does it take to maximize the impact of using VFDs and VSDs? - Part 1

By Jeff Shepard
Contributed By DigiKey's North American Editors

Part 1 of this article series looks at what to consider when selecting motor connection cables, output reactors, braking resistors, line reactors and line filters. Part 2 continues by looking at the differences between VSDs/VFDs and servo drives, reviewing uses for AC and DC rotary and linear servo motors, considering where soft start-stop units fit into industrial operations, and Looking at how DC converters are used to power peripherals like sensors, human-machine interfaces (HMIs), and safety devices.

Using variable speed drives and variable frequency drives (VSDs/VFDs) is necessary to maximize industrial operations' efficiency and sustainability, but it's not sufficient. To get the maximum benefit from VSDs/VFDs, additional components like high-performance cables, braking resistors, line filters, line reactors, output reactors, and more are needed.

Cabling is ubiquitous and critical. A poorly specified cable connecting the VSD/VFD to the motor can significantly degrade system performance. Other elements like braking resistors, filters, and reactors vary from installation to installation and can be very important to a successful deployment.

For example, some systems operate in areas where it's necessary to control electromagnetic interference (EMI) and can benefit from using line filters that meet EN 61800-3 Category C2. Applications where rapid deceleration is required will need braking resistors. Line reactors can improve the power factor and boost efficiency, and output reactors can enable the use of longer cables.

This article begins with a look at some considerations when selecting motor connection cables and presents typical cabling options from LAPP and Belden. It then reviews factors that impact the selection of output reactors, braking resistors, line reactors, and line filters, including representative devices from ABB, Schneider Electric, Omron, Delta Electronics, Panasonic, and Siemens.

Motor cables are available in various configurations to meet specific application requirements. They typically have three main power conductors, often insulated with cross-linked polyethylene (XLPE). Some have uninsulated grounding wires. There can be various signal wires and numerous braided and foil shielding choices. The entire assembly is encased in an environmentally rugged outer jacket (Figure 1).

Even basic cables like Belden Basics part number 29521C 0105000 are complex assemblies of conductors, shielding, and insulation. These cables have three 14 American Wire Gauge (AWG) (7x22 strands) copper conductors covered with XLPE insulation and three 18 AWG (7x26 strands) uninsulated copper ground wires. These six wires are surrounded by dual helical tape shields that provide 100% coverage, and the

Figure 1: VFD motor cables come in a wide range of configurations. (Image source: Belden)

entire cable assembly is encased in a polyvinyl chloride (PVC) jacket for environmental protection.

Belden Basic cables are suited for use in class 1 division 2 hazardous locations as defined in the National Electrical Code (NEC). Class 1 refers to facilities for handling flammable gases, vapors, and liquids. Division 2 specifies that these flammable materials are not ordinarily present in concentrations high enough to be ignitable.

Some cable series, like LAPP's ÖLFLEX VFD 1XL, are available with and without signal wires. Applications that benefit from having signal wires can turn to LAPP's 701710 cable. It includes three power conductors, a ground conductor, and a pair of signal wires. The power conductors are 16 AWG (26x30 stranding) with XLPE (plus) insulation. The signal pair are individually foil shielded.

The entire assembly is shielded with barrier tape, triple-layer foil tape (100% coverage), and tinned copper braid (85% coverage). The outer jacket is a specially formulated thermoplastic elastomer (TPE) resistant to disinfecting solutions and is typically used in the food, beverage, chemical, and related industries.

In addition to reliably and efficiently handling power and signals, VFD cables need to be able to handle high

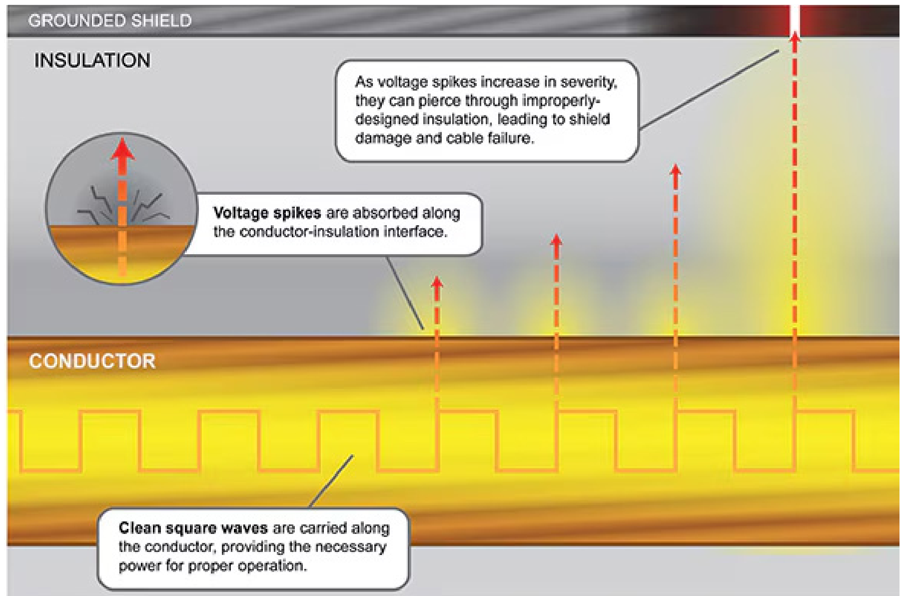


Figure 2: Uncontrolled high voltage spikes can pierce the insulation and result in cable failure. (Image source: LAPP)

voltage spikes and electromagnetic interference (EMI) noise levels resulting from the drive's high-frequency operation. While VFD cables are designed to contain and manage high voltage spikes and EMI, they have their limits (Figure 2). That's when load reactors reduce high voltage spikes and EMI.

For a more detailed discussion of VFD cable selection, see "Specifying and Using VFD Cables to Improve Reliability and Safety and Reduce Carbon Emissions."

Load reactors

Load reactors, also called output reactors, are connected close to the drive's output to reduce the impact of high voltage spikes and EMI, and they protect wire insulation in both the cable and motor. VSDs/VFDs produce a high-frequency (usually between 16 and 20 kHz) output. The high-frequency switching results in voltage rise times of a few microseconds, causing high voltage spikes that can exceed the motor's peak voltage rating, resulting in insulation breakdown.

Depending on the type of motor used, load reactors are often recommended if the VFD cable length exceeds 30 m (100 ft.). There are exceptions; for example, if the motor meets the NEMA MG-1 Part 31 standard, it may be possible to have a 90 m cable (300 ft) without using a load reactor.

Regardless of the motor type, a load reactor is generally recommended if the cable length exceeds 90 m. If the distance exceeds 150 m, a specially designed filter is usually recommended. In EMI-sensitive environments, using a load reactor for all applications is usually good practice.

Load reactors are often designed for use with specific drive models. For example, the Omron model 3G3AX-RAO04600110-DE load reactor is rated for 11 A and 4.6 mH and designed for use with 400 V three-phase 5.5 kW motors driven by the company's 3G3MX2-A4040-V1 VFD.

Braking resistors and thermal overloads

In addition to a load reactor, a braking resistor and thermal overload shutdown device can be essential additions to the output side of a VSD/VFD. Braking resistors enable maximum transient braking torque by absorbing the braking energy. Most braking resistors dissipate the energy, while some are used as part of a regenerative braking system that captures and recycles the energy.

Dissipative braking resistors are rated for specific applications. The Schneider Electric VW3A7755 8 Ω braking resistor can dissipate up to 25 kW, while the Delta Electronics BR300W100 100 Ω braking resistor is rated for 300 W.

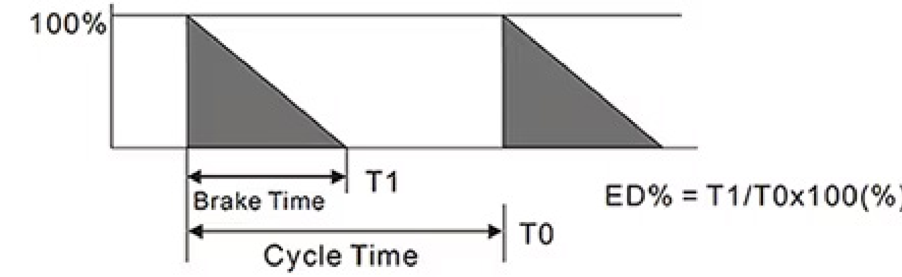


Figure 3: Definition of percentage of energy dissipation (ED%). (Image source: Delta Electronics)

Braking resistor applications are defined using a percentage of energy dissipation (ED%). The defined ED% ensures the resistor can effectively dissipate the heat generated during braking. ED% is defined relative to the peak dissipation, the braking interval (T1), and the overall cycle time (T0) in Figure 3.

Depending on the severity of the braking, ED% is specified to ensure adequate time for the brake unit and brake resistor to dissipate the heat generated by braking. If the brake resistor heats up due to inadequate thermal dissipation, its resistance increases, reducing the current flow and the brake torque absorbed.

Braking resistors can be defined by various dissipation cycles like:

- Light braking, where the braking power is limited to 1.5 times the nominal torque (Tn) for 0.8 s every 40 s. Used with machines with limited inertia, like injection molding machines
- Medium braking, where the braking power is limited to 1.35 Tn for 4 s every 40 s. Used with machines with high inertia, like flywheel presses and industrial centrifuges
- Severe braking where the braking power is limited to 1.65 Tn for 6 s and Tn for 54 s every 120 s. Used with machines with very high inertia, often accompanied by vertical movement, like hoists and cranes

In addition to a braking resistor, most systems include a thermal overload unit connected to the brake resistor as a safety precaution, like the ABB Control TF65-33 thermal overload relay. The thermal overload unit protects the resistor and drive system from too frequent or too strong braking. When a thermal overload is detected, the drive is turned off. Turning off the braking function only could result in serious damage to the drive.

Protection on the drive input

Line reactors and filters on the drive input limit low-frequency harmonics and high-frequency EMI, respectively (Figure 4). Line reactors help reduce harmonic distortion of the AC input power caused by the drive circuitry. They can be especially useful in applications that must meet the requirements of IEEE-519, "Harmonic Control in Power Systems."
Line reactors also smooth out disturbances on the mains power like surges, spikes and transients, increasing operating reliability, and preventing overvoltage shutdowns.

Examples of line reactors include the DV0P228 2 mH inductor rated for 8 A that's part of the Minas family of three-phase drives and accessories from Panasonic and Siemens' 6SL32030CE132AA0 2.5 mH inductor rated for drives up to 1.1 kW that draw up to 4 A of input current and operate from 3-phase 380 V_{AC} -10% to 480 V_{AC} +10% power.

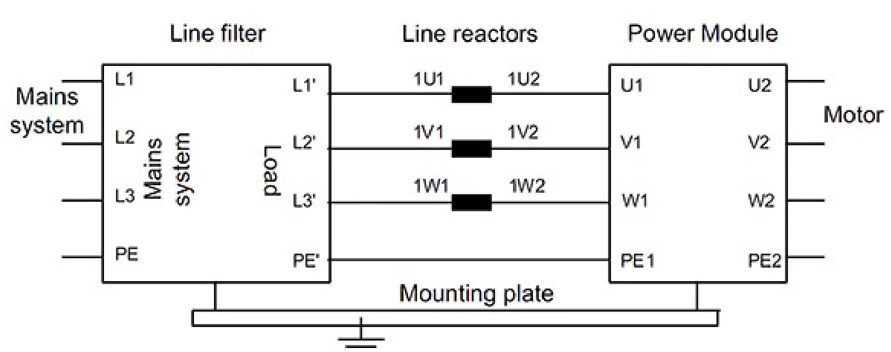


Figure 4: Line filters limit high-frequency EMC, while line reactors limit low-frequency harmonics. (Image source: Siemens)

Line filters

Line filters are required to support electromagnetic compatibility (EMC) and provide EMI protection in most applications. Depending on the specific environment, two classifications of EMI filters, Class A and Class B, are used in industrial and commercial (building) environments, respectively. Class B demands a higher level of filtering than Class A because commercial environments (offices, administration, etc.) generally include electronic systems that are more sensitive to EMI.

The relevant EMC standards include EN 55011, which details emissions limitations for industrial, scientific, and medical equipment, and IEC/EN 61800-3, which relates specifically to adjustable speed drives.

VFDs/VSDs are available with and without integrated line filters. If they have a filter, it may be Class A or Class B. Depending on the environment and installation factors like cabling lengths, even a drive with an integrated filter may require additional filtering. A drive rated for operation in Class A environments can also be used in Class B environments with the addition of an optional filter.

IEC/EN 61800-3 defines EMC requirements based on Environments and Categories. Residential buildings are defined as the First Environment, and industrial installations connected to the medium-voltage distribution network through their transformers are the Second Environment.

The four Categories defined in EN 61800-3 include:

- C1 for drive systems for rated voltages < 1000 V for unlimited use in the first environment
- C2 for stationary drive systems for rated voltages < 1000 V for use in the second environment and possible use in the first environment
- C3 for drive systems for rated voltages < 1000 V for exclusive use in the second environment
- C4 special requirements for drive systems for rated voltages ≥ 1000 V and rated currents ≥ 400 A in the second environment

Generic line filters are available, but like line reactors, line filters are often designed for use with specific drive families. For example, the VW3A4708 line filter from Schneider Electric is rated for 200 A (Figure 5). It's designed for the company's Altivar VSDs and Lexium servo drives. It's rated for mains voltages from 200 V_{AC} to 480 V_{AC} and has a protection index of IP20. Its EN 61800-3 rating depends on the motor cable length:

- Category C1 using up to 50 m of shielded cable
- Category C2 using up to 150 m of shielded cable
- Category C3 using up to 300 m of shielded cable

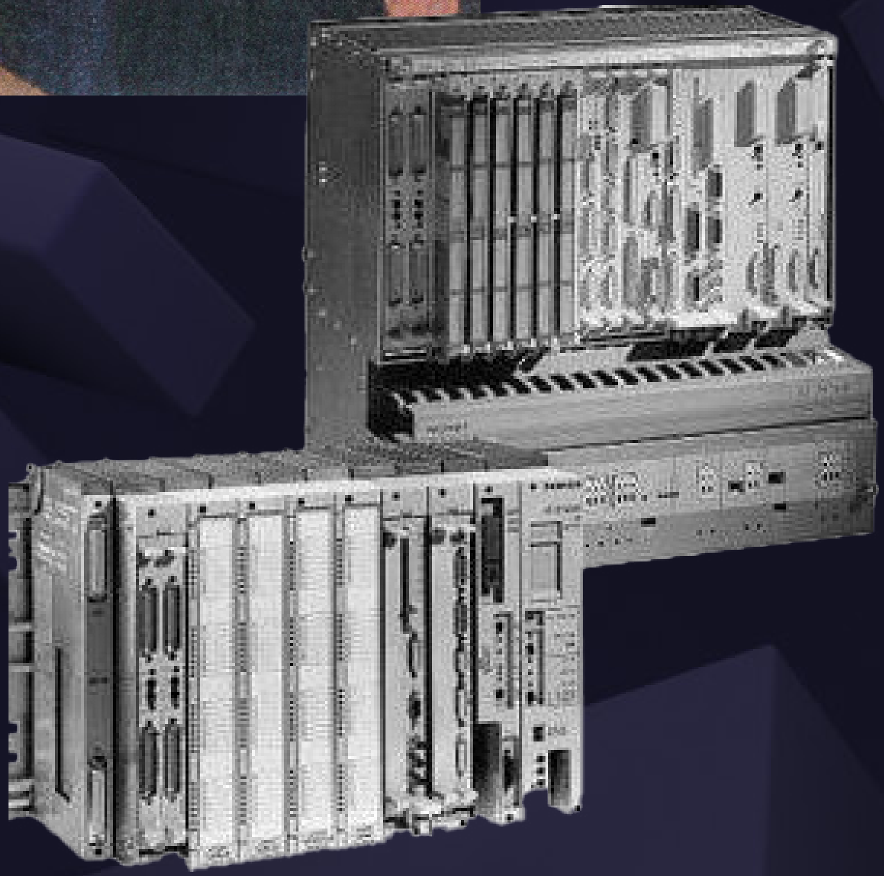
Conclusion

VSDs and VFDs are important systems for maximizing the efficiency of industrial operations and minimizing greenhouse gas emissions. These drives require several support components to ensure effective and reliable installations that meet the relevant international standards, including VFD cables, output reactors, braking resistors, line reactors, and line filters.

Figure 5: 200 A line filter rated for mains voltages from 200 V_{AC} to 480 V_{AC}. (Image source: Schneider Electric)

The Automation Revolution: Modicon 084

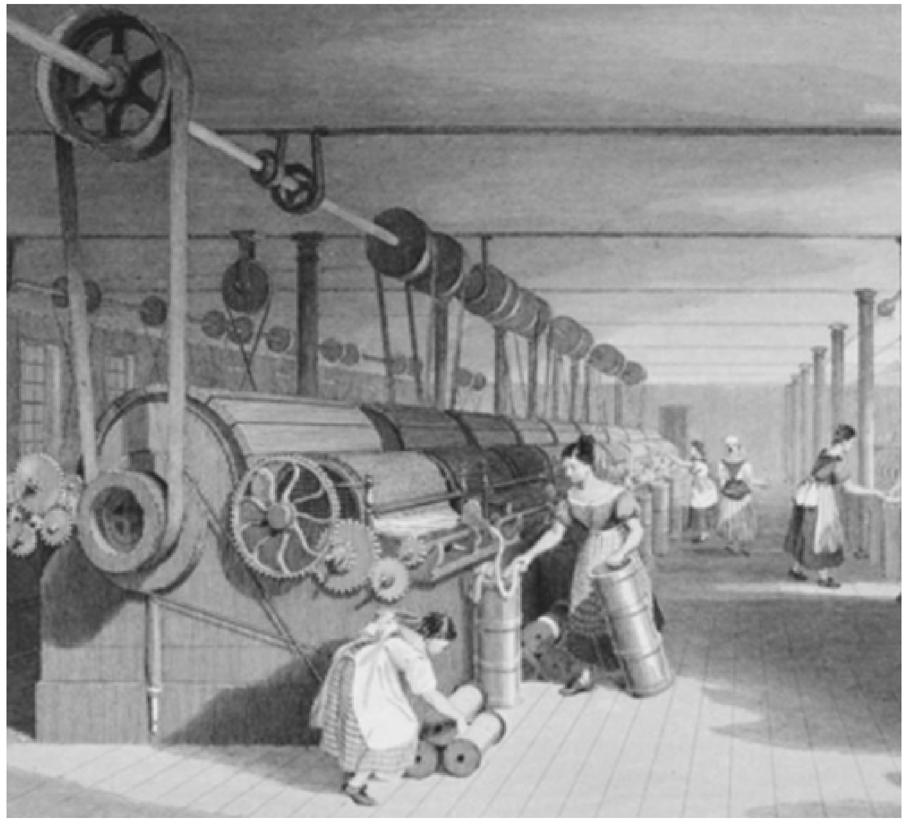
By David Ray, Cyber City Circuits



> "Don't go to the future with your plans. Go to the future with your mind. Bring the future to the present. Don't take the present into the future. Take the future and bring it back to the present."
>
> - Dick Morley

The third Industrial Revolution

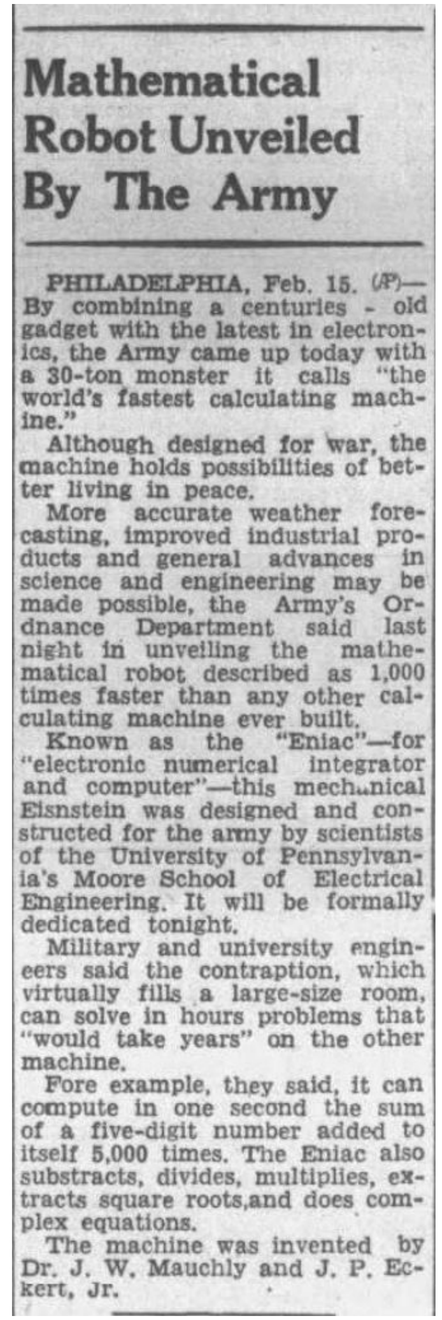
The eighteenth and nineteenth century was marked by unprecedented economic growth driven by the **First Industrial Revolution**. Inventions like the steam engine and the cotton gin helped turn tedious manual tasks into machine tasks using mechanical power. Gears, belts, chains, and pulleys made an intricate array of machines move. With very little in the way of process control, they were still able to out-produce the existing cottage industry manufacturing.



The late 1800s saw the golden age of invention. Frank Sprague's invention of the Electric Traction Motor, set the Second Industrial Revolution off. No longer did you have to rely on burning coal or power driven by beasts and livestock. Suddenly a person could get more power from an electric motor than could be had from dozens of horses. Everything in every industry was exponentially enhanced by electrification.

Retro Electro: Learn more about Frank Sprague's journey to the first EV in the article 'Frank Sprague and the Richmond Union Passenger Railway' (https://www.digikey.com/en/emedia/emagazine/2024/transportation?page=9).

It would be another century before another invention would revolutionize industry, once again. The reader may think of the transistor, or the computer and they would be incorrect. The thing about those inventions and others was that they had no practical utility in manufacturing. The marker for the beginning of the Third Industrial Revolution is Bedford Associates' Modicon 084 Programmable Controller (Today known as Programmable Logic Controller or PLC).



Mathematical Robot Unveiled By The Army

PHILADELPHIA, Feb. 15. (AP)—By combining a centuries - old gadget with the latest in electronics, the Army came up today with a 30-ton monster it calls "the world's fastest calculating machine."

Although designed for war, the machine holds possibilities of better living in peace.

More accurate weather forecasting, improved industrial products and general advances in science and engineering may be made possible, the Army's Ordnance Department said last night in unveiling the mathematical robot described as 1,000 times faster than any other calculating machine ever built.

Known as the "Eniac"—for "electronic numerical integrator and computer"—this mech..nical Eisnstein was designed and constructed for the army by scientists of the University of Pennsylvania's Moore School of Electrical Engineering. It will be formally dedicated tonight.

Military and university engineers said the contraption, which virtually fills a large-size room, can solve in hours problems that "would take years" on the other machine.

Fore example, they said, it can compute in one second the sum of a five-digit number added to itself 5,000 times. The Eniac also substracts, divides, multiplies, extracts square roots,and does complex equations.

The machine was invented by Dr. J. W. Mauchly and J. P. Eckert, Jr.

"Although designed for war, the machine holds possibilities of better living in peace."

The world of computers up to 1968

The first programmable controller was not considered a computer at the time. Lore has it that, during the design process, any notes that had the word 'computer' on them were balled up and thrown away on sight. At the time, 'computer' was a four-letter word that took an entire wing of a building to maintain and a monthly air conditioning bill that would make any bean counter cry. This was still years before the release of the Intel 4004 or the MOS 6502.

The first electric computer was announced in 1946. Weighing thirty tons, the ENIAC (Electronic Numerical Integrator and Computer), also known as the 'Mathematical Robot,' was designed for the US Army to assist with advanced calculations such as artillery trajectory and weather forecasting. World War II had effectively ended before ENIAC could be publicly announced.

The machine was alive with the clicking of relays and the heat of filament vacuum tubes. Soon after, companies were quick to try to make a mass-producible computer, but they were far more limited by the day's technology than they realized.

The following year, 1947, three engineers at Bell Labs developed the first transistor, which allowed current to be switched on and off, like a vacuum tube but as a solid-state device. You know this, but the collision of those two inventions drove the change in the twentieth century.

It took a while to get it worked out, but Bell Labs, in conjunction with the US Air Force, developed the first transistorized computer, TRADIC (TRAnsistorized DIgital Computer), in 1954. TRADIC used several hundred 'point contact transistors' and over ten thousand germanium diodes.

While TRADIC was a milestone creation, it was primarily used for R&D and never meant for any commercial use. By the end of the 1950s, it was clear to the industry that computers were the next big thing, but even into the 1960s there were still a lot of vacuum tubes, filament bulbs, and relays.

In 1964 IBM released a new flagship computer product line called System/360. Some historians mark this as the formal beginning of the 'Computer Age.' These computers cost over a million dollars, so most of them were leased by service providers. These leases could cost over $80,000 a month, with the higher-end models costing up to $115,000 a month. Often these computers would be leased to time-share companies, and they would sell mainframe time to their clients, but larger companies like General Electric would have their own computer.

The problem was that there was no practical way for the manufacturing industry to take advantage of them, no matter how much they cost. How does having a five-ton machine in a hot room help someone like General Motors make more automatic transmissions? The economic growth of the late 1960s was ending, and manufacturers knew this. The industry was reaching the limits of what technology was capable of.

Challenges of Pre-PLC automation

Before the PLC became available on the market in 1969, engineers and manufacturers encountered various challenges when trying to automate machinery and processes.

Here's a look back at some of the significant hurdles:

- **Relay Logic:** Automation was primarily achieved through relay logic systems, where numerous relays, timers, and counters were wired together to control machinery. This approach was not only complex but also very expensive due to the high cost of relays and the labor-intensive wiring process.
- **Space and Maintenance:** Large panels filled with relays took up significant space, and diagnosing issues or changing the control logic required extensive rewiring, leading to downtime and maintenance nightmares.
- **Inflexibility:** Once a control system was set up using relays, changing the sequence or logic of operations was a daunting task. It often meant redesigning and rewiring significant portions of the control panel, making the system highly inflexible to adapt to new processes or minor adjustments.
- **Mechanical Wear:** Relays and other mechanical components were susceptible to wear, resulting in frequent failures. Consequently, the reliability of these systems was lower than desired, particularly in harsh conditions like dust, heat, or vibration.
- **Scalability:** Expanding an existing system or integrating new machinery was challenging. Each addition or change could necessitate a complete overhaul of the control system, making scalability a significant issue.
- **Manual Configuration:** Without digital means, programming was essentially done through physical wiring. Wires would be wrapped around posts, changing the actions of the relay logic. Debugging required manual tracing of wires and logic, making it time-consuming and very prone to errors.
- **Lack of Documentation:** Over time, as systems evolved, documentation often became outdated or incomplete, complicating maintenance and upgrades. The machines were built on-site by brilliant minds who left and moved to the next factory to do it over again.
- **Safety Concerns:** The use of high voltage in relay systems posed safety risks for workers, especially during troubleshooting or maintenance activities. Factories were very dangerous for several reasons and electrocution was absolutely one of them.
- **Speed and Efficiency:** The response times of relay-based systems were slower compared to what would become possible with digital technology. Every click-and-clack takes time that a transistor wouldn't need. This limitation affected the efficiency of manufacturing processes, especially in high-speed applications.

Globalization and labor shifts driving automation

The late 1960s was a pivotal time for manufacturing. The rapid globalization of trade and rising competition from overseas manufacturers put pressure on American industries to increase efficiency and reduce costs. Labor unions were also growing in strength, leading to higher wages and benefits for workers. While these advancements improved worker conditions, they simultaneously drove the need for manufacturers to offset rising labor costs through automation.

These factors underscored the necessity of a more flexible and scalable manufacturing process for companies like General Motors. While relay logic systems were serviceable, they were too slow, inflexible, and maintenance-heavy to keep pace with the market's growing demands. Automation technology could offer faster production setup times, greater adaptability, and reduced reliance on human manual labor.

> Retro Electro fun fact: Dick Morley would have attended MIT at the same time as Kenneth Olsen, the founder of Digital Equipment Corporation (DEC), which later became one of his most significant competitors. There is no evidence that they knew each other, but Olson was a research assistant, so he could have been an instructor in a few of Morley's classes.

Dick Morley

Richard Morley (Dick Morley) was born in 1932 on a farm in Massachusetts. He attended MIT in the early 1950s but dropped out before graduating. He claims that he dropped out because he spent too much time partying and that he didn't study enough.

After college, he worked as a machinist and worked with RADAR systems, but the 9-to-5 life was not for him, as he told it, he quit his job because he wanted to be able to go skiing on the weekdays, when it was less crowded. I'm sure there is more to it, but his career before Bedford Associates isn't known to the writer.

Bedford Associates

Growing up on a farm, he was instilled with an entrepreneurial spirit. In 1964 he and some colleagues started a company named 'Bedford Associates Inc.' which worked primarily in numerical control and facsimile transmission as consultants in product development.

"Engineering is not solving problems (and) innovation is making problems. Innovation comes from the road and the observation of it, not the destination of the road."

– Dick Morley

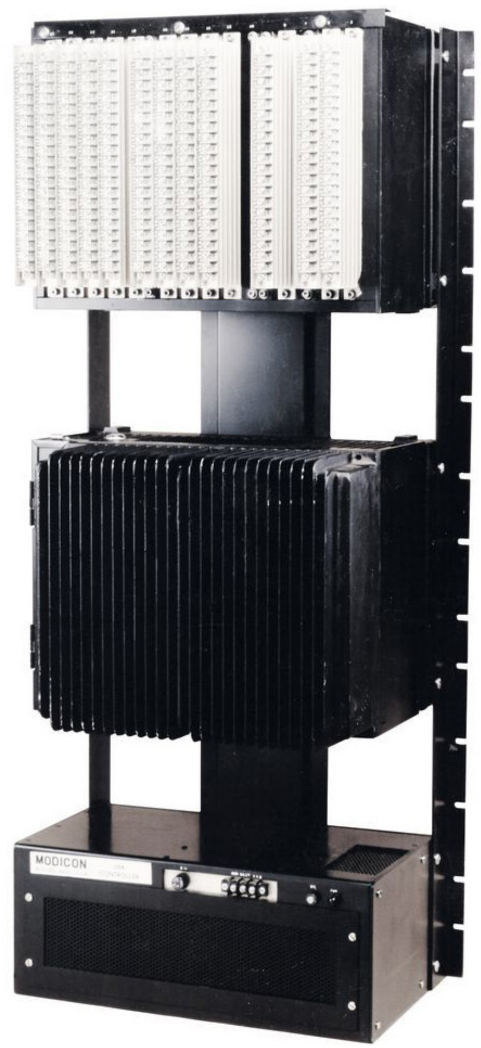
Ultimately, Bedford Associates was a group of 'inventors for hire.' The industry would send them requests for proposals and specifications for a machine, relay box, etc., and they would design and build it for the customer. Manufacturers like General Motors and Western Electric would hire them to build logic machines to help automate machine tasks and motors. Through a series of intricate and complicated relays, they would integrate relay controls into factory lines, along with other projects.

Retro Electro bonus fact: Morley has credited involvement with the invention of the floppy disc and anti-lock braking systems.

Modicon 084

According to varying accounts, on New Year's Day 1968, Morley stayed up too late, getting drunk the night before. Some months earlier, General Motors sent a 'Request for Proposals' for a system that could better automate their new transmission factory. Morley had worked in the manufacturing industry for some years at this point, and most of the projects they completed had many things in common, so he felt that he could make a standardized and adaptable machine. He wanted to finish the proposal to send out before Christmas so it could get there before all the executives came back from their vacations and today was Monday, January 1st.

The proposal itself isn't readily available online. In interviews, Morley describes it as a way to get General Motors to produce more trucks faster. He stated that it could take them four months to set up a new production line for a car, but with his proposal, he can reduce that time to a month and a half. He describes it as a "black box" that you tell to do a task, and it gets it done. He says that his description was purposefully vague because he wanted to hurry up and finish writing it so he could go to sleep.



Modicon 084 on Display in the Smithsonian Museum.

Retro Electro bonus fact: In 1971, the IEC released IEC61131-3 for programmable logic controllers. This standard dictated the types of programming languages that could be used, formalizing ladder logic in the PLC world.

In his proposal, he lists the problems with automation lines and simply claims to fix each one. That list of fixes essentially became the requirements list. They didn't have any microprocessors (they didn't exist yet), but 4700-series TTL logic ICs were starting to become widely available.

Later in the year, he and his team of engineers and marketers, including Tom Boissevain, George Schwenk, Jonas Landau, Mike Greenberg, and Roland Hebert, completed Project 084, better known as the Modicon 084. The Modicon 084 is the first machine to bring real automation and process control to manufacturing. Using a proprietary programming setup, this machine cut the automation setup time by as much as 80%, allowing the factory to make even more high-quality products in that time.

In the same year, Bedford Associates started a new company named **Mo**dicon, Modular **Di**gital **Con**troller, to market the new PLC. Soon after, the Modicon 184 was released to huge success.

The story after

Modicon

Modicon continued for a handful of years before being purchased. It is tough to chase the lineage, but it eventually became part of the Schneider Electric (https://www.digikey.com/en/supplier-centers/schneider-electric) product catalog.

Caption: Modicon 184

Retro Electro bonus fact: Whether you believe it or not, the Modicon 184 is still used in factories around the world today. (If you're reading this magazine, you probably believe it.)

Bedford Associates

In the early 1980s, Bedford Associates partnered with Tandem Computers on a airline reservation system called SPAR. In 1987, British Airways purchased the company for $23M.

Dick Morley

Dick Morley continued to work in the industry, teaching courses, writing books, and developing groundbreaking new theories on measurement. He received over a dozen prestigious awards, including being a member of the 'Measurement, Control, and Automation Hall of Fame' and 'The Control System Integrators Association Lifetime Achievement Award.'

Over the decades, he and his wife took in and adopted as many as forty foster children and orphans. He spent much of his later years investing in new technology as an 'angel investor.'

The fourth Industrial Revolution

In the 20th century, many improvements were made to the PLC concept, including human-machine interfaces (HMIs) and computer interfaces. However, when PLCs were connected to the Internet, they initiated the fourth industrial revolution that we are living in today. People speculate that edge AI and machine learning are bringing us to the brink of the fifth industrial revolution right now.

"Progress is only made down the road and the road has bumps in it. Without those bumps you're not making progress. Don't be afraid of bumps. Don't try to make a smooth road and then go. Go first."

- Dick Morley"

1932
Dick Morley born in Massachusetts.

1946
ENIAC, the first electronic computer, is announced to the public.

1947
Bell Labs invents the transistor, enabling solid-state electronics.

Early 1950s
Morley attends MIT but drops out before graduating.

1954
TRADIC, the first transistorized computer, is announced.

1964
Morley co-founds Bedford Associates with colleagues.

1964
IBM System/360 launches, marking the start of the Computer Age.

Late 1960s
Relay-based logic systems reach their limits, necessitating new automation solutions.

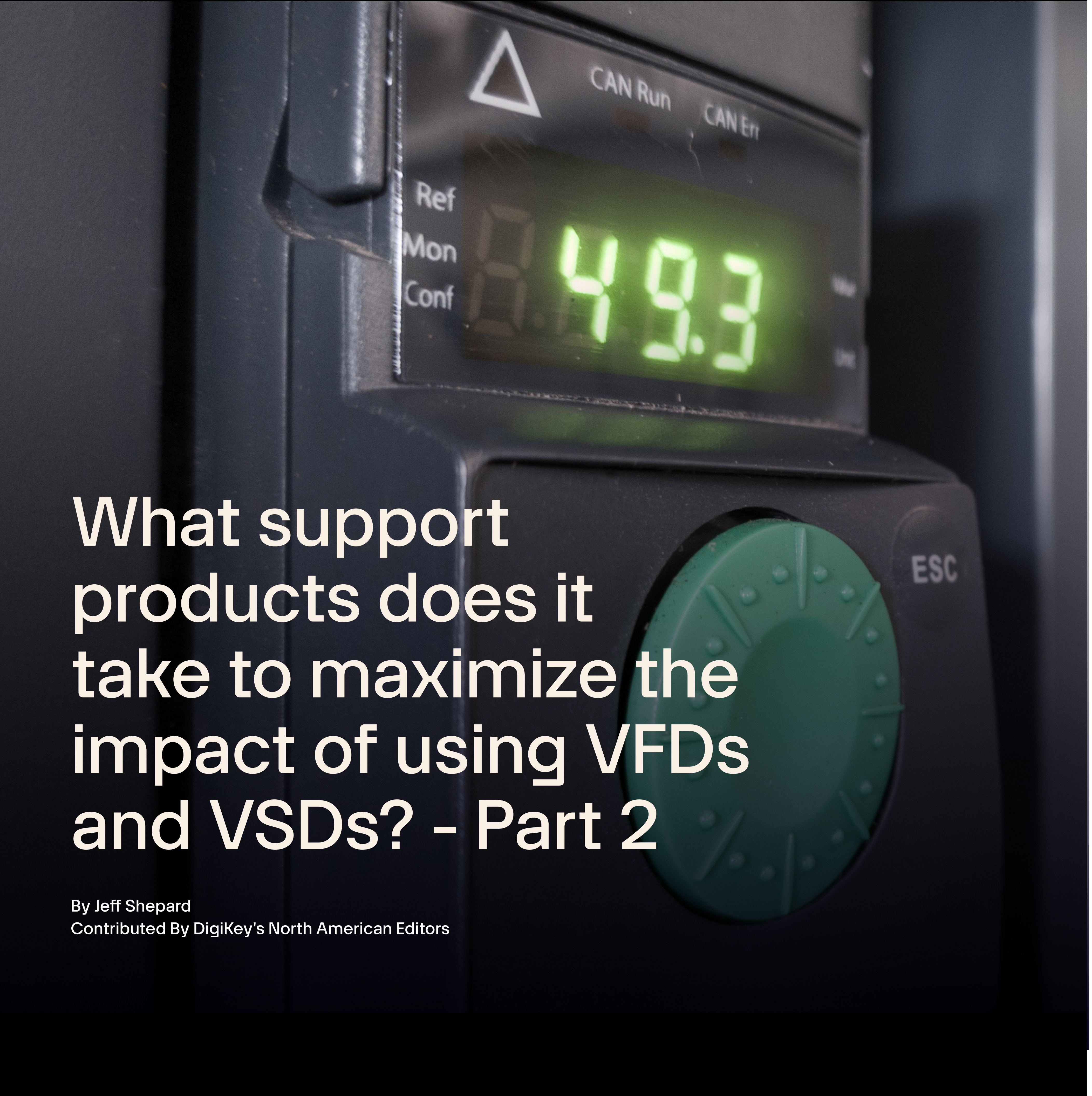
January 1, 1968
Dick Morley writes a proposal for a "black box" automation solution.

1969
Modicon 084 debuts, cutting automation setup times by up to 80%.

1971
IEC formalizes PLC programming, including ladder logic.

1987
British Airways acquires Bedford Associates' SPAR reservation system for $23M.

1990s-Present
Modicon becomes part of Schneider Electric.



What support products does it take to maximize the impact of using VFDs and VSDs? - Part 2

By Jeff Shepard
Contributed By DigiKey's North American Editors

Part 1 of this article series looked at what to consider when selecting motor connection cables, output reactors, braking resistors, line reactors and line filters. Part 2 continues by looking at the differences between VSDs/VFDs and servo drives, reviewing uses for AC and DC rotary and linear servo motors, considering where soft start-stop units fit into industrial operations, and Looking at how DC converters are used to power peripherals like sensors, human-machine interfaces (HMIs), and safety devices.

Variable speed drives and variable frequency drives (VSDs/VFDs) are essential to maximizing industrial operations' efficiency and sustainability, but they're not the only tools available. To get the ultimate performance, VSDs/VFDs often need to be supplemented by other devices like servo drives and motors, soft start-stop units, direct current (DC) converters, and direct current (DC) input uninterruptible power supplies (UPS) to arrive at an optimal industrial automation architecture.

AC and DC servo motors and drives are suited for various applications, from simple 1- or 2-axes tasks to complex tasks with 256 or more axes of motion. Servo motor-controlled actuators provide precise and repeatable movements for industrial machines and are available with rotary and linear motion configurations.

Constant speed applications like conveyors, pumps, and overhead cranes can often benefit from using soft start-stop units instead of VSDs/VFDs.

Depending on the application requirements, designers can select between redundant DC power supplies, a Class 2 power supply as defined in the U.S. National Electric Code (NEC), or a DC UPS to handle unpredictable mains power and improve system reliability.

This article begins with a look at the differences between VSDs/VFDs and servo drives, reviews uses for AC and DC rotary and linear servo motors, and considers where soft start-stop units fit into industrial operations. It continues by reviewing how DC converters are used to power peripherals like sensors, human-machine interfaces (HMIs), and safety devices. It examines when to use a redundant DC architecture or a DC UPS to power those devices and the choice between battery and supercapacitor energy storage. Representative devices from Schneider Electric, Omron, Lin Engineering, and Siemens are presented in each case.

Servo motor systems can complement VSDs/VFDs in industrial automation architectures. Servo motor systems are designed for complex and dynamic motion systems and can support precise positioning. Servo drives are used with permanent magnet motors and encoders for closed-loop control. They are designed to support rapid acceleration and deceleration and can support linear or non-linear motion profiles.

Many VSDs/VFDs use open-loop control to manage motor speed. They don't support the precision or responsiveness available with servo motor systems. In addition, open-loop motor control means that VSDs/VFDs don't necessarily compensate if the load changes or the motor stalls. While servo motor systems are used in highly dynamic applications, VSDs/VFDs are used in applications that maintain a constant speed, or relatively few speed changes, over a long period.

Servo motor systems tend to be smaller than VSD/VFD drives, with typical power levels from 40 to 5,000 W. They feature high speeds, up to 5,000 revolutions per minute (rpm), low noise, low vibration, and high torque. Servo motors are available in various frame sizes, up to 180 mm or larger. For example, the SBL40D1-04 from Lin Engineering is a 40 mm, 60 W brushless DC (BLDC) servo motor with a rated voltage of 36 V_{DC}.

Servo motors are often paired with drives. Schneider Electric offers the LXM28AU07M3X drive and BCH2LF0733CA5C 5,000 rpm servo motor, both rated for 750 W (Figure 1). The drive features integrated CANopen and CANmotion communication interfaces and can operate with single-phase or three-phase power. The companion 80 mm motor is IP65 rated and can operate from -20°C to +40°C.

Linear and cartesian motion

Linear motion is used in various industrial processes, from coating materials and 3D printing to inspection systems, and is available in several embodiments. Some are based on rotary stepper motors, and other designs use linear motors. Rotary stepper motors produce linear motion using a threaded shaft. There are two basic designs, external-nut and internal-nut, sometimes called non-captive.

Figure 1: Matched 750 W servo drive and IP65-rated motor. (Image source: Schneider Electric)

The nut is mounted on the threaded shaft in an external-nut linear actuator. The shaft is fixed on both ends. As the stepper motor rotates, the nut moves back and forth along the shaft, carrying the object (payload) to be moved. In a non-captive design, the payload is attached to the motor. The shaft is fixed at both ends, and the motor carrying the payload moves along the shaft.

Linear motion stages with high-efficiency iron-core linear motors, magnet tracks, and absolute encoder technology can provide repeatable sub-micron precision and 5G acceleration, moving up to 5 m/s for high-speed industrial applications. Unlike threaded shaft designs, linear motors can provide higher positioning accuracy and faster movement.

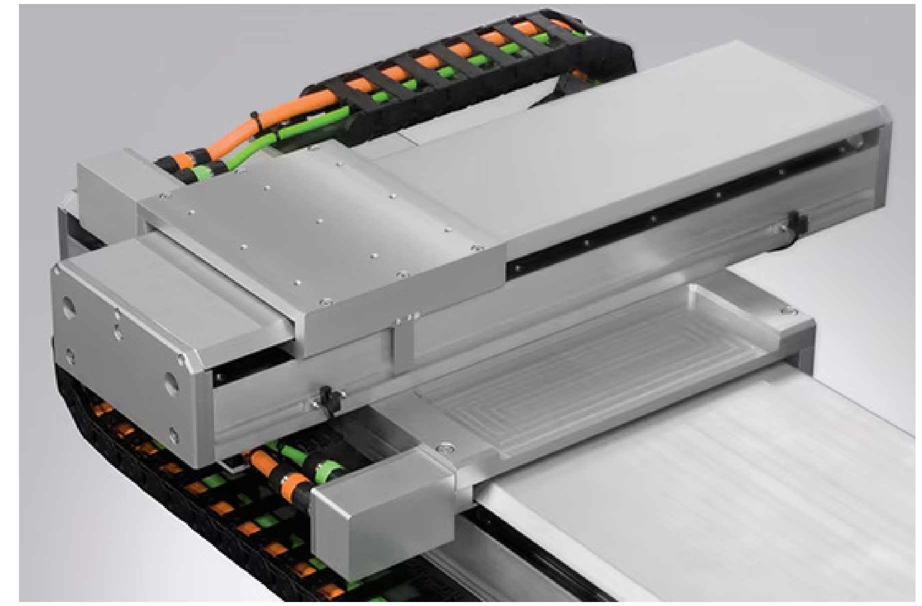


Figure 2: Two linear motor stages can be stacked to support cartesian motion. (Image source: Omron)

The mechanical parts of linear motion stages can be packaged in highly enclosed structures for environmental protection. Omron offers linear motion stages based on iron core motors ranging from 30 mm active magnet width and three coils to 110 mm active magnet width and 15 coils. They are rated to deliver from 48 Newtons (N) to 760 N of force.

The R88L-EA-AF-0303-0686 linear actuator motor is available in 230 V and 400 V models. It has a rated force of 48 N and a peak force of 105 N. It can be driven with the R88D-KN02H-ECT servo driver that includes EtherCAT communication for integration into industrial networks. Two linear motion stages can be stacked to provide motion in a cartesian coordinate system (Figure 2).

Soft start-stop units

While VFDs/VSDs and servo drives control motors' speed and torque while running, soft start-stop units limit current inrush when a motor is started to protect the motor and provide a smooth ramp up in speed and torque. They provide smooth ramp downs in speed as the motor is stopped. They also protect the mechanical components in the system from damaging torque spikes when starting or stopping.

A motor soft start-stop unit can benefit applications like conveyors, pumps, fans, overhead traveling cranes, and automatic doors that don't need high levels of start-up torque and run at constant speeds. Controlled and predictable speed changes also improve operator safety.

Motor starting and stopping speeds are guided using solid-state devices like silicon-controlled rectifiers (SCRs) that control the voltage and the current to the motor. Once the motor is fully started, the SCRs are bypassed using a contactor to improve operational efficiency.

Soft start-stop units like the Alistart 22 family from Schneider Electric can handle a wide range of three-phase asynchronous motors from 4 kW to 400 kW. They include Class 10 motor overload and thermal protection, providing a fast-tripping time of 8 to 10 seconds. The power ratings of soft start-stop units often depend on the motor's operating voltage. For example, Schneider Electric's ATS22D17S6U unit can handle motors rated for 3 hp with 208 V power, 5 hp with 230 V power, 10 hp with 460 V power, and 15 hp with 575 V power (Figure 3). It requires 110 V_{AC} 50/60 Hz power for the control circuitry.

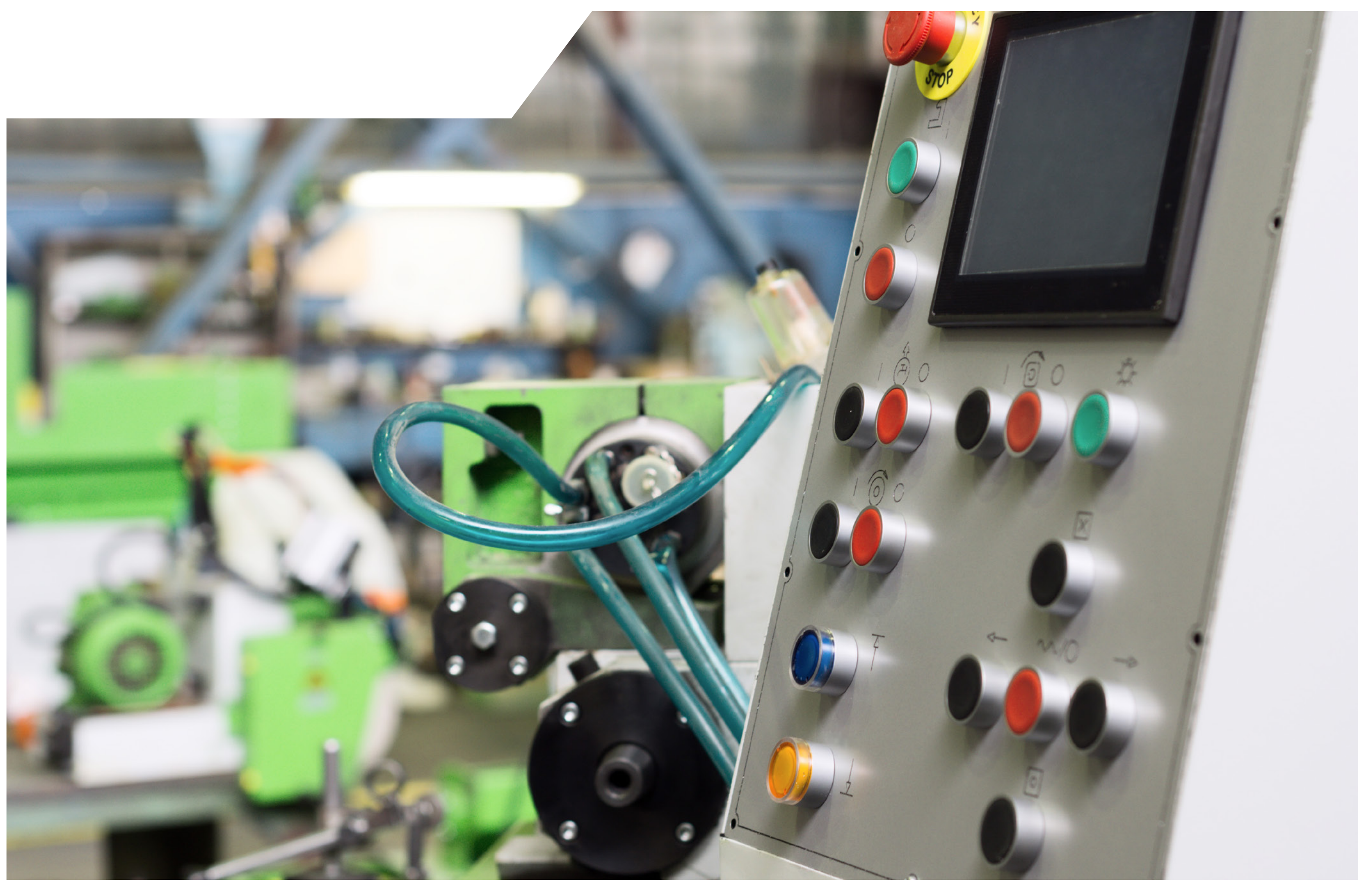
Figure 3: This soft start-stop unit can handle motors up to 15 hp. (Image source: DigiKey)

Redundant power

Industrial systems use 24 V_{DC} power for various functions like sensors, HMIs, and safety devices. Basic redundant power can improve the reliability of industrial installations. Redundant power uses two power supplies connected in parallel to power a load where each power supply is sufficient to power the entire load should the other supply fail. When two power supplies are used, it's called 1+1 redundancy. Both power supplies must fail for the system power to fail.

Using more power supplies in an N+1 configuration can increase the reliability of the overall power delivery system. A 3+1 redundant power architecture uses four power supplies, any three of which can power the entire load.

A redundancy module typically uses diode isolation to connect the power supplies to ensure that the failure of any one power supply does not affect the operation of the other power supplies. For applications that require even higher reliability, multiple redundancy modules can be employed to eliminate the possibility of a single point of failure (Figure 4). For example, Omron's S8VK-C12024 AC/DC power supply can support 24 V loads up to 120 W. Two of those power supplies can be connected using the S8VK-R10 redundancy module to create a 120 W 1+1 redundant power system.



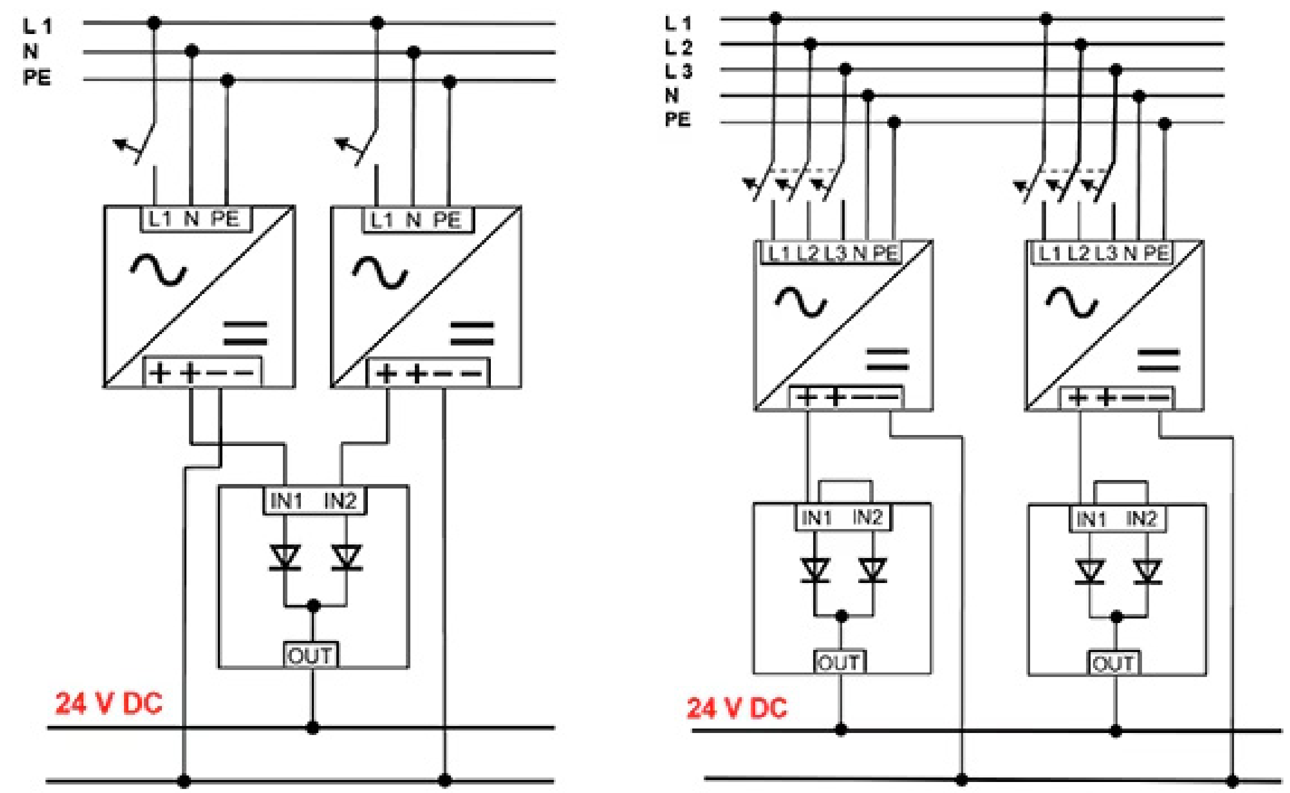


Figure 4: Using multiple redundancy modules (right) can eliminate the single point of failure and enhance reliability. (Image source: Siemens)

Class 2 and redundant

Class 2 power can be an important safety factor in industrial installations. As defined in the U.S. NEC, Class 2 power supplies have an output limited to less than 100 VA. Class 2 power is also required or recommended with some industrial devices outside of the U.S.

Limiting the power reduces the risks of electric shock and fire. As a result, Class 2 installations do not require the power cables to be routed through conduits or ducts, simplifying installation and reducing costs. In addition, simpler inspections are required for Class 2 installations, further reducing costs.

There are two ways to achieve a Class 2 power rating. Power supplies that internally limit the output power to under 100 VA are available. Or, a higher wattage power supply like the 480 W (24 V_{DC} and 20 A) 6EP15663AA00 from Siemens can be used with redundancy modules like Siemens' s that limit the output power as well as providing redundancy for multiple loads (Figure 5).

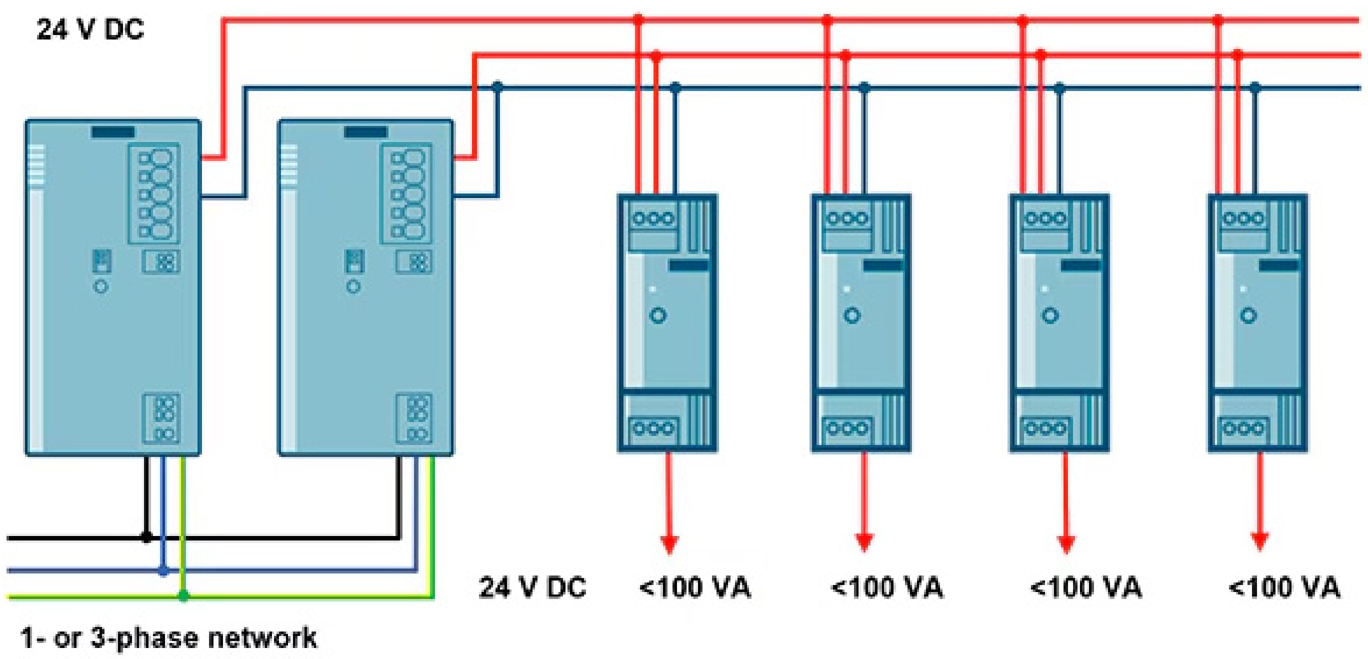


Figure 5: 1+1 redundant power supplies (left) connected to four loads through Class 2 redundancy modules. (Image source: Siemens)

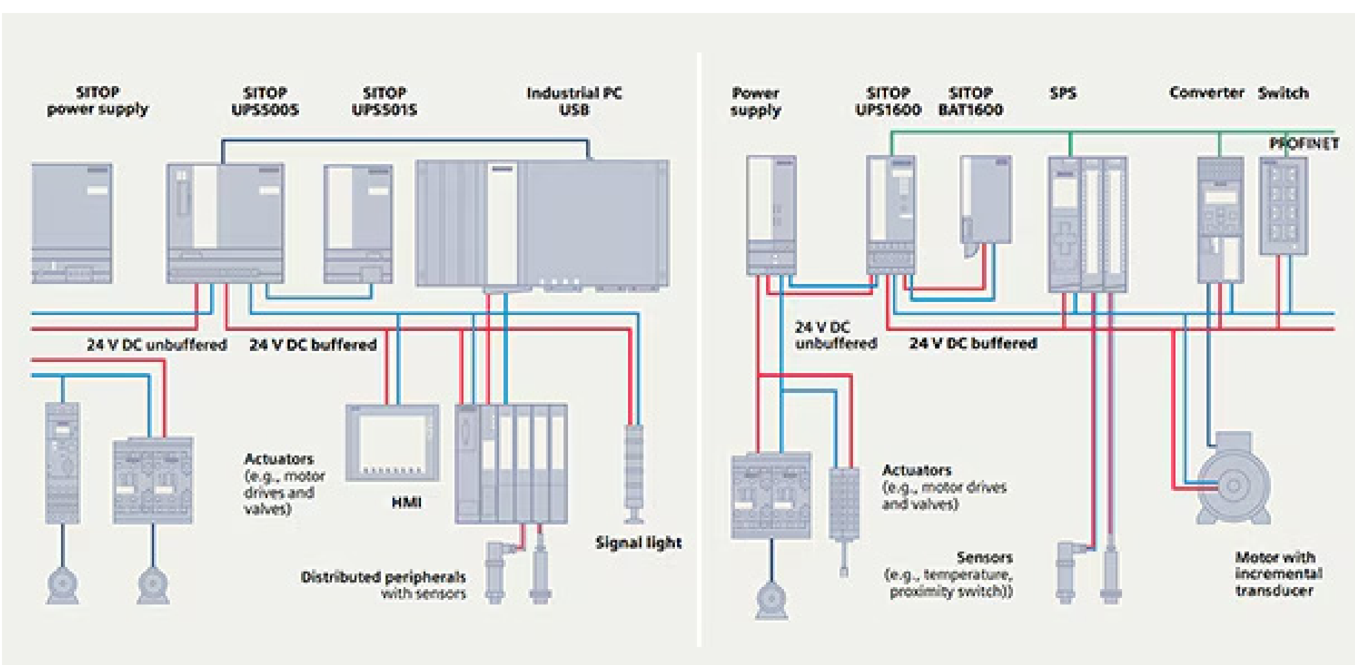


Figure 6: Ultracapacitors (UPS5005 and UPS501S) can provide short-term backup power (left), while batteries (UPS16090 and BAT1600) can support much longer backup power operation (right). (Image source: Siemens)

Uninterruptible power

Redundant power can be useful, but it's not enough for critical applications. When traceability and data collection are mandatory, safety is a concern, or uninterrupted operation is required, a UPS like the 6EP41363AB002AY0 SITOP UPS from Siemens will be needed. This UPS provides a 24 V_{DC} output and can deliver up to 20 A.

One of the key questions when selecting a UPS is the energy storage technology. Ultracapacitors, also called double-layer capacitors, are suited for short-term backup power needs like saving process data and orderly shutdown of industrial PCs and other devices. They have a long life and can provide up to 20 kilowatt seconds (kWs) of backup power. For example, Siemens' model 6EP19332EC41 capacitor energy storage unit can provide up to 2.5 kWs of backup power.

Lead-acid and various lithium-ion chemistries can be useful for longer backup power needs, which take up to several hours for critical communications or process operations (Figure 6). Basic DC UPS battery modules with up to 38 Ah of storage are available. Multiple battery modules can be used to provide backup times of several hours. The 6EP19356MD31 DC UPS battery module from Siemens uses maintenance-free sealed lead-acid batteries to provide up to 15 A with a storage capacity of 2.5 Ah.

Conclusion

VSDs/VFDs are often considered to be the workhorses of industrial automation. However, a comprehensive industrial automation architecture requires more, including servo drives, motors, and soft start-stop units. Industrial automation system designers also have numerous DC power architectures to select from when optimizing uptime and reliability.

What are some key considerations when selecting industrial automation equipment?

By Jeff Shepard
Contributed By DigiKey's North American Editors

Optimal selection of industrial automation equipment like motors, drives, and communications modules requires careful attention to detail. For example, there are numerous differences between the National Electrical Manufacturers Association (NEMA) in North America and the International Electrotechnical Commission (IEC) in Europe regarding motor and drive ratings.

When selecting motors, drives, and controllers, some considerations include the input and output voltages and tolerances, required speed range and regulation needs, torque requirements, acceleration, braking duty cycles, special needs like quick speed or torque response, and environmental factors, including thermal management.

Communication needs vary depending on where the equipment is in the industrial control hierarchy. At the level nearest the edge of the factory floor, protocols like IO-Link can be used for intelligent sensors and actuators, and EtherCAT, PROFINET, Modbus, and other protocols can connect motion, safety, I/O, and vision.

The highest level of the factory automation network often uses Ethernet/IP to connect with various automation controllers, programming interfaces, and the cloud, as well as a protocol like DisplayPort to connect with human machine interfaces (HMIs). In between, combinations of Ethernet/IP, EtherCAT, and other protocols can link the factory floor's field level to the operation and control levels.

The details are too numerous to do them justice in a single discussion. Instead, this article presents several guideposts to consider when specifying motors, drives, and communications modules, along with examples of application, hardware, and protocol from Siemens, Phoenix Contact, Omron Automation, Panasonic Industrial, and Schneider Electric.

Shifting focus

Motors and drives are a common thread across many industrial automation systems. As a starting point for this discussion, it's helpful to see where motor efficiency fits into the wider considerations of industrial automation system performance and how the focus is shifting.

Using higher-efficiency motors can produce energy savings of up to 6%. That's good. However, adding a high-efficiency drive along with support components can boost energy savings by up to 30%.

A real game-changer occurs when the focus is shifted to overall system optimization. Considering all the mechanical components and adding communication to tie into the Industrial Internet of Things (IIoT), including the operational and plant levels and ultimately to the enterprise level, as well as the cloud, can result in up to 60% energy savings plus higher productivity (Figure 1).

Ecodesign for motor systems

Part 2 of IEC 61800-9, "Ecodesign for motor systems - Energy

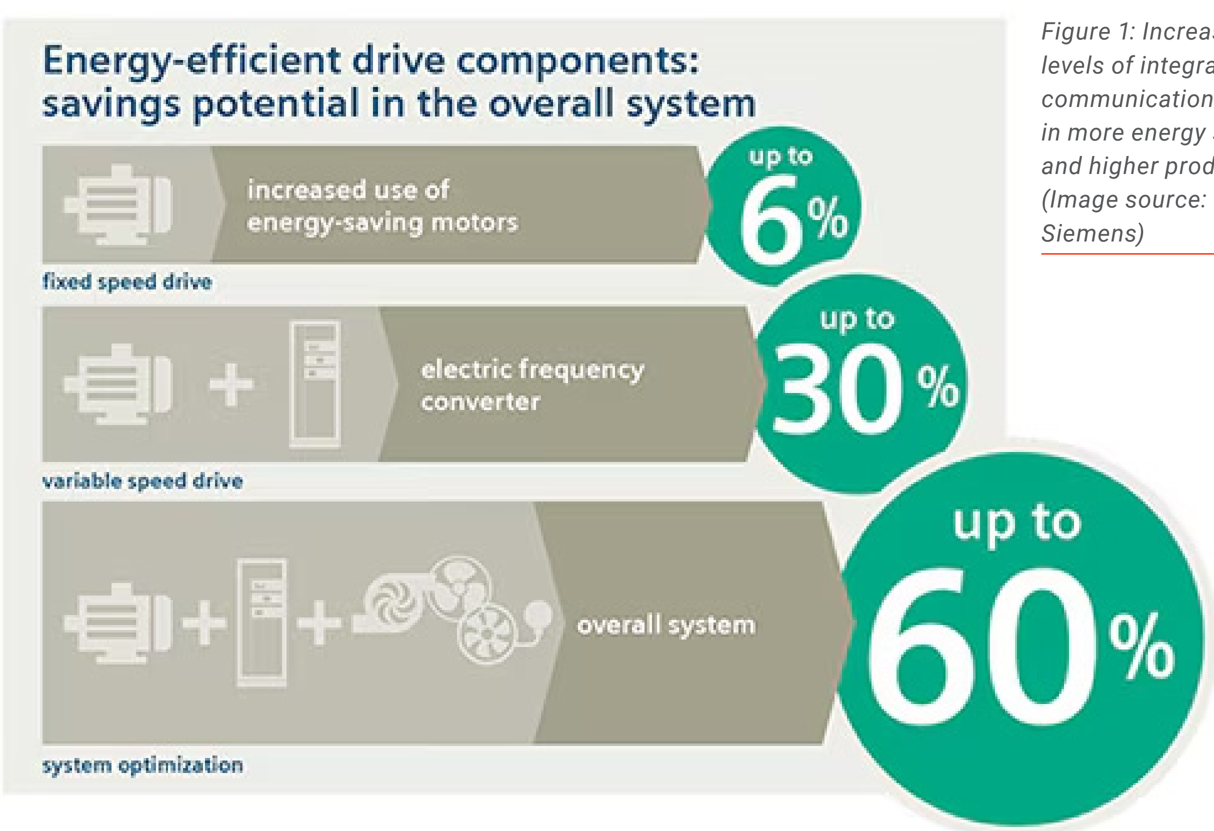


Figure 1: Increasing levels of integration and communication result in more energy savings and higher productivity. (Image source: Siemens)

efficiency determination and classification," can be a key resource. Instead of focusing solely on motor efficiency, it details a series of higher-level performance factors for "electric motor-driven systems." VFDs are considered in the context of a complete drive module (CDM) that includes the AC input '" feeding section," a "basic drive module" (BDM) like a VFD, and "auxiliaries" that include input and output filters, line chokes, and other support components.

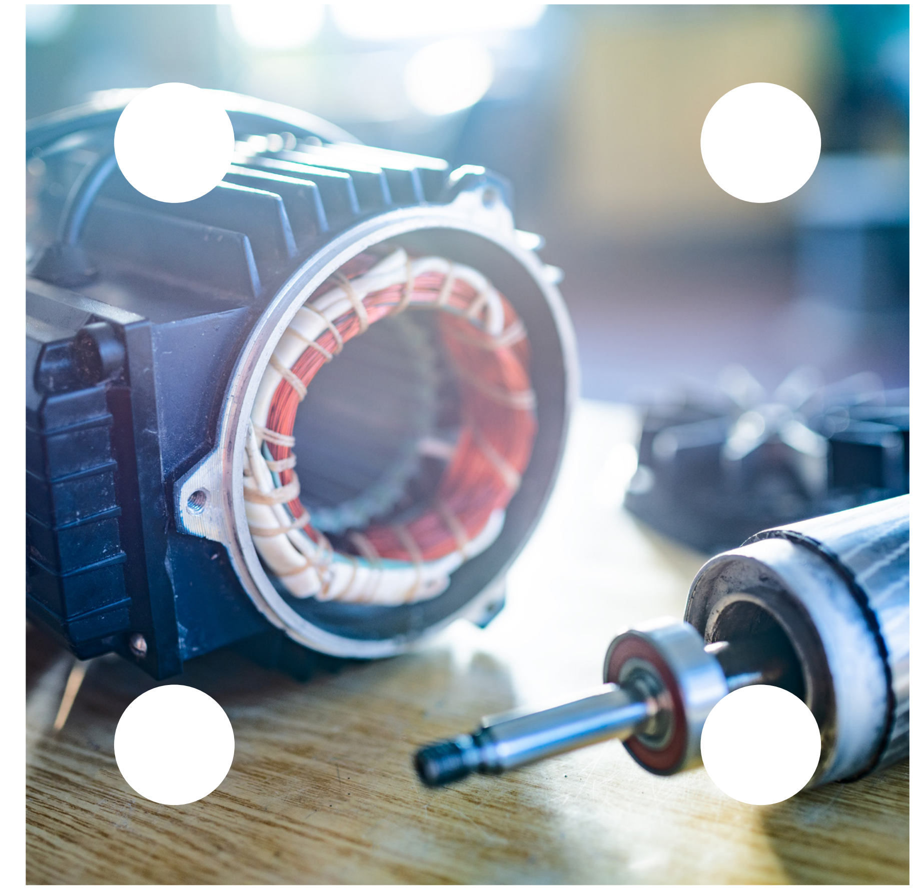
The standard also defines a power drive system (PDS) as the CDM plus the motor. Next up the hierarchy, the standard describes the motor system as the PDS plus motor control equipment like contactors.

At the highest level is the extended product, or overall system in Figure 1, which adds mechanical drive equipment like a transmission and the load machine. For a more detailed review of IEC 61800-9-2 PDS efficiency standards, check out the article "What are the different types of adjustable speed industrial motor drives?"

The starting point for specifying "electric motor-driven systems" is the motor.

Motor matters

Electric motors can be highly efficient machines if properly



specified and used. That makes specifying motors an important task for machine designers.

The IEC quantifies motor power in kilowatts (kW), while NEMA uses horsepower (hp), which can be easily equated. However, IEC and NEMA use different efficiency calculations, and IEC nameplate efficiency can be slightly higher than the NEMA rating for the same motor design.

Actual motor efficiency is strongly tied to the specific use case. As a result, motor efficiency standards are often discussed in terms of reductions in energy losses rather than absolute efficiency.

IEC 60034-30-1 recognizes five motor efficiency classes, from IE1 to IE5. Energy losses decline 20% between classes. That means an IE5 "Ultra Premium" motor has 20% lower losses than an IE4 "Super Premium" motor. There's more to consider. In some cases, the power factor (PF) declines for motors with higher efficiency.

In North America, NEMA has fewer energy efficiency classes,

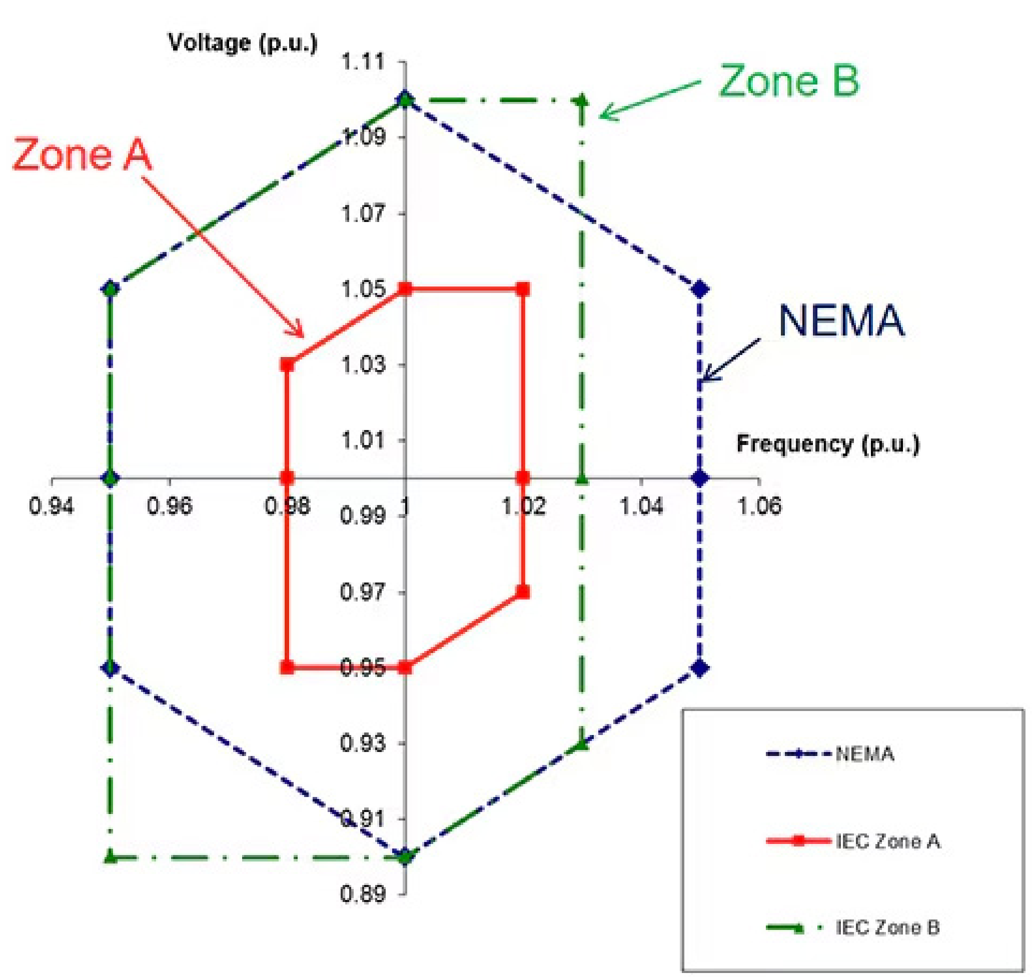


Figure 2: Comparison of NEMA and IEC industrial AC voltage and frequency ranges. (Image source: NEMA)

which are just as important. NEMA recognizes motor service factors (SF) not included in IEC standards. A NEMA motor with an SF of 1.15 can be run continuously at 115% of its rated capacity, albeit the motor runs hotter, which can result in reduced bearing and insulation life.

Instead of SF, IEC recognizes ten duty types or service factors (S1 to S10) based on considerations like continuous versus intermittent operation, speed variations, and the use of braking.

Operating voltage and frequency ranges differ for NEMA and IEC, but both are expressed as "per unit" (p.u.) quantities. In the p.u. system, quantities are expressed as fractions of the base value. NEMA recognizes one range of motor voltages and frequencies. IEC recognizes two "Zones" (Figure 2).

Driving for PDS efficiency

Motor drives are key elements of PDS efficiency as defined in IEC 61800-9-2. They can be classified in several ways, such as motor voltage, power level, motion types, supported applications, etc. Motion types can be classified as continuous or discontinuous. They can be further categorized as low, medium, and high performance based on the maximum required power output.

Different types of drives support various system needs. Servo drives and motors are well suited when fast acceleration, deceleration, and precise positioning are needed in applications like robotics. Soft starters are suited for continuous operations like conveyors that benefit from smooth startup and deceleration. VFDs are used in a wide range of industrial machines.

Some VFD product families are optimized for operations like pumping, ventilating, compressing, moving, or processing. Siemens SINAMICS G120 line of universal drives are available with power ratings from 0.55 to 250 kW (0.75 to 400 hp) for use in general industrial applications in automotive, textile, and packaging operations.

Model 6SL32203YE340UF0 uses 3-phase power with an operating voltage range of 380 to 480 Vac +10 % / -20 %. It's specified for 400 V operation with motors rated from 22 to 30 kW in Europe and 480 V in North America for motors rated from 30 to 40 hp (Figure 3).

VFDs are not the only key to efficient PDS design. The article "What support products does it take to maximize the impact of using VFDs and VSDs? - Part 1" reviews some of the required support components.

Figure 3: This VFD can be used with motors rated from 22 to 30 kW, depending on the operating voltage. (Image source: DigiKey)

Communication and system optimization

While motors and drives are on the factory floor in Level 1, or the field level, they are not at the lowest level of the Industry 4.0 communication hierarchy. That position falls to functions like sensors and actuators on Level 0. In addition, there are multiple levels above the field level. Timely and efficient communication up and down the communication hierarchy up to the cloud is necessary to maximize the overall efficiency, productivity, and sustainability of Industry 4.0 factories. Cloud connectivity is facilitated using protocols like (Figure 4):

- uOPC PubSub Bridge consolidates multiple operational technology (OT) data streams.
- MOTT BRoker receives messages and forwards them to users based on the message subject.

There's more to Level 1 than drives and motors. Field bus master units (FMUs) can facilitate communication and simplify the integration of drives and other devices. FMUs are available for various protocols, including PROFINET, PROFIBUS, DeviceNet, CANopen, etc. The use of FMUs can enable manufacturer-independent connectivity.

Model AFP7NPFNM from Panasonic is a PROFINET FMU. It comes with integrated function libraries for the programming software, significantly reducing the time needed to develop application-specific solutions.

Level 0 for sensors, actuators, and safety

Pushing the PDS energy savings gains from VFDs higher requires pushing connectivity lower to Level 0. Integrating sensors,

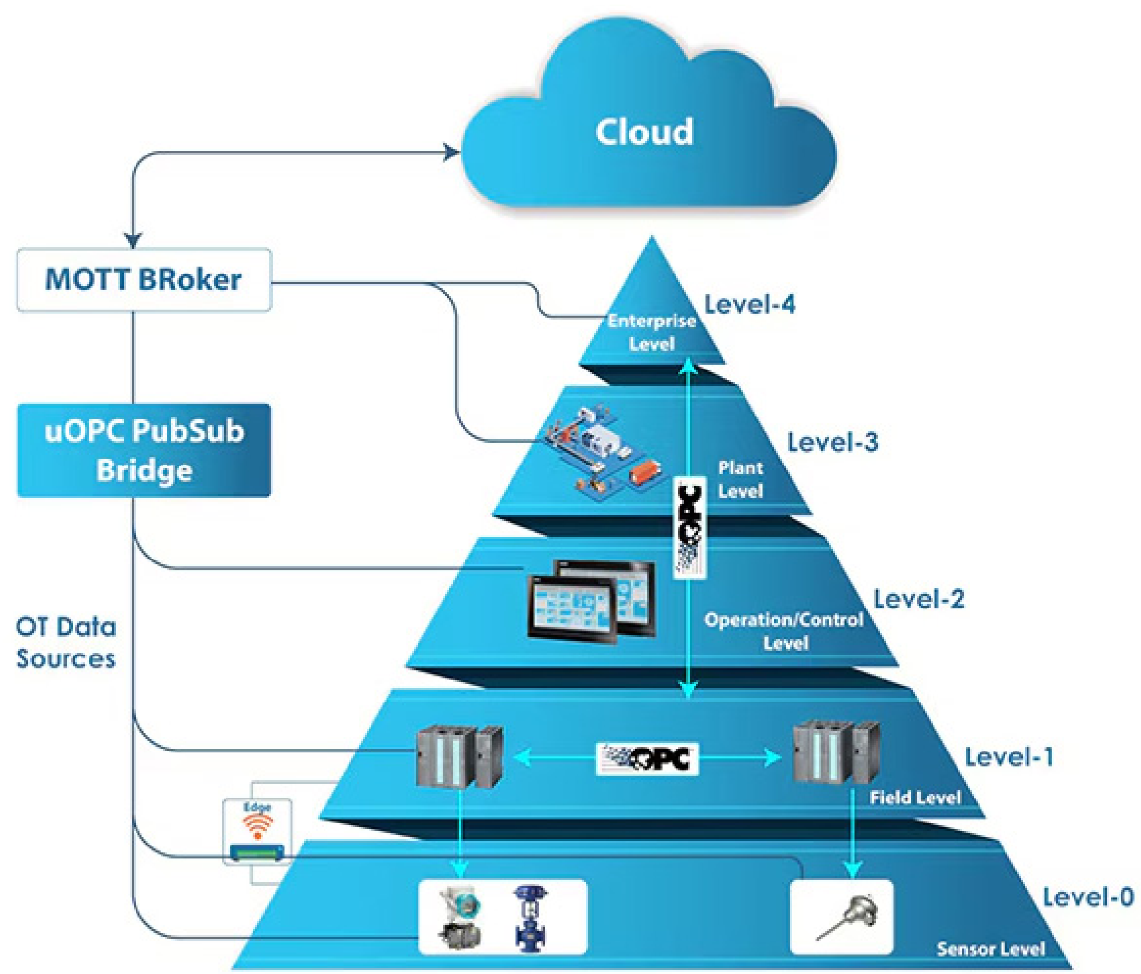


Figure 4: All levels of the Industry 4.0 communications hierarchy have the possibility of connecting directly to the Cloud. (Image source: OPC Foundation)

actuators, and safety devices like light curtains on Level 0 can significantly enhance efficiency improvements and push energy savings up beyond 30%.

Common protocols used to connect Level 0 functions include DeviceNet, HART, Modbus, and IO-Link. IO-Link is a point-to-point protocol that connects sensors and actuators to higher-level controls. It's available as a wired or wireless standard and is increasingly deployed in Industry 4.0 as a cost-effective alternative.

The NX-ILM400 IO-Link master units from Omron can mix standard I/O with high-speed synchronous I/O. The standard digital I/O's have 16 connections per unit with a choice of (Figure 5):

- Four 3-wire sensor connections with power supply
- Eight 2-wire contact inputs or actuator outputs
- Sixteen 1-wire connections for sensors and actuators connected to a common power supply

Level 2 for PDS and beyond

Higher-level communications can help improve field-level operations, but they are mandatory to maximize

Figure 5: This IO-Link master unit supports standard and high-speed synchronous I/O. (Image source: Omron Automation)

organizational efficiency and productivity. Reaching from Level 2 up to Levels 3, 4, and the cloud requires protocols like Ethernet/IP, EtherCAT, and Modbus TCP/IP.

Equipment possibilities for making those connections include programmable logic controllers (PLCs) or industrial personal computers (IPCs). PLCs are computers optimized for industrial automation and control. In a typical application, a PLC monitors inputs from the machine and related sensors, makes decisions based on its programming, and sends control outputs.

While IPCs can perform functions like PLCs, they are more general-purpose devices. They run an operating system like Linux or Windows, giving them access to an array of software tools, and are usually connected to an HMI (many PLCs can also connect to HMIs). PLCs tend to be machine-focused, while IPCs have more operational functions.

Figure 6: Fanless IPC with a mini PCIe expansion slot and multiple communication options. (Image source: Schneider Electric)

The differences between PLCs and IPCs are blurring. For example, the 1069208 PLC from Phoenix Contact runs the Linux operating system. Like traditional PLCs, it can be programmed with symbolic flowchart (SFC), ladder diagram (LD), function block diagram (FBD), and structured text (ST). It includes three independent Ethernet interfaces and can connect to the PROFICLOUD.

Schneider Electric offers the HMIBMIEA5DD1E01 IIoT Edge Box for applications that can benefit from an IPC. This fan-less design includes an Intel Atom Apollo Lake E3930 dual-core processor running at 1.8 GHz. It has a mini PCIe expansion slot and nine communication ports (Figure 6).

Conclusion

This article has provided a brief overview of some guideposts designers should consider when specifying motors, drives and communications modules for Industry 4.0 installations. It's far from exhaustive. It is intended to provide food for thought and some resources for further investigation.

Savoring success: efficient motion for OEMs in food and beverage

By Thomas Kuckhoff, Andrew Borczak

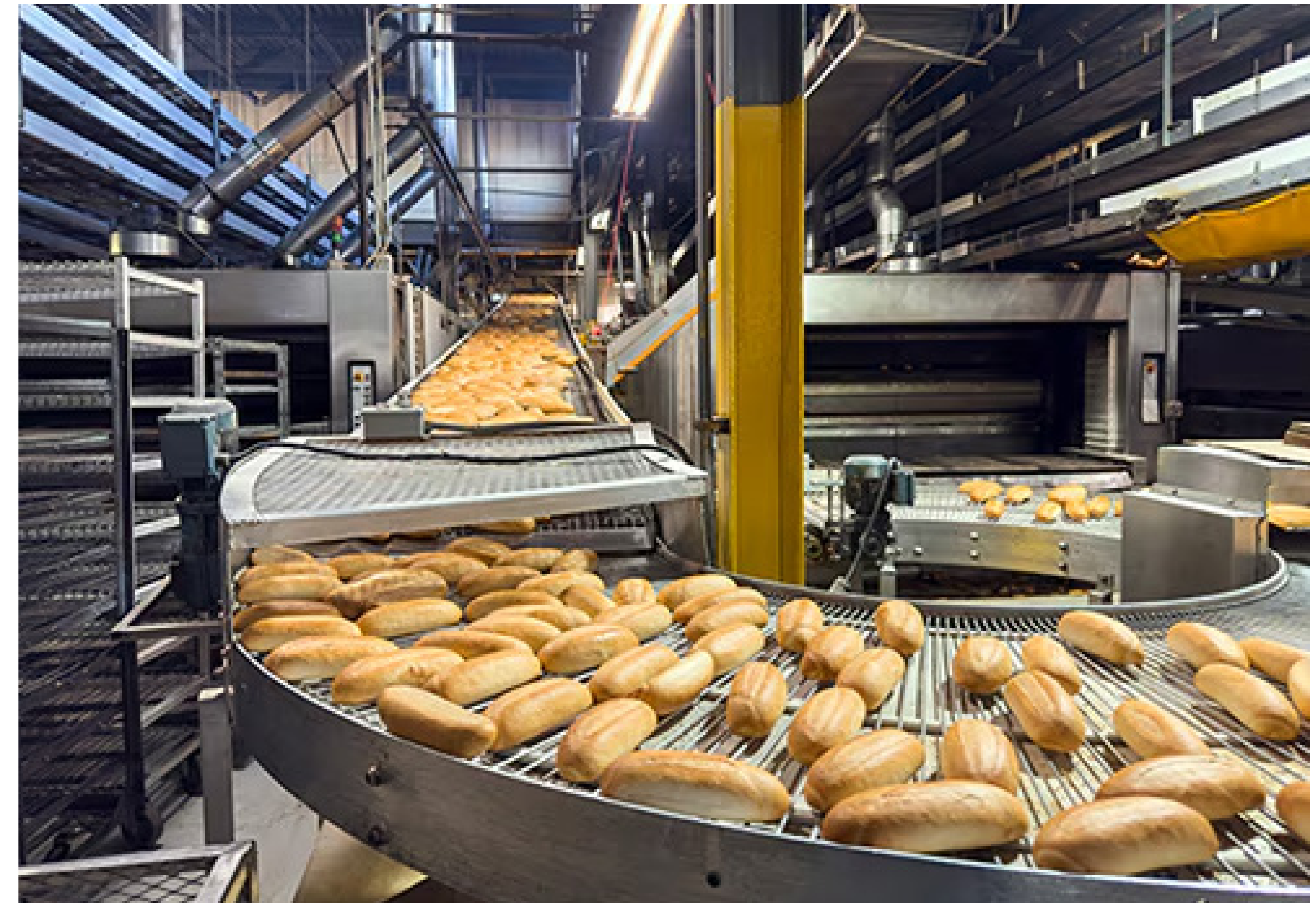


Figure 1: Automated bread factory. (Image source: Getty Images)

Reliability in automation motion control is a critical factor for original equipment manufacturers (OEMs). Directly impacting the machine's overall equipment efficiency, the three key variables that contribute to reliability are servo position accuracy, trajectory repeatability, and overall system efficiency. Any failure in these variables can lead to negative consequences such as longer design times for new equipment, commissioning resource runover, and increased production costs for end users.

OEMs face the challenge of increasing the number of competitive features on their equipment while adhering to design constraints that aim to maintain profitability margins. In this context, having confidence in automation motion control becomes essential. By ensuring high levels of reliability in servo position accuracy, trajectory repeatability, and system efficiency, manufacturers can mitigate risks and enhance their competitive edge. This confidence in automation motion control enables them to deliver equipment that meets customer expectations, reduces downtime, and optimizes production processes.

In this article, the food (Figure 1) and beverage (Figure 2) OEM machine lifecycle will be followed from design, to commissioning, to production. Best practices will be introduced that enhance equipment confidence through motion control accuracy, repeatability, and efficiency. In each section, the focus will be on maximizing system performance through simplicity of design, while ensuring that future deployment of data aggregation is non-intrusive.

Figure 2: Automated bottling factory. (Image source: Getty Images)

Design

When designing automation control systems, it is important to consider accuracy, repeatability, and efficiency from the beginning. The choice of network protocol plays a significant role in determining the complexity and performance of the machine downstream. The complexity of device communication can be measured by measuring the timeline for design revisions and the scale of the bill of materials. In food and beverage facilities, where product life cycles can last many years, selecting the appropriate network protocol can greatly impact the long-term ownership costs of operating the machine by minimizing any re-certification costs for original equipment.

The Design of Position Accuracy - EtherCAT® for time synchronization. The globally open industrial protocol, EtherCAT®, is designed for communication efficiency. The EtherCAT® master communicates through a single packet of data that travels to each of the field devices, dropping off and receiving data for each device as the packet passes through each node and back, whereas Ethernet traffic is an individual conversation between a PLC and each field device, regardless of the protocol. EtherCAT® achieves real-time deterministic communication, with cycle rates down to 125 µs. This high-speed communication removes jitter from the servos that can hinder accurate motion control. In sealing applications, being able to seal accurately is critical. This not only helps minimize material waste for downstream users, but also strengthens brand reputation and customer satisfaction.

The Design of Trajectory Repeatability – EtherCAT® for guaranteed command delivery. EtherCAT® is designed to ensure real-time motion control. Eliminating packet collisions that could occur when a PLC is having an individual conversation with each device and ensuring that the right packet is delivered to the right location, at the right time. In applications where precision is required over numerous cycles, like filling and sealing machines, bottling lines, and sterilization systems, EtherCAT® offers repeatable motion accuracy. The central processing unit synchronizes all EtherCAT® operations based on the primary motion task. Depending on the desired level of repeatability, three main EtherCAT® modes can be selected.

- ***Free Run Mode*** - The EtherCAT® cycle is asynchronous to the controller bus cycle. Where multiple refreshes are removed during an EtherCAT® cycle, although inputs and outputs are not refreshed at the same time across the network.
- ***Synchronous Mode*** - The EtherCAT® cycle is synchronized with the controller bus cycle. Synchronous reading of inputs and synchronous refresh of the outputs are performed at fixed intervals on multiple EtherCAT® devices simultaneously.
- ***Time Stamp Mode*** - The EtherCAT® cycle is synchronized with the controller bus cycle. Synchronous reading of the entries is based on the EtherCAT® distributed clock. This allows for precise timings down to micro-seconds.

The Design of System Efficiency – EtherCAT® for quick design and future scalability. EtherCAT® is an industrial protocol that is open globally, enabling different manufacturers to communicate on a shared network. This has led to a consistent adoption rate of 12% compound annual growth over the past fourteen years in the industry. This growth is not only a testament to the accuracy and precision of EtherCAT®, but also the sustained competitive advantage it provides to those who adopted this inclusive network protocol. Processors and packagers who implemented EtherCAT® in 2010 not only positioned themselves for future growth but also avoided significant redesign costs in the process.

Commission

With a robust architecture design, validating performance before a first-pass not only greatly diminishes the risk of performance failing to meet customer expectations but also allows the team to remove inefficiencies from a system before deployment. The commissioning process maximizes machine performance while also minimizing any risks associated with deployment in the downstream user's facility. While commissioning is usually completed during the runoff stage, where equipment is fully assembled, commissioning can be completed in parallel to machine builds without any hardware, reducing total production time without eroding the robust quality standards that have established strong OEMs.

The Commissioning of Position Accuracy – Servo selection without hardware. The proper sizing of a servo is crucial for achieving both cost-effectiveness and accuracy in machine performance. Oversizing a servo increases the machine's overall cost, while under-sizing it hampers the overall performance of the machine. By utilizing an integrated development environment on an all-in-one automation platform, OEMs can streamline the process.

With this approach, a single program can be used to verify the performance of the machine, incorporating motor sizing add-ins to ensure the correct selection. By completing the verification of motor size and the machine program within the same software package, the complexity of using additional software is eliminated, reducing the risk of errors during the selection process. This integrated approach simplifies the process and enhances the accuracy of servo sizing, leading to improved machine performance.

The Commissioning of Trajectory Repeatability – Motion simulation without hardware. Motion trajectories have a symmetrical effect on overall equipment efficiency, where the acceleration, deceleration, and motion paths affect throughput times, probabilities of crashes, and quality of the final product at a disproportional rate compared to other aspects of the machine design. Simulating trajectories in the same software environment as the program is created not only removes the risks of creating an unstable process on the factory floor, but gives end users confidence that the product will perform in production the same as it performs during the runoff.

The Commissioning of System Efficiency – 3D simulation without hardware. 3D simulation can be used instead of physical hardware to simulate the entire assembly, which can greatly improve the commissioning process. It is important to consider that motion is not the only factor on the factory floor. It is also necessary to verify motion alongside safety processes and data collection. This is common when traceability and vision are intricate to production processes. By utilizing 3D models provided by manufacturers and simulating them in the same software environment as the program, teams can ensure safety without introducing risks during commissioning. Additionally, this allows teams to create an optimal operating procedure and enables runoff teams to validate performance against a known standard before approving the construction of the equipment. This significantly increases the likelihood of the machine exceeding the expectations of downstream users before investing in physical construction.

Production

Designing and commissioning original equipment can be a significant investment for manufacturers. However, the key to securing repeat customers resides in the performance stage of the equipment's lifecycle. Factors such as future scalability, process uptime, and the ability to gather process data can greatly impact the overall customer satisfaction with the automation system and their potential for future business.

The Production of Position Accuracy – Automation modularity flexible to future demand. The highest-performance all-in-one automation platforms not only have hundreds of off-the-shelf modular IO part numbers for plug-and-play installation but also a single software with drag-and-drop programming. These platforms connect using globally open industrial protocols beyond EtherCAT®, extending a modular PLC's connectivity beyond a motion by leveraging the network effects of these open networks and using Fail Safe Over EtherCAT®, EtherNET/IP™, CIP Safety ™, IO-Link, MQTT, OPC UA®, and SQL all as each was intended to be used. The most OEM conducive automation platforms have been designed to adopt new technologies quickly from the very beginning and without introducing undue complexity to the factory floor. For example, handheld traceability that communicates over Ethernet is becoming more common in motion applications. OEMs can use pre-published third-party connectivity guides and function blocks to help bridge the gap between manufacturers while preserving the modularity required for food and commodity manufacturers to remain flexible to evolving industry standards, new packaging materials, and shifting consumer trends.

The Production of Repeatability - Automation playback capturing production events autonomously. When faults in automation result in events that cause downtime, finding the root cause of the fault quickly and verifying the finding is critical to restoring confidence in process stability. The convergence of data, video, program structure, and ladder logic in playback is increasingly becoming the norm. All playback is time synced and event-triggered to allow local and remote team members to diagnose issues quickly and accurately without interrupting production nor requiring operator presence during faults. When paired with simulated performance in the commissioning state, data playback over open protocols such as EtherCAT® gives downstream users the ability to realize continuous improvement without compromising machine performance metrics.

The Production of System Efficiency – OPC UA®™ built-in servers feeding holistic process data to central locations. OPC UA®™ server functionality, which is now a standard feature on many controllers, enables open communication with field devices. This ensures that the SCADA software can meet its communication requirements, as the embedded OPC UA®™ server allows for simultaneous connections from multiple clients. By opting for OPC UA™, users of downstream machines can promptly utilize the security benefits offered by OPC UA®™ to prevent unauthorized client access. As OPC UA®™ server functionality becomes increasingly prevalent, OEMs can establish stronger connections with users. This enables them to offer more comprehensive support for existing equipment and gain valuable insights into potential future equipment opportunities within their install base.

Downstream user satisfaction of OEMs' motion control is rooted in the ability for the motion to meet key production metrics today without hindering the operational success of tomorrow. To enhance the competitiveness of their equipment, OEMs must prioritize robust designs, instill confidence during commissioning, and enable efficient troubleshooting. This is particularly important as industry standards demand higher levels of compliance. By focusing on these aspects, manufacturers can expand the range of competitive features offered by their equipment, ultimately increasing their market share. All-in-one automation platforms use globally open industrial protocols, such as EtherCAT®, to create simple architectures through the design phase, create multiple simulations in a single design environment during the commissioning phase, and create flexible data aggregation for future scaling during production.

Conclusion

As we anticipate future challenges in the food and beverage industry, certain standards will emerge. These include the need for efficient and inclusive networks, rapid development of new equipment with robustness, and non-intrusive yet holistic data aggregation. The encouraging news is that the technology required to address these challenges is already available. OEMs can leverage this technology today to fortify their sustainable competitive advantage for the future. To this end, Omron Automation and Safety has EtherCAT® compatible equipment available for automation and control designs to ensure successful industrial operation.

How new IO-Link masters can balance the benefits of cloud connectivity and local control in industry 4.0 factories

By Jeff Shepard
Contributed By DigiKey's North American Editors

Balancing the needs for Cloud connectivity and local control using programmable logic controllers (PLCs) in industrial networks just got easier. Industry 4.0 networks are complex and include multiple levels of connectivity from IO-Link on the factory floor to field busses like EtherNet/IP and PROFINET connecting machines and PLCs and an Open Platform Communications Unified Architecture (OPC UA) interface reaching up to the Cloud.

In a traditional Industry 4.0 network, sensors, actuators, and other devices use an IO-Link master to connect with the field bus network, and devices on the field bus network use OPC UA and other protocols to connect with the Cloud.

Machine and factory network designers now have a new tool — IO-Link masters — that combines the usual EtherNet/IP, PROFINET, and other field bus connectivity with an OPC UA interface for direct connection to the Cloud. That can be used to flatten connectivity and speed the delivery of critical data to the highest levels of the network.

This article starts with a review of the use of local control and Cloud connectivity in a traditional network architecture. It then presents the flattened architecture enabled by the new IO-Link masters from Pepperl+Fuchs, which includes field bus and OPC UA connectivity and can support multiple parallel connections. It also considers how the new Ethernet advanced physical layer (APL) technology fits in.

It closes by detailing the new IO-Link masters with OPC UA connectivity and compatible IO-Link hubs for network expansion, along with a few representative IO-Link devices and the use of an IO-Link USB master for configuring, commissioning, and trouble-shooting IO-Link devices.

Industry 4.0 factories require varying mixes of local control and Cloud connectivity. Each has its benefits. The best solution often combines PLCs and edge computers for responsive local control while using the Cloud to analyze complex data.

PLCs are rugged and designed for use in industrial environments. They are generally modular and can accommodate the changing needs of Industry 4.0 factories. PLCs are more compact and reliable than the relay-based systems they often replace. Perhaps most importantly, PLCs can support real-time control in critical applications with direct feedback from the connected machines and sensors.

Cloud connectivity provides essentially unlimited storage and computational capabilities. It can link data from various applications, controlled by individual PLCs, and support a harmonized and optimized overall factory operation. Cloud connectivity can offload administrative tasks from PLCs, and Cloud computing services can be quickly and economically scaled.

Traditional IO-Link

IO-Link is a point-to-point protocol, not a field bus. In a traditional Industry 4.0 network, IO-Link masters are the intermediaries between IO-Link devices on the factory floor and the field bus network. Each port on an IO-Link master connects to a single IO-Link device. The IO-Link master consolidates and translates communication from connected IO-Link devices and sends it on to the field bus network.

IO-Link masters are available for installation inside the control cabinet. They can connect to the field bus network as a remote connection point with an IP20 environmental rating or be used on the factory floor with an IP65/67 rating (Figure 1). There's no direct connection between traditional IO-Link masters and the Cloud; all communications to the Cloud are channeled through and controlled by devices on the field bus.

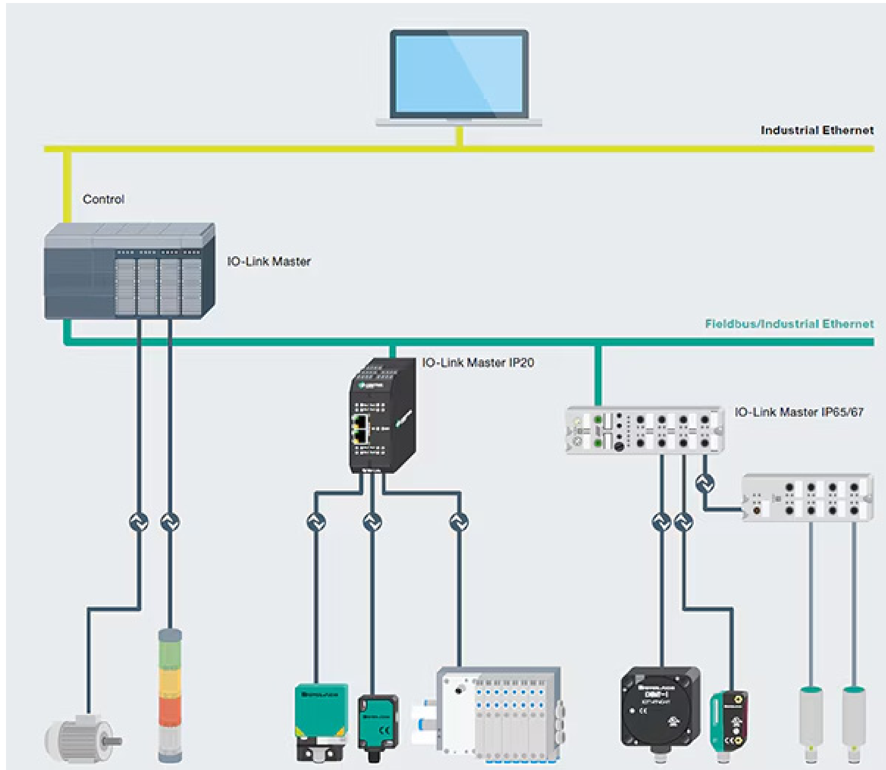


Figure 1: Traditional network application of IO-Link connected to a field bus. (Image source: Pepperl+Fuchs)

Enhanced IO-Link and a parallel network

Adding OPC UA connectivity into an IO-Link master dramatically changes the possibilities for industrial network architectures. It's no longer necessary for communications to be channeled onto the field bus to get up to the Cloud.

Time-sensitive data for real-time control can still be put onto the field bus. Less time-sensitive data can be aggregated and sent directly to the Cloud, removing that communication overhead burden from the field bus devices.

Pepperl+Fuchs refers to this new structure as a "parallel" architecture since it can be used in parallel with standard industrial machine control systems. The key is the company's MultiLink™ technology that supports the parallel use of an industrial Ethernet field bus for connecting with PLCs using a protocol like EtherNet/IP and message queuing telemetry transport (MQTT). This open-source messaging protocol uses OPC UA and can connect with devices on the Industrial Internet of Things (IIoT), like industrial computers, supervisory control and data acquisition (SCADA) systems, and the Cloud.

To complete the package, IO-Link masters with MultiLink also include an integrated web server and IO-Link device description (IODD) interpreter that supports the configuration of the field bus connection and attached IO-Link devices using a web browser (Figure 2).

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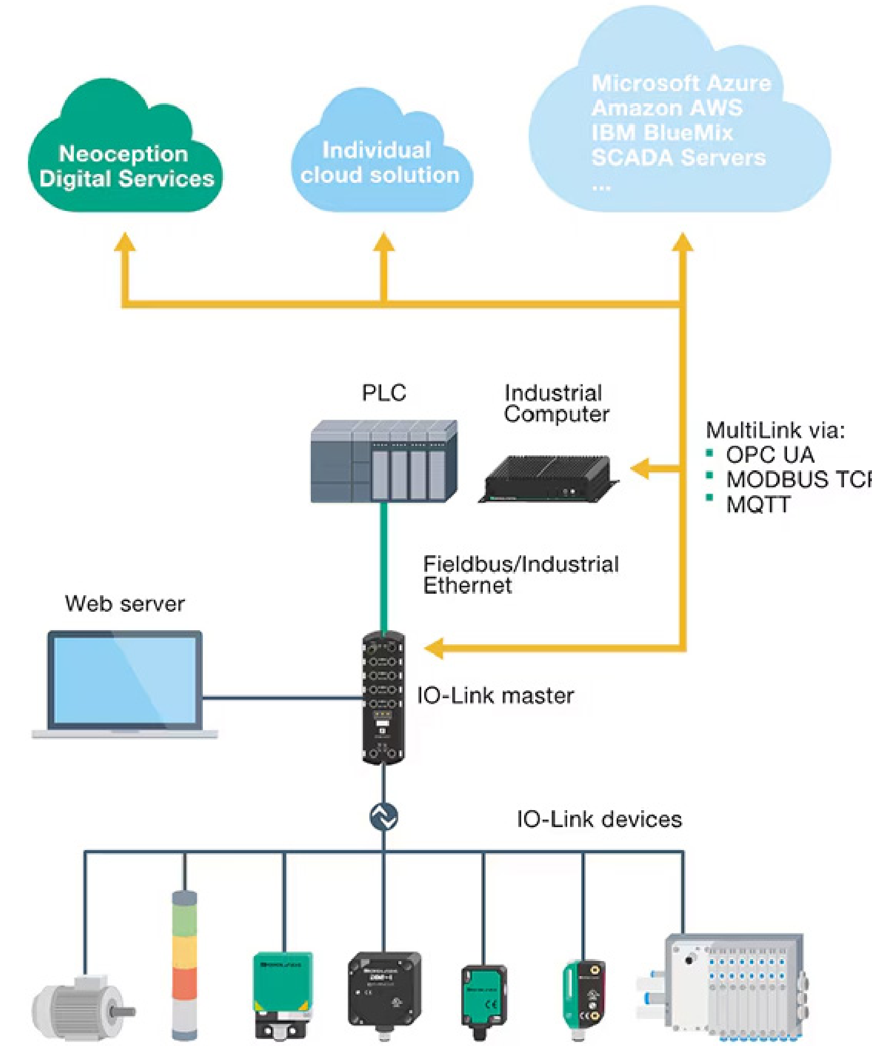

Figure 2: New IO-Link network architecture using OPC UA for direct Cloud connectivity and a flatter network structure. (Image source: Pepperl+Fuchs)

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More networking choices

In addition to enabling the new parallel network architecture described above, IO-Link masters with OPC UA and MultiLink can be used for other use cases like:

Retrofits – This conventional IO-Link master can be replaced by one with OPC UA and MultiLink connectivity to add the benefits of parallel communication into an existing network.

Applications without a traditional PLC – Some applications, like an enterprise resource planning (ERP) or manufacturing execution system (MES), gather data from sensors on the factory floor and don't need a PLC. An IO-Link master with OPC UA can send the data directly to the cloud, which can be aggregated, analyzed, and acted on to maximize productivity.

Applications with multiple PLCs – Complex welding cells are an example of an application with multiple PLCs and multiple protocols that can benefit from the addition of OPC UA. For example, a primary PLC can control the overall process using PROFINET communication, an industrial PC can control optical quality monitoring with EtherNet/IP communication, and various robots and other equipment may use proprietary control protocols. OPC UA with Pepperl+Fuchs' MultiLink technology enables communication and data exchange between the systems despite the different field bus protocols, and it can link the entire welding cell to the Cloud.

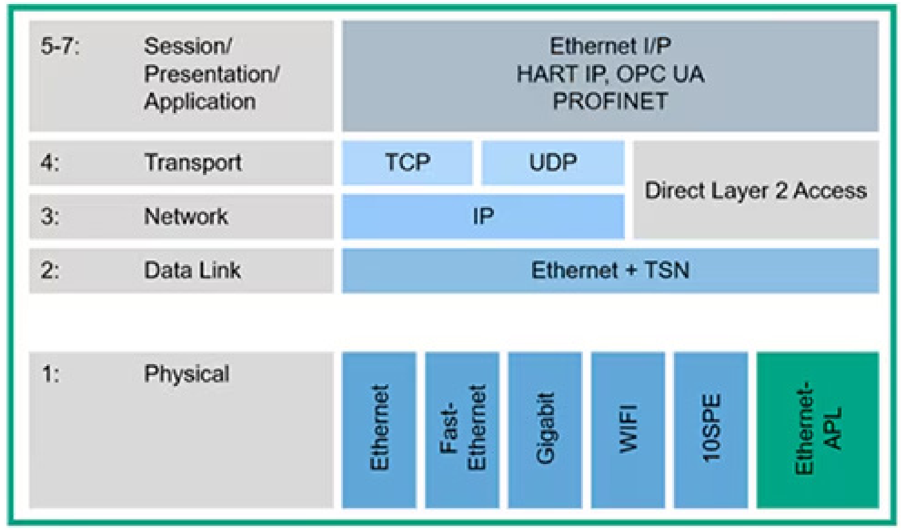

Figure 1: Traditional network application of IO-Link connected to a field bus. (Image source: Pepperl+Fuchs)

Built on the foundation of Ethernet APL

MultiLink technology is built on the foundation of the Ethernet advanced physical layer, or Ethernet-APL, that allows Ethernet to be used for communication and power with process instrumentation over long distances. It's based on the 10BASE-T1L Ethernet physical layer standard.

With a speed of 10 Mbps and a 1,000-meter range, Ethernet-APL was designed for real-time process monitoring and control, enabling parallel access. It supports EtherNet/IP, HART-IP, OPC UA, PROFINET, and other higher-level protocols. It eliminates the need for gateways or other protocol conversions. It implements 10BASE-T1L using a special Ethernet physical connection (PHY) in Layer 1 of the Open Systems Interconnection (OSI) model (Figure 3).

The new industrial networking tools

For industrial network designers who want to take advantage of the new possibilities enabled by IO-Link masters with OPC UA MultiLink parallel connectivity, Pepperl+Fuchs offers the ICE2 (with EtherNet/IP) and ICE3 (with PROFINET) IO-Link master series. Both types of IO-Link masters have eight inputs and outputs and come with a web-based configuration capability for setting all module parameters and all connected IO-Link devices (web IODD operation). They include integrated IODD storage for over 100 IODDs. Other features include:

- The PortVision® DX software supports network configuration, device management, and settings cloning/backup in one application.
- All module settings can be saved as a separate file and transferred to a new device using the cloning function to speed deployments.
- Block models have two L-coded M12 power connector plugs rated for 16 A. The inputs and outputs have A-coded M12 connector plugs, and connection to the field bus is made through D-coded M12 connector plugs.
- DIN rail models are available with screw terminals or pluggable push-in connectors.
- Degrees of protection: Block models are IP67 rated, and DIN rail models are rated for IP20 (Figure 4).

Exemplary IO-Link masters with OPC UA MultiLink include:

- The ICE2-8IOL1-G65L-V1D is a block-style EtherNet/IP and Modbus IO-Link master with four IO-Link Class A ports that can provide up to 200 mA of power for connected devices and four IO-Link Class B ports for higher-power devices with their own independent power source.

Figure 4: Examples of DIN rail (left) and block style (right) IO-Link masters. (Image source: Pepperl+Fuchs)

- The ICE2-8IOL-K45P-RJ45 is a DIN rail-style EtherNet/IP IO-Link master with eight inputs/outputs and push-in connectors.
- The ICE3-8IOL1-G65L-V1D is a block-style PROFINET and Modbus IO-Link master with 4 IO-Link Class A and 4 IO-Link Class B ports.
- The ICE3-8IOL-K45S-RJ45 is a DIN rail style PROFINET IO IO-Link master with eight inputs/outputs and screw terminals.

Hubs & converters for network expansion

IO-Link hubs support expanding networks of sensors, actuators, and other devices. IO-Link hubs allow several digital sensors and actuators to be connected to an IO-Link master using a standard sensor cable. For example, the ICA-16DI-G60A-IO IO-Link hub can handle up to 16 PNP digital inputs, and the logic level can be configured individually for each port. Depending on the capability of

Figure 5: Examples of the wide range of available IO-Link devices. (Image source: Pepperl+Fuchs)

the connected IO-Link master, this hub can deliver up to 500 mA of power to connected devices. It's rated for IP65, IP67 and IP69K.

When a sensor with an analog output needs to be connected to an IO-Link network, designers can turn to the ICA-AI-I/U-IO-V1 IO-Link converter with an analog input for current or voltage and an IO-Link output. It's rated for IP67, and the input can be set as follows:

- Current input can be set as 0 to 20 mA or 4 to 20 mA.
- Voltage input can be set as -10 to 10 V or 0 to 10 V.

IO-Link device offering

A comprehensive ecosystem of IO-Link devices is available for almost every industrial process, including sensing and control needs. Pepperl+Fuchs' IO-Link portfolio includes inductive proximity sensors, inductive positioning systems, photoelectric sensors, ultrasonic sensors, vibration sensors, rotary encoders, and identification systems (Figure 5). Examples include:

- The VDM28 distance measurement device uses Pulse Ranging Technology (PRT) to deliver a repeat accuracy of 5 mm with an operating range of 0.2 to 15 m and an absolute accuracy of 25 mm.
- The IUT-F191-IO-V1-FR2-02 RFID read/write device is optimized for industrial applications involving distances up to about one meter. The device reads and writes passive tags based on ISO/IEC 18000-63.

Figure 6: This IO-Link USB master connects to a PC to speed network deployments. (Image source: Pepperl+Fuchs)

USB master for commissioning IO-Link devices

When it's time to install and commission IO-Link devices, network technicians can turn to the IO-LINK-MASTER02-USB (Figure 6). This USB master can connect IO-Link devices to a USB port on a PC. It's designed to support testing, configuration, and servicing activities. Connected devices can be configured and parameterized. Device diagnostics is also supported. Devices with a low current consumption can be powered directly from the USB master. Devices with higher power needs can be connected to an optional external power supply.

Conclusion

The addition of OPC UA parallel connectivity to IO-Link master devices has dramatically changed the options available to designers of Industry 4.0 networks. It's now possible to flatten the network architecture and provide direct connections between the IO-Link devices on the factory floor and the Cloud. The new technology can be used in various use cases to improve operational efficiency.

Smart manufacturing

By Eric J. Halvorson
Contributed By DigiKey's North American Editors

Since the dawn of manufacturing, companies have continuously sought to create efficient processes. From the invention of the assembly line to the onset of AI and digital twin, manufacturing has undergone massive evolutionary changes that have created a whole new world of manufacturing possibilities.

Industrial robotics have been utilized in manufacturing prominently since the 1960's. GM's Unimate robot weighed more than 4,000 lbs, and was used to move die castings from the assembly line to the welding line. The robot was very rudimentary in comparison to robots of today, but for the time it was a huge advancement in manufacturing technology. Today, robots come in many different shapes and sizes, are more nimble, and capable of handling a myriad of tasks. Their flexibility with tooling, as well as their ability to be redeployed quickly, enables manufacturers to capitalize on their versatility. But it goes far beyond moving die castings from the assembly line to the welding line. Now with the introduction of collaborative robots and even automated mobile robots (AMRs), they are popping up all over the factory floor. They work along side their human counterparts while performing simple, repetitive, and in some case hazardous tasks. This frees up their human counterparts to focus on more difficult tasks, as well as solve any problems.

Industrial robots are only a small piece of the equation. To be effective in this new age of manufacturing, there is also a need for an immense amount of data collection. To accomplish this, sensors are deployed throughout the factory floor to maintain effective control at every point in the manufacturing process. Vision sensors onboard the robots, as well as along the conveyor path, help provide quality assurance. LiDAR is also being utilized in robotic applications to protect workers and assets, allowing an AMR to navigate the factory floor and to avoid collisions. By integrating sensor fusion, the entire process and environment can be monitored in real time.

The number of sensors deployed on a factory floor is jaw-dropping. Incorporating all of them and collecting their data requires a network platform such as IO-Link. IO-Link is a point-to-point, bidirectional communication network standard that enables communication with sensors and actuators through a wired or wireless connection. An IO-Link Master can communicate with a large number of sensors and actuators (IO-Link devices). Each sensor or actuator is assigned a unique IO Device Description (IODD) that allows it to be identified.

Manufacturers can now utilize data collected from a vast sensor network to analyze every step within a manufacturing process across all lines simultaneously. Sensors collect data on temperature, vibration, humidity, voltage/current, and much more. As a result, manufacturers can quickly identify when a piece of equipment is operating out of specification, which can be a warning of a potential failure. By identifying this early, maintenance can be performed in a timely manner to reduce downtime, as well as costly repairs. Through a predictive maintenance program, a manufacturer can increase equipment longevity, reduce errors, reduce damage to equipment and materials, as well as protect workers from potential injury. Not to mention the cost savings in energy and resources.

A few years ago, a revolutionary technology called "digital twin" was introduced to the manufacturing world. By creating a digital copy of the factory floor down to the most minute detail, a manufacturer can analyze trends in production, material shortages, efficiencies, and forecast peaks and valleys in their process. It also gives them the ability to make programming changes in a simulated manufacturing environment to predict how it would affect a real-world scenario.

Adding AI technology into digital twin creates an even more powerful tool for manufacturers. Rather than passively monitoring a production process, AI can analyze data and make real-time adjustments to create a more efficient process. By incorporating adaptive learning, creating greater accuracy and effectiveness can be achieved. Utilizing this new AI component, digital twin can not only monitor when a machine is beginning to fail, but can literally predict the type of failure, and preemptively order its repair at a time that won't delay production.

Smart manufacturing today means more efficiency through better production processes. It helps to reduce workplace injuries, reduce waste, increase quality, increase productivity, and increase competitive advantage. Manufacturers today, face a host of obstacles. o combat these obstacles and stay competitive, manufacturers must turn to smart manufacturing technologies such as industrial robotics, wireless sensor networks, AI and digital twin.