JUNE/JULY 2025

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A MESSAGE FROM ISA

The International Society of Automation (ISA)'s CEO and executive director, Claire Fallon, and other experts recently discussed the present and future of manufacturing and automation on WRAL News, a TV station near ISA headquarters in Durham, North Carolina. Fallon discussed the evolution of manufacturing and the critical role of technician training with reporter Dan Haggerty.

"We absolutely can bring manufacturing back and make it stronger," said Fallon. "It's evolved, though — it's not going to be the manufacturing that we saw in the '50s and '60s. Last year alone, [ISA] trained over 14,000 people, and many of them were technicians, not just engineers and managers. There is a great demand for those technicians and people to have those credentials."

"Automation depends on people," Fallon added. "That's the sentiment that inspired International Automation Professionals Day when we started celebrating it four years ago. Automation professionals are the driving force behind the systems, technologies and processes that make the world a better place. To realize automation's greatest potential, a skilled, knowledgeable and trained workforce has never been more important."

Find information on the ISA training and certification programs discussed in the segment at www.isa.org/training. Fallon also mentioned ISA position papers, which can be found at www.isa.org/position-papers.

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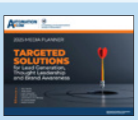

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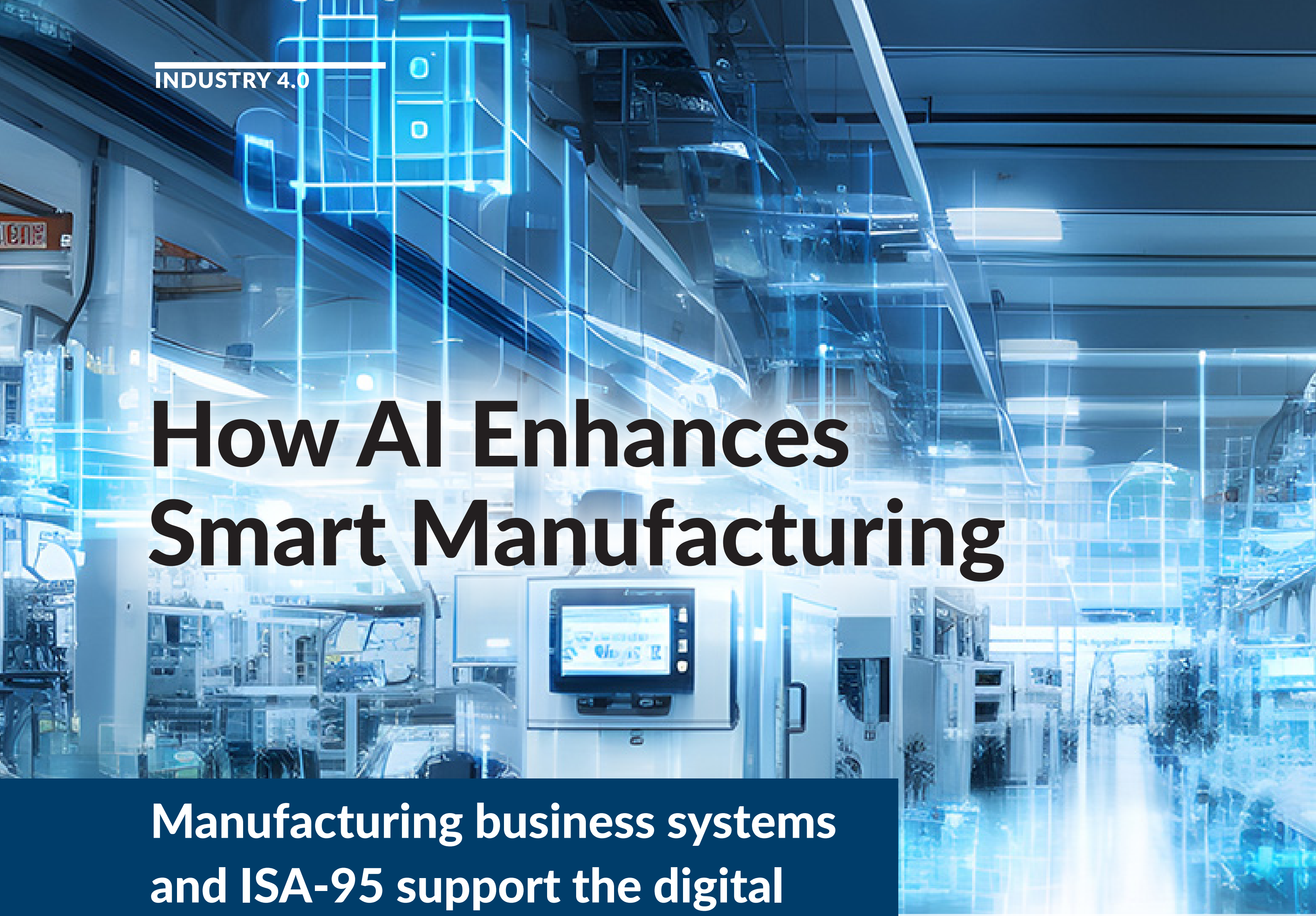


How AI Enhances Smart Manufacturing

Manufacturing business systems and ISA-95 support the digital transformation of manufacturing.

By Jack Smith

In its "Smart Manufacturing Dictionary," MESA International defines smart manufacturing as "...the endeavor to design, deploy and manage enterprise manufacturing processes, operations and systems that enable proactive management of the manufacturing enterprise through informed, timely (as close to real time as possible), in-depth decision execution. Systems with smart manufacturing capabilities are realized through the application of advanced information, communication and manufacturing process technologies to create new and/or extend existing manufacturing system components. These components integrate synergistically to create new or extend existing manufacturing systems that possess the desired advanced automation, analysis and integration capabilities."

Smart manufacturing is another name for Industry 4.0, Industry 5.0 or digital transformation. It is intended to help meet business challenges and changes using digital means. It is typically a journey that includes many projects. Smart manufacturing is generally intended to improve these issues:

- Efficiencies: yield, uptime, capacity utilization and quality
- Agility
- Decision-making data access
- Knowledge retention
- Supporting less-skilled workers
- Enabling new business models.

Technologies enable and support new processes and the people in the company. MESA's model (Figure 1) includes lifecycles, cross-lifecycle threads and enabling technologies. Every discipline in the company and every process may be affected. It is a journey for the entire manufacturing enterprise.

The current state of smart manufacturing

Rockwell Automation's 10th annual "State of Smart Manufacturing Report" highlights how companies are turning to smart manufacturing technologies to manage risks, improve performance and support their workforce. The report also examines the adoption of emerging technologies including artificial intelligence (AI), machine learning (ML) and cloud based systems.

According to the report, which is based on feedback from 1,560 respondents, 81 percent of manufacturers say external and internal pressures are accelerating digital transformation, with cloud/SaaS [software as a service]; AI; cybersecurity; and quality management ranking as the top areas of smart manufacturing technology investments. The report said 95 percent of responding manufacturers have invested in—or plan to invest in—AI/ML over the next five years.

Organizations investing in generative and causal AI increased 12 percent year-over-year, which signals a maturing approach to advanced technologies beyond experimentation. Cybersecurity ranks as the second biggest external risk, with 49 percent of manufacturers planning to use AI for cybersecurity in 2025—up from 40 percent in 2024.

In addition, 48 percent of manufacturers plan to repurpose or hire additional workers due to smart manufacturing investments. Also, 41 percent are using AI and automation to help close the skills gap and address labor shortages.

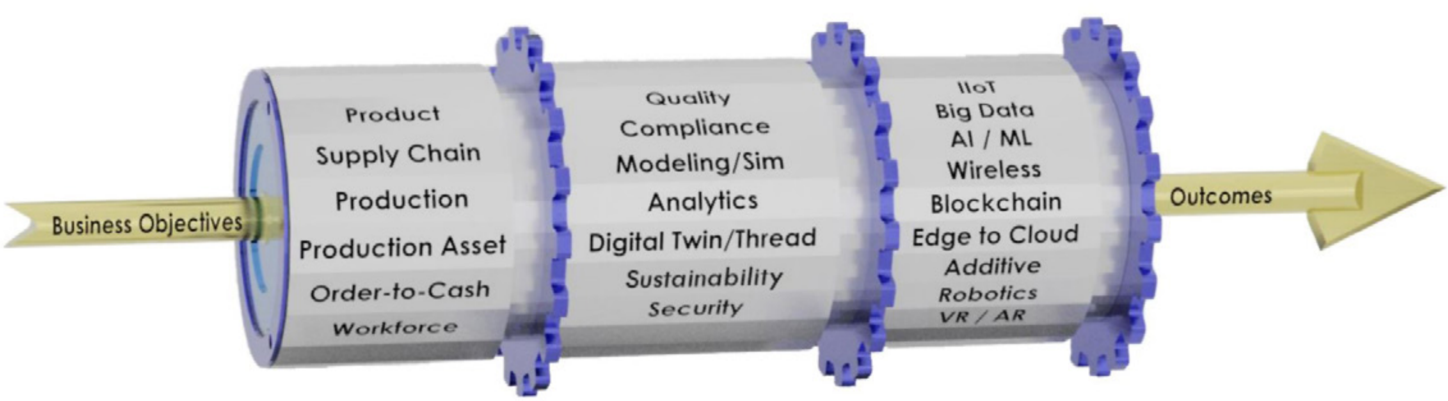


Figure 1. The MESA smart manufacturing model illustrates that there are many aspects to be considered. Courtesy: MESA

Quality control remains the top AI use case for the second year in a row, with 50 percent planning to apply AI/ML to support product quality in 2025.

The report reflects a broader movement toward more efficient and adaptive operations. Manufacturers are using smart technologies to strengthen supply chains, accelerate sustainability initiatives and make faster, more informed decisions. There has also been a 5 percent rise in the importance of analytical and AI skills for leaders, which shows that talent development and technical innovation must go hand in hand.

However, many manufacturers face challenges when implementing AI. Nearly half of respondents say the ability to apply AI is now an extremely important skill, up from just 10 percent last year, according to the Rockwell report.

Both the Rockwell Automation report and research from MESA International illustrate AI's evolving role in smart manufacturing. Compared to previous survey results, more organizations plan to use AI/ML for cybersecurity in the next 12 months, highlighting the evolving role of advanced technologies in enhancing cybersecurity measures. AI/ML are also poised to transform supply chain management, with a third of respondents planning to use them for managing their supply chain (Figure 2).

Smart manufacturing characteristics

Regardless of the terminology—Industry 4.0, Industry 5.0, digital transformation or smart manufacturing—the characteristics are identified in ANSI/ISA-95.00.01-2000, Enterprise-Control System Integration. ISA-95, also known as ANSI/ISA-95 or IEC 62264, is an international set of standards aimed at integrating logistics systems with manufacturing control systems. It organizes technology and business processes into layers defined by activities taking place, and it outlines how an enterprise can set up an interface to communicate among these layers, according to the International Society of Automation (ISA).

ISA-95 is the most comprehensive definition of modern manufacturing information exchange in the world. Manufacturers rely on these standards to define, develop and integrate many complex systems and processes in Industry 4.0 and beyond.

Figure 2. Top uses for AI/ML over the next 12 months. Courtesy: Rockwell Automation

The ISA-95 standards framework is widely accepted as essential to modern manufacturing. It relies on the Purdue Reference Model for computer-integrated manufacturing to describe network segmentation in industrial control systems. ISA-95 establishes an architecture based on this model that enterprises can apply regardless of the technology used. This equipment hierarchy model can also be applied across discrete, continuous and logistics industries, according to ISA.

ISA developed ISA-95 to create an abstract model for information exchange among manufacturing control functions and business functions in an enterprise. The ISA-95 standards framework defines the interface between these functions to build an exchange that is robust, safe and cost-effective. It also helps manufacturing personnel and information technology (IT) personnel collaborate by determining key terms for integration projects, reducing the risk, cost and errors associated with their implementation.

Technology has evolved since ISA-95 was established in the mid-1990s, but the standards framework presents an abstract model that accommodates a wide range of technologies and systems. Its scope prioritizes activities—not technologies—and its intended purpose as a tech-agnostic communication model remains relevant.

In the current state of Industry 4.0, the Internet of Things (IoT) and smart manufacturing, data flows are more distributed, and the ISA-95 model originated as a hierarchy. Still, the levels allow practitioners to describe boundaries between systems, which is an essential step in integration projects. ISA-95 remains in wide use today among manufacturing enterprises as a reference architecture and as an effective way to drive interoperability.

Roadblocks to smart manufacturing

"Making Manufacturing Analytics and AI Matter" is the title of the 2025 edition of MESA International's Analytics and Metrics that Matter research. Based on feedback from more than 420 manufacturing professionals, this year's study reveals that AI is no longer just a buzzword—it's a game-changer, which indicates that AI is necessarily a significant element of smart manufacturing. Despite challenges, manufacturers are seeing real, measurable value from AI and analytics initiatives.

ISA developed ISA-95 to create an abstract model for information exchange among manufacturing control functions and business functions in an enterprise.

MESA's research explored what companies are doing, why and how. Responses are from global manufacturing companies. The companies investing in analytics and AI are gaining substantial benefits that matter because they are in areas that match the most common objectives of cost, efficiency/productivity, quality and error-proofing.

All of these respondents face significant challenges; 99 percent of them are investing in manufacturing operations, analytics and AI to address these challenges. "Those using analytics and AI longer tend to see benefits in more areas. Top performers doing better on operations metrics are also outperforming others on business metrics. What are they doing differently? More of them are using dashboards, analytics and AI. They also prioritize use cases based on business value," according to the MESA research.

A characteristic identified by the MESA survey as significant for smart manufacturing performers is having a comprehensive digital view of the plant floor, which requires the integration of operational technology (OT) with real-time IT. Barriers to obtaining that view, according to MESA, include:

- Poor data quality (60 percent of companies report this issue).
- Inconsistent data and lack of governance (41 percent).
- Difficulty accessing data quickly enough for real-time decisions (37 percent).
- Poor data visualization tools.

Top performers are addressing these challenges by investing in dashboards, AI-driven analytics and digital twins to create more accurate and actionable insights. Top performers are defined by their ability to outperform their peers on overall equipment effectiveness (OEE), first-pass yield, throughput and capacity utilization. They also perform better on business metrics.

Pathway to smart manufacturing best practices

In its report, "Making Manufacturing Analytics and AI Matter," MESA offers several recommendations: Smart manufacturing and analytics investments, a strong manufacturing data management foundation, frontline workforce empowerment, preparing for AI and following top performers' examples.

Invest in smart manufacturing and analytics. Now is the time to invest in smart manufacturing and analytics solutions. Whether the need is for descriptive, predictive or supportive AI, they all are effective. Users who adopt these solutions gain even more benefits over time. Investments should be made in open, modern and analytics-ready or AI-infused software.

Build a robust manufacturing data management foundation. Users should drive toward data management. Start on focused AI and analytics projects with only the needed data. For most companies, this is a multi-faceted investment that includes people, processes and technology. Ensure that organizations such as IT and OT are ready to work closely together. In addition, create processes to improve data handling and governance. Use common data models and integration frameworks to ensure data is reliable, available and in context.

Give frontline workers all they need. To support frontline workers, provide access to job-relevant key performance indicators (KPIs). Deliver timely views into all the data the personnel need for tasks, or further, have analytics and AI deliver actionable insights based on data to them. Capture knowledge before the best employees retire. Use this valuable knowledge to guide and boost current and future workers' performance and further improve KPIs. Educate personnel to counteract concerns and enable them to use analytics to their maximum extent and benefit.

Prepare for AI. Barriers for both predictive analytics or AI and supportive or GenAI tend to emerge during the implementation journey. Now is the time to start evaluating data for completeness, quality and context to identify what must be done to succeed with analytics models and algorithms. Educate employees and executives to minimize the risk of cultural resistance or lack of trust. Recognize that choosing a pilot use case may require considering the future rollout and prioritizing the most prevalent issues.

Follow top performers' paths; they show the way on this journey. Invest in smart manufacturing, analytics and AI. Focus on getting data to operations personnel for decisions. Ensure use cases are based on business value. Seek vendor-delivered analytics that are specific (and relevant) to the industry or need. Be willing to experiment with analytics and AI.

A Step Toward Smarter Manufacturing

Users who seek to lower the total cost of ownership (TCO) for manufacturing IT architectures and manufacturing, as well as reduce supply chain operational costs, would do well to check into the methodologies and technical applications presented in the first annual ISA-95/MESA Best Practices book to get started on the right track. "The Hitchhiker's Guide to Manufacturing Operations Management" for $24.99 is available from MESA International.

The book provides in-depth coverage on how users can apply ISA-95: Enterprise-Control Integration Standard to help lower TCO of MOM systems and their enterprise and plant interfaces. It consists of a series of related how-to white papers described in the context of ISA-95 models, definitions and data exchanges.

To be competitive, manufacturing operations activities must be highly interactive in the supply chain and enterprise processes for effective collaboration and competition. This is the domain of collaborative and flexible MOM system architectures. The book explains the business cases for using evolving ISA-95 methods to effectively design, implement, change and optimize the MOM business processes and supporting MOM system architectures within the distributed pull supply chains.

ABOUT THE AUTHOR

Jack Smith is senior contributing editor for Automation.com and *Automation.com Monthly* digital magazine, publications of ISA, the International Society of Automation. Jack is a senior member of ISA, as well as a member of IEEE. He has an AAS in Electrical/Electronic Engineering and experience in instrumentation, closed loop control, PLCs, complex automated test systems and test system design. Jack also has more than 20 years of experience as a journalist covering process, discrete and hybrid technologies.

What Is the Best VFD Design and Installation Plan?

ISA automation professionals explain key considerations for using variable frequency drives.

By Gregory K. McMillan, Erik Cornelsen, Michael Taube, Matthew Howard, Michel Ruel, and Peter Morgan

Variable frequency drives (VFDs) are widely used in industrial fan, pump, and air compressor applications, which constitute a substantial portion of the electricity consumed by U.S. industrial operations. VFDs are used to get the most out of an ac motor. This month's question is: What is the best VFD design and installation plan considering noise, linearity, slip, reliability, rangeability and response time?

The first answer is from Erik Cornelsen: When selecting a VFD for an application, I consider a few key factors to ensure optimal performance. Understanding the relationship between torque and speed is fundamental. Applications generally fall into two categories: constant torque, like conveyors, material handling systems and hoists, or variable torque, where torque is proportional to the square of the speed, as in fans and pumps. Most VFD manufacturers provide models tailored to these categories, making it easier to choose the right one.

Matching the VFD to the motor is equally important. Selecting a VFD with a power rating slightly above the motor's ensures it can handle the application without strain or performance issues.

During commissioning, I configure parameters such as motor nameplate details and acceleration/deceleration ramp times and then perform an auto-tune operation. This allows the VFD to account for actual installation factors like cable distances and fine-tune its settings for optimal performance.

These are the basic steps to get the motor running, but fine-tuning is often necessary to tailor the system for the specific application. I monitor and adjust parameters such as duty type (heavy or normal, selecting heavy for higher overload tolerance), motor control mode (e.g., vector control or V/f), maximum motor frequency, control method (e.g., Ethernet or hardwired signals), brake release configuration (if the motor has a brake) and IGBT switching frequencies.

Many of these adjustments are guided by field observations, alarms and warnings displayed by the system. The ultimate goal is to achieve smooth operation during both starting and stopping. Key parameters I monitor include motor current and motor speed to ensure the system is functioning efficiently and reliably.

Greg McMillan: Best practices

In an AC induction motor, the rotor and hence the pump shaft speed lag behind the speed of the rotating electrical field of the stator because a difference in speed is needed to provide the rotor current and consequently the torque to balance any motor losses and the load torque from pump operation. This difference in speed between the stator field and the rotor of the motor is called slip. There is a dynamic slip for large changes in the pump load (e.g., static head) or desired flow rate (speed signal). There is also a steady-state slip for operation at a particular load and speed.

It is important to note that VFD speed slip is not the same as valve stroke slip. In speed slip, the speed still responds smoothly to a change in the drive signal. At low speed, the loss in pump efficiency and an increase in slip cause a dip in flow. Slip affects the minimum controllable speed and hence the VFD rangeability, particularly for high static heads.

In a synchronous motor, the rotor is designed to inherently eliminate slip so the rotor speed is at the synchronous speed of the stator. Synchronous motors are significantly more expensive and complicated and are used only where inherent fast and precise speed regulation is needed. Synchronous motors have been used for ratio control of reactants or additives, where small transients or offsets in the speed could cause a significant variation in the product concentration.

If there were no static head and no slip, and the motor and frame are properly designed to prevent overheating at low flows, the rangeability of a VFD would be impressive. A drive with closed-loop slip control by the cascade of speed to torque control can achieve a rangeability of 80:1, which is comparable to the rangeability of a magnetic flow meter.

When the pump head is operating near the static head, the minimum controllable flow is set by rapid changes in the static head and frictional loss. These rapid changes could be due to noise and sudden or large disturbances. The speed cannot be turned down below the amplitude of these fast fluctuations. The rangeability for a static head that is more than 30% of the system head at 100% speed is only 2:1, regardless of drive technology.

What is interesting is that a control valve's rangeability deteriorates for a valve pressure drop that is less than 30% of the system pressure drop. Thus, if you had a situation where the frictional losses in the piping are low, like in pH control, but the static head was high, a control valve with minimal stiction and lost motion would have much greater rangeability than a VFD.

Here are some best practices for VFD design and installation:

- High-resolution input cards
- Pump head well above static head
- On-off valves for isolation
- Design B TEFC motors with class F insulation and 1.15 service factor
- Larger motor frame size
- XPLE jacketed foil/braided or armored shielded cables
- Separate trays for instrumentation and VFD cables
- Inverter chokes and isolation transformers
- Ceramic bearing insulation
- Pulse width modulated inverters
- Minimum deadband and rate limiting in the drive configuration
- Drive control strategy to meet rangeability and speed regulation requirements
- If tachometer feedback control is used, speed control should be in the drive, not the DCS
- External reset feedback (dynamic reset limit) using tachometer or inferential speed feedback to prevent PID output from changing faster than the drive can respond.

For more details, see Chapter 7: Effect of Valve and Variable Frequency Drive Dynamics in my book, *Tuning and Control Loop Performance, Fourth Edition*. It is available as a free download. Another extensive resource is The Control Techniques Drives and Controls Handbook, edited by Bill Drury and published by The Institution of Electrical Engineers, London.

Michael Taube: Stop controllers from 'fighting'

Both Greg and Erik have addressed aspects of VFD applications that I never considered—nor would have thought of! Admittedly, my exposure to VFD application has been limited to just some pump applications and, invariably, the controls design (by others) was less than optimal: In most instances two separate controllers were implemented, one using the VFD and another manipulating a control valve to "control" the same variable (e.g., level, flow, etc.), which, of course resulted in the controllers "fighting" each other, or as the operators would say: "It just doesn't work!"

When I've encountered such applications, I recommend that the VFD be used as a valve position controller that adjusts the motor speed to keep the control valve (which maintains the process variable of interest, e.g., level, flow, etc.) in some "optimal" range (nominally 60-70%). The VFD controller would be tuned to react to changes in the control valve position "slowly," perhaps even using an error-squared algorithm, as well as a filtered value of the valve position. There's no need to have the VFD react to every tick, jerk or movement of the control valve.

Thinking further on the topic, I have to question why have both a VFD and a control valve? Some years ago, when meeting with a prospective client about implementing pipeline automation, the client pointed out that it was far more energy efficient (meaning, lower in operational cost) to modulate the speed of the pipeline pump(s) rather than run them at constant power and then dissipate that energy across a control valve. So, if "energy efficiency" is the justification for using a VFD, then don't bother with a control valve! And, as you point out, there is turn-down performance in addition to system hydraulics to consider if pursuing such a design.

Matthew Howard: Pulp and paper

My experience is in line with Michael's second paragraph. We use VFDs with no valves for optimum energy efficiency. If we have a valve downstream, it is often due to the minimum pumping of the VFD being too large for the process, so the valve is used to backpressure, usually in a split-range control scheme. A "valve" position controller is better, but I would prefer to move the VFD more quickly than the valve. This is because the VFD has more precision and no stiction.

Also, my experience in pulp and paper is that there are "drives guys" and "controls guys." My experience is limited, but drives seem to be a subset of controls that is very specialized and electrical in nature, similar to our quality control system (QCS) scanner systems. It is unlikely in my experience for a DCS manager to spec out and be an expert in VFD selection and installation.

Michel Ruel: Loop tuning with VFDs

I agree with the comments from my colleagues and would like to add my thoughts on loop tuning with VFDs. Proper VFD configuration is crucial, and a common mistake is using inappropriate parameters, particularly the current limit and acceleration/deceleration ramps.

When a PID controller sends a signal to the VFD, if the change is within the configured limits, the control loop behaves as expected. However, if the PID controller requests a large change, the VFD's limits (e.g., current limit or ramp time) will restrict its behavior. This restriction can cause the loop to appear as if it has a large time constant, which may lead to the mistaken conclusion that a higher proportional gain is needed.

There's no need to have the VFD react to every tick, jerk or movement of the control valve.

If the loop is tuned for large changes (which involve these limits), it will work well for those cases. But when the process variable (PV) is close to the setpoint (SP) and the PID controller makes small adjustments, the dynamics change. The apparent time constant for these small changes becomes much smaller, which can lead to oscillations in the loop.

It is common to see cycling loops with VFDs when the PV is close to the SP. The key is to focus on tuning for small changes, rather than large ones. Properly setting the VFD parameters is also essential to ensure stable loop performance.

Greg McMillan's follow-up

As I previously noted, there is a serious decline in VFD rangeability when the static pressure is large compared to the system pressure drop. A possible option to extend the rangeability I have not tested, but was mentioned in an email to me eight years ago by ControlSoft Inc., is the option of installing a throttling valve that is normally wide open. Split-range control is used to start to throttle the valve when the VFD reaches its low-speed limit to move the intersection of the system curve with the VFD curve to a lower flow on the plot of pressure versus flow.

The tuning for when the VFD speed is being modulated and when the throttle valve is being positioned is quite different, requiring scheduling of the tuning settings. Directional move suppression offered by external reset feedback might be useful in suppressing unnecessary crossings of the split range point.

Also, moving the speed control from the drive into the DCS can result in complications in coordination with speed to torque cascade control and a slower response due to DCS scan time and update rate. In the meantime, more information on variable speed drives can be found in my book, published by ISA, *Essentials of Modern Measurements and Final Elements*.

More Advice on VFDs

ISA senior member Peter Morgan provides his insights on variable frequency drives in an extended version of this article available as a PDF resource from Automation.com. He discusses a modelling project he has just started and some of his previous and earliest experiences with pump control. He has experience, for example, using a valve directly to control flow and modulating pump speed to maintain constant differential pressure across the valve. "This and other possible alternatives for flow control using a variable speed pump, either as the only means of flow control or in combination with valve adjustment, will be the subject of a planned study by Greg McMillan and me, with an article forthcoming soon," Morgan said.

This discussion is part of the Ask the Automation Pros series from the International Society of Automation, https://www.isa.org. Find previous posts from this series on the ISA Interchange blog. Past Q&A videos are available on the ISA YouTube channel; view the playlist here.

ABOUT THE AUTHORS

ISA Fellow Gregory K. McMillan retired as a Senior Fellow from Solutia Inc. in 2002 and retired as a senior principal software engineer in Emerson Process Systems and Solutions simulation R&D in 2023. McMillan is the author of more than 200 articles and papers, 100 Q&A posts, 80 blogs, 200 columns and 20 books. McMillan received the ISA Lifetime Achievement Award in 2010, the ISA Mentor Award in

Continued on next page

2020 and the ISA Standards Achievement Award in 2023. He was also one of the first inductees into the Control Global Process Automation Hall of Fame in 2001.

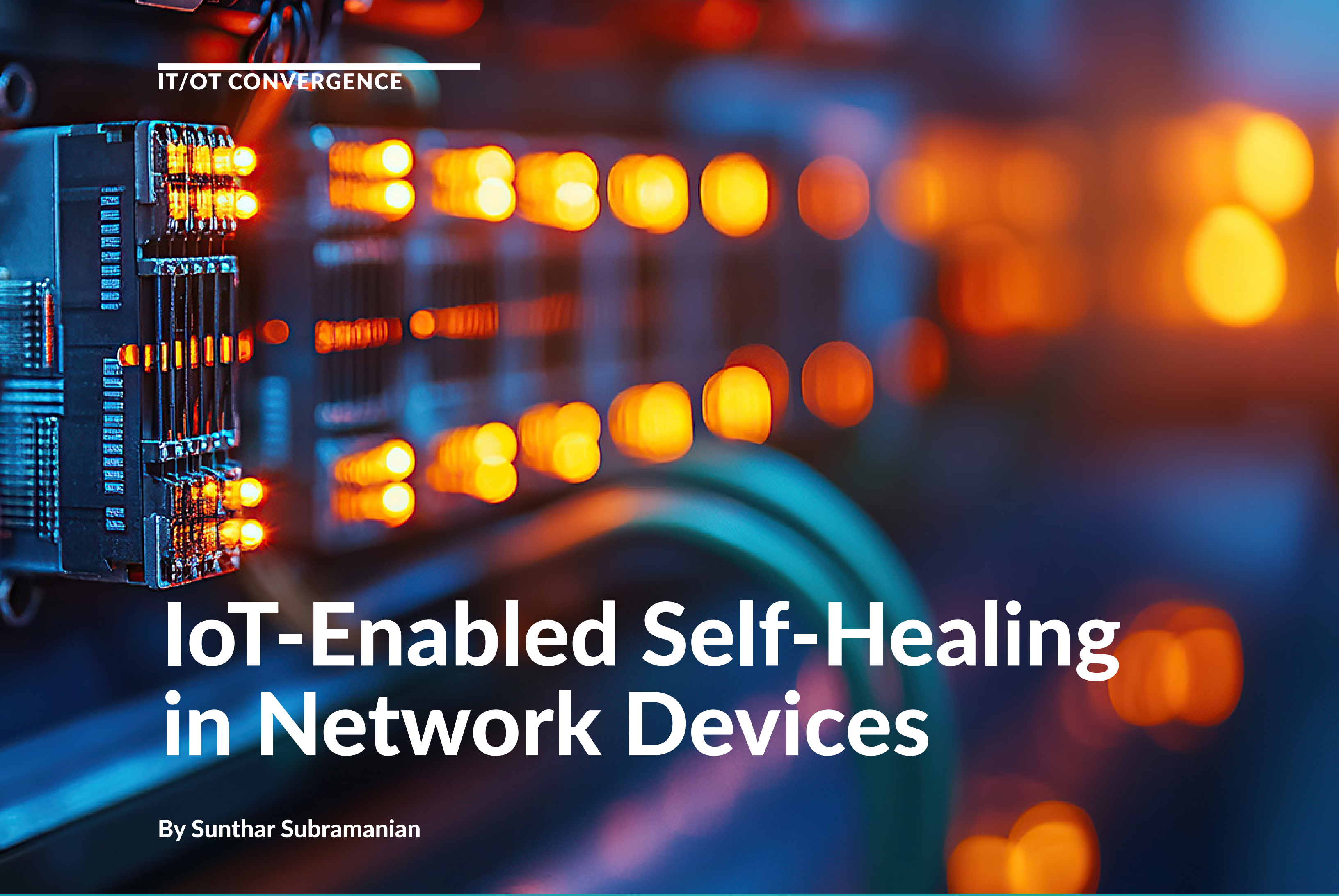
Erik Cornelsen is an automation and process control engineer at DPS Group, a leading system integrator based in Scotland. With more than a decade of experience, Cornelsen has worked and lived in six countries, contributing to diverse industrial sectors, including food and beverages, logistics and construction materials. He has a master's degree in mechanical engineering from INSA de Lyon (France) and is a Chartered Engineer, a member of the Institution of Mechanical Engineers (UK), and an active member of ISA.

Michael Taube is a principal consultant at S&D Consulting, Inc. Serving the greater process industries as an independent consultant since 2002, he pursues his passion to make things better than they were yesterday by identifying the problems no one else sees or is willing to admit to and willingly "gets his hands dirty" to solve the problems no one else can. He collaborates with operational excellence and safety culture experts to promote a real and lasting cultural shift in the process industries to help make zero incidents a reality. He graduated from Texas A&M University in 1988 with a Bachelor of Science degree in chemical engineering.

Matthew Howard is the pulp mill area systems manager for Sappi North America, Somerset Mill, Skowhegan, Maine, a large fully integrated pulp and paper manufacturing facility. He is responsible for multiple DCS systems maintenance and integration. He prefers to use his UMaine chemical engineering and technical background to implement process improvements with or without capital investment. Informed by an early stint as a frontline supervisor, he also strives to steadily improve the operator effectiveness of his plant in accordance with ISA standards ISA-101 and ISA-18.2.

ISA Fellow Michel Ruel is a recognized expert in process control and control performance monitoring and a frequent speaker. Now retired, he led a team that implemented innovative and highly effective control strategies across a wide range of industries, including mining and metals, aerospace, energy, pulp and paper and petrochemicals. An accomplished author of numerous books and publications, Ruel is also a software designer specializing in instrumentation and process control. He is the founding president of Top Control Inc. and has contributed to projects in multiple countries.

Peter Morgan is an ISA senior member with more than 40 years of experience designing and commissioning control systems for the power and process industries. He was a contributing member of the ISA 5.9 PID committee, for which he won the ISA Standards Achievement Award, and is a frequent feature article author.



IoT-Enabled Self-Healing in Network Devices

By Sunthar Subramanian

Edge computing, machine learning algorithms and centralized management platforms work in tandem to ensure industrial systems keep running.

Network devices with self-healing mechanisms enabled by Internet of Things (IoT) technology represent a significant advancement in maintaining network reliability and minimizing downtime. These intelligent systems use real-time data from IoT sensors to detect, diagnose and automatically resolve network issues, often before they impact user experience. The architecture behind such systems typically involves a combination of edge computing, machine learning algorithms and centralized management platforms that work in tandem to ensure rapid response and adaptive problem-solving capabilities.

In traditional network environments (Figure 1), resolving an unresponsive router, switch or access point typically requires manual intervention, often involving IT staff physically accessing the device to perform a hard reboot. This process introduces delays,

IoT-Enabled Self-Healing in Network Devices

Characteristic	Traditional Network	IoT-Based Self-Healing
Issue Resolution	Manual intervention	Automated system resolution
Anomaly Detection	Requires manual monitoring	Smart sensors detect anomalies
Reboot Process	Physical access for hard reboot	Remote, intelligent reboot sequence
Failure Response	Reactive, after user impact	Proactive, predictive self-healing

Figure 1. With traditional network devices, manual intervention can introduce delays and increase costs. With an IoT-based self-healing architecture, smart power controllers and embedded sensors can detect anomalies and proactively respond.

increases operational costs and is prone to human error. However, in an IoT-based self-healing architecture, strategically placed smart power controllers and embedded sensors can detect anomalies such as sustained packet loss, high CPU/memory usage or frozen system processes.

When these conditions are met, business rules engines (BREs), either at the edge or in the cloud, can automatically trigger a safe and intelligent reboot sequence. These actions may include gracefully shutting down services, issuing restart commands via secure APIs, or even initiating a remote power cycle through IoT-controlled outlets or power distribution units (PDUs). This ensures a minimal disruption window and avoids cascading failures that might affect dependent systems or services.

The architecture typically includes:

- **Edge-based logic** where localized rules enable instant actions like auto-reboots or hardware resets.
- **Monitoring and task agents** that track device health metrics, execute tasks in real time and report anomalies.
- **Cloud-based orchestration** that validates and logs actions while enabling policy enforcement across a distributed network.
- **Redundancy-aware algorithms** that ensure reboot commands are only executed when it is safe to do so, e.g., avoiding restarts if multiple redundant links are already down

Machine learning algorithms can further refine this process by learning which conditions most frequently precede critical failures. Over time, these systems can shift from reactive to predictive self-healing, initiating reboots proactively before the user experience is affected.

The foundation: IoT sensors and edge devices

IoT sensors, integrated into network hardware such as routers, switches, access points and power units, collect a wide array of performance metrics in real time. These metrics may include network traffic volume and patterns, device connectivity status, signal strength and latency measurements.

These sensors also capture environmental data such as temperature, humidity and power consumption. This comprehensive data collection enables network administrators to gain deep insights into the overall health and performance of the network infrastructure.

IoT sensors within a network can detect and record information such as:

- Temperature, voltage and power consumption levels
- CPU or OS services hang and process freezes
- Network latency and throughput
- Error rates and packet drops
- Port activity and link status
- Ping/heartbeat response failures
- Power supply anomalies
- CPU hangs and process freezes.

Centralized intelligence for network health

The cloud acts as the "brain" for the entire network infrastructure, correlating data from individual devices to understand the bigger picture and orchestrate more complex remediation strategies. It typically performs the following functions:

- **Device-specific data aggregation.** Cloud platforms ingest and organize telemetry data from diverse network devices (routers, switches, firewalls from various vendors). Data lakes provide scalability to handle this volume and variety.
- **Centralized network visibility.** A unified dashboard gives administrators a holistic view of connected devices' health and performance, highlighting potential issues and self-healing system actions.
- **Firmware and configuration management.** The cloud platform serves as a central repository for device configurations and firmware updates, enabling consistent policy enforcement and security patching.
- **Correlation and advanced analytics.** The cloud enables correlation of events across devices. A pattern of increasing latency across multiple switches might indicate a broader network issue requiring a coordinated response.

Over time, these systems can shift from reactive to predictive self-healing, initiating reboots proactively before the user experience is affected.

Ensuring visibility and feedback loops

With help from the components that enable real-time telemetry, system health checks and feedback loops, the system could understand whole picture and initiate complex remediation strategies using agents, message queues (MQTT, Kafka) and APIs.

Software agents in network device operating systems collect and transmit telemetry data. These agents must be resource-efficient to avoid impacting primary networking functions. Standard protocols like SNMP can be augmented by more efficient streaming telemetry protocols (e.g., gRPC Network Management Interface, or gNMI).

Optimized telemetry pipelines enable efficient data transport. For network devices, this involves protocols that minimize overhead and handle intermittent connectivity. Quality of service (QoS) mechanisms may prioritize critical telemetry data.

Network devices also expose secure APIs (e.g., RESTCONF, NETCONF) that allow central platforms or edge controllers to query information or trigger management actions, including controlled reboots or configuration changes.

These components ensure a continuous flow of vital operational data from the network devices to the central intelligence, enabling real-time monitoring and informed decision-making.

AI/ML engines for fault prediction and remediation

Artificial intelligence and machine learning (AI/ML) models are trained on network behavior to predict failures, trigger alerts and even initiate corrective actions such as reconfigurations or rerouting traffic autonomously.

ML models can be trained on performance data to predict hardware failures (based on temperature or power fluctuations) or software issues (recurring crashes or memory leaks). AI algorithms can learn normal traffic patterns and identify deviations that might indicate security threats, misconfigurations or performance bottlenecks.

ML can analyze device configurations and suggest optimizations for performance, security or resilience. Based on predictions and anomalies, AI can trigger specific actions, such as:

Graceful service restarts. Attempting to restart failing processes before a full device reboot.

Traffic shaping or QoS adjustments. Dynamically altering traffic priorities to mitigate congestion on interfaces or devices or adjust quality of service.

Automated configuration rollback. Reverting to known good configurations if recent changes cause issues.

Controlled remote reboots. Initiating safe reboot sequences via secure APIs or integrated smart power capabilities.

The AI/ML layer transforms network device management from reactive troubleshooting to proactive prevention and intelligent automation.

The future: Autonomous networks with predictive self-healing

Develop insights through trends like zero-touch network operations, digital twins and the convergence of AI, IoT and predictive analytics to build networks that not only fix themselves but prevent failures proactively.

- **Zero-touch provisioning.** Network devices will automatically provision and configure upon deployment, reducing manual intervention.
- **Digital twins.** Virtual replicas of routers, switches and firewalls will enable simulation of changes and prediction of impacts before live implementation.
- **Intent-based networking.** Administrators will define business intents, and network devices using AI and self-healing capabilities will configure and adapt to meet those intents, autonomously resolving issues.
- **Predictive maintenance.** AI will enable network devices to predict hardware failures, allowing proactive replacement before outages occur.

The future envisions network devices that are increasingly autonomous, capable of not only healing themselves but also anticipating and preventing issues, contributing to a truly resilient and self-managing network infrastructure.

By focusing specifically on network devices, we can see how the principles of IoT-enabled self-healing are becoming integral to their design and management, promising a future of more reliable and less manually intensive network operations. This architectural system aims to minimize downtime, reduce operational costs , and avoid human error in network maintenance. It can trigger automatic reboot sequences or other corrective actions when anomalies are detected, ensuring minimal disruption and preventing cascading failures.

Originally posted on ISA Interchange blog.

ABOUT THE AUTHOR

Sunthar Subramanian is a digital transformation and innovation leader in IoT, AI, data, Industry 4.0 and sustainability technologies. At Cognizant, he has consulted and transformed many retail and consumer goods customers to realize value and growth through these technologies. His areas of focus and expertise include IoT and AI-enabled transformative solutions for stores, warehouses and factories.

Unlocking Smarter Manufacturing

Use this three-stage blueprint to ensure success when rethinking industrial operations.

By Gregory Tink

Have you ever walked into a facility that seems to run like clockwork – where downtime is rare, output is steady, and every decision feels informed and timely? More often than not, the real advantage doesn't come from the number of robots on the shop floor, but from how effectively that facility harnesses its data. At the heart of today's most successful industrial operations is the seamless convergence of people, data, and technology – all working together to build smarter, more resilient manufacturing systems.

This is the promise of digital transformation in the industrial space. However, for many companies, the path to getting there is less clear. According to the World Economic Forum, over 70% of companies are stuck in "pilot purgatory," struggling to adopt new technologies and failing to see meaningful returns or efficiency gains from their early digital initiatives.

Why? Because transformation isn't just about installing new tech – it's about rethinking how operations work at their very core.

Common pitfalls and success factors

Even with the right roadmap, many transformations falter. Common missteps include focusing only on technology while neglecting cultural or procedural readiness; underestimating the need for upskilling, leaving employees overwhelmed or resistant; and skipping foundational steps and jumping straight to advanced tools without the data maturity to support them.

On the flip side, companies that succeed in transformation tend to appoint dedicated leadership for the transformation effort; set a clear operational vision and use it to filter ideas and priorities; celebrate small wins, reinforcing the value of change and keeping momentum alive; and work with the right partners who bring both technology and domain expertise.

At its best, digital transformation aligns three forces: people, processes, and technology. When these elements work together, the impact can be profound: lower operational costs, reduced downtime, better energy use, improved product quality and more empowered workers. However, transformation also introduces new complexities. Traditional silos between IT and OT teams must be dismantled. Legacy equipment needs to be integrated into the digital ecosystem. And, perhaps most critically, organizations need a roadmap that balances long-term vision with day-to-day operational realities.

While every transformation journey is unique, our experience guiding hundreds of industrial sites has revealed a common path to success: a three-stage approach: Evaluate your site, digitize the core, and digitize at scale.

Stage 1: Evaluate your site

Digital transformation must start with a clear-eyed assessment of where you are today. This foundational stage helps you define your goals, engage stakeholders, and identify gaps in data, infrastructure, and skills. Start by asking:

- What operational challenges are we trying to solve?
- Where are the bottlenecks?
- What data do we have and what data do we need?

At this stage, collaboration between IT and OT is essential. Many transformation efforts stall because teams don't share the same language or priorities. IT might focus on data architecture and cybersecurity, while OT is more concerned with uptime and safety. However, successful digital projects hinge on their integration. That requires establishing cross-functional planning and design, with leadership actively involved to align incentives and expectations.

This assessment stage also involves understanding your infrastructure maturity. What equipment can be connected? Where will you need upgrades? And how do you balance near-term wins with long-term scalability?

Stage 2: Digitize the core

Once your roadmap is in place, the next step is to digitize essential operations by moving away from manual processes (think clipboards and spreadsheets) to real-time, connected systems. The goal is to establish a digital foundation robust enough to support more advanced tools down the line. Key priorities include:

- Connectivity. Establish reliable, secure data transmission between equipment and central systems.
- Cybersecurity. As you digitize, your attack

surface expands. Build cybersecurity into the architecture, not as an afterthought.

- Lean digital practices. Integrate digital tools with Lean management systems to drive continuous improvement and visibility.
- Workforce enablement. Make the transformation human-centered by training staff not only to use digital tools but also to contribute to their evolution.

At this stage, many companies begin piloting IIoT platforms, edge computing, and digital twin simulations to unlock predictive maintenance, real-time quality monitoring, and faster issue resolution. But beware of the "pilot purgatory" trap: without clear objectives and a path to scale, many digital initiatives remain confined to isolated test cases.

Stage 3: Digitize at scale

This is where transformation gets real. Scaling digital practices across sites, lines, or geographies requires standardization. While different teams and facilities may have different habits, software, or priorities, true transformation isn't possible unless your systems can communicate seamlessly. Scaling involves:

- Centralizing data. Aggregate data from disparate systems — machines, power grids, building controls — into a unified platform.
- Standardizing processes. Define shared ways of working that align local flexibility with enterprise-wide goals.
- Driving cultural change. Make transformation part of the company's DNA by aligning KPIs, incentive structures, and career growth to digital success.

This is also the stage where advanced technologies, like AI, machine learning, and digital twins, can deliver their full value. However, their success depends on the groundwork laid earlier: reliable data, clean architecture, and a digitally fluent workforce.

It's not a sprint, it's a system

Digital transformation requires patience, persistence, and adaptability. But more than anything, it's a system—a way of aligning tools, people, and processes around a shared goal: smarter, safer, more resilient operations. The key is not just starting strong; it's building a system that sustains itself over time, evolves with your business, and empowers every worker to drive better outcomes.

The future of industrial operations isn't about adding more machines—it's about making the machines, and the people who run them, smarter. Start with your why. Build your how. Then, scale your success.

ABOUT THE AUTHOR

Gregory Tink is Digital Transformation Director for Schneider Electric. The company's Industrial Digital Transformation Services consultants help companies make operations more efficient, sustainable, resilient, and secure. Find out more and read the white paper to get practical guidance for achieving impactful digital transformation.

How To Get **Maximum** Value From Your MES

Follow best practices when implementing a manufacturing execution system.

By Nikhil Makhija

The implementation of a manufacturing execution system (MES) demands detailed planning as well as strategic execution and knowledge about typical implementation problems. The article includes the best practices and challenges that ensure your MES implementation will provide maximum value for your manufacturing operations.

A strategic foundation must be built through planning before starting an MES implementation project. Your MES deployment must start by defining how it enables your organization to meet its corporate objectives. The system becomes a purposeful addition when properly aligned to business goals instead of remaining a standalone technological solution.

Your organization should perform a complete assessment to determine both problems and opportunities in its manufacturing operations. You need to understand how the manufacturing execution systems supports your operational targets, which can include time reduction, product quality enhancement and standard compliance. Then create specific measurable targets that describe your MES project implementation.

Choosing the right solution

The selection of appropriate MES software stands as a key determinant for implementation success. Every MES varies in its capabilities and organizations need to conduct detailed assessments to find the appropriate fit. The evaluation process needs to assess vendors through their knowledge of your sector, as well as their solution adaptability and growth potential and their commitment to supporting your business from present to future needs.

When evaluating MES systems, organizations need to determine the appropriate level of customization versus standardization that suits their needs. A customized solution provides optimal alignment but typically requires additional expenses and longer installation periods. The system must integrate seamlessly with your current systems, especially with enterprise resource planning (ERP), Legacy, supervisory control and data acquisition (SCADA) and programmable logic controllers (PLCs).

Implementation framework and approach

A proper framework for implementation is essential to achieve successful MES deployment through the integration of systems along with scalability and process continuity.

Phased implementation approach. The complete implementation of MES throughout the entire operation becomes too complex to handle during one single deployment. A phased approach allows for:

- Implementation becomes easier to manage while troubleshooting also becomes simpler and will result in reduced operational disturbances in the current activities.
- Quicker realization of benefits in priority areas

Functionality-based implementation stands as a better strategy than attempting full system implementation from the beginning. The approach grants greater flexibility to handle specific problems through systematic methods while providing agility.

Integration strategy. The implementation of MES faces major integration difficulties when working with existing system infrastructure. To overcome this:

- Your MES should link directly with the current ERP system along with SCM and all other related systems, if exists.
- The integration plan should be clarified at the beginning of implementation.
- The integration process between MES and legacy systems requires careful evaluation of middleware solution implementation.
- System integrators with experience and MES vendors who demonstrate excellent integration capabilities should be brought in for collaborative work.

Data management and analytics

The complete potential of MES depends on effective data management together with strategic analytics deployment.

Ensuring data quality. MES produces its highest value through precise data processing operations. A robust data validation system must be created to verify the accuracy of the data used by the MES. MES implementation requires data governance and cleansing practices before starting the process. Regular data audits combined with ongoing maintenance of data sources must be performed to maintain current information.

Leveraging analytics. MES analytics tools enable organizations to gain meaningful insights from their operational data. You should track key performance indicators (KPIs). Analysis of production data will reveal operational bottlenecks and enable process improvement opportunities. Real-time data enables production managers to base decisions on information for their processes.

Change management and user adoption

The adoption and training of users plays a crucial role in maximizing MES benefits because it directly influences both system effectiveness and overall manufacturing productivity.

Stakeholder engagement. The implementation should include stakeholders from all relevant teams who should start their involvement at the beginning of the project. A dedicated team consisting of production personnel, information technology (IT) staff, quality control specialists and management representatives should oversee implementation. All staff members need thorough early knowledge of planned MES solution implementations. The organization should maintain regular meetings across different levels to guarantee universal understanding.

Training and support. The success of system adoption depends heavily on providing extensive training to all users.

- Develop robust training programs tailored to different user roles
- Training includes hands on practice combined with web-based materials and continuous technical support.
- Operators need to understand the work improvements that the MES will bring to their operations.

Common pitfalls to avoid

By identifying common implementation challenges, you can better anticipate and handle potential difficulties that may arise.

Lack of proper planning. MES implementation will easily get off track when the implementation team does not have a clear understanding of objectives, resources and timelines. The beginning of implementation requires conducting a detailed evaluation of present processes along with resources and goals. The implementation process requires an assessment of the MES to determine its ability to work with current infrastructure and connect with other systems.

Poor communication. During MES implementation, various stakeholders need effective communication to avoid misunderstandings and project delays:

- The project needs a defined communication framework that combines with a specific project management system.

- The team should maintain regular sessions combined with progress reports and feedback opportunities.
- Take action to resolve employee concerns as soon as they appear during the initial stage of the process.

Resistance to change. The implementation process of MES leads to process changes, which affect existing workflows. The production staff must participate in implementation activities from the first moment of the project. The system demonstrates to staff members how it will enhance their operational tasks. The organization should listen to feedback and solve employee concerns as quickly as possible.

Excessive customization. Excessive customization results in both project delays and higher costs and produces system performance issues and future upgrade difficulties. Striking a balance between standardization and customization requires identification of core functionalities that should stay standard while customizing only essential aspects for your unique processes.

Insufficient testing. The absence of adequate testing leads to price-intensive errors. Every phase of the implementation process requires complete testing procedures.

The testing process must include three types of assessment: functional testing, integration testing and user acceptance testing. The testing process requires qualified staff members who possess suitable skills and experience.

Wrapping up

Successful MES implementation requires a structured approach, strategic deployment and continuous optimization. By following these best practices, manufacturers can maximize the benefits of their MES investment, including improved production efficiency, enhanced quality control and increased operational visibility. The journey to manufacturing excellence through MES implementation may be challenging, but the rewards—in terms of competitive advantage and improved operational performance—make it well worth the effort.

ABOUT THE AUTHOR

Nikhil Makhija is a senior manufacturing systems analyst at Fujifilm Dimatix and an advocate for Industry 4.0 innovation and digital transformation. A Senior Member of ISA and Program Chair of the ISA North Texas Section, Makhija brings more than 17 years of expertise in implementing smart manufacturing solutions using a combination of IoT, data driven analytics and enterprise solutions such as SAP Manufacturing Suite to drive operational excellence and scalability. He is dedicated to empowering organizations to achieve their digital transformation goals through cutting-edge strategies and technology integration. Makhija actively supports ISA initiatives and can be reached at LinkedIn.

Technologies Driving Robotics and Motion Control Advances

By Drew Thompson

Robotics and motion control advances reduce manufacturing costs.

Technological advances have transformed the robotics and motion control industries. This transformation has dramatically reduced the costs associated with deploying these technologies. As a result, robotics technology and motion control systems are being deployed across a wide range of novel applications. Traditional technologies, such as sensors and actuators, are being used alongside artificial intelligence (AI), machine learning and edge computing to bring robotics and motion control to life.

Sensor systems. To safely and effectively work, robots and other autonomous machines need to gather and monitor information about their environment. This is done through the use of sensor systems.

Vision systems. Vision systems can be thought of as specialized sensors. Vision systems allow robots and autonomous machines to capture, process and interpret visual information from the world around them to make decisions. This is crucial for performing tasks such as navigation, inspection and manipulation.

Advanced actuators. Broadly, actuators allow robots and autonomous machines to act upon—or react—to the data gathered from the various sensor systems. Innovations in actuators—from electric, hydraulic and pneumatic systems—have led to more precise, powerful and efficient motion control.

Edge computing and IoT. The integration of edge computing and Internet of Things (IoT) technology enables real-time data processing and decision-making at the robot or individual machine level, thereby reducing latency and improving efficiency in robotic systems.

AI and machine learning. The recent advances in AI and machine learning are among the most important factors driving robotics and motion control systems. Adaptive robotics and motion control systems, specifically those that use AI and machine learning, can learn from data and adapt to rapidly changing conditions. Adaptive systems can make decisions based on patterns and trends in the data without being explicitly programmed for every possible scenario.

Industries most affected by improved robotics

Manufacturing, health care, autonomous vehicles and military/aerospace are a few of the industries and applications most affected by improved robotics and machine control systems.

[run-in head] Manufacturing. Taken as a whole, the manufacturing industry has benefited the most from the improvements in robotics and motion control. Specifically, improved robotics and motion control technology have completely transformed the industrial automation segment of manufacturing (Figure 1).

The traditional approach to automation and robotics, which relies on if-then-else,

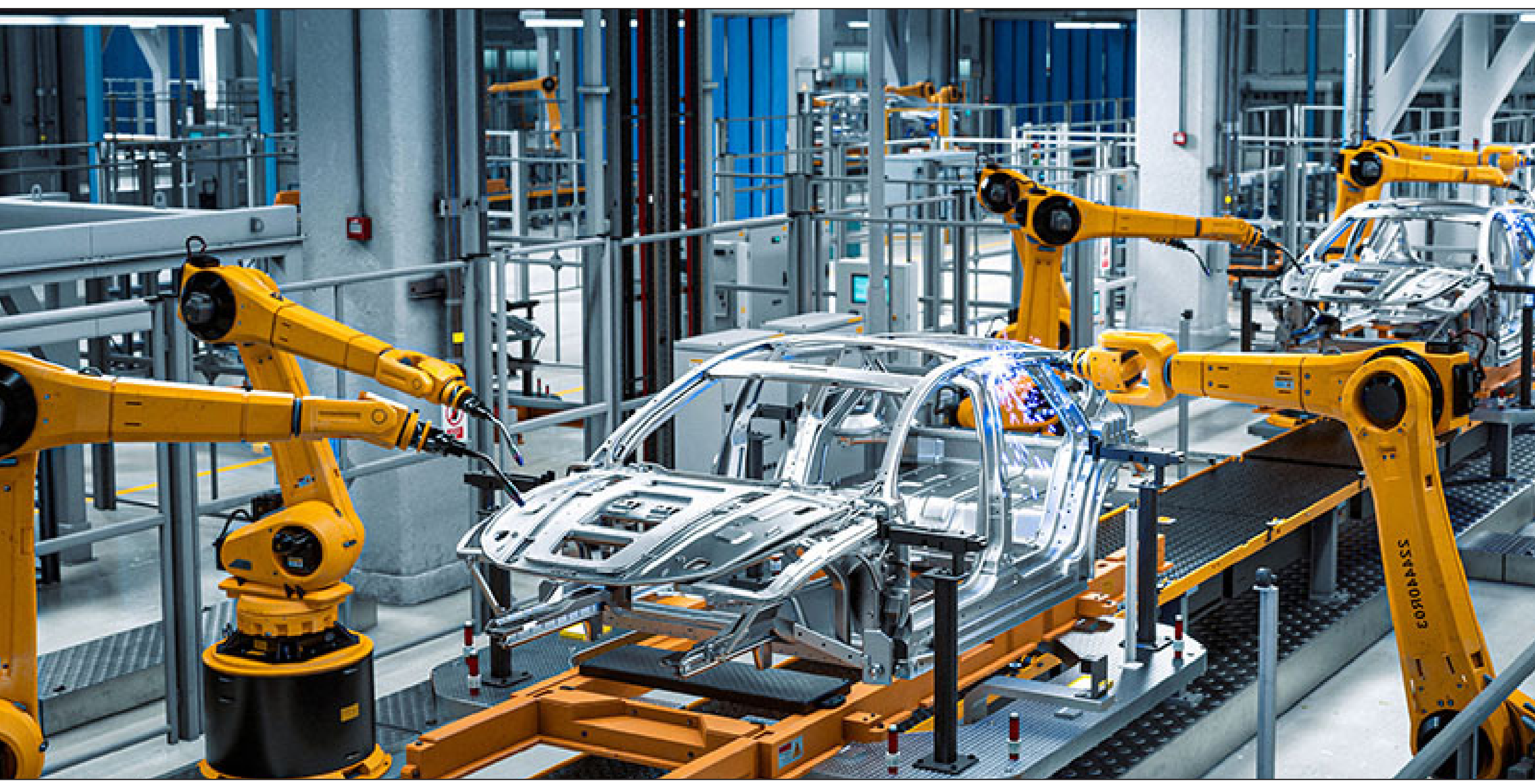


Figure 1. Robotic arms used in a vehicle assembly line.

Figure 2. A surgeon manipulating a robotic surgical device.

rule-based programming, is limited in terms of flexibility and its ability to respond to novel scenarios that fall outside of explicitly defined parameters. However, the shift toward adaptive robotics and motion control, powered by AI and machine learning, brings increased flexibility, predictive capabilities and the ability to handle complex decision-making, which contributes to more efficient and responsive processes. Essentially, AI and machine learning enable robots and other autonomous machines to learn from data, adapt to new situations and improve their performance over time. Robots and robotic arms have been adopted across the board in many novel applications as control systems have made it possible for them to carry out the precision assembly tasks that require pinpoint accuracy.

Vision systems have dramatically improved the speed of quality control and product inspections by allowing automation of many of the tasks.

Health care. The health care industry has also seen major benefits from improved robotics and motion control systems. The effect of the new technology has not been in just one specific area, but throughout the entire industry.

Using robotic surgery systems—such as the da Vinci Surgical System or one of many systems from Globus Medical—allows surgeons to perform complex procedures with enhanced precision, flexibility and control (Figure 2). These systems translate the surgeon's hand movements into smaller, precise movements of tiny instruments, which leads to less invasive surgeries with smaller incisions, reduced blood loss and faster recovery times.

Similarly, advances in robotics and high-speed communication networks enable surgeons to perform remote surgeries on patients located in different geographic locations. This is particularly useful in emergencies where specialist expertise is required but not locally available.

AI-powered robots and systems analyze medical images such as X-rays, MRIs or CT scans to detect anomalies such as tumors, fractures or other issues with much higher accuracy than human eyes alone.

Autonomous vehicles. Another industry segment that has seen tremendous growth from the advance of robotics and motion control is the development and manufacturing of autonomous vehicles (AVs). Beyond the changes and benefits to the manufacturing process, robotics and motion control systems are driving substantial improvements in AV functionality, safety and efficiency.

The perception and sensing functionality of AVs has grown significantly, both in terms of accuracy and in the ability to react, in the last few years. In large part, this has been facilitated by the development of high-quality sensor systems and the process of sensor fusion. Many autonomous vehicle sensors—and even whole sensor systems—have overlapping functionality. By design, this approach provides redundancy, which means that even in the case of a failure of one or more sensors, the vehicle can still operate safely. Combining real-time data from a variety of sensors and sensor types through sensor fusion reduces the uncertainty of the data set as a whole.

Another area of rapid AV improvement is in motion planning and control functionality. The robotic and motion control hardware inside AVs is now able to compute the safest and most efficient path for the vehicle while considering factors like road conditions, traffic and obstacle avoidance. Further, the decision-making in AVs can mimic human driving behaviors by enabling the vehicles to handle complex driving scenarios such as merging, overtaking and yielding.

AI and machine learning, advanced actuators and edge computing are the core technologies propelling these innovations forward

Military and aerospace. Military and aerospace are other industry segments that have benefited from robotics and motion control system advances. Many of the same advances in consumer-grade AVs apply to military and aerospace vehicles such as unmanned aerial vehicles (UAVs), unmanned ground vehicles (UGVs) as well as seagoing drones: unmanned surface vehicles (USVs) and autonomous underwater vehicles (AUVs).

In addition to the various vehicle-type drones, there is a whole class of autonomous combat robots currently in use or active development. This includes programs like the modular advanced armed robotic system (MAARS), or special weapons observation reconnaissance detection system (SWORDS) or the remotely operated TALON robot, which has seen widespread deployment in a variety of applications—from explosive ordnance disposal to disaster response.

There has also been a recent push to automate segments of military logistics through the use of autonomous trucks and UGVs. Specifically, to transport supplies and equipment in contested or dangerous areas to reduce the risk to human drivers and ensure reliable logistics.

The future

The rapid advances in robotics and motion control systems have significantly transformed various industries by driving down costs and enhancing performance across multiple applications. Sensor systems, vision systems, AI and machine learning, advanced actuators and edge computing are the core technologies propelling these innovations forward. These technological advances are not only transforming existing practices but also paving the way for innovations and applications. As robotics and motion control systems continue to evolve, their impact will undoubtedly expand, which will further integrate these technologies into everyday operations and strategic initiatives across diverse sectors.

ABOUT THE AUTHOR

Drew Thompson is a technical writer and content specialist for Sealevel Systems, a designer and manufacturer of embedded computers, industrial I/O and software for critical communications. A writer/editor by training, Thompson spends his days creating and delivering content relevant to Sealevel's technical community and business partners.

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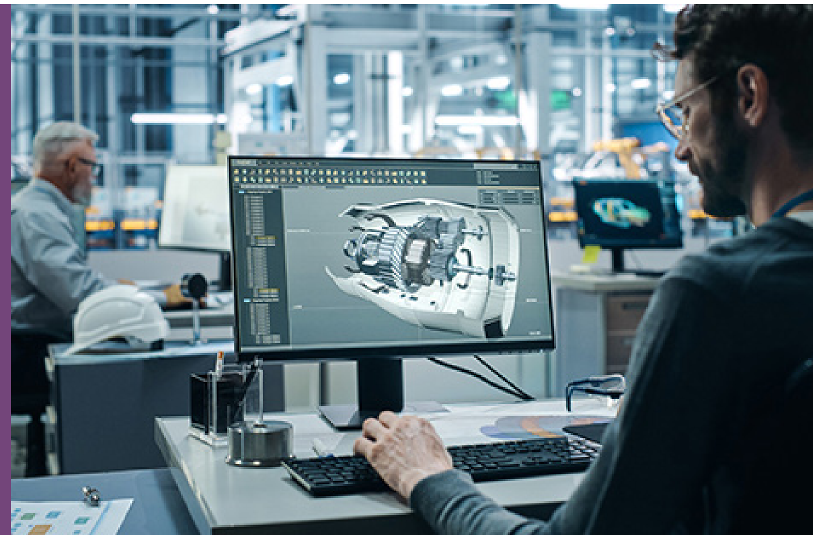
How Artificial Intelligence is Transforming Manufacturing



By Dr. Matthias Loskyll

Embedding AI systems into products makes AI accessible and usable for a wide range of users.

According to a study by the World Economic Forum, more than 70 percent of industrial AI projects are abandoned after the pilot phase. While some companies successfully integrate artificial intelligence (AI) into their operations and achieve significant economic benefits, others face major challenges. However, many examples show that AI can be effectively used in manufacturing and has become a vital element of flexible, efficient production (Figure 1). Today, AI solutions are available that not only integrate smoothly into industrial processes but can also handle complex tasks with high efficiency.

Visual quality control

Quality assurance is a key task in industrial manufacturing. AI-powered image processing systems now make reliable quality inspections possible. One example is Inspekto, a solution for visual quality inspection that enables companies to automate product checks without needing deep AI or image-processing knowledge. The intuitive system can be ready for use in less than an hour and needs only about

Figure 1. Industrial AI is poised to change the way we know manufacturing and the implications of this change are vast and far-reaching.

twenty sample images classified as “good” to deliver accurate results. Basic production knowledge of quality testing is enough—no AI expertise is required (Figure 2).

For example, the mid-sized company MTConnectivity Power2pcb uses Inspekto to inspect connectors to identify minimal deviations and slightly bent contacts. By integrating this AI-based system into its production line, the company ensures continuous quality assurance, improves reliability and shortens delivery times.

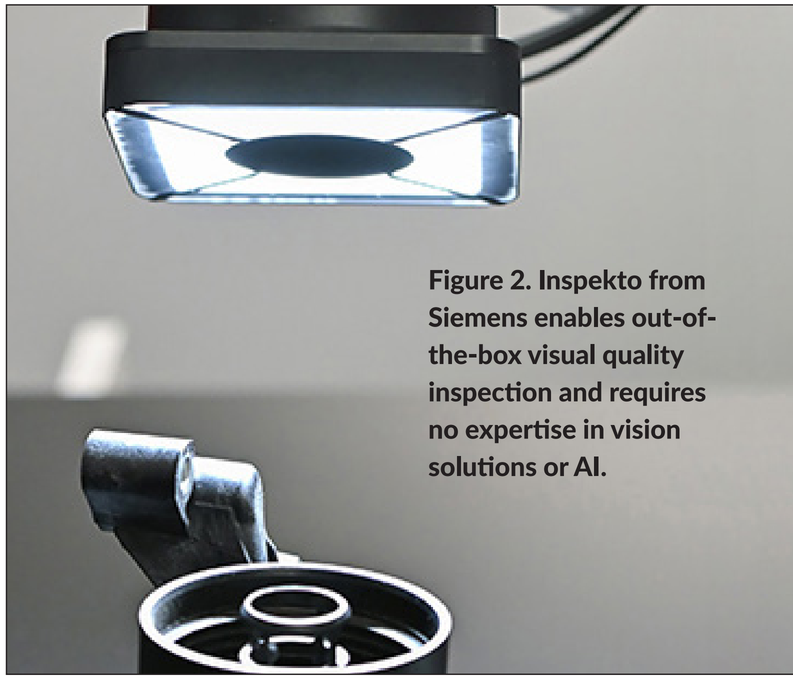


Figure 2. Inspekto from Siemens enables out-of-the-box visual quality inspection and requires no expertise in vision solutions or AI.

Generative AI in manufacturing

The application and implementation of generative AI models are more complex. Siemens’ Industrial Copilots are designed to improve human-machine collaboration and accelerate innovation across the entire value chain—from design, planning and engineering to operations and service. The Industrial Copilot for Operations is currently being piloted at customer sites and Siemens factories to test its reliability. Meanwhile, the Industrial Copilot for Engineering is already available as a finished product (Figure 3).

Thyssenkrupp Automation Engineering, a specialized machinery and equipment manufacturer, has integrated the Siemens Industrial Copilot into its systems for handling round cells used in battery inspections for electric vehicles. The Copilot automates repetitive tasks like data management, sensor configuration and detailed reporting that helps meet strict battery inspection standards. By managing routine tasks, the Copilot allows engineering teams to focus on complex, high-value activities, while solving problems in real time, minimizing downtime and ensuring smooth production.

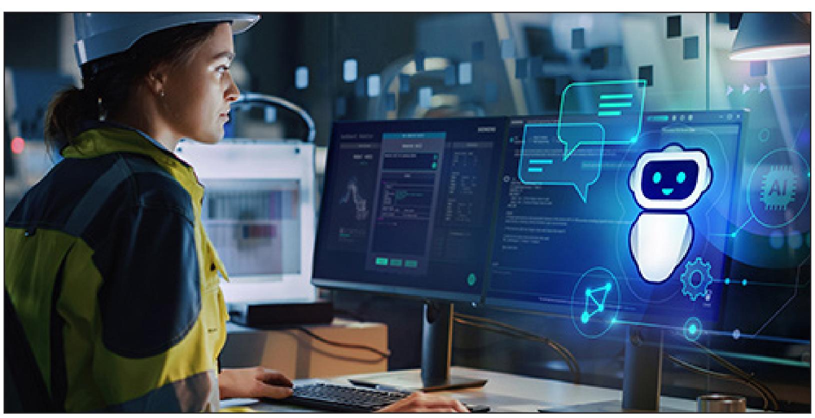


Figure 3. Siemens’ vision of Industrial Copilots along the entire value chain aims to unlock the potential for improving human-machine collaboration and accelerating development and innovation cycles.

Predictive maintenance with AI

AI is also revolutionizing predictive maintenance. Instead of relying on fixed maintenance intervals or manual analysis, AI uses continuous machine data monitoring to detect early signs of wear and suggest maintenance actions. Siemens' Senseye Predictive Maintenance solution identifies deviations in temperature, vibration and torque data to offer early warnings and recommendations (Figure 4).

Mercer Celgar, a producer of pulp and wood products, uses this technology to monitor its machinery in real time. Data from multiple production lines is combined into a central platform that provides a full overview of the manufacturing process and significantly reduces downtime.

Seamless integration of AI models

Even companies that have already adopted AI face challenges when scaling their solutions. Issues such as time-consuming updates, poor connectivity or complex maintenance often arise. To address these challenges, the Industrial AI Suite is available. Industrial AI Suite is a platform for the smooth implementation of AI solutions on the shop floor.

These solutions are customized in close collaboration with customers to combine their existing AI expertise with Siemens' infrastructure for scalable deployment . Depending on the use case, these solutions use edge or cloud computing to integrate services like AWS or Microsoft Azure. AI models can be trained in the cloud and then easily deployed to production floors using the AI Inference Server. The Industrial Edge application enables customers to deploy and run trained AI models in production, directly on the Industrial Edge, even with GPU-accelerated inferencing.

The Industrial AI Suite also manages the full AI model lifecycle, which allows easy updates and automatic detection of performance issues. For example, Siemens helped a food and beverage company integrate AI-based soft sensors into its production. These sensors ensure consistent product quality and taste by analyzing process parameters in real time and dynamically adjusting target values to optimize production and reduce waste.

In electronics manufacturing, Siemens' electronics factory in Erlangen, Germany, uses machine learning models to detect errors in circuit board assembly, which improves speed and cost-efficiency with the help of the Industrial AI Suite.

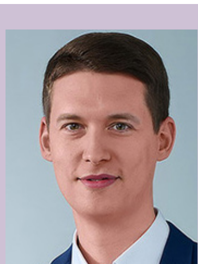
Figure 4. Senseye Predictive Maintenance uses AI to enable asset intelligence across plants without the need for manual analysis.

Making AI accessible and practical

These real-world examples show that AI plays a crucial role in modern industry. Embedding AI systems into products hides the complexity from users and makes AI accessible and usable for everyone. The key to success lies in flexible infrastructures that allow companies to tailor AI solutions to their specific needs.

Industrial AI is no longer a futuristic vision—it is already delivering real competitive advantages today.

Images courtesy of Siemens.



ABOUT THE AUTHOR

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Remote Operations Need Peak-Performance Batteries

TADIRAN BATTERIES

By Sol Jacobs

Expert recommendations can help optimize the supply of power to wireless devices in remote locations.

Inexpensive off-the-shelf solutions may be adequate for certain consumer electronic devices powered by alkaline or lithium-ion batteries, especially when the batteries are easily replaceable and operate in moderate environments. However, consumer batteries typically do not meet the needs of industrial applications, especially those that involve hard-to-access locations, extreme environments and large-scale installations where multiple simultaneous battery failures could be highly disruptive and costly.

Specifying an ultra-long-life lithium battery requires detailed due diligence to understand the power requirements and challenges specific to each application. This process can be facilitated by a qualified applications engineer who—using proprietary data intelligence—can help identify the optimal power supply solution that provides the best long-term value.

Applications matter

Too often, the battery specification process is treated as an afterthought rather than a crucial step in maximizing product performance and cost effectiveness. Understanding application-specific power needs and validating the choice of battery is essential to ensuring reliable operation in remote or extreme environments where replacement is costly or impossible.

Design optimization starts by understanding each application's unique performance requirements. The answer can vary depending on whether the device is providing backup power or is serving as the main power source, whether extended shelf life is necessary, whether the power demand calls for a primary cell or if it requires energy harvesting coupled with rechargeable Li-ion batteries. Answers to questions like these can vary significantly across Industrial Internet of Things (IIoT) applications like supervisory control and data acquisition (SCADA), process control, robotics, asset tracking, safety systems, environmental monitoring, machine-to-machine (M2M), machine learning (ML) and wireless networks.

TADIRAN BATTERIES

Key considerations for specifying a battery include electrical, environmental, size and weight.

Electrical requirements. Start by knowing maximum, nominal and minimum voltage needs; higher voltage batteries may reduce the number needed.

Battery capacity, measured in Ampere-hours (Ah), determines the cell's maximum theoretical life based on annual energy consumption. High capacity and energy density are crucial for miniaturization. Calculating the average current drawn helps estimate annual losses in capacity. High pulses, if needed, should also be considered for advanced functions such as two-way wireless communications. Predicting capacity loss also involves accounting for storage time and expected losses due to self-discharge.

Environmental requirements. Extreme temperatures impact battery performance by reducing capacity, causing voltage drops and increasing self-discharge rates. Some battery chemistries perform better under such conditions (see Table 1).

Understanding the operating environment is crucial for remote wireless devices in extreme conditions. You must calculate expected temperatures during operation and storage, including time spent in each phase. Bobbin-type lithium thionyl chloride ($LiSOCl_2$) batteries offer the widest temperature range (-80°C to 125°C), the highest ca-

Primary Cell	$LiSOCL_2$ Bobbin-type with Hybrid Layer Capacitor	$LiSOCL_2$ Bobbin-type	Li Metal Oxide Modified for high capacity	Li Metal Oxide Modified for high power	$LiFeS_2$ Lithium Iron Disulfate (AA-size)	$LiMnO_2$ Lithium Manganese Oxide
Energy Density (Wh/Kg)	700	730	370	185	335	330
Power	Very High	Low	Very High	Very High	High	Moderate
Voltage	3.6 to 3.9 V	3.6 V	4.1 V	4.1 V	1.5 V	3.0 V
Pulse Amplitude	Excellent	Small	High	Very High	Moderate	Moderate
Passivation	None	High	Very Low	None	Fair	Moderate
Performance at Elevated Temp.	Excellent	Fair	Excellent	Excellent	Moderate	Fair
Performance at Low Temp.	Excellent	Fair	Moderate	Excellent	Moderate	Poor
Operating Life	Excellent	Excellent	Excellent	Excellent	Moderate	Fair
Self-Discharge Rate	Very Low	Very Low	Very Low	Very Low	Moderate	High
Operating Temp.	-55°C to 85°C, can be extended to 105°C for a short time	-80°C to 125°C	-45°C to 85°C	-45°C to 85°C	-20°C to 60°C	0°C to 60°C

Table 1. Numerous primary lithium battery chemistries are available.

pacity and energy density and can endure humidity, shock and vibration.

Size and weight requirements. Size and weight restrictions can impact battery selection. Miniaturization improves logistics and ergonomics by reducing space and weight. Smaller batteries also serve to reduce the high cost of transporting hazardous goods according to UN and IATA regulations.

A structural integrity application

Resensys provides a powerful platform for protecting infrastructure systems against aging and malfunction by remotely monitoring strain (stress), vibration (acceleration), displacement, crack activity, tilt, inclination, temperature and humidity. These high-precision sensors provide durable and reliable structural-monitoring solutions for bridges, tunnels, buildings, dams and cranes, to name a few.

Resensys wireless sensors are mounted beneath bridge trusses (Figure 1) to measure structural stress. These locations are highly inaccessible and the use of a bobbin-type $LiSOCl_2$ battery serves to maximize return on investment by extending operating life and by increasing product reliability in harsh environments.

Figure 1. Structural stress sensors mounted beneath bridge trusses require extended-life life bobbin-type $LiSOCl_2$ batteries.

High pulses for wireless communications

Certain low-power remote wireless devices require high pulses up to 15 A to power remote wireless communications. Standard bobbin-type $LiSOCl_2$ cells can't provide these pulses due to their low-rate design. However, a hybrid solution has been developed that combines a standard bobbin-type $LiSOCl_2$ cell for low-level base current in combination with a patented hybrid layer capacitor (HLC) that generates pulses up to 15 A when needed. As the cell nears its end-of-life, the HLC exhibits a voltage plateau that indicates a "low battery" status.

While consumer devices often use supercapacitors for similar purposes, they are typically unsuitable for industrial applications due to limitations like short power duration, linear discharge, low capacity, low energy density and high self-discharge rates. Supercapacitors linked in series require expensive cell-balancing circuits, which drain extra current, thereby reducing battery life further.

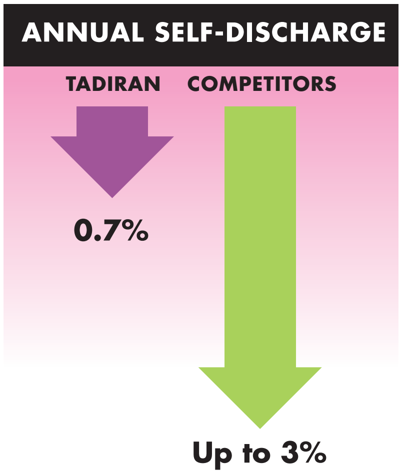
Sol Jacobs is the vice president and general manager at Tadiran Batteries.

IIoT devices run longer on Tadiran batteries.

PROVEN 40 YEAR OPERATING LIFE*

Remote wireless devices connected to the Industrial Internet of Things (IIoT) run on Tadiran bobbin-type $LiSOCl_2$ batteries.

Our batteries offer a winning combination: a patented hybrid layer capacitor (HLC) that delivers the high pulses required for two-way wireless communications; the widest temperature range of all; and the lowest self-discharge rate (0.7% per year), enabling our cells to last up to 4 times longer than the competition.



Looking to have your remote wireless device complete a 40-year marathon? Then team up with Tadiran batteries that last a lifetime.

TADIRAN BATTERIES

* Tadiran $LiSOCL_2$ batteries feature the lowest annual self-discharge rate of any competitive battery, less than 1% per year, enabling these batteries to operate over 40 years depending on device operating usage. However, this is not an expressed or implied warranty, as each application differs in terms of annual energy consumption and/or operating environment.

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More from Automation.com

This month's feature roundup will help you decide when it's time to replace old equipment, how technological advancements are transforming the robotics and motion control industries, and how to leverage simulation software to address the skills gap. Be the first to see every automation news update and trend by subscribing to Automation.com.

IIoT & Digital Transformation

A Leap Ahead for IIoT and Cloud Communications: Data is the heart of digital transformation, the essential enabler of the transition to Industry 4.0 and the industrial internet of things (IIoT). Advanced sensors have been generating and sending data to programmable logic controllers (PLCs) for decades to optimize industrial processes and operations. Now, a new sensor integration gateway based on IO-Link technology can send data to both IIoT/cloud and PLC destinations.

From Concept to Completion: How Digital Twins Impact the Entire Product Lifecycle: The global digital twin market is projected to grow from $10.1 billion in 2023 to $110.1 billion by 2028, with a compound annual growth rate of 61.3%. Today, manufacturers are increasingly leaning on digital twins in many stages of the product lifecycle, including product development production processes, operations & maintenance and sustainability.

Factory Automation & Control

Automated Packaging Coming to the Forefront of the Automated Warehouse: While automation has made significant strides in labor-intensive areas like picking and palletizing, packaging has lagged behind until recently. But as more parts of the warehouse become automated, packaging is emerging as a growing area of focus for end-customers.

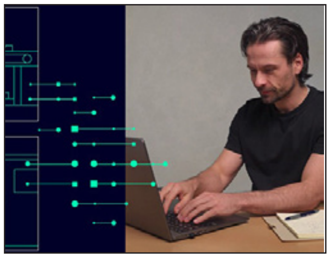
Technologies Driving Robotics and Motion Control Advances: Technological advances have transformed the robotics and motion control industries. This transformation has dramatically reduced the costs associated with deploying these technologies. As a result, robotics technology and motion control systems are being deployed across a wide range of novel applications in a variety of industries such as manufacturing, health care and aerospace.

Process Automation & Control

Automated Test Equipment (ATE): The Backbone of Scalable Electronics Manufacturing: In today's electronics manufacturing landscape, ensuring high product quality, reducing human error and meeting demanding time-to-market goals is more important than ever. This is where Automated Test Equipment (ATE) comes into play, serving as a critical enabler for reliable, fast and repeatable product validation.

Top Tips for Troubleshooting Electronic Systems: The military has a procedure for everything, including a 6-step procedure for maintaining electronic systems. Digikey's Aaron Dahlen, who is a 27-year military veteran, explains the Navy Electricity and Electronics Training Series (NEETS), Module 19 – The Technician's Handbook, NAVEDTRA 14191.

Enterprise Architecture and Networks



The Future of Automation Is Software-defined: Are You Ready?: In the rapidly evolving industrial landscape, Software-Defined Automation (SDA) is emerging as a transformative force, integrating Information Technology (IT) methodologies into Operational Technology (OT) use cases. This convergence is not merely a trend but a fundamental shift that is redefining the paradigms of industrial automation.

Overcoming Five Cybersecurity Challenges of Rugged Devices: Rugged devices are critical to many heavy industrial operations. While these endpoints can withstand extreme environments, their cyber defenses are often less strong than their physical ones. As attacks against these sectors become more common, rugged device cybersecurity becomes increasingly crucial.

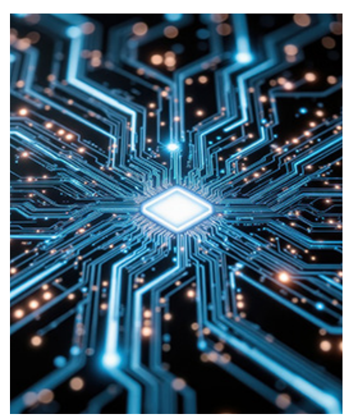
Operations and Management

The Replace, Repair or Retrain Decision: Here are four helpful steps to help you determine whether it's time to replace, repair or retrain an aging machine. 1) Assess machinery and operator level skills, 2) Evaluate repair versus replacement costs, 3) Understand new machine advantages, and 4) Realize new machine benefits.

Leveraging Simulation Software to Address the Manufacturing Skills Gap: The manufacturing landscape has transformed dramatically over the past five years, as smart factories, interconnected systems and data-driven operations have replaced traditional manufacturing models. Yet as technology advances, the human element remains irreplaceable, especially in evolving roles that require new skill sets. That alone is quite a challenge, but when you consider the worker shortage, it becomes even more complicated.

Product Updates

Schneider Electric Launches Data Center Solutions for High-density AI and Accelerated Compute Applications: Evolving its EcoStruxure Data Center Solutions portfolio, Schneider Electric introduced a Prefabricated Modular EcoStruxure Pod Data Center solution that consolidates infrastructure for liquid cooling, high-power busway and high-density NetShelter Racks.



Datanomix Expands AI Capabilities to Help Manufacturers Tackle Labor Shortages and Drive Smart Production: Datanomix, the leader in Data-Powered Production intelligence for precision manufacturers, has announced expanded AI functionality across its software portfolio, designed to help shops overcome the growing challenges of labor shortages, on-time delivery pressures, and process control.

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FROM THE EDITOR

Tools for More Secure, Resilient OT Environments

As digital transformation breaks down the walls between operational technology (OT) and information technology (IT) systems in pursuit of innovation and efficiency, new cybersecurity threats can emerge. That means it's never been more important to cross-train OT and IT security teams and build a solid threat assessment, mitigation and response plan. This summer, the International Society of Automation expanded the resources available to meet those needs.

The two-day 2025 ISA OT Cybersecurity Summit in Brussels, Belgium, delivered multiple sessions across two tracks—threat intelligence and securing the supply chain—to educate professionals focused on OT cybersecurity for industry and critical infrastructure.

Keynote speaker John Fitzpatrick, founder of Lab539, discussed how zero-day vulnerabilities can be leveraged, explained why patching may not always be the solution, and explored security testing within OT networks. Fitzpatrick said so-called "insecure" systems often pose minimal risk in OT contexts. "By relying on OT's established strategies, we can effectively protect critical infrastructure from modern threats while maintaining the core principles that define OT security," he explained.

In another session, ISASecure Program Manager Dr. Mark DeAngelo provided early details on a new ISA initiative: the ISASecure Industrial Automation Control System Security Assurance (ACSSA) inspection and certification scheme. This new program will offer a common, industry-vetted method for evaluating the conformity of an industrial automation and control system to the ISA/IEC 62443 series of standards.

ACSSA evaluates conformity to ISA/IEC 62443-2-1, 2-4, 3-2 and 3-3 requirements by verifying processes, procedures, support from service providers, and the configuration and utilization of control systems capabilities. It was created to help bridge lingering gaps in operational site assurance.

"Despite the comprehensive nature of ISASecure and cybersecurity expert programs, asset owners have relied on a patchwork of internal policies and third-party audits that vary across sites, leading to inconsistent security postures, compliance gaps, increased risk exposure and increased liability and regulatory non-compliance," said DeAngelo.

ACSSA aligns all stakeholders—asset owners, insurance providers, product suppliers, service providers, conformity assessment bodies and government bodies—around a consistent, standards-based program to help create a more secure and resilient environment.

Renee Bassett Chief Editor,
Automation.com Monthly