AUTOMATION 2024

MARCH | VOLUME 1

IIoT & DIGITAL TRANSFORMATION

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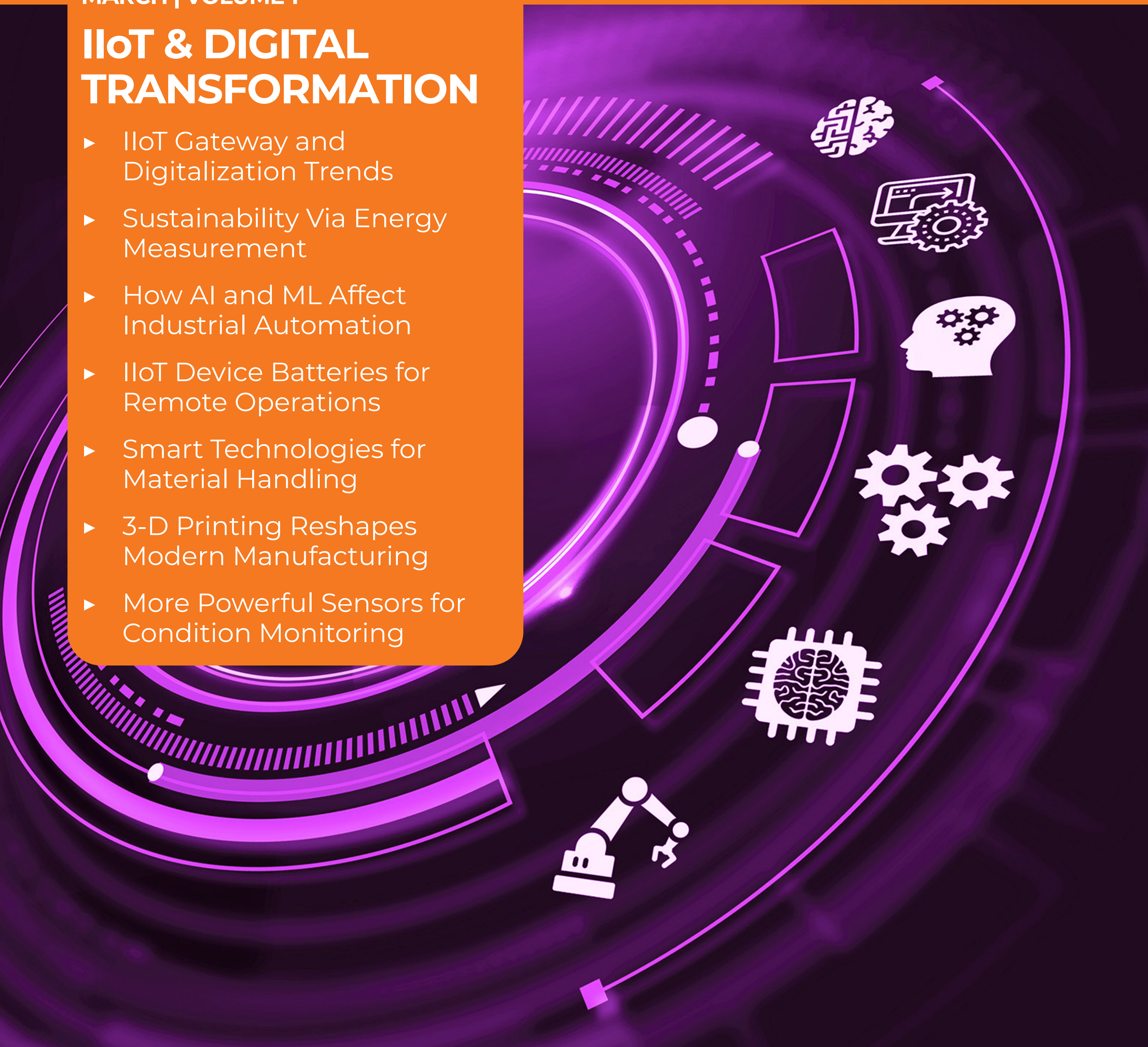

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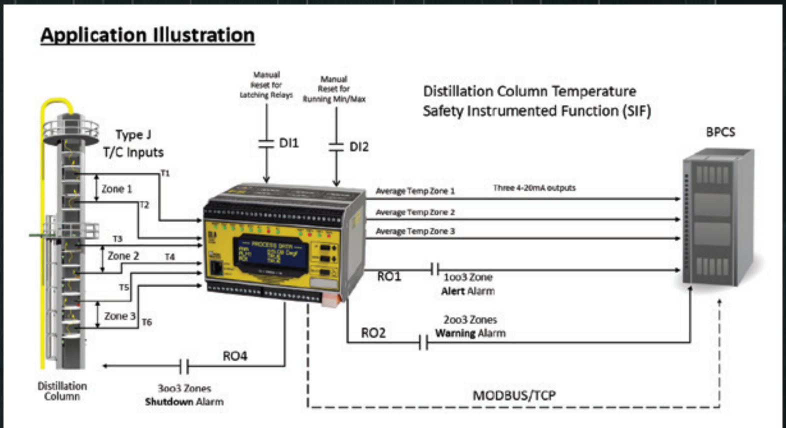

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Introduction

IIoT & Digital Transformation in 2024

The publications of the International Society of Automation are designed to keep you informed and inspired as automation systems evolve. Discussions about the many subtopics related to Smart Manufacturing and Industry 4.0 are multiplying across the blogosphere and industrial news sites. This March issue of AUTOMATION 2024 digital magazine highlights a half dozen key concepts including IIoT devices, artificial intelligence, and digital transformation of manufacturing, operations, and material handling. Visit Automation.com to drill down into these concepts and others or to subscribe to a topic-specific newsletter. Even just a few months into the year, we're already seeing interesting developments. The rest of the year no doubt holds more revelations.

Renee Bassett
Chief Editor
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Renee Bassett, Chief Editor
rbassett@automation.com

Chris Nelson, Advertising Sales Rep
chris@automation.com

Richard T. Simpson, Advertising Sales Rep
rsimpson@automation.com

Gina DiFrancesco, Advertising Sales Rep
GDiFrancesco@automation.com

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Additive Manufacturing is Reshaping Modern Manufacturing

3-D printing is well suited for Industry 4.0; the technology enables manufacturers to produce customized products on demand.

By Kristi Perkins, Rockwell Automation

A transformative force that's reshaping the landscape of production and design has emerged in modern manufacturing and its push toward Industry 4.0. Additive manufacturing—also called three-dimensional (3-D) printing—is where digital precision converges

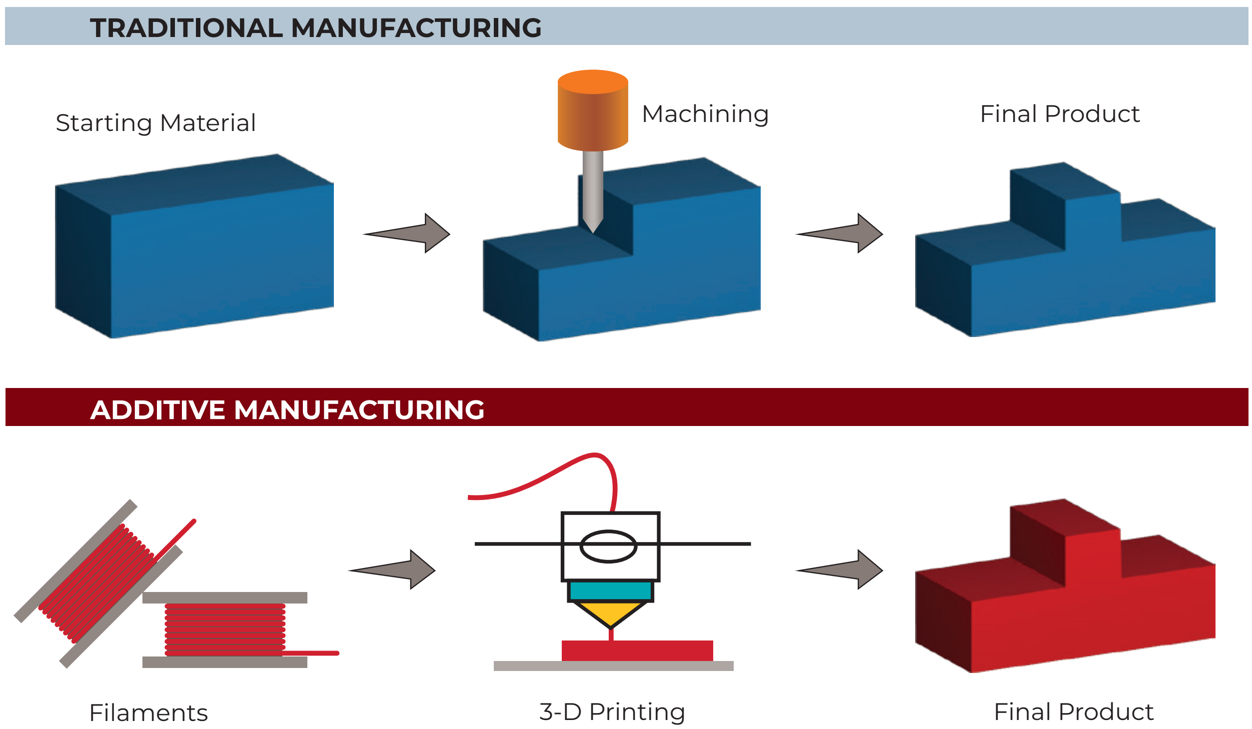

Figure 1. The traditional subtractive (machining) process versus the additive (3-D printing) process.

with material innovation to construct objects layer by layer. Unlike traditional subtractive methods—namely, machining—that carve away from a solid block of metal, plastic or other material, 3-D printing builds objects from the ground up. This offers flexibility in creating intricate geometries and optimized parts, while reducing waste and material costs (Figure 1).

The process of 3-D printing an object begins with a digital blueprint, a design crafted using computer-aided design (CAD) software. This digital blueprint is then sliced into thin cross-sectional layers that guides

By integrating 3-D printing with other Industry 4.0 technologies, organizations can enhance their adaptability and responsiveness.

the 3-D printer in understanding the object's geometry. With precision, the printer adds layers of material until the final product emerges (Figure 2). Post-processing steps such as cleaning, polishing, or painting are typically performed to achieve the desired finish.

Adopting 3-D printing propels industries into the era of Industry 4.0, fostering agility and adaptability. This technology enables on-demand production of customized products without the need for costly retooling and production delays, offering a rapid response to evolving market demands. The benefits extend beyond customization; 3-D printing accelerates product development cycles through rapid prototyping, supporting decentralized manufacturing and minimizing supply chain disruptions.

By integrating 3-D printing with other Industry 4.0 technologies, organizations can enhance their adaptability and responsiveness. The fusion of 3-D printing with technologies like the Internet of Things

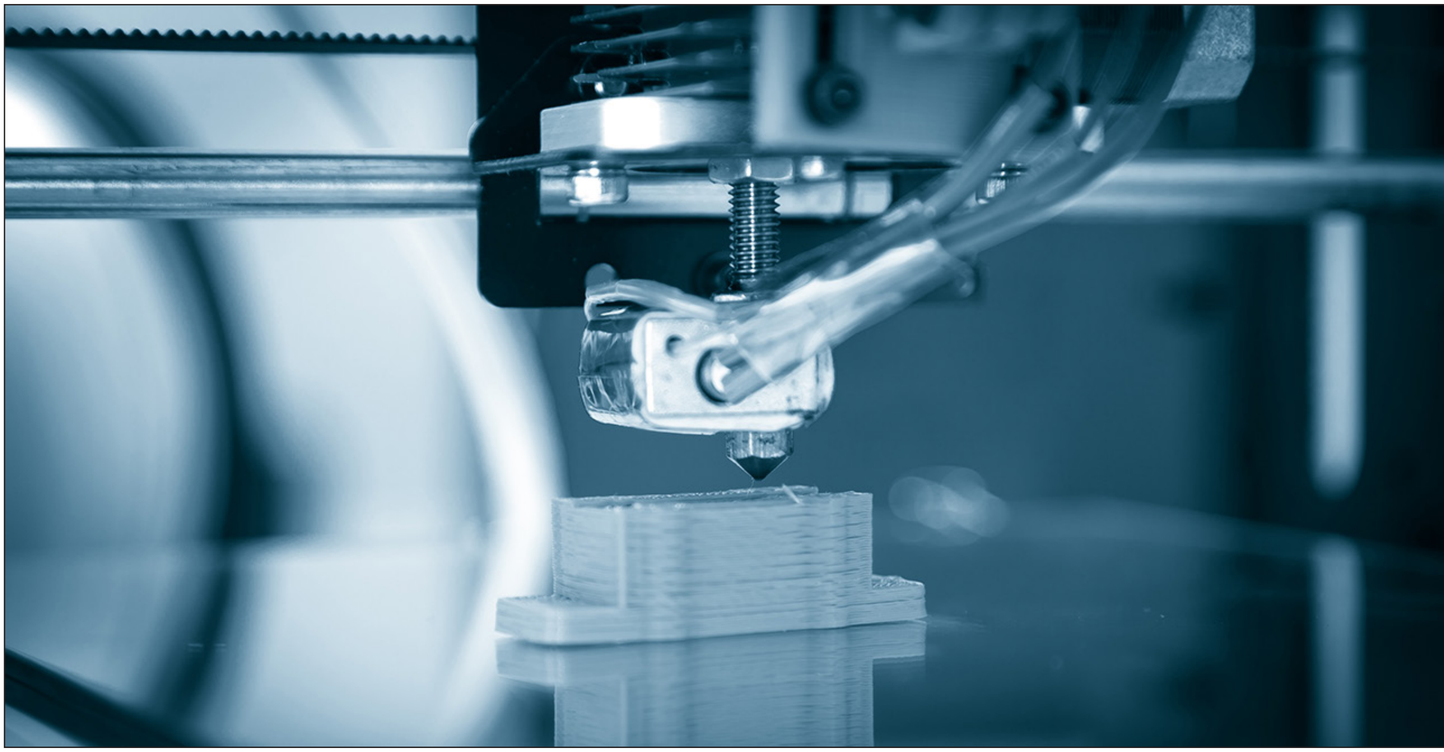

Figure 2. An example of a 3-D printer creating a plastic part layer by layer.

(IoT), artificial intelligence (AI), machine learning (ML), digital twin technology, cloud computing, and blockchain amplifies its impact, fostering innovation and efficiency across diverse sectors.

Applications for 3-D printing reach across several industries:

- **Health care:** Personalized prosthetics, dental implants, and even bioprinting tissues for research or potential transplants.
- **Aerospace and defense:** Crafting lightweight yet durable components and intricate shapes with on-demand part printing.
- **Automotive:** Rapid prototyping and, in some cases, end-use part production for custom or high-performance vehicles.
- **Construction:** Large-scale 3-D printers are fabricating building components and structures, revolutionizing construction timelines.

Additive manufacturing methods

Additive manufacturing/3-D printing encompasses a range of technologies such as digital light processing (DLP), fused deposition modeling (FDM), selective laser melting (SLM), and electron beam melting (EBM), each with its unique advantages. Choosing the right technology depends on factors like product requirements, materials, and costs, posing a challenge in finding the perfect fit for modern manufacturing. These methodologies vary in terms of their working principles, materials, and applications, allowing a diverse range of 3-D printing capabilities across different industries and use cases.

DLP uses a digital light projector to cure liquid photopolymer resin layer by layer. The process typically offers high resolution, making it suitable for detailed and intricate models. Materials are limited to photopolymer resins that can be cured by light. DLP is commonly used in industries requiring high precision and detail such as jewelry, dental, and prototyping.

The FDM process involves extruding thermoplastic filaments layer by layer through a heated nozzle. The layer resolution is typically lower than that of DLP, making it suitable for general-purpose printing. This process uses a wide range of thermoplastic materials like polylactic acid (PLA), acrylonitrile butadiene styrene (ABS), polyethylene terephthalate glycol (PETG), thermoplastic polyurethane (TPU), and composite materials. FDM is versatile and widely used for prototyping, functional parts, and hobbyist projects.

The SLM process uses a high-powered laser to selectively melt and fuse metal powders layer by layer. It offers high resolution and precision in metal printing. Commonly used materials include metal powders like titanium, aluminum, and stainless steel. The SLM process is widely used in aerospace, health care, and automotive industries for producing complex metal components.

Additive manufacturing/3-D printing encompasses a range of technologies each with its unique advantages.

The EBM process is like SLM except EBM uses an electron beam instead of a laser to melt and fuse metal powders. Its layer resolution is comparable to SLM, providing high resolution for metal printing. This process uses metal powders like titanium, cobalt-chrome, and nickel alloys. EBM is commonly used in aerospace and medical industries for manufacturing high-strength metal parts.

Trends in 3-D printing

The 3-D printing industry is experiencing significant growth and showcases trends such as compact modular systems, a surge in metal 3-D printing, streamlined workflows, advances in materials, and improving economics for manufacturing. In North America, the additive manufacturing market, valued at $3.7 billion in 2021, is set to grow at a staggering CAGR of 19.8 percent from 2022 to 2030. Global venture capital investments in additive manufacturing companies reflect a robust growth trajectory, with a focus on specialized product-market fit opportunities and an increase in product customization on demand.

Globally, North America is leading with more than 34.1 percent revenue share, driven by developed economies and early technology adoption. Europe is following closely with strong technological expertise in additive manufacturing. The Asia Pacific region is poised for significant growth with the highest CAGR, driven by manufacturing developments and urbanization.

Broken down by common printer types, industrial 3-D printers had a respectable revenue share of more than 64 percent in 2021. These printers find applications in prototyping, designing, and tooling across various industries. Originally for hobbyists, desktop 3-D printers are gaining traction in household, education, and small business settings.

Stereolithography (SLA) had more than 9 percent revenue share in 2021. FDM, direct metal laser sintering (DMLS), selective laser sintering (SLS), inkjet printing, PolyJet printing, DLP, and EBM are gaining traction. Prototyping has more than 56 percent revenue share; 3-D printing for prototyping is widely used in automotive, aerospace, and defense industries.

Key 3-D printing advantages

Advantages of 3-D printing include flexibility and customization, speed and efficiency, cost reduction, sustainability, supply chain simplification, and more.

Flexibility and customization: 3-D printing allows the creation of custom and complex geometries, bringing in the era of mass customization tailored to individual needs. It allows the use of various substrates from metal, plastics, and resin-based materials to fit many use case applications.

Speed and efficiency: Directly translating digital designs into final products, 3-D printing reduces lead times and promotes rapid prototyping for swift design iterations.

Cost reduction: Eliminating the need for expensive tooling, 3-D printing is cost-effective for low-volume production, where traditional methods might be economically impractical. It yields higher quality results with precision.

Sustainability: The additive nature of 3-D printing results in less waste compared to subtractive methods, contributing to increased sustainability. Decreasing the use of electricity, plant floor space, and minimal chemical production helps with a company's initiatives of near net-zero emissions.

Supply chain simplification: On-demand manufacturing reduces the need for extensive inventories, streamlining the supply chain and minimizing transport costs and delays.

Guidance for automation professionals

In the dynamic field of 3-D printing, adherence to industry standards is vital. Leveraging standards from ASTM International, ISO/ASTM 52900:2015, FDA guidance, NIST AM standards, and VDI 3405 ensures consistent, safe, and high-quality practices.

For automation professionals delving into 3-D printing, a comprehensive understanding of technology, materials, CAD/CAM, process optimization, quality control, automation integration, and safety considerations is crucial. This knowledge empowers professionals to harness the potential of 3-D printing, integrating it seamlessly into their projects and driving innovation in the realm of automation.

As 3-D printing continues to reshape industries and redefine manufacturing possibilities, staying informed about the latest trends, market dynamics, and best practices is essential for professionals navigating this transformative landscape.

ABOUT THE AUTHOR

Kristi Perkins is account development manager, Semiconductors & Advanced Electronics at Semiconductor Production, Rockwell Automation. She is a highly skilled professional with an MBA from Eastern Washington University specializing in semiconductor production. Perkins helps customers enhance their production and automation capabilities. She is also a member of the International Society of Automation, SMIIoT Division.

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IIoT Gateway and Digitalization Trends

Users want direct control of data and digitalization platforms, and greater compute power at the edge.

By Oliver Wang, Moxa Americas

Over the past 35 years, my company has earned a reputation as a manufacturer of highly reliable communications hardware that is easily and cost effectively integrated with other devices and systems. These qualities have also made Moxa a popular choice for companies with Industrial Internet of Things (IIoT) and digitalization initiatives, giving the company a front-row seat to developing trends. This article describes three IIoT gateway and digitalization trends we are currently seeing and responding to.

1. Increased compute requirements at the edge

(1)

A major trend going into 2024 is the demand for greater compute power at the edge. This is particularly noticeable among users that have had initial success with IIoT and digitalization:

- Many users that were the most active and successful with IIoT also encountered some form of sticker shock at the costs of bringing data to the cloud, especially if they are paying for both the long term evolution (LTE) connection and the cloud service/platform itself. The expenses from metered connections and recurring fees add up quickly, and we are having a lot of discussions with customers that now want to handle more of the data processing at the edge rather than in the cloud.
- Popular edge software platforms and operating systems have also grown more CPU intensive over time, with older versions reaching end of life and losing support for updates and security patches. Running the latest approved operating system and software often requires an upgrade in the hardware as well.
- This past year, artificial intelligence (AI) has taken tremendous strides in becoming mainstream and accessible, and industrial users are actively exploring how to implement it at the edge in a commercially viable manner. The edge compute devices that have powered successful digitalization projects present a natural entry point for forward-thinking users that are exploring this next frontier. We anticipate significant ongoing development in this area as CPU and graphics processing unit (GPU) options converge and lower the barrier to entry.

The edge compute devices that have powered successful digitalization projects present a natural entry point for forward-thinking users that are exploring this next frontier (AI).

2. Fiscal concerns over platform control and support

(2)

We are also seeing casualties in the IIoT space as organizations grow less patient in waiting for tangible returns on their investment. Many IIoT startups have folded or pivoted because they were unable to find a sustainable business model, resulting in additional collateral damage to users that have had to quickly migrate to other solutions or build their own. With the IIoT hype cycle appearing to have run its course, companies are entering 2024 with a much more conservative mindset and heightened focus on fiscal sustainability:

- There is growing demand for industrial users to have direct control of their digitalization platform and data, whether to save costs on expensive name-brand solutions with high vendor lock-in, or to mitigate against the risks of a vendor discontinuing support for a platform. Some users are opting to build the platform themselves, while others are carefully selecting proven and cost-effective providers that have already proven themselves at scale, such as Ignition.
- We are also seeing initially successful IIoT organizations reaching the limit of what is possible with their in-house teams as they start to reach a certain scale. Using an internal team to build, provision, and maintain custom IIoT gateway hardware is becoming a bottleneck to growth, so these users are exploring options for achieving scale by migrating to off-the-shelf hardware.

3. Growth in IT collaboration and cybersecurity awareness

(3)

In the past year, we have seen information technology (IT) departments more deeply and openly involved in IIoT and digitalization initiatives, sometimes through the creation of a separate division specifically to support operational technology (OT) users. It's fair to say that in years past, it was not uncommon for prospective IIoT users to actively avoid involving IT, but there is now a growing acceptance of IT's indispensable role in supporting a company or customer's digitalization infrastructure.

A more open and productive conversation between OT and IT is leading to greater maturity in the path to digitalization. Companies are carefully establishing guidelines for internal business units that are pursuing digitalization projects and are learning how to specify approved vendors and solutions. We are also seeing more productive discussions around managing cybersecurity, and there is an appreciation for vendors that are able to participate in these discussions in a meaningful way. Familiarity and compliance with international sourcing and IEC 62443-4-2 guidelines does a lot to reassure industrial users of a vendor's legitimacy and ability to support their digitalization efforts over the long run.

There is now a growing acceptance of IT's indispensable role in supporting a company or customer's digitalization infrastructure.

The industry is rapidly maturing

As we navigate the evolving IIoT and digitalization landscape, it's clear that the industry is maturing rapidly. Trends such as increased edge computing power, greater attention to fiscal responsibility, and deeper collaboration between OT and IT departments are reshaping the way organizations approach their digital transformation journeys.

At Moxa, we remain committed to providing reliable, cost-effective solutions that empower our customers to leverage the latest technologies while maintaining control over their platforms and data. As we move forward into 2024 and beyond, we eagerly anticipate continued innovation and adaptation to meet the evolving needs of the industrial landscape.

ABOUT THE AUTHOR

Oliver Wang is the product marketing manager for Moxa's industrial computing lines. He has 15 years of experience in industrial communications and has supported large deployments in industries like oil and gas. Wang frequently contributes to technical articles, webinars, and videos on industry developments.

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Meet Sustainability Goals with Energy Measurement and Management

Smart utility consumption monitoring reduces operational costs.

By Cory Marcon, Endress+Hauser

The use of utilities is directly correlated with profits and carbon footprint, incentivizing companies to minimize consumption, while upholding safety and quality. Utilities are a necessary expenditure, but there are almost always opportunities for savings, which can help companies reduce operational costs, increase product margins, and meet ambitious environmental stewardship targets.

Central to both operational efficiency and energy savings are the ability to squeeze as much production or output from the smallest net input possible, while maintaining high safety, quality, reliability, and uptime. However, proper energy management requires accurate data capture and appropriate analysis. None of this is possible without reliable instrumentation to monitor plant processes and utility consumption.

Utilities can be broadly placed into two camps. Tier-one utilities are typically purchased directly from an external supplier, including electricity, water, liquid fuel, and various industrial gases. These are used directly to power many operational components within a facility, but additional general-purpose products are also required to run particular processes such as purging or cooling. These tier-two utilities—created from tier-one supplies—include steam, compressed air, treated water, and heat. This information empowers plant personnel to establish baselines, monitor process efficiency, identify opportunities for savings.

There are many areas for potential savings in steam, compressed air, heating, cooling, and industrial gas usage. These are common process inputs for plant operation in many industry sectors, and vast quantities of energy are expended in the production and distribution of these utilities. This is why identifying opportunities for consumption reduction in plant processes is so critical.

Comprehensive utility monitoring and optimization can regularly reduce energy consumption by 5 to 15 percent.

For example, steam drives heat exchangers, distillation column reboilers, and similar applications because it is an efficient and controllable mechanism for delivering energy precisely where it is needed. But it is also expensive to produce and distribute, which calls for careful measurement and control.

Comprehensive utility monitoring and optimization can regularly reduce energy consumption by 5 to 15 percent, but this requires establishing the right energy performance indicators (EnPIs) and making appropriate process operational tweaks or investments. Reduction opportunities depend on instrumentation that can objectively quantify energy flows, energy consumption, and process data according to ISO 50001 and ISO 50006, with related systems presenting this data in terms of EnPIs.

Guidance from standards

ISO 50001 is a universal energy management standard, specifying the establishment of EnPIs for setting up an energy management system. These indicators must be regularly reported, checked, and compared against an energy baseline (EnB) created prior to introducing measures for increased energy efficiency (Figure 1).

Based on this information, potential areas for savings are evaluated, and improvement measures can be initiated for single processes as well as throughout buildings, plants, or entire factory complexes.

The ISO 50006 standard provides step-by-step guidance to companies for defining robust EnPIs and an accurate EnB for later comparison. The standard also contains several real-life examples, which are helpful because it can be difficult to initially identify relevant variables in an energy system from which to determine EnPIs. Such variables include weather conditions, balance period, plant size, production variations, and energy sources, to name a few.

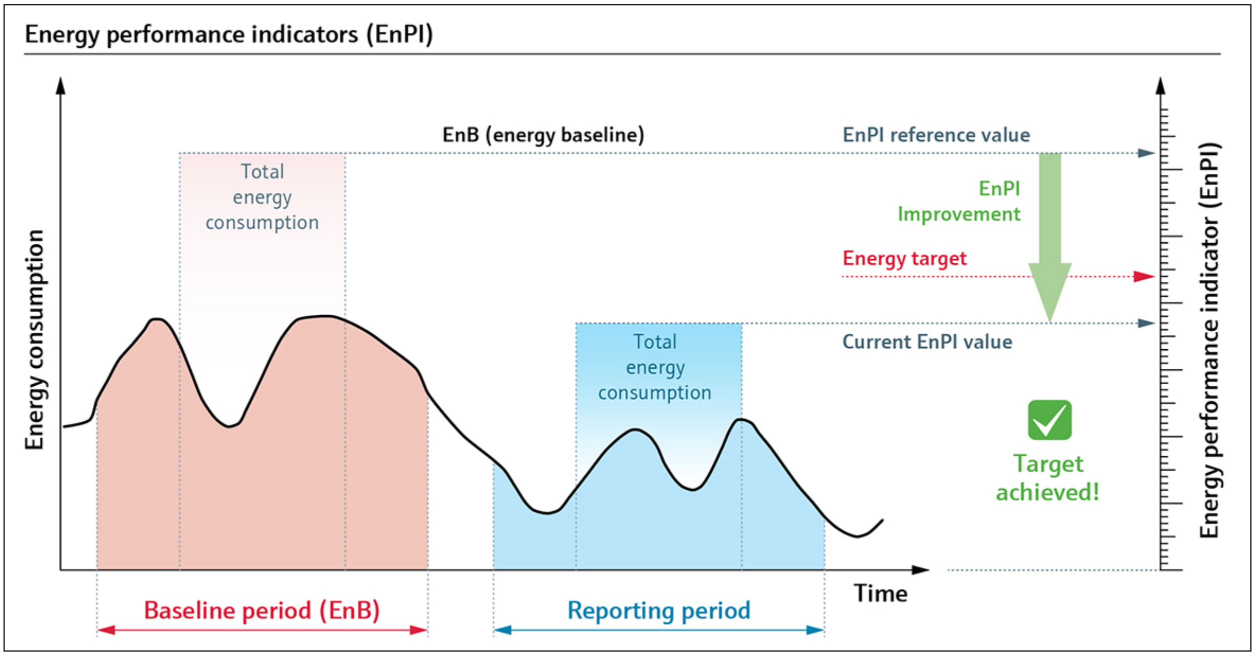

Figure 1. Defining effective energy performance indicators and comparing results against an energy baseline enables organizations to see the results of their energy efficiency enhancements.

Common EnPI examples include:

- Adjustment for primary energy demand (MWh/year)
- Total primary energy consumption (MWh/year)
- Improvement in energy intensity for the baseline year (percent)
- Energy savings for the current year (MWh/year)
- Total consumed primary energy (MJ/year)
- Energy savings since the baseline year (MWh/year)
- Improvement in energy intensity for the current year (percent)
- Electricity, water, or fuel consumption (total values, peak loads, etc.)
- Specific energy consumption, i.e., energy consumption per quantity of produced media, like compressed air (kWh/Nm^3), steam (MJ/t), and hot water (kW/kg)
- Efficiency of steam boilers (percent).

Software-aided savings

Installing instrumentation across flow, temperature, pressure, and other critical measurements is crucial for energy management systems, but these systems are not complete without a means to visualize measured values and energy data. This element is the basis for detailed evaluation, compliant with the ISO 50006 standard.

Energy management software is used to analyze measurement data and create energy reports, and the applications on the market today typically provide access to entire plant monitoring systems via an internal intranet or the Internet. The best software packages incorporate:

- Web-based secure local or remote access
- Automatic data import from data loggers, supervisory control and data acquisition (SCADA) systems, production systems, and building management systems

- Simple operation and easy-to-use interfaces with drop-down menus
- Simple integration into existing operating data recording systems
- Modular application design for simple customization
- Simulation and calculation using multivariate mathematical functions
- Energy analysis that includes energy consumption monitoring, efficiency assessment, target/actual energy data comparison, and peak values identification
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  - Create and monitor budget plans.
  - Cost comparison.
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Installing instrumentation across flow, temperature, pressure, and other critical measurements is crucial for energy management systems, but these systems are not complete without a means to visualize measured values and energy data.

Measurement for monitoring

Getting started can be overwhelming. However, reliable instrument installation lays the foundation for effective energy management system rollouts (Figure 2). Engaging the right experts can ease the journey from first steps to final refinements by providing end users with high-quality instrumentation, system components, software solutions, and support.

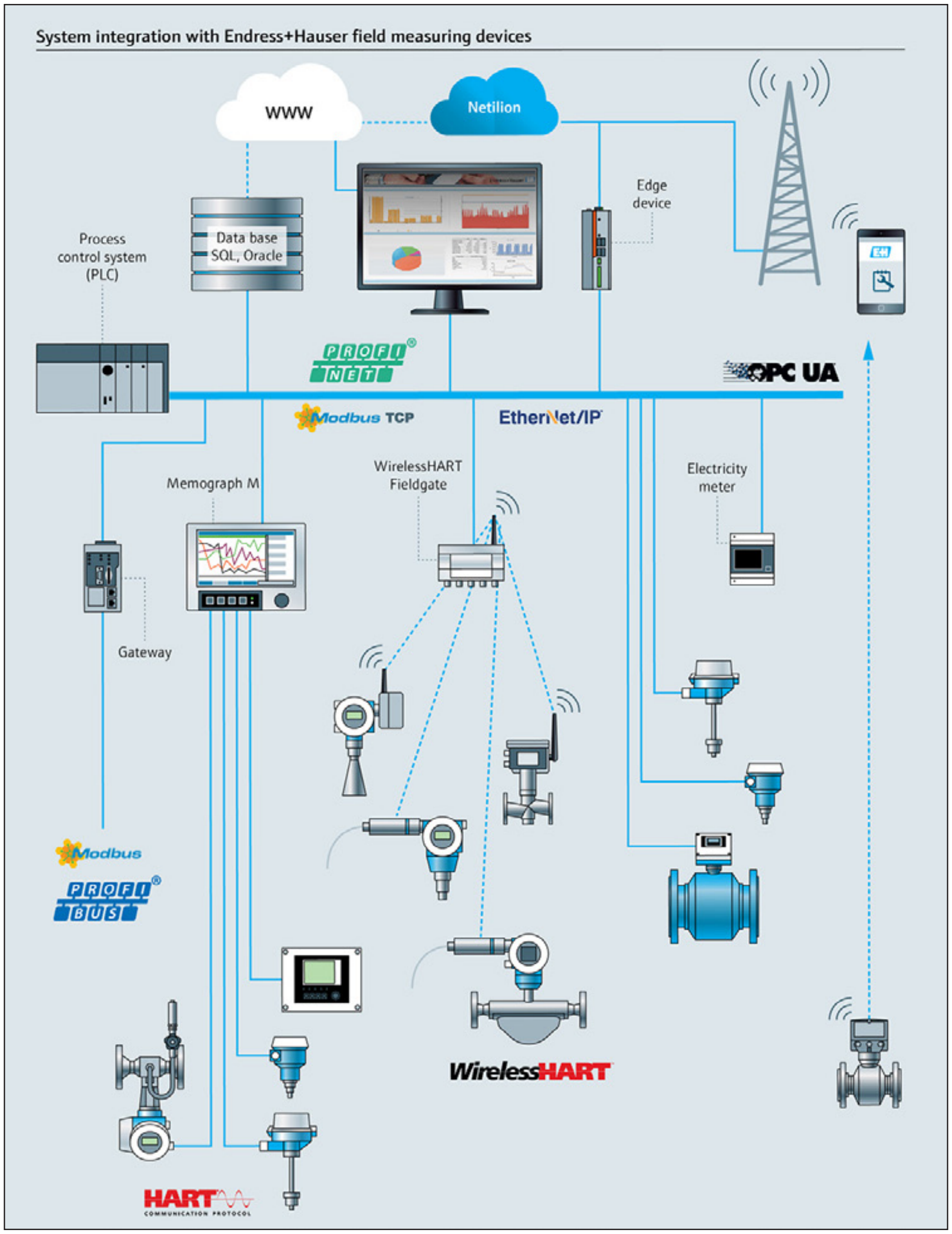

Figure 2. This instrument portfolio helps companies manage their utilities reliably and save energy.

Components and services to look for in an industry partner include:

- Robust instrumentation with high accuracy, reliability, and repeatability
- Smart devices for data logging and transfer
- Engineering and project management for single applications—e.g., boiler efficiency monitoring—and system-wide solutions
- EMAS- and ISO-compliant calibration services
- Professional planning, commissioning, and maintenance of energy monitoring and management systems
- Expert support from qualified specialists
- A wide-reaching service network.

Looking toward a sustainable future

When implementing initiatives to reduce energy consumption in industrial applications, accurate measurements are essential for making informed decisions. By generating reliable utilities data, carefully evaluating it in energy management systems, and making informed process adjustments, companies can reduce operating costs, while leading the way with energy-efficient practices for a sustainable future.

All figures courtesy of Endress+Hauser

ABOUT THE AUTHOR

Cory Marcon is the power & energy industry marketing manager for Endress+Hauser USA. He is responsible for the overall business development and growth of the company position related to traditional power generation and the energy transition. As part of his role, he serves as the U.S. representative in the global SIG (Strategic Industry Group), helping develop education, the long-term vision, brand, and product direction within Endress+Hauser as the world actively works toward carbon neutrality. Marcon is a 2012 graduate of McGill University with a decade of experience in many forms of energy, including solar, wind, and gas.

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How AI and ML Affect Industrial Automation

Recent advances significantly shift away from traditional processes and methodologies.

By Drew Thompson, Sealevel Systems, Inc.

Artificial intelligence (AI) and machine learning (ML) are rapidly changing many industries. While these two terms are often—and incorrectly—used interchangeably, machine learning is a subclass of artificial intelligence. Put simply, AI is an overarching concept of creating intelligent machines that can perform tasks that generally require human intelligence, including problem-solving, pattern recognition, natural language processing, and decision making. Machine learning is a specific approach within the broader field of AI that focuses on training machines to learn from data, and to make improvements in processes without being explicitly programmed to do so.

Although industrial automation has been one of the major drivers of Industry 4.0, the recent advances in AI and ML technology represent a significant shift away from traditional automation processes and methodology. This shift is quite clear in adaptive automation; programming, system design, and flexibility; and decision making.

Traditional automation systems only perform tasks or processes when given explicit rules or commands.

Rule-based automation versus adaptive automation

Traditional automation systems rely on rule-based programming. In this framework, machinery and technology are programmed to respond to a set of predefined if-then-else type rules. Engineers and developers explicitly define rules and instructions for the machinery and technology to follow. Rule-based automation is effective for simple processes, but this type of system has limited adaptability when presented with unforeseen scenarios and can struggle in complex, changing environments.

Adaptive automation systems, specifically those that use AI and ML, 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.

Programming, system design, and flexibility

Traditional automation systems require a large amount of upfront programming and coding. The if-then-else type rules must be explicitly programmed into the system. Essentially, every potential action and response from the automated machinery must be predefined. This approach is acceptable for very simple systems with one or two possible outcomes. However, as systems become more complex, the amount of coding and programming increases nearly exponentially. Further, the functionality of traditional automation systems remains static unless they are manually reprogrammed. This rigidity has the overall effect of limiting the flexibility and adaptability of traditional automation systems.

Alternatively, automation systems powered by AI and ML can rapidly adapt to changes, often with little or no human input. Adaptive automation systems are driven by ML algorithms that enable continuous adaptation and process optimization without the requirement of reprogramming or reengineering.

Decision making

Perhaps the most important difference between traditional rule-based automation and adaptive automation lies in how each respond to novel or complex problems and edge cases. Traditional automation systems only perform tasks or processes when given explicit rules or commands. As the complexity of a system increases, traditional systems struggle to adapt to dynamic environments. These traditional systems are "dumb" in the sense that they only react based on defined logic.

Adaptive automation systems powered by AI and ML can impart a measure of device intelligence into these formerly "dumb" systems and devices by making use of data gathered over time. Whereas traditional systems are reactive and follow predefined logic, adaptive systems can refine and optimize processes and react to unforeseen scenarios. By analyzing the data and learning patterns, adaptive systems can handle complex decision making. Through analysis of historical data, these systems can anticipate and predict component or subsystem issues that enables proactive maintenance. According to the International Society of Automation (ISA), adopting a preventive maintenance approach can provide savings from eight percent to 12 percent over reactive maintenance, and can reduce equipment and machinery downtime by 35 percent to 45 percent.

AI and ML are changing automation

The use of AI and ML is dramatically changing the industrial automation industry. The traditional approach to automation, which relies on if-then-else, 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 automation systems, powered by AI and ML, brings increased flexibility, predictive capabilities, and the ability to handle complex decision making, contributing to more efficient and responsive industrial processes.

Several components make up an industrial automation system using AI and ML. These include sensors or other data gathering and data acquisition devices, data storage, a processing component, AI and ML models and algorithms, control systems that translate the AI and ML decisions into actions, a human-machine interface (HMI), and a communications network. These complete solutions are being deployed across industries, from improving ADAS systems in automotive manufacturing to data acquisition in materials production to communications for pharmaceutical testing.

ABOUT THE AUTHOR

Drew Thompson is a technical writer and marketing specialist for Sealevel Systems, the leading 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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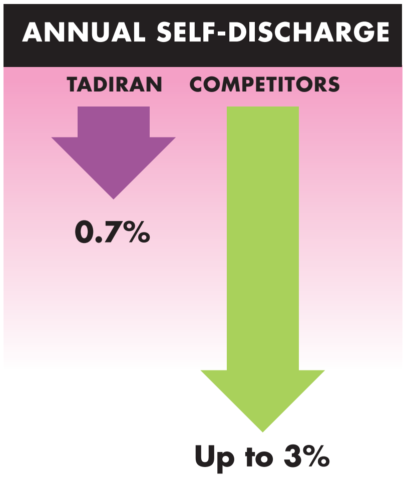

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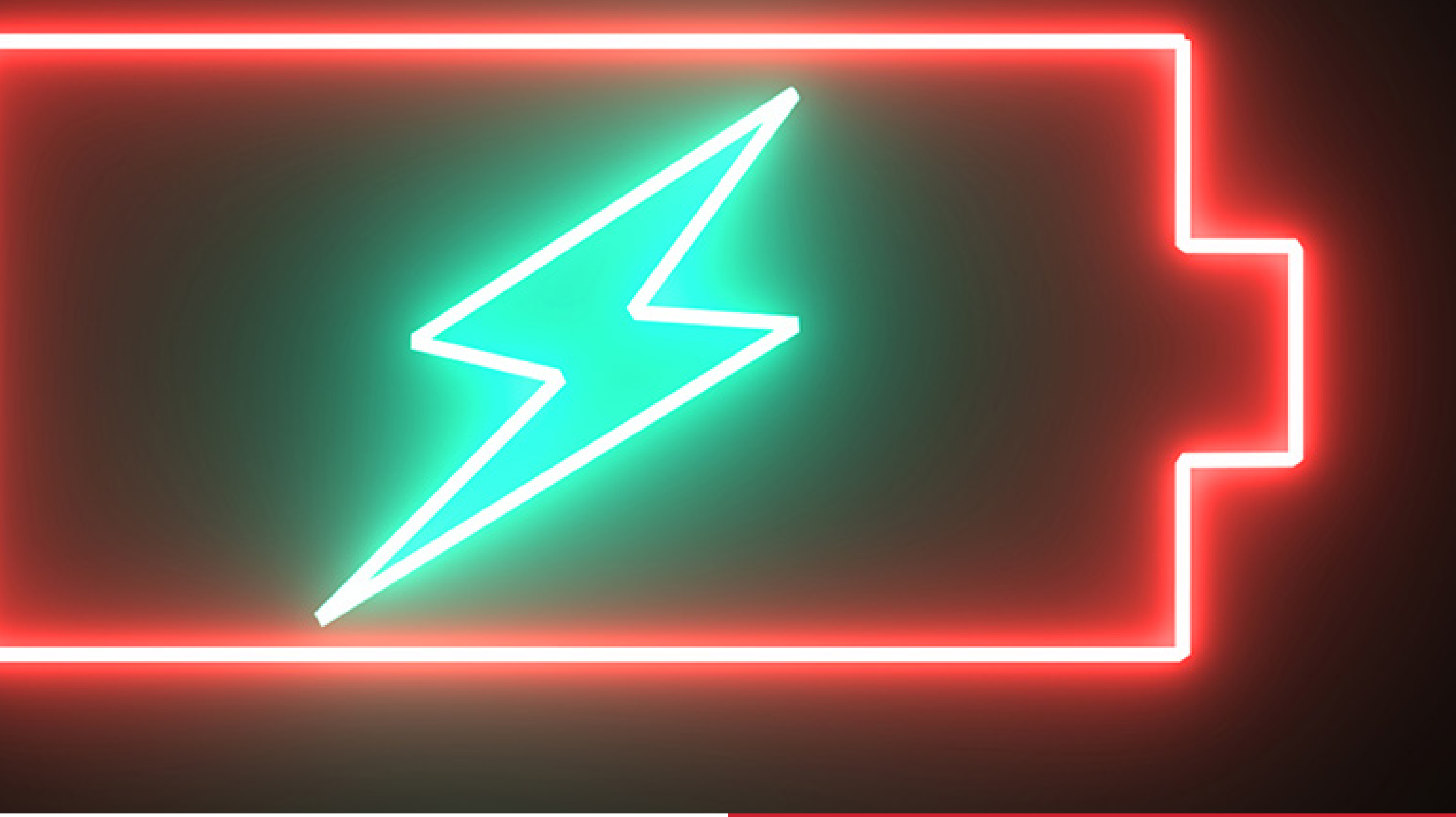

By Vitaly Milner, Ph.D., Tadiran Batteries

> The right power supply is essential when battery replacement is prohibitively expensive or impossible.

Perhaps nowhere does the adage “time is money” apply more appropriately than with battery-powered remote wireless devices. Battery-powered devices provide an economical means for expanding the Industrial Internet of Things (IIoT) beyond the electrical power grid to virtually anywhere at reasonably low cost. An example involves structural stress sensors that are attached to the underside of a bridge truss (Figure 1), where the cost of replacing the battery is exponentially higher than its initial expense, without considering the added safety risks.

In certain situations, battery replacement may be impossible. If the battery fails, it will result in permanent system failure, thereby causing a total loss of investment and compromised data integrity. An example is a seismometer placed on the ocean floor to detect earthquakes and warn of potential tsunamis.

Figure 1. Mounted beneath bridge trusses and other hard-to-access locations, Resensys structural stress monitors use ultra-long-life bobbin-type $LiSOCl_2$ batteries to reduce the need for battery maintenance. Courtesy: Resensys

It doesn't pay to be "penny wise and pound foolish" when specifying a battery for a long-term deployment in a harsh environment. The challenge is to identify the battery that delivers the best overall value by providing the required performance while minimizing the risk of premature battery failure. This is especially true for industrial applications such as asset tracking, supervisory control and data acquisition (SCADA), automated meter reading/advanced metering infrastructure (AMR/AMI), tank level and flow monitoring, environmental monitoring, machine-to-machine (M2M), artificial intelligence (AI), and wireless mesh networks, to name a few.

Based on the cell's total capacity, its maximum run time can be estimated based on the average current being drawn.

Reducing cost requires intelligent power management

Specifying a primary (non-rechargeable) battery for long-term deployment in a harsh environment can be a complex decision-making process requiring a solid understanding about the strengths and weaknesses of the various competing battery technologies.

Primary batteries power the vast majority of low-power devices that draw average current measurable in micro-Amps along with periodic high pulses in the multi-Amp range to support wireless communications. However, certain niche applications may require the use of an energy harvesting device in combination with an industrial grade rechargeable Lithium-ion (Li-ion) battery to store the harvested energy. These applications draw average current measurable in milli-Amps with pulses in the multi-Amp range, which may be enough to prematurely exhaust a primary battery.

To support energy harvesting applications, Tadiran developed TLI Series rechargeable Lithium-ion (Li-ion) batteries that can last up to 20 years and 5,000 full recharge cycles while delivering high pulses along with the ability to be recharged and discharged at extremely cold temperatures.

Advantages of lithium-based chemistries

Numerous primary battery chemistries are available (Table 1), the least expensive of which is the ubiquitous consumer grade alkaline chemistry. While renowned for delivering high rates of continuous current (i.e., powering a flashlight or a toy), alkaline chemistry involves numerous tradeoffs that make it inappropriate for use with most industrial applications, including a very high self-discharge rate (up to 60 percent per year) along with very low capacity and low energy density, which may require the use of additional cells that add size, bulk, and expense. In addition, alkaline cells use a water-based chemistry that is more susceptible to freezing than lithium.

Primary cell	$LiSOCL_2$	$LiSOCL_2$	Li metal oxide	Li metal oxide	$LiFeS_2$	$LiMnO_2$
	Bobbin-type with hybrid layer capacitor	Bobbin-type	Modified for high capacity	Modified for high power	Lithium iron disulfate (AA-size)	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.

Lithium-based chemistries are far better suited for industrial applications. As the lightest non-gaseous metal, lithium offers an intrinsic negative potential that exceeds all other metals, resulting in the highest specific energy (energy per unit weight), highest energy density (energy per unit volume), and higher voltage (OCV) ranging from 2.7 V to 3.6 V. Lithium-based chemistries are also non-aqueous, thus less prone to freezing than alkaline cells.

Of the various lithium-based chemistries that are commercially available, bobbin-type lithium thionyl chloride ($LiSOCl_2$) batteries (Figure 2) are overwhelmingly chosen for ultra-long-life applications. Bobbin-type $LiSOCl_2$ chemistry stands apart for delivering the highest capacity, highest energy density, and widest temperature range (-80°C to +125°C) of all. The highest quality bobbin-type $LiSOCl_2$ cells feature a self-discharge rate of only 0.7 percent per year, thus enabling them to last up to 40 years. $LiSOCl_2$ batteries can also be manufactured with a spiral wound design that delivers higher rates of energy flow with the tradeoff being a higher annual self-discharge rate.

The overall advantages of bobbin-type $LiSOCl_2$ chemistry include:

- Longer operating life of up to 40 years to lower the cost of ownership.
- A wider temperature range of -80 to +125°C to survive extreme environments.
- High energy density and capacity which could permit the use of fewer or smaller batteries.
- Higher voltage which could permit the use of fewer batteries.

Figure 2. Bobbin-type $LiSOCl_2$ batteries are overwhelmingly preferred for long-term deployments at remote sites and extreme environments because they have higher capacity and higher energy density, among other attributes. *Courtesy: Tadiran*

Bobbin-type $LiSOCl_2$ batteries are marginally more expensive, so users need to determine whether the added performance is cost effective based on the potential long-term savings.

Harsh environments impact battery performance

A battery's potential lifespan is initially dictated by its storage capacity, which is measured in Ampere-hours or Amp-hours (Ah). Based on the cell's total capacity, its maximum run time can be estimated based on the average current being drawn. For example, a device consuming 1 mA of average current with a storage capacity of 1,200 mAh can have a maximum run time of 1,200 hours. However, such theoretical battery life is often far from reality, as actual performance can be negatively affected by such factors as prolonged exposure to extreme temperatures during storage and/or deployment, which can accelerate the annual self-discharge rate.

Self-discharge results from the chemical reactions that occur even when there is no connection between the battery's electrodes or to any external circuit. As a result, many low-power devices consume more energy because of self-discharge than is required to operate the device.

Batteries are often refrigerated during storage to reduce their annual self-discharge rate by slowing down the electrochemical and diffusion reactions to reduce energy flow. However, prolonged exposure to extremely cold temperature should be avoided whenever possible. Likewise, prolonged expose to extreme heat can degrade battery performance by increasing chemical reactivity, which can lead to accelerated self-discharge, voltage delays and drops, power delays, and the depletion of electrochemical constituents.

Other variables can also impact a battery's self-discharge rate, including the peak current, consumption profile, temperature range, age of the cell, and the leakage current drawn by individual components within the device, to name a few.

Passivation pays dividends

The principal reason why bobbin-type $LiSOCl_2$ batteries deliver the lowest possible self-discharge rate is due to their unique ability to harness the passivation effect. In essence, passivation involves the formation of a thin film of lithium chloride (LiCl) on the surface of the anode, which then acts as a separation barrier from the electrode to limit the chemical reactions that cause self-discharge. Whenever a continuous current load is applied, the passivation layer initially causes higher resistance and a drop in voltage until the continuous discharge reaction causes the passivation layer to begin dissipating. Once a battery becomes inactive for an extended time, the passivation layer returns, requiring another round of de-passivation.

The level of passivation varies based on several factors, including the cell's construction, its current discharge capacity, the length of time in storage, the storage and discharge temperature, as well as prior discharge conditions such as partially discharging a cell and then removing the load. While passivation is ideal for extending battery life, it must be carefully managed to avoid any over-restriction of energy flow.

Experienced battery manufacturers can maximize the passivation effect through proprietary cell construction techniques and by using higher quality raw materials. As a result, the highest quality bobbin-type $LiSOCl_2$ batteries can feature a self-discharge rate of just 0.7 percent per year, able to retain 70 percent of their original capacity after 40 years. Conversely, lower quality bobbin-type $LiSOCl_2$ cells can have a self-discharge rate of up to 3 percent per year, exhausting roughly 30 percent of their available capacity every 10 years because of self-discharge, making 40-year battery life impossible.

Understanding the power demand

Product designers use a variety of methods to minimize energy consumption, including the use of low-power chipsets and components, low-power communications protocols, and other proprietary techniques. While these methods may be helpful in reducing energy consumption, they are typically dwarfed by the choice of battery.

Another important consideration is the cell's ability to generate high pulses during "active" mode, as low-power devices often require pulses of up to 15 A to power bidirectional wireless communications. Standard

Figure 3. Bobbin-type $LiSOCl_2$ batteries can be combined with a patented hybrid layer capacitor (HLC) to deliver up to 40-year service life in harsh environments while delivering the high pulses required to power wireless communications. *Courtesy: Tadiran*

bobbin-type $LiSOCl_2$ cells are not designed to deliver such high pulses due to their low-rate design. This challenge can be easily overcome by incorporating a patented hybrid layer capacitor (HLC) (Figure 3).

Using this hybrid approach, the bobbin-type $LiSOCl_2$ cell delivers low-level base current during "standby" mode while the HLC delivers high pulses during active mode. The HLC also features a unique end-of-life voltage plateau that can be interpreted to deliver money-saving "low battery" status alerts that extend battery operating life through predictive battery maintenance.

Supercapacitors perform a similar role by generating high pulses for consumer electronic devices. However, supercapacitors are ill-suited for most industrial applications due to numerous drawbacks, including short-duration power, linear discharge qualities that do not allow for the use of all available energy, low capacity, low energy density, and very high self-discharge rates of up to 60 percent per year. When supercapacitors are linked in series, they require the use of expensive cell-balancing circuits that add bulk while draining additional current to further reduce their operating life. In certain instances, supercapacitors can be paired with bobbin-type $LiSOCL_2$ cells to enhance voltage response.

Do your due diligence

When ultra-long battery life is essential, it pays to do your research and invest in a higher quality battery that can reduce or eliminate the need for costly battery replacements over the expected lifetime of the device.

Unfortunately, differentiating a superior grade battery from a lesser quality cell can be nearly impossible based on short-term test results, which tend to be highly inaccurate because the long-term effects of a higher self-discharge rate can take years to become fully measurable. The limitations of short-term testing can be further magnified by using relatively small sample sizes and by underestimating the passivation effect as well as the impact from prolonged exposure to extreme temperatures.

When extended battery life is essential, users must seek to verify the promotional claims of potential battery manufacturers. To properly evaluate competing brands, users should require fully documented and verifiable test reports. Also, request data measuring the long-term performance of actual batteries in the field that have been operating under similar loads and environmental conditions, both during storage and deployment. It is also highly recommended that you contact numerous customer references.

Since short-term test data tends to be highly inaccurate, Tadiran has amassed a huge and continually expanding database by monitoring long-term battery performance over decades under laboratory conditions. Tadiran also monitors the long-term performance of customer-supplied samples from the field that are representative of virtually all operating conditions. As an added benchmark, Tadiran performs long-term tests on competing battery brands.

Identifying the right battery is an application-specific decision. For example, if a battery life of 10-15 years is sufficient, then numerous chemistries could be considered. However, if the application calls for an ultra-long-life power supply that can last for up to 40 years, then your choice may be limited to bobbin-type $LiSOCl_2$ chemistry.

Another important consideration is whether the battery is being used as the main power source or as a backup energy source. If the battery is serving as a backup power supply and could sit idle for extended periods, then you need to carefully consider the operating environment, the cell's self-discharge rate, and the need for fast battery response, where applicable.

Every application is unique, and numerous variables can affect battery performance, so it pays to consult with an experienced applications engineer who can review your operational profile to help identify the ideal power management solution: one that delivers the biggest bang for the buck by neither under- nor over-performing.

ABOUT THE AUTHOR

Vitaly Milner, Ph.D. is product and marketing manager at Tadiran Batteries. He has more than 20 years of experience in industrial roles, including 14 years in the battery sector. Milner specializes in innovative battery applications for IIoT, transportation, oil & gas, telecom, utilities, and more. He has a Doctor of Philosophy degree in physics and mathematics from Lomonosov Moscow State University.

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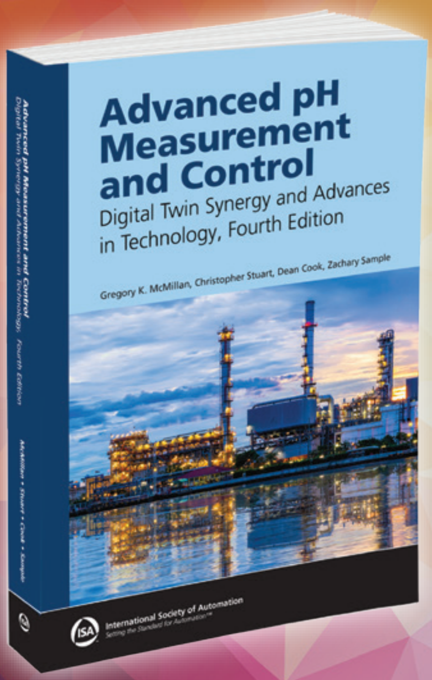

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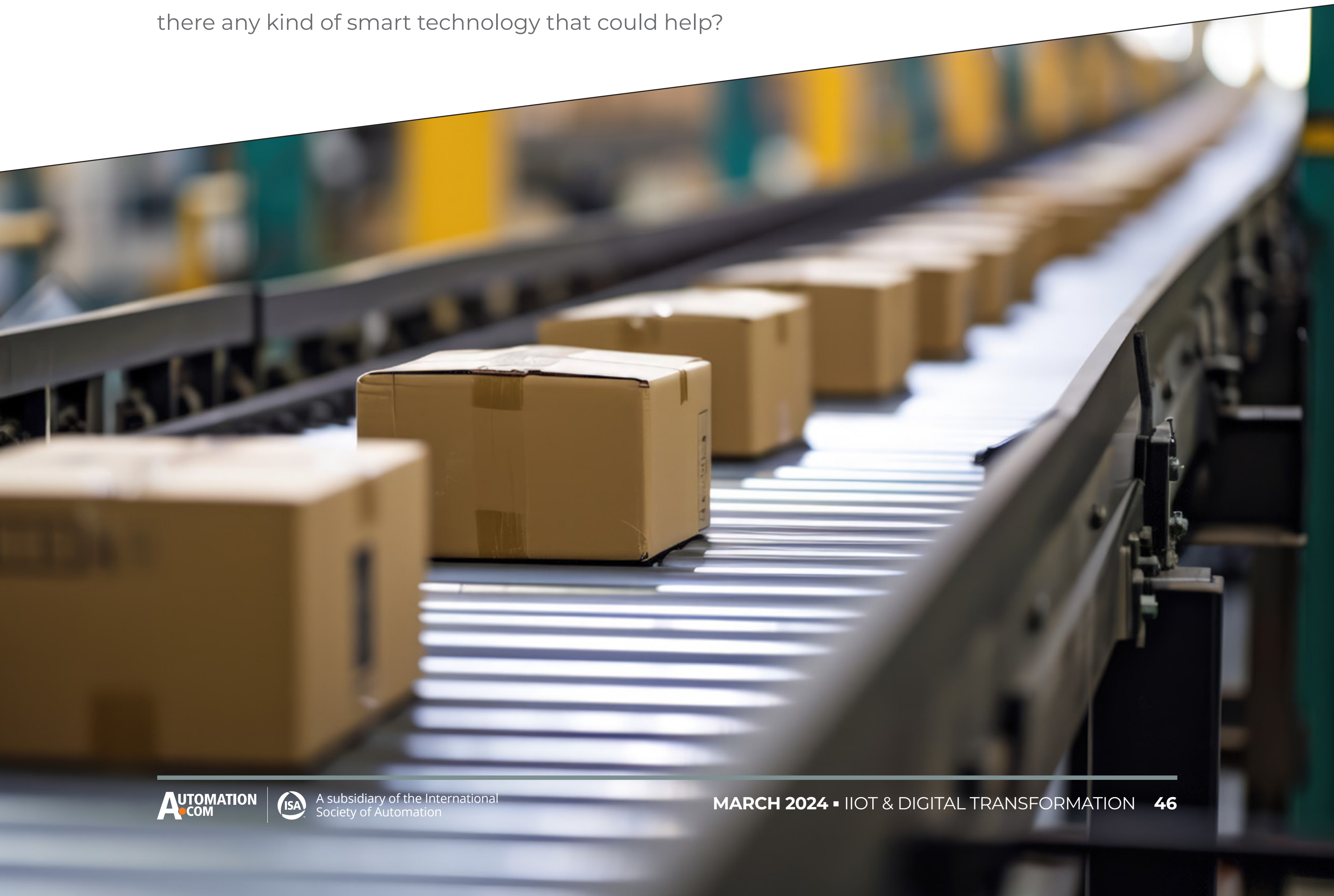
Advances in Smart Technologies for Material Handling

Advanced connectivity and data analytics enable manufacturers to optimize operations.

By Tom Eure, Regal Rexnord

Inside a large distribution warehouse in Charlotte, N.C., a team of workers faced a daunting challenge: Manually handling incoming package types ranging from boxes to polybags while managing other business. The polybags were placed into totes, which helped ensure proper package conveyance. However, the totes also increased manual labor and the time it took to sort bags. The team spent 80 hours per week manually grabbing and pulling totes at a labor rate of $21.50. Was there any kind of smart technology that could help?



The material handling and intralogistics industries are driven by sustainability, automation, and innovation. In baggage handling, postal and parcel centers, and warehouses and distribution centers, revenue is determined by the performance of downstream industries and markets that bolster industry demand. Margins are thin, which is why so many facilities are excited by digital transformation.

Manufacturing industries are experiencing a significant shift toward investing in the Industrial Internet of Things (IIoT) and smart technology. With advanced connectivity and data analytics capabilities, manufacturers are leveraging smart technology to optimize operations, decrease downtime, and prolong the lifespan of mission-critical equipment.

Material handling solution

The solution to the distribution warehouse's material-handling challenges was the low maintenance ModSort Divert and Transfer Module from Regal Rexnord, which was installed in the facility to assist the workers by conveying polybags without totes (Figure 1). Quiet, safe, and low maintenance, the ModSort offers run-on-demand technology on only 24 Vdc. The ModSort module integrated

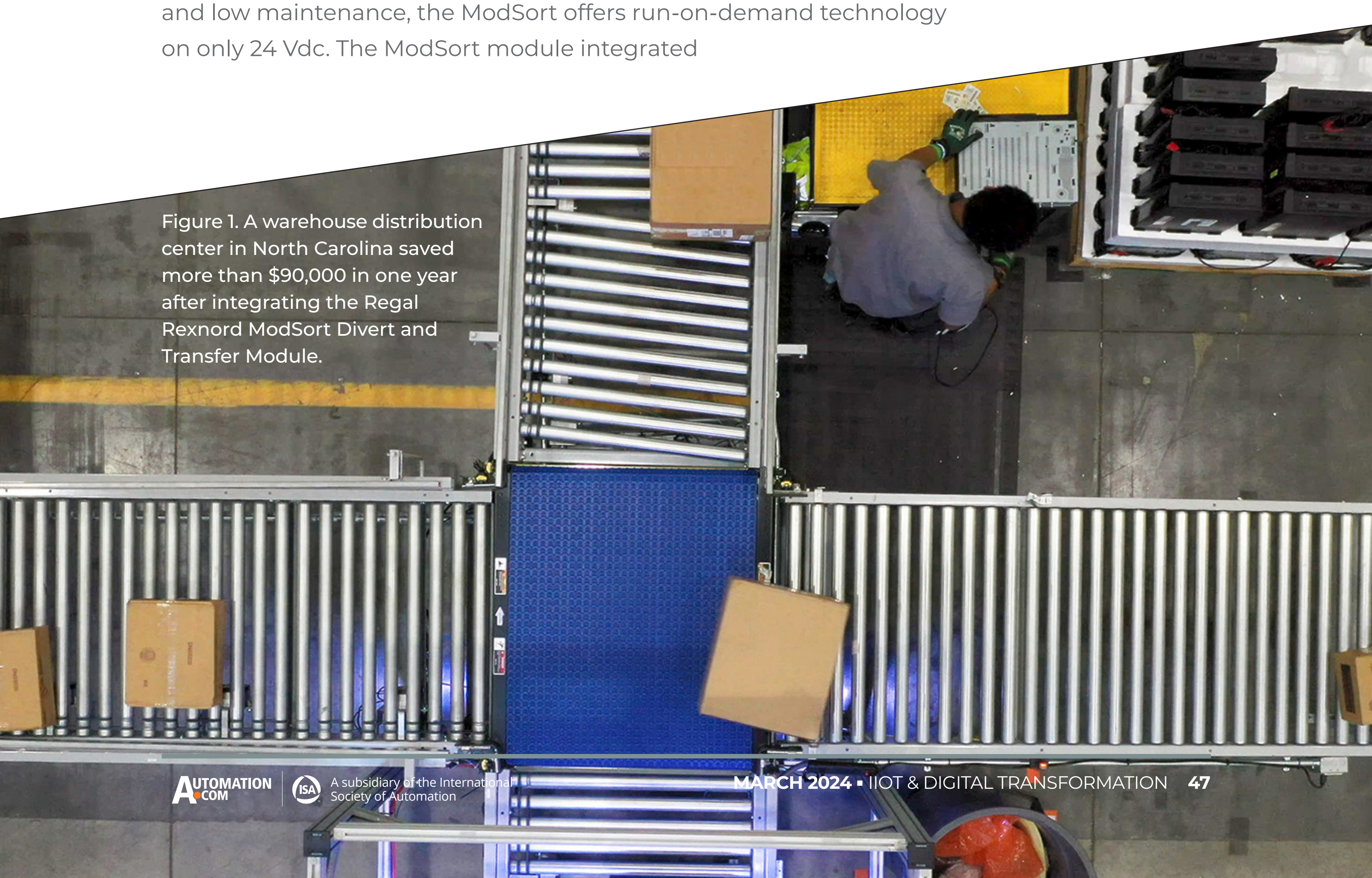


Figure 1. A warehouse distribution center in North Carolina saved more than $90,000 in one year after integrating the Regal Rexnord ModSort Divert and Transfer Module.

into the warehouse's package handling process. Conveyor speeds increased from 50 to 90 ft/min. Annual labor costs dropped by $90,000. This is a true story, and it's one Regal Rexnord is proud to tell.

How does ModSort work? The idea for ModSort started in 2015 with a blue System Plast belt with embedded rollers. Original equipment manufacturers (OEMs) were excited by the technology but needed help developing it to meet their system needs. ModSort evolved to include a belt and motorized drive rollers (MDRs). ModSort now comes in many sizes and can include Perceptiv IIoT sensors, motors, bearings, and gearing. It has flexibility to meet the demands of various applications.

In addition to end-to-end powertrain solutions such as ModSort, Regal Rexnord offers Perceptiv Intelligent Reliability Solutions, an interconnected matrix of sensors, gateways, and data, which empowers manufacturers to monitor products in real time and make data-backed decisions.

Manufacturing industries are experiencing a significant shift toward investing in IIoT and smart technology.

Smart technology boosts sustainability, worker safety

Change is hard. There is always an upfront cost; sensors to monitor brake oil levels or coupling vibration are not free. A custom-engineered ModSort sortation system takes time and money to develop. However, the return on investment, coupled with increased productivity, sustainability, and decreased downtime proves the value.

When it comes to conveying and sorting, older technologies are not as efficient as newer options in the marketplace. Many have old-style pusher arms that are very loud and run by pneumatics. Those require frequent maintenance and adjustments to make them functional. On the other hand, ModSort is designed from the ground up to be a maintenance-friendly product. It's easy to take apart and put back together, and if there is a problem it doesn't take much time to figure out what that is. ModSort takes no compressed air and runs on 24 Vdc. It is quiet, approachable, and safe.

ModSort is just one example, but like many smart technologies, its benefits are far greater than economic. Worker safety and sustainability increase while maintenance and downtime decrease.

Looking ahead

While the industry has advanced considerably in recent years, its digital transformation is far from over. As artificial intelligence (AI) and language learning networks continue to evolve, manufacturing technologies will as well. It is critical that engineers, integrators, equipment manufacturers, and end users stay up to date on the latest developments.

Looking ahead to near future technologies, automated guided vehicles (AGVs) will minimize energy consumption and optimize production output by combining the ModSort system with Kollmorgen technology (Figure 2).

Smart systems that are IIoT-enabled are backed by decades of application knowledge and engineering expertise. Not only are the products reliable; engineers are often a phone call away.

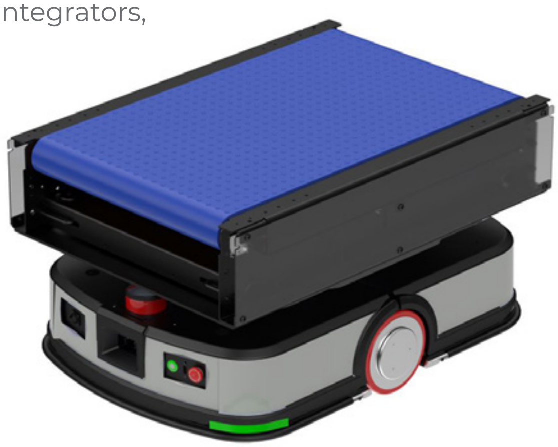


Figure 2. Regal Rexnord AGVs optimize facility operations and decrease downtime.

ABOUT THE AUTHOR

Tom Eure is a strategic account executive at Regal Rexnord. He has worked in the packaging and material handling industry since 1999. He started his career as a conveying engineer with System Plast. He and his colleagues have tailored solutions for many beverage producers in North America. Eure is a graduate of East Carolina University.

Less Power, More Powerful: Sensors for Condition Monitoring

Energy-efficient sensors drive innovation for machine maintenance.

By Matthew Negaard, IMI Sensors

In the rapidly evolving Industrial Internet of Things (IIoT) landscape of industrial condition monitoring, the shift from reactive to predictive maintenance strategies has significantly changed the approach to machine health, operational efficiency, and equipment lifecycle management. Engineers and system designers prioritize efficiency and scalability, choosing monitoring solutions that balance convenience and ease of use with uncompromised data integrity. Gone are the days of traditional route-based (read: labor-intensive) condition monitoring, or even online, single-point analog systems, which can prove costly and challenging to implement.

Next-generation tools

In their place is a generation of sophisticated wireless maintenance tools that extend monitoring capabilities to areas that were once thought inaccessible, or too critical for novel, battery-powered devices. As the adoption of wireless monitoring grows, deploying a greater number of nodes across factory floors, so does the requirement for the embeddable accelerometers in these systems to produce data of increasingly higher fidelity. This surge in data generation is instrumental in providing the detailed insights necessary for smarter predictive maintenance strategies, but it also brings to the forefront the critical need for wireless accelerometers that can sustain prolonged operation without frequent battery replacements.

The key factors influencing battery consumption are the current draw and the time it takes for a sensor to “wake up” from a dormant state to an active one.

Piezoelectric accelerometers have long been recognized for their exceptional ability to provide high-fidelity readings and detect the high-frequency vibrations that signify the earliest fault stages but have only recently solidified their value for wireless condition monitoring through the development of new, ultra-low-power variants. Compared to their micro-electromechanical systems (MEMS) counterparts, these piezoelectric accelerometers offer significant advantages in terms of energy efficiency and battery life extension, while remaining on par in terms of affordability and ease of implementation.

The key factors influencing battery consumption in both sensor types are the current draw and the time it takes for a sensor to “wake up” from a dormant state to an active one. Innovations in amplifier and circuitry design in piezoelectric devices are continually improving upon these aspects, significantly reducing both the energy draw during operation and the wake-up time. Modern designs boast a substantially reduced current draw of 60 µA when active and almost instantaneous startup time of 350 µs.

Given the market trend toward more frequent data readings for continuous asset monitoring, these developments prove to extend the life of monitoring systems in the field by months to even years (depending on the frequency of measurements) before battery replacements are needed. The combination of lower current draw and faster startup times allows users to benefit from significantly reduced energy consumption, whether sensors are kept in a low-power standby mode or powered down entirely between readings. This distinct advantage positions piezoelectric sensors favorably against MEMS sensors, which tend to consume more power even in standby modes than piezoelectric sensors during active measurement periods and require a constant current draw to mitigate startup delays.

As predictive maintenance culture continues to embrace wireless condition monitoring, ultra-low-power piezoelectric sensors provide a promising path toward achieving smarter operations in industrial plants. The design not only aims to prevent equipment failure, but also contributes to the overarching goal of enhancing plant efficiency, reflecting a significant shift toward more sustainable industrial practices.

ABOUT THE AUTHOR

Matthew Negaard is business development manager, Industrial and Digital Sensors at IMI Sensors, PCB Piezotronics Inc.