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The process controls whisperer

The automation community mourns the passing of controls legend F. Greg Shinskey

WHEN F. Greg Shinskey was inducted into the inaugural class of the Process Automation Hall of Fame in 2001, he was already an icon to more than one generation of process control practitioners. Many have personally benefitted from his acute intellect, genial manner and creative problem-solving, while legions more learned the tools of our trade second-hand from the series of seminal textbooks and articles he penned in a publishing career spanning more than five decades.

So, when on Sept. 25, 2021, Shinskey died peacefully at age 89 at his North Sandwich, N.H., home, word travelled quickly through the process automation community.

"As I started my career in automation, there were some stars to guide the way," says Nick Sands, senior manufacturing technology fellow, DuPont Water & Protection. "Two that guided me through their writings were F. Greg Shinskey and Greg McMillan. Shinskey's *Process Control Systems* captured so much practical knowledge that it changed how many plants operated, including where I worked, as I found solutions to longstanding problems in his book.

"It was amazing to meet Greg at an ISA conference and find him so approachable and willing to talk with an aspiring controls engineer," Sands adds. "With Greg's passing, a star is lost, but his knowledge lives on in his many books. His passing is also a reminder to appreciate the stars we have."

"The loss of Shinskey is exceptionally sad for our profession and to me personally," says McMillan, currently a senior principal software engineer with Emerson. "Shinskey has been my most extensive source of process control knowledge since I started my career over 50 years ago. He was able to show how process knowledge affects the dynamics, design and performance of the control system. He detailed how PID excelled at closed-loop control particularly in rejecting load disturbances."

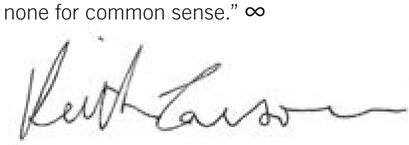
"Greg was my idol, a guru, an icon, a remarkable author, a process control passionate!" gushes Michel Ruel, principal consultant, advanced control, BBA Consultants. "I met him for the first time at the end of the 1980s. I presented a paper at an ISA conference; he asked very good and acute questions at the end—I was already a fan."

"Every time I hired a new process control engineer, studying Shinskey's books and his clever control strategies was mandatory," Ruel continues. "We all became such fans that eight years ago, with Greg's permission, we named our main conference room for him."

"In my mind, Greg Shinskey was the exemplar of a process control engineer," offers George Buckbee, head of performance solutions, Neles USA. "He was fully steeped in the theory of control, yet grounded in the experience and practicalities of the industrial environment. I was most impressed by his ability to quickly whittle any problem down to its pure fundamentals, and state the 'obvious' solution in just one or two short sentences. He was also very interested to codify his knowledge, and pass it on to coming generations. I will be forever grateful that Greg chose to devote some of his time to share his insights with the rest of us in the process control world."

"Greg would be amazed to know how many people he inspired to follow in his footsteps," says James F. Beall, principal process control consultant with Emerson's control and operator performance team. Beall was one of that number, having been inspired by a Shinskey session on process control at an annual Texas A&M Instrumentation Symposium. "That was it for me. I made up my mind to pursue process control for the rest of my career!"

Sigifrido Nino, a Shinskey mentee and now CEO of Summa Control Solutions Inc., summarized his mentor's contributions to the profession in the legend's own words on the importance of understanding one's process before attempting to control it: "There is no substitute for process knowledge," he wrote in 1994, "and certainly none for common sense." ∞



KEITH LARSON
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"He was able to show how process knowledge affects the dynamics, design and performance of the control system. He detailed how PID excelled at closed-loop control particularly in rejecting load disturbances."

NEWS & BLOGS

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Ethernet-APL: why HART-IP will be critical to industry adoption

The introduction of Ethernet-APL technology earlier this year is an important technology milestone, enabling a new, high-performance paradigm of digital field communications for the process industry. We'll soon have at our disposal loop-powered, two-wire, intrinsically safe Ethernet that's orders of magnitude faster than past generations of field communications. But to make sure that Ethernet-APL doesn't underachieve like fieldbus before it, we need to make sure the impact on current work processes and associated tools is kept to a minimum. In this webinar, Keith Larson, editor-in-chief of *Control* reviews the case for HART-IP over Ethernet-APL as the most expedient path to Ethernet-APL success.
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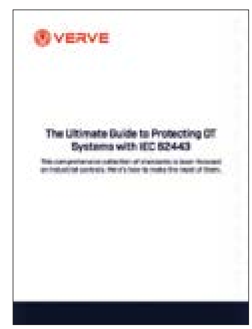
The ultimate guide to protecting OT systems with IEC 62443



The ISA/IEC 62443 standards were built to address security issues unique to industrial automation, control systems and operational technology. But how do they differ from other industry standards? How can you leverage them in your industrial organization? And where should you start? This comprehensive guide from Verve explains what IEC 62443 is, how you can take advantage of its broad applicability and inclusiveness, how to complete a risk assessment with IEC 62443, and more.
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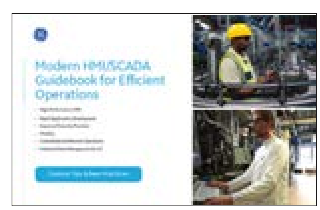

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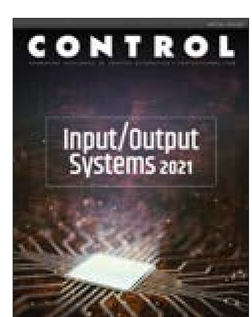
2021 State of Technology Report: I/O Systems



In this new State of Technology Report from the editors of *Control* and Controlglobal.com you'll read about the latest technology and trends in input/output (I/O) systems. Download your copy to learn how a sour gas plant shaved three months from its schedule despite a rush of last-minute design changes, why adding loads should raise questions about the roles of loop power supplies, where help is available to optimize the use of the Industrial Internet of Things (IIoT), and why removing wires doesn't automatically make equipment safe for hazardous areas.
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Why HART-IP is critical to Ethernet-APL success

Contents

Let's plan for Ethernet-APL success

The new, high-speed option for field communications must coexist with current technologies for years to come. The ability to extend HART-IP to high-speed instrumentation over Ethernet-APL is an essential aspect of industry's path forward

The introduction of Ethernet-APL technology earlier this year is an important technology milestone, enabling a new, high-performance paradigm of digital field communications for the process industry.

Its dramatically higher bandwidth promises to enable a new generation of more capable field devices and Industrial IoT solutions hardly yet imagined. And, because it's based on Ethernet, it promises to unify and dramatically simplify the control and information architecture of tomorrow's plants.

But even for a greenfield facility, that fully realized tomorrow is only a few years away. A necessarily conservative lot, end users will need to test out the technology in labs, pilot plants and non-critical applications, while device manufacturers must produce a critical mass of the various field devices needed. Meanwhile, most brownfield process plants face decades during which new technologies will coexist with today's solutions. No one anticipates that otherwise functional systems will be ripped out and replaced with ones based on Ethernet-APL. Instead, Ethernet-APL will have to compete opportunistically with current technologies and present advantages that outweigh the price of change: if adoption requires unfamiliar tools and work processes, those advantages will be harder to come by.

We've been here before. Fieldbus, the last effort to fully digitalize field communications, was a technical success but a commercial underachiever. It introduced new complexity that was simply a price too high to catalyze widespread adoption. To carry the chemical reaction analogy one step further, we as an industry must aim to keep the "activation energy" of new technology adoption as low as possible.

Enter HART-IP

While Ethernet-APL is a triumph of technology, offering 10-Mbps, two-wire, powered communications over long distances and in hazardous locations, it's only part of the puzzle. APL stands for "advanced physical layer," which means that complementary application protocols are needed to fill out the communications stack. And since it's Ethernet, we can even use multiple such protocols over the same pair of wires at the same time.

It's both liberating and potentially confusing to contemplate the coexistence of multiple protocols in the digital field. But it's just like the network one has at home or in the office. Since it's Ethernet and Internet Protocol (IP), you can browse websites, send emails, print documents and stream video—each time transparently using a different application-level protocol over a shared Ethernet IP infrastructure.

Similarly, when it comes to the digital field, a range of "industrial Ethernet" networks are likely to play roles depending on the application and industry in question. But when it comes to the configuration, monitoring and diagnostics of process instruments and final control elements—and the process control they enable—one industrial Ethernet protocol stands alone in its ability to carry forward existing tools, work practices and workforce familiarity and to lower the activation energy of adopting Ethernet-APL. And that's HART, specifically in the form of HART-IP.

HART-IP was first introduced in 2007 as a high-speed Ethernet protocol to communicate HART data collected from WirelessHART gateways. The original HART, in turn, dates back to the 1980s when it was developed and released as an open standard for smart transmitter communications. Uniquely, the original HART protocol still communicates over the 4-20mA analog instrumentation current loops first standardized in the 1950s. Today, tens of millions of 4-20mA analog instrument with HART constitute the vast majority of installed instrumentation around the world. Even today, it dominates shipments of new instruments to the global process industries.

Future-proof evolution

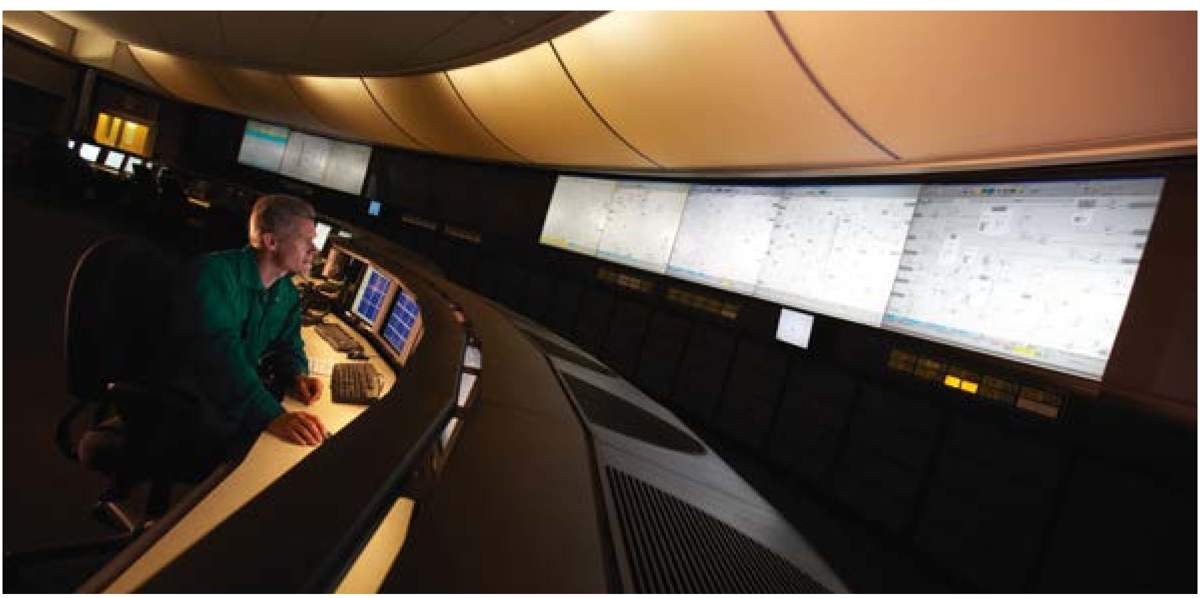
In recent years, the utilization of HART data from existing devices has only continued to increase. For many end users, the primary use case for the 4-20mA version of HART was during device installation and commissioning, after which they turned to handheld communicators for periodic field troubleshooting and calibration.

But booming interest in realizing the benefits of digital transformation has more and more users seeking to continuously expand upon HART data in their instruments. In fact, more than one industrial network infrastructure provider has reported that the Ethernet multiplexers used for such purposes are flying off the shelves. This means that end users are only increasing their investments in the HART ecosystem.

Meanwhile, today's HART-IP has advanced significantly since it was first introduced. Adding an integrated security model in the latest version of the HART IP standard was key to establishing a proper cybersecurity posture on the next generation of Ethernet field devices. It's also important to realize that in HART-IP, the 4-20mA analog signal is replaced with secure, high-speed digital transmission of process variables and control instructions. In short, HART functionality is no longer limited to monitoring and diagnostics—with HART-IP it does control, too. Tests performed on Ethernet-APL indicate bandwidth that is more than sufficient for closing the loop on most process control applications. For example, even with 150 devices reporting 20 updates per second over a 10 Mbps subnet, only 30% of available bandwidth was consumed. (Visit fieldcommgroup.org/technologies/HART-IP/explained for more details.)

WirelessHART already is being used to manage data streams from quite sophisticated instruments such as vibration sensors for condition monitoring. Entire frequency waveforms are being communicated via HART-IP, and the core HART data model handles all that detail with aplomb.

But what's even more special about HART is that the protocol remains consistent across all these architectures—Ethernet-APL, WirelessHART and 4-20mA HART. And that means minmal changes to existing tools plus little training up of plant personnel on new work practices upon adding Ethernet-APL to the mix.



Indeed, the biggest beef against 4-20mA HART has always been speed, making configuration and other tasks both time-consuming and cumbersome. But with HART-IP over Ethernet-APL, it'll be like someone swapped out your old dial-up modem for a modern WiFi connection. One's desktop computer, email software and web browser are unchanged; they all work just as before—albeit orders of magnitude faster.

That's what HART-IP over Ethernet-APL promises: all the advantages of higher bandwidth without incurring the activation energy penalties that often come with technology adoption. And, if someday an even more powerful network platform comes along to complement Ethernet-APL, it's a safe choice that the proven ability to abstract network particulars from the HART protocol's data model will work there as well.

Interoperability preserved

Bringing HART along as we move toward an Ethernet-APL future also allows us to preserve what has become industry's best example of ecosystem interoperability among different suppliers' devices and systems.

Decades of effort have resulted in Field Device Integration (FDI) technology that helps to ensure proper field device management by the host—including device configuration, replacement, maintenance and diagnostics—that is standardized and usable across all systems, independent of device or system suppliers or vendor-specific tools. Today's FDI technology even allows instrument makers to create secure, application-specific web apps for their devices.

The HART protocol with Ethernet-APL doesn't just benefit end users. It also promises to ease the development burden for device manufacturers, who can spend less time on their communication stack and more time figuring out what advanced functionality they can implement with the greater power that Ethernet-APL delivers: from less than 40mW intrinsically safe power with a 4-20mA transmitter to 500mW intrinsically safe power with Ethernet-APL.

Importantly, Ethernet-APL also affords coexistence of application protocols in the same architecture, even over the same pair of wires. This means that using HART-IP to communicate with process instruments and control valves doesn't impinge on using an alternative protocol for other application domains. For example, if current tools and work processes leverage EtherNet/IP or Profinet to talk with drives and motor control centers, Ethernet-APL teamed with these protocols will make the transition for the personnel responsible for these assets just as easy as it is for the instrumentation and control personnel already familiar with HART.

Manage the risks, reap the rewards

Adoption strategies for Ethernet-APL will hinge on where it brings greatest value to your operations. While more speed is always a good thing, implementation thresholds will vary, especially between brownfield units and new projects

Adoption strategies for Ethernet-APL will be very much intertwined with the value proposition it represents relative to current technologies. The grassroots unit or production facility is one extreme, where, given a clean design sheet and a critical mass of available Ethernet-APL devices, the simplicity and advantages of a unified high-speed network architecture that extends from field instruments to the cloud—yet preserves existing workforce familiarity with HART—is quite compelling.

But that greenfield plant design is still a ways off, given the lead time for instrumentation and system developers to bring the necessary solutions to market, not to mention the testing, trials and tire-kicking that end-user organizations will demand before betting a new plant on any new technology.

At 3M, for example, initial laboratory tests will be followed by pilot-plant implementations plus assurance testing that the technology passes the company's rigorous internal standards for intrinsically safe operation before Ethernet-APL will be approved for a production environment or for widespread use, according to Robert Sentz, senior engineering specialist.

Bottom line, while the ultimate value proposition of Ethernet-APL will be in a greenfield facility, progressive end-user organizations will meanwhile be looking for more isolated use cases at brownfield facilities to test out and prove the new technology's worth. Testing is appropriate, but for Ethernet-APL to win on its own merits in a brownfield environment, "It's got to be a pretty specific use case that really needs that higher bandwidth or will benefit from the greater amount of power that can be delivered over APL," notes Peter Zornio, CTO Automation Solutions, Emerson. "It's a very simple rule: if you're not putting in new instruments, you're not going to broadly deploy APL," he adds.

The need for speed

Many of the most apparent use cases for HART-IP over Ethernet-APL derive from the increased availability of data that higher bandwidth affords. In a brownfield context, this is most relevant when adding complex new instruments that generate more data of diagnostic significance.

Real-time access to valve signature data from a valve controller, for example, can be used to diagnose a range of issues before they lead to unscheduled process downtime. The same can be said for Coriolis meters, magnetic flowmeters and radar level gauges (see sidebar). Process analyzers in particular will benefit from the order of magnitude increase in power made available to instruments by Ethernet-APL relative to 4-20mA,

‘BEST BET’ USE CASES FOR ETHERNET-APL

While industry awaits the opportunity to deploy a critical mass of Ethernet-APL devices in a new plant or unit, we’ll also be looking for opportunities to verify the benefits of the new technology when adding new instruments to an existing operation. These “best bet” use cases that can begin to bring value in the absence of a full architectural shift will be those instruments that will benefit most from the dramatically faster data rates or higher power that Ethernet-APL can deliver. Here, then, a roll call of top prospects.

Digital valve controllers are among the most promising use cases for Ethernet-APL plus HART-IP in part because there’s so much HART data related to their operation that it’s hard to gain an accurate picture of their operation in a timely fashion via traditional HART communications. That usually means a trip out into the field with a handheld communicator or PC, but “running a detailed valve analysis might still take 15 or 20 minutes to complete,” notes Kurtis Jensen, valve instrumentation portfolio manager, Emerson. “But with HART-IP over Ethernet-APL, engineers and technicians will be able to see things that they hadn’t before.”

Coriolis meters are similarly complex and pack a lot of localized intelligence such as for remote verification that the meter’s operating characteristics have remained unchanged since installation. With today’s communication technologies, most users rely on a simple pass/fail command to transmit their verification status back to the control room, but the increased bandwidth of HART-IP over Ethernet-APL would allow personnel to dig into the raw data behind the test and determine the root cause—all from the relative safety and comfort of the control room or even a remote service center.

Magnetic flowmeters also include sophisticated onboard diagnostics to verify the continued integrity of the tube, coil and electronics. Again, HART-IP over Ethernet-APL would allow a remote user the ability to dig into the raw data behind these pass/fail tests.

Radar level gauges are a third group of instruments whose sensors have a characteristic signature that can be used to verify proper operation or alert the operator to problems such as an antenna coating interfering with its proper operation. Such signatures consist of a large amount of data that cannot be efficiently communicated via traditional HART and would benefit from HART-IP over Ethernet-APL.

Process analyzers are a good candidate for Ethernet-APL because the new physical layer can deliver nearly 10 times the intrinsically safe power of a 4-20mA analog loop. So, one may be able to provide both power and high-speed communications over a single, two-wire Ethernet-APL connection rather than the power wiring plus four-wire Ethernet connection traditionally required.

Multivariable measurements are yet another promising use case for HART-IP over Ethernet-APL, making it easier to power and communicate HART diagnostics from multiple related instruments, such as the multiple sensors included in a temperature-compensated, differential-pressure flowmeter. It could also allow for one Ethernet-APL spur to connect with multiple temperature sensors, obviating the need for separate transmitters.

representing a less expensive installation than the power supply plus four-wire Ethernet connections that otherwise might have been needed.

But the larger context of increased secondary data bandwidth is the ability to collaborate more effectively, and to send that more nuanced secondary data more easily to the individuals—and applications—that can make effective use of it. Think of a diagnostic application that pulls some data from the instrument, some from the computerized maintenance management system (CMMS), some from a condition monitoring system and some from the distributed control system (DCS). A beleaguered engineer might spend all day manually pulling that data into a spreadsheet before even beginning to analyze its meaning. Or think of the roaming technician who can quickly access real-time HART device data through a tablet wirelessly connected to the plant's WiFi infrastructure—access that was previously available only back in the control room, didn't reflect real-time conditions, and even then, was accessible to the technician only via walkie-talkie or a physically connected, low-bandwidth handheld.

Transitional architectures

For most end users—especially in the US, where few greenfield facilities are expected to be built in the near term—their first experiences of Ethernet-APL will be in hybrid environments that also include 4-20mA HART devices. On the positive side, with the debut of fully configurable input/output (I/O) systems some 10 years ago, industry already is on its way to moving I/O from control room environments out into field junction boxes.

Configurable I/O has delivered substantial benefits of its own, helping to decouple hardware design from system software development and taking instrumentation and control system design off the critical path of project execution. It's also reduced costs and system footprint, eliminating traditional marshalling cabinets in many newer facilities. Like fieldbus before it, Ethernet-APL effectively distributes I/O even further, relocating the transition between analog sensor signals and the digital world of ones and zeroes into the field devices themselves.

From a practical perspective, this means that the remote junction box is where 4-20mA HART and Ethernet-APL are most likely to converge. That remote junction box could relatively easily include both configurable I/O as well as an Ethernet-APL switch—both of which speak HART-IP over Ethernet up into the control system architecture. Further, a potential mix of Ethernet-APL with traditional 4-20mA HART devices will likely entail a range of network infrastructure devices designed to accommodate the transitional hybrid architectures required.

While dual devices sharing an Ethernet connection in the same box are easy to imagine, hybrid approaches are also likely. Analog Devices, one of the suppliers of chipsets for Ethernet-APL as well as the multiplexers that extract HART data from 4-20mA loops, has envisioned a device with hybrid functionality. And for suppliers like Emerson,

> "We try to give our customers one standard protocol throughout the plant design, and HART is pervasive. Everybody has HART."
>
> — Robert Resendez, Control Systems Supervisor, Bechtel

> "I believe true benefits tend to be sustained for a longer period when you have that ecosystem of knowledge and existing tools that are proven in use."
>
> — Jason Urso, Chief Technology Officer, Honeywell Process Solutions

which uses a physical module to characterize its remote I/O channels (rather than software), a new Ethernet-APL module under development will allow these new digital channels to coexist side-by-side with their 4-20mA HART counterparts.

In all three of these scenarios, a shared commitment to the HART ecosystem and data model will ease the industry's ultimate transition to Ethernet-APL as the standard physical layer for field instrument communications

Greenfield benefits await

In the not-too-distant future, a greenfield facility or new production unit offers the most fertile ground for Ethernet-APL technology, since the baseline will involve comparing proven Ethernet-APL plus HART-IP technologies with the 4-20mA plus HART *status quo*. A greenfield design need not weigh sunk costs against new benefits. Rather, a clean-sheet design will allow end users to realize the full benefits of a secure, unified digital infrastructure that reaches from field devices to enterprise systems and the cloud.

> "With Ethernet-APL, the first thing is faster data. So, if it helps during startup and commissioning there will be a real advantage."
>
> — Jeff Konrad, Technical Solutions Team Leader, Automation Interfaces, Dow

Having a critical mass of instrument types available that support Ethernet-APL will be critical for greenfield designs to succeed, believes Robert Resendez, control systems supervisor for the oil, gas and chemicals division of Bechtel. "I remember finding all the instruments we needed being a challenge in the early days of fieldbus," he says. "We try to give our customers one standard protocol throughout the plant design, and HART is pervasive. Everybody has HART—even some of the smaller PLC (programmable logic controller) manufacturers."

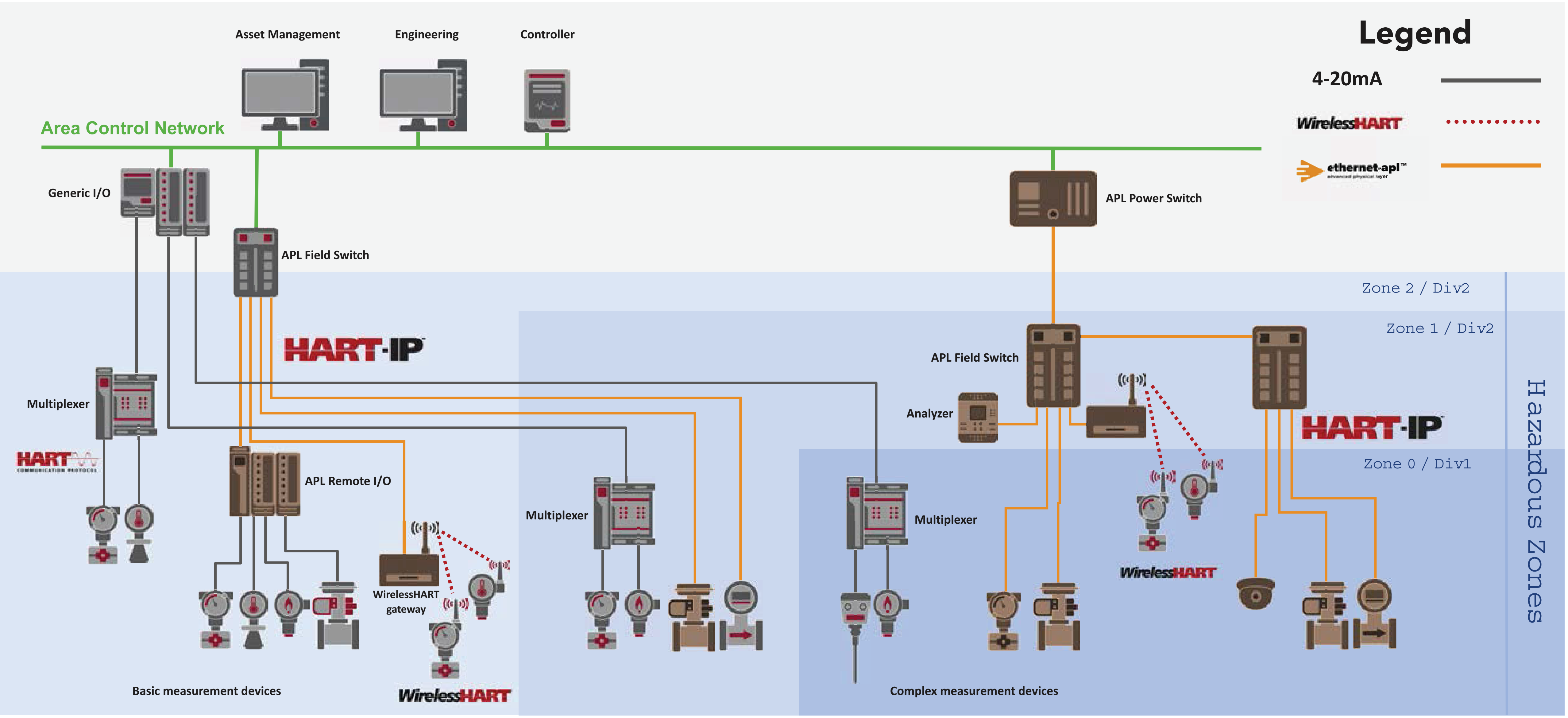
From an architecture perspective, tomorrow's Ethernet-APL systems won't look all that different from the remote, configurable I/O systems that Bechtel advocates today, Resendez adds. Indeed, replacing remote enclosures filled with configurable I/O with remote enclosures filled with Ethernet-APL switches may even allow system designers more flexibility when it comes to how many devices can be connected through a remote enclosure of given dimensions.

In any case, the transition to Ethernet-APL spurs (out to individual instruments) should be a relatively straightforward adjustment from a design perspective. The addition of the APL trunk concept will allow for new distribution models in areas lacking infrastructure for power and communications. And when it comes to installing and commissioning this new breed of devices in a greenfield facility, users will really begin to benefit from the dramatic improvements in communications speed that the move to Ethernet-APL represents.

Dow has used "smart" instruments ever since they were first available, but only relatively lately begun to rely on continuous monitoring of its instruments' HART data for predictive diagnostics applications, says Jeff Konrad, technical solutions team leader in the realm of automation interfaces. "So, with Ethernet-APL, the first thing is faster data," he says. "My first questions are during commissioning and startup. We know sometimes it's hard to communicate via traditional HART—sometimes it's slow, sometimes we have interruptions. So, if it helps during startup and commissioning there will be a real advantage."

Jason Urso, chief technology officer for Honeywell Process Solutions, cautions that we as an industry really need to focus a bit less on how great it will be to get more data faster and instead figure out just what we'll do with even more data once it arrives. "I'm a big advocate of APL," he says, "and I think we've got to continue moving in that direction. But let's also figure out what we're going to do with all that data now that we're collecting it."

Urso also agrees that standardizing on HART-IP over Ethernet-APL will help instrument and system suppliers get to market more quickly with the product offerings that end users need to take advantage of this new field networking technology. "HART's well known to us in part because it's used extensively used by our customers," he says. "They have the knowledge. They have the competence, the expertise and the track record. And I believe true benefits tend to be sustained for a longer period when you have that ecosystem of knowledge and existing tools that are proven in use."



MIGRATION ROADMAP

Today's HART-based control architecture relies on devices using the 4-20mA (grey connections) or WirelessHART (dotted red connections) physical layers. Often, the WirelessHART gateway connects to the control network with HART-IP over 4-wire standard Ethernet. Additionally, multiplexers and remote I/O may use RS 485 and Modbus to communicate data back to the area control network. As Ethernet-APL instruments become available, they can be connected to the area control network via HART-IP (orange connections) though a simple APL field switch. And as confidence grows, an APL power switch can be added to bring power and communications to multiple field switches that power many instruments, including new instrument types like video cameras or thermal imaging systems.

Novel devices and new superpowers

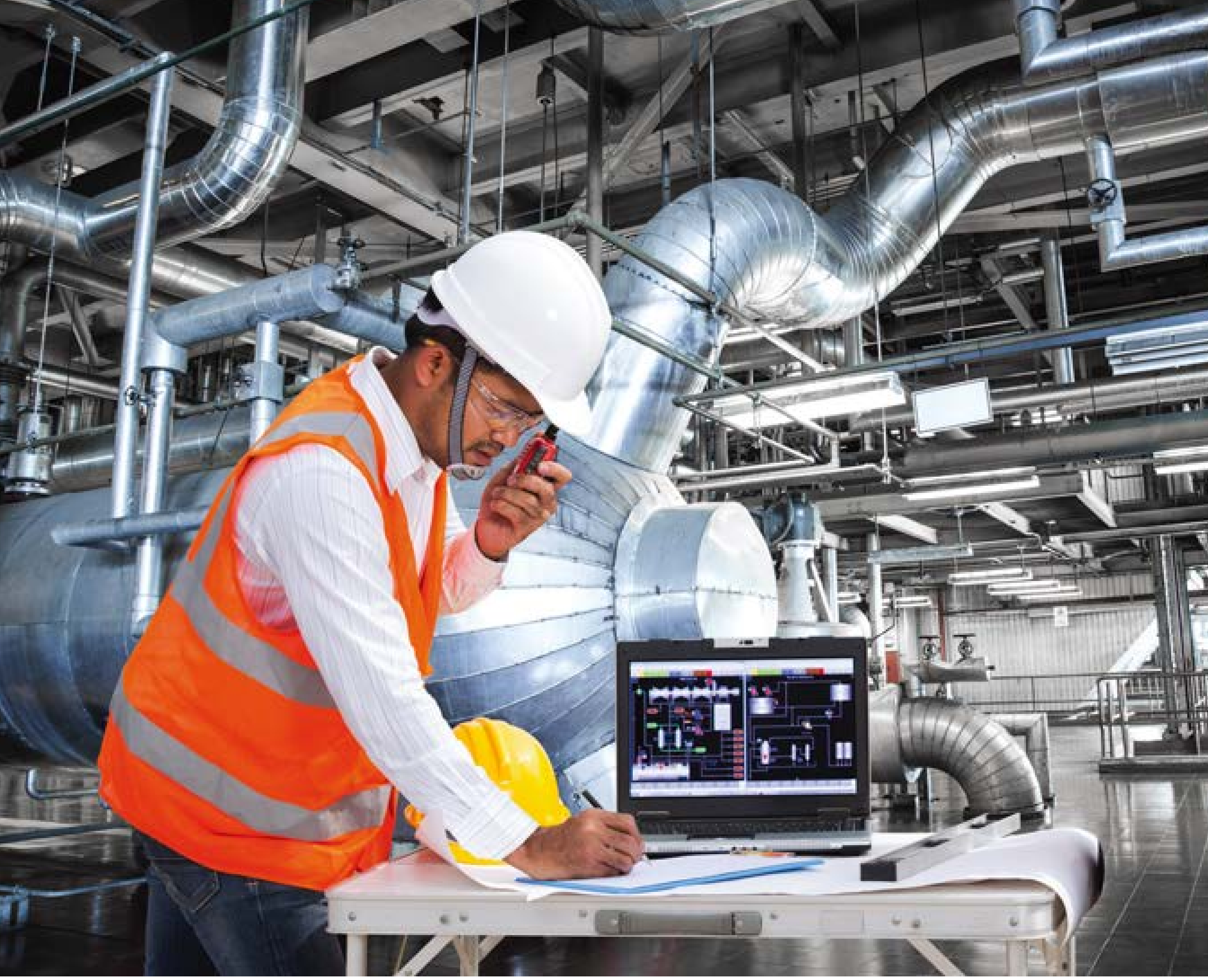
Ethernet-APL promises to open the digital field to entirely new types of devices. The higher power and faster bandwidth of HART-IP over Ethernet-APL will also make possible a host of new capabilities in the field instruments of tomorrow

The first leg of the journey to Ethernet-APL is to fully liberate all that secondary instrument data that has long gone underutilized across the process industries. Indeed, a growing number of progressive process manufacturers are using multiplexer technology to extract all that rich, digital HART data from their 4-20mA analog loops—and already are using that data to effectively advance their digital transformation initiatives. HART-IP over Ethernet-APL will just make that access simpler, faster and easier.

Over the past several years, network infrastructure specialist Phoenix Contact has seen a significant uptick in the number of users retrofitting their plants to bring previously stranded HART data up into asset management and other monitoring systems, according to Garrett Schmidt, senior product manager.

"We know that most of these devices are going into brownfield facilities," Schmidt explains. "They're connecting to 4-20mA HART instruments with the highest value data first—typically more complex instruments such as valve controllers and flowmeters—then building out from there." A confessed IoT junkie, Schmidt attributes the growing interest in continuous, full-time access to HART data to organizations' digital transformation initiatives.

3M is among those end-user companies that has placed a new emphasis in recent years on the value it can derive from continuous access to HART data, according to Robert Sentz, senior engineering specialist. "We are using more and more of that the available diagnostic data from smart valve positioners, smart pressure, temperature and flow instrumentation," he says. Indeed, the company is betting its operational future on digital technologies such as performance-driven analytics and prescriptive maintenance enabled by instrument data. "All that



HART information is getting to be almost as critical as the process measurement, the process control piece itself," Sentz says.

"HART over analog loops is very robust, but it's also slow," Sentz adds. "So, I'm very intrigued by the potential to further improve plant performance and availability with Ethernet-APL and HART-IP."

And while HART-IP over Ethernet-APL will dramatically improve the accessibility and utility of data in today's instruments, the second leg of the Ethernet-APL journey will pair that new speed with higher instrument power and protocol independence to launch a whole new world of transformative possibilities.

Enhanced capabilities

Higher bandwidth and more available power will allow makers of today's process instruments to create new sources of value in their next-generation, Ethernet-APL-enabled devices. Future pressure transmitters, for example, may include multiple, automatically ranging sensors, which would allow a given transmitter to cover a broader range of pressures without sacrificing accuracy, envisions Jonas Berge, senior director, applied technology, Emerson. Notably, this would solve the problem of needing to stock a large inventory of pressure transmitters for various applications.

Similarly, more available power will allow makers of two-wire flowmeters to increase the excitation signal of Coriolis or magnetic flow-tubes, enabling higher turndown ratios—and more accurate measurements at low flow rates. It will also allow two-wire, Ethernet-APL flowmeters to handle larger pipe sizes than currently possible.

More available power would also allow two-wire flowmeters to continuously perform a broader range of process diagnostics, for example, detecting corrosion in Coriolis meter tubing and adjacent piping, says Andy Kravitz, senior product manager, connectivity solutions, Emerson. Currently, the negative effects of corrosion can be detected by initiating a Smart Meter Verification test, but that test only gives a pass/fail result—not a clear indication of the source of the problem. "In effect, the ability to measure corrosion in real-time would be an added feature of my Coriolis meter," Kravitz explains.

Process-induced measurement noise is a problem for many sensors today, adds Berge. But with more power for the microprocessor, future sensors may feature more advanced signal processing to overcome the effects of noise. And in extreme cases, the sensor may be able to leverage the capabilities of a remote server to provide further analysis. "Perhaps next-generation, non-intrusive ultrasonic flowmeters will perform at a level high enough to calculate mass and energy balances on heat exchangers," Berge says. "This would solve the problem of having to cut and weld pipes or otherwise disrupt the process to get a reliable flow measurement."

> "All that HART information is getting to be almost as critical as the process measurement, the process control piece itself."
>
> **— Robert Sentz, Senior Engineering Specialist, 3M**

Pressure drop, flow, vibration and acoustic noise are useful inputs in detecting and predicting control valve failures, but typically go unmeasured on a routine basis. With Ethernet-APL networking, it will be more practical to measure and integrate such external variables into valve diagnostics to provide more predictive and prescriptive analytics.

The scope of diagnostics for instruments such as digital valve controllers will also begin to include other related data from "peer" devices on the network, predicts Kurtis Jensen, valve instrumentation portfolio manager, Emerson. "Instruments will become more process aware," he predicts. "If my valve controller shows the valve is closed, yet there's still pressure drop across a downstream orifice plate, it can tell me there's a problem."

More broadly speaking, Ethernet-APL will make it possible to utilize instruments' auxiliary variable measurements more fully. For example, measures of ambient temperature across all instrumentation points in a plant could be used to create a thermal map of the entire facility, providing early detection of a fire or fire hazard. Most field instruments already include such auxiliary measurements today, but they usually go unutilized.

Another transformative aspect of Ethernet-APL technology will be to replace the patchwork of application-specific networks used in process environments, building toward a single, unified network architecture. For example, today's addressable fire and gas (F&G) detectors use proprietary application protocols and therefore require dedicated networks. In the future, F&G detectors of various kinds may share the same Ethernet-APL/HART-IP network with the rest of a plant's instrumentation. Such solutions will likely be more economical to deploy, allowing more detectors for better coverage in tight spaces such as offshore rigs and production units. The units will be safer, and the systems easier to maintain as a result.

One significant new capability of Ethernet-APL instrument networks actually has nothing to do with the instruments. Rather, it's built into the network itself. Sometimes referred to as intelligent networking, the communications chips provided by Analog Devices continuously measure noise levels on each network segment and can alert if link quality degrades. Devices can be configured to run such link quality diagnostics on a regular basis, and if there is an issue, the diagnostics can even indicate the location of the problem, explains Fiona Treacy, marketing manager, Analog Devices. "We can pinpoint the location of a problem to within 1%," she says. "So, for a kilometer of cabling you can tell where a short is to within 40 meters."

Novel devices, complementary protocols

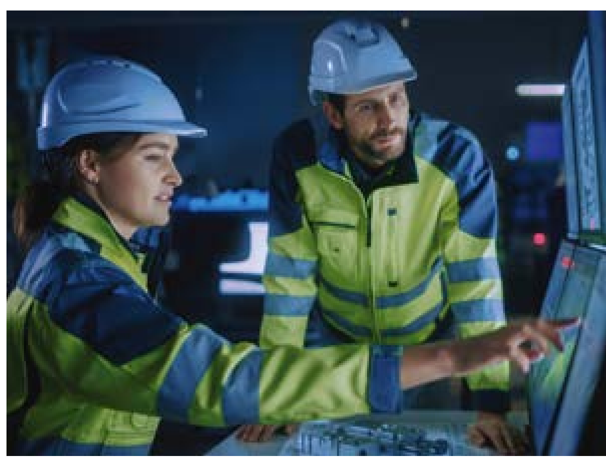
Some in industry envision a real-time digital field network as just a replacement of 4-20mA process variables, control commands and secondary diagnostic and configuration data using digital HART-IP signals. But the possibilities are much greater than simply enhancing the capabilities of current field instruments and rapidly sharing their data with the people and applications that can put it to work. Rather, we should also recognize the potential for Ethernet-APL to enable entirely new kinds of field instruments solving previously unsolved problems.

Setting the range in a pressure transmitter without applying an input might have been impressive 30 years ago. But today we expect far more from a "smart" device. We should expect other time-consuming tasks to be eliminated or simplified in similar ways. And with 4-20mA signals replaced by HART-IP over a fully digital Ethernet-APL infrastructure, field instrumentation will finally be able to benefit from the dramatic technology advances that have transformed computing and communications in our personal lives.

Indeed, today's expectations for new smart devices for industry should model the breakthroughs brought about by the mobile phone network. Once the GMS network supported GPRS data, it wasn't long before the first smartphone appeared. Little did we realize; the smartphone was a full-fledged pocket computer and communicator that coincidentally made phone calls. So, expectations for industry's future should not be just better transmitters, but also new classes of field devices.

Among other implications, digital transformation of plant operations means that many monitoring tasks which have until now been done manually by operators on rounds with portable testers will instead be done continuously and automatically by permanently installed sensors.

> "Instruments will become more process aware. If my valve controller shows the valve is closed, yet there's still pressure drop across a downstream orifice plate, it can tell me there's a problem."
>
> — Kurtis Jensen, Valve Instrumentation Portfolio Manager, Emerson



Common examples of this include vibration, temperature, acoustic noise and corrosion (wall thickness) measurements.

Audible noise sensors (microphones) that share the common Ethernet-APL backbone may be used to identify noisy hotspots, helping to assure protective measures for employees, the tranquility of neighboring communities and compliance with ever more stringent regulations. The abundant power and high bandwidth of Ethernet-APL networking may also enable noise spectrum analysis, identifying sources of noise and possibly diagnosing process and equipment problems from changes in noise patterns.

Machine vision has been used in discrete manufacturing for years. In the future, perhaps there will be two-wire infrared cameras for liquid leak/spill detection sharing the same Ethernet-APL network as other devices. And instead of portable thermographic cameras to measure equipment temperatures, there may be permanently installed two-wire thermographic cameras to automate manual inspection. Other possible applications include flare monitoring and smoke detection, recognition of unauthorized intruders as well as proper use of personal protective equipment by authorized personnel. All these measures could reduce hazards and improve security and safety.

A field-mounted two-wire vibration transmitter sharing the same HART-IP over Ethernet-APL network as other field instruments may in the future support sophisticated, fast-Fourier-transform (FFT) edge analytics to head off quickly developing problems with pumps, fans and other rotating equipment. Operations, maintenance and reliability personnel may even collaborate over a livestreamed vibration spectrum, including waveforms and orbits, to better understand potential issues.

While HART-IP over Ethernet-APL is suitable for many of these new devices, others will operate best through other Ethernet application protocols often developed specifically for that type of device. A key attribute of Ethernet-APL is that contrary to previous field device communication alternatives, it is non-exclusive. That is, a mix of application protocols can be used simultaneously,

"Users are connecting to HART instruments with the highest value data first—typically more complex instruments such as valve controllers and flowmeters—then building out from there."

— Garrett Schmidt, Senior Product Manager, Phoenix Contact

even on the same pair of wires. On the industrial side, HART-IP can co-exist with Profinet, EtherNet/IP, OPC UA and others. Meanwhile, it can also coexist with non-automation protocols such as RTP or RTSP for digital video.

So, all devices on the network need not use the same protocol. Not even all the instrumentation. A transmitter using HART-IP and a valve using Profinet can even participate in the same control loop—but the controller in between must be able to handle both protocols.

A more transparent future

A key advantage of implementing Ethernet-APL together with HART-IP is the extensive, global interoperability ecosystem supporting HART together with industry-wide familiarity with HART and the tools and work processes that support it. Preserving this common ground will be critical to easing industry's transition to an Ethernet-APL future.

Longer term, higher bandwidth and more powerful devices will make understanding the underlying protocols less significant for end users, predicts Peter Zornio, CTO Automation Solutions, Emerson. "Eventually, talking about whether a particular instrument is using HART-IP, Profinet or EtherNet/IP will be like talking about whether our cell phones are using CDMA or TDMA." Similarly, intelligent device management software promises to abstract the management of field devices from the details surrounding Field Device Integration technology and underlying profiles.

In the near term, however, what doesn't go away is the interoperability ecosystem that underlies the HART configuration and management tools in every distributed control system (DCS) and asset management system on the market, Zornio stresses. "When you sit down at the DCS to configure a new Ethernet-APL device, you don't have to care about the new physical network or the protocol—it's just a HART device like 4-20mA HART and WirelessHART devices," he says. "Granted, a lot more data comes out a lot faster than it used to. And if we can deliver that impact without changing a lot of processes along the way, we'll have accomplished our goal."

> "When you sit down at the DCS to configure a new Ethernet-APL device, you don't have to care about the new physical network—it's just a HART device like 4-20mA HART and WirelessHART devices."
>
> — Peter Zornio, CTO Automation Solutions, Emerson

A secure yet familiar path forward

To reap the benefits of Ethernet-APL, potential barriers to industrywide acceptance must be minimized. In the process industries, only HART-IP delivers both the built-in security and comfort level needed to achieve that reality

Bringing Ethernet technology that last mile to the field instrument represents perhaps the ultimate convergence of information and operational technology (IT/OT) for the process industries. For operational technologists, it's an opportunity to fully capitalize on the dramatic advances in networking technology that have already transformed the architectures of the automation and information management systems upon which they rely. But it's also like facing the loss of a familiar old friend in the form of the 4-20mA analog loops that have served industry so well for so long.

Yes, HART-IP over Ethernet-APL replaces that analog signal with fully digitalized process variables and control signals. But it also brings forward HART's industrywide familiarity, unrivaled interoperability ecosystem and proven utility when it comes to instrumentation monitoring and diagnostics data.

More than 30 years ago, HART was created as a command/response protocol, in which a host issues a command, and a device responds. When there are many devices in an installation and a host is communicating with many of these devices, the host needs to know the name or address of the device it wants to issue a command to. This addressing scheme is defined in the HART protocol specification.

But when HART was adapted to Internet Protocol (IP) back in 2007 to backhaul data from WirelessHART gateways, the addressing scheme defined by HART was no longer required. Rather, IP-addressing is used, and each device is assigned an IP address. It's as simple as that: HART-IP is the same as HART, but with IP addressing. It's the Ethernet-APL physical layer that makes it dramatically faster.

Inherent security

While Ethernet and IP represent much of what's good in the networking world, IP-addressable devices also come with the need to address potential security concerns. "If you're going all digital with an IP-routable protocol, you have to ensure security," says Peter Zornio, CTO Automation Solutions, Emerson. "And with HART-IP, these security features are mandatory, not optional as they are with some other device protocols for Ethernet-APL."

So, with the 2020 revision 7.7 of the HART specifications, requirements for specific security suites are now specified to provide communication security, audit logs and syslogging.

Communication security requires that new devices support the industry standard Internet Protocol Transport Layer Security (TLS) and Datagram Transport Layer Security (DTLS) suites. HART commands have been added to simplify security deployment and aid users in navigating multiple security options. Additional diagnostics and forensic requirements are also included.

Devices are required to capture audit logs that summarize communications activities, including records such as client identification, connection start/stop times and whether the device configuration was changed in that session.

Finally, HART-IP devices also must support syslogging, an industry standard means of publishing device events to a network's security information and event management (SIEM) system. All HART-IP devices must support network time using either Network Time Protocol (NTP) or Precision Time Protocol (PTP). Consequently, all syslog messages from all network devices are time synchronized, enabling forensics on network-wide behavior and activities.

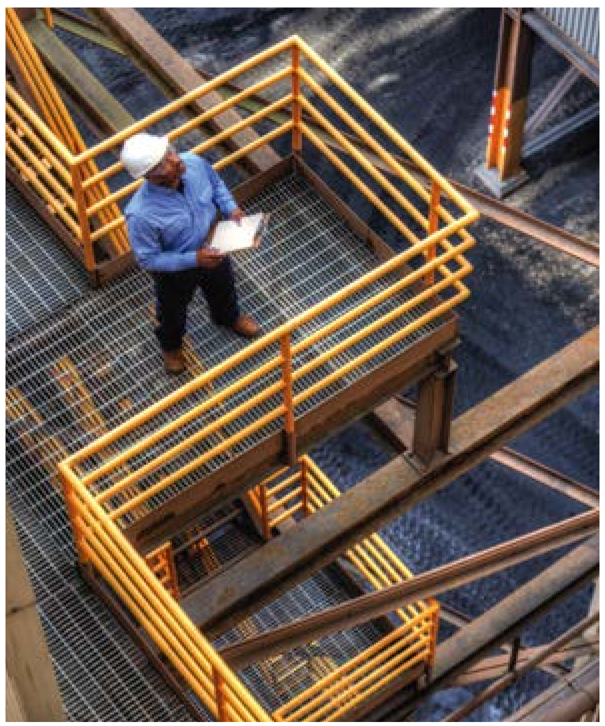
Combining communication security, audit logs and syslogging results in robust security for HART-IP enabled products.

"With Ethernet-APL, operators will have the need to really be up to date with all the of the firmware and the software they're using," says Thomas Rummel, senior vice president of engineering and product management, Softing Industrial Automation. "In the past, the attitude was 'it's running now, so never change it,'" Rummel explains. "But in the future, you'll have to ensure that all security patches are kept up to date and no back doors are left open."

These new requirements for intelligent device management, switch configuration and other similar tasks may well present the opportunity to have IT-trained personnel contribute more directly to the support of process operations.

"For years, we've talked about the convergence of IT and OT," notes Wally Pratt, director of field communication protocols for FieldComm Group. "And while there's sometimes been resistance from the operational side of things, it's in the IT group's wheelhouse to take to care of tasks like network security management, patching, firewall configurations and the like. Let the IT people do what they do best."

> "Let's build on a widely adopted and pervasive infrastructure where we have lots of people that understand it and know how to maintain it."
>
> — Jason Urso, Chief Technology Officer, Honeywell Process Solutions



> "We might want to add to what's available in HART-IP, but starting there with the ability to grow would allow for a smoother transition."
>
> — Robert Sentz, Senior Engineering Specialist, 3M

Easy does it

And with HART-IP, securely commissioning a new Ethernet-APL device can be just as easy as it is to securely commission a WirelessHART instrument, Pratt continues. "Take it out of the box, put it on the bench, hook up a handheld and enter a network ID and join key. Then just put it out in the plant and it works. We're trying to do the hard stuff inside to make it simple on the outside."

Both Dow's Jeff Konrad, technical solutions team leader, automation interfaces, and 3M's Robert Sentz, senior engineering specialist, envision that Ethernet-APL field network security would be an extension of the long-established IT security practices now used at the higher levels of their companies' Ethernet-based automation and information networks.

And when it comes to 3M's first adventures in Ethernet-APL, "it might be nice start with something that looks very familiar," Sentz says. "I expect that we might want to add to what's available in HART-IP, but starting there with the ability to grow would allow for a smoother transition."

Jason Urso, chief technology officer, Honeywell Process Solutions, agrees that industry shouldn't waste a lot of time worrying about how devices talk to one another. "Let's build on a widely adopted and pervasive infrastructure where we have lots of people that understand it and know how to maintain it. We may find that new devices and different industries are better suited to other protocols than HART-IP, but Ethernet-APL doesn't preclude us using them as well."

"So, let's get this technology out to our customers as quickly as we can," Urso says. "So we can learn from it, adopt and adapt."

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Please Recycle This Magazine

Prep needed for student engineers

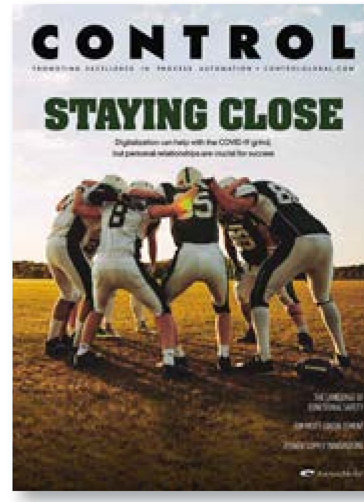
The heart of the piece with R. Russell Rhinehart's advice to graduates, "From student to practitioner" (Aug '21, p 45), is very sound; I liked it a lot.

But I think he let both academics and employers off the hook too easily.

There is a transitional period consisting of approximately the last year of schooling and the first two years of work when a new engineer is, in effect, an apprentice. An apprentice needs to receive practical instruction and mentorship. Academe fails to acknowledge that the first year of that apprenticeship is best incorporated into senior engineering courses because the students are all there studying full time in an atmosphere designed for teaching, and because many practical concepts are applicable to the entire profession. Senior year instruction tends to favor the research interests of professors rather than practice topics that would benefit the soon-to-be-professionals. Seniors should be receiving training in process safety, various aspects of detailed design (including automation) and practical statistics directed towards continuous improvement, quality management and reliability engineering.

Employers need to acknowledge the nature of the apprenticeship, allocate a fraction of new hires' work time to structured professional training, and devote experienced professional man-hours to giving that instruction, either internally (larger companies) or collectively with other companies. Mentorship should be explicit. Employers should also direct their hiring to those schools that include practice education, rather than those schools with impressive research pedigrees.

Yes, there is a widening chasm between academe and industry. Simply acknowledging the gap and blaming the other side isn't sufficient. Both sides need to invest in building their half of the bridge over it, especially the painful need to allocate precious headcount resources in academic faculties and industry engineering groups to address the problem. Good solutions require people and time.



We may be headed for a future where young engineers learn some or all of this online, but good universities and good companies will strive for better than that because in-person instruction makes for better engineers.

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In praise of print

In reference to Jim Montague's column, "Print is old news" (Aug '21, p 54), my online learning always turns into a free-for-all of YouTube and Google searches. I use textbooks and print magazines for serious learning.

I abandon online articles at a high frequency. I don't skim as rapidly with print magazines, and in many cases, I read quite intently. I sometimes Google things in an online article, and get sucked into other interesting stuff. The emails are always coming. Work is beckoning me to stop slacking. The music streaming needs attention. The ad needs skipping. You know.

The last article before yours was Greg McMillan's control loop discussion. I read it very slowly and carefully. I just don't do that online, even when I try. There's a Zen quality to sitting in the La-Z-Boy with a novel. Not so online.

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The forces reshaping tomorrow's DCS

MARK TAFT
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solutions.abb/controlsystems

SINCE its introduction more than four decades ago, the distributed control system (DCS) has made enormous contributions to the safe, efficient, and reliable operation of innumerable industrial processes around the world. And when it comes to global footprint, one supplier, ABB, has had market-share bragging rights for at least half that time, according to ARC Advisory Group's annual reports.

It should come as no surprise then that ABB is paying very close attention to the technological and demographic winds of change that are reshaping how automation gets done in the 2020s and beyond. To learn more about these forces—and how ABB is responding to them—*Control* caught up with Mark Taft, group vice president responsible for ABB's process control systems offerings worldwide.

Q: At this moment in time, there seems to be a confluence of user-driven initiatives toward control system openness that show real promise. What do you see as the motivating force for these movements, and how do you expect they'll affect ABB's DCS offering in the months and years to come?

A: One key difference with initiatives like OPAF, NOA and Modular Automation is that customers have taken a much more active role in driving them forward. Because of that, I believe there will be much broader adoption and engagement, and ultimately, they'll achieve their objectives.

One of the major drivers for DCS owners is a frustration that lifecycle costs for supporting their automation assets are higher than they'd like them to be. Further, they feel locked in by suppliers and control architectures that make it hard to innovate or add new functionality. Our customers' businesses have changed, too. They've overhauled the portfolio of products they take to market through divestitures and acquisitions. So, we now have companies that once relied on one or two suppliers for their automation needs facing a portfolio of very diverse automation technologies. This is especially stressful for central support organizations.

DCS owners are looking for a more simplified engineering and commissioning paradigm than what they've faced in the past. They need to be more agile, able to reconfigure their manufacturing processes to deploy new product variants. And, they're building plants in parts of the world that just don't have automation expertise available. So, they need a system that can be automatically commissioned and isn't so reliant on having expertise on the ground.

Q: "The Power of Integration" has long been a rallying cry for ABB. But in earlier days we were more concerned with the integration of control platforms with other plant systems to deliver synergistic value. What does the Power of Integration mean today in the context of these new dynamics?

A: I still think integration is going to be desirable and it's something that our customers are still going to be very interested in. But I think the role of the control system in providing that integration is going to change. Until now, the DCS was the glue that provided that integration, and as such we were focused on integrating other systems with the control system itself, and then exposing that information in a way that was easy to use for our customers. Looking forward, the control system will still be key in providing information from the plant floor. But with evolving, standardized models such as OPC UA, the ability to exchange information between applications from different suppliers will be easier.

I also think that how that integration is supported will remain a key area of potential differentiation in this new standards-driven market. In this brave new world, it's up to us, as suppliers, to anticipate and fill those gaps. We need to ensure that customers meet their objectives, and don't have to compromise.

Q: Another undeniable trend affecting the process industries is a demographic shift from the generations that created and optimized the original DCS to digital natives unfamiliar with the "old" technology that we sometimes find so comforting. Will this shift accelerate the uptake of new automation paradigms?

A: Frankly, my generation has started to retire, and that transformation has begun. This new generation of management, engineers and operators want to see something more modern, more like the technology that they've grown up with. They're much more willing to tackle their automation and optimization challenges in new ways.

Another result of this shift is an exodus of the most experienced personnel. We have to provide an automation platform that incorporates innovative new technologies providing intelligent, guided assistance to the people using these systems.

Q: While we strive to recover from the COVID-19 pandemic, waiting in the wings is the even more urgent issue of climate change and industrial sustainability. What role can automation platforms play in helping society make strides toward a decarbonized industry?

A: First, as a product supplier, ABB has a keen focus on supporting a low carbon society. We've set a target to be completely carbon neutral in our own operations by 2030. And that means we need to deliver products that are more energy efficient in their designs, and incorporate sustainable materials to help meet that objective. And, of course, we'll focus on providing products that have lower cooling requirements, lower power consumption and use recyclable materials, not only in our products, but in the packaging that we used to ship them around the world.

Another aspect of sustainability is reducing the amount of hardware required to run a system by taking advantage of virtualization and other technology advances in that area. So, as a product supplier, that's where we play. But probably the bigger impact is that ABB has also set a target to support our customers to reduce their carbon emissions by at least 100 megatonnes by 2030. That's about 100 billion kilograms, equivalent to taking 30 million combustion vehicles off the road.

The distributed control systems of tomorrow will be increasingly open, modular, intelligent and secure, facilitating agile innovation while continuing to protect end users' intellectual property investments.

Q: From a higher view, what will the DCS of the future look like compared to the traditional DCS we used for the past 30 years?

A: From an engineering standpoint, there's a real push from our customers now to raise the level of engineering above the coding of control logic for every automation project. Rather, I see us raising project engineering to a more modular level from both software and hardware perspectives. That will help with agile innovation, making it easier to add new functions and technologies and deploy what we call extended automation components in a way that doesn't affect the entire system. We need to have modular components that can be upgraded separately and still play together. This desire to develop applications in a way that's completely divorced from how they'll be deployed will be fulfilled.

Cybersecurity will be out of the box, built into the components rather than layered on top. I also see us working to automate engineering and commissioning activities. And you won't need to have the same innate, deep knowledge that you do today about how the system works to deploy it and support it in the field.

It's also very important to ABB to think of new technologies in the context of the thousands of automation systems already in use out there. From our perspective, that's going to be critical: helping our customers make that jump forward to the new technologies, but retain the intellectual investments they've made to get them to where they are today. ∞

To hear more of Mark Taft's insights into the future of the DCS, listen to the companion *Control Amplified* podcast episode on ControlGlobal.com or subscribe at the iTunes store or Google Play podcasts.

The first rule of digital transformation

Is to talk about your digital transformation. Industry opens up—to everyone's benefit

ALLISON BUENEMANN
Industry Principal
Seeq Corp.

"A rise in publicly available data storage, infrastructure, analytics tools and open-source algorithms has differentiated between competitive advantage and simply embracing new technology."

QUESTIONS around digital transformation in the heavy process industries no longer begin with "if," but instead with "when" and "how." By now it's universally acknowledged that the digital technologies of the fourth industrial revolution can generate significant return on investment (ROI). These technologies center around data and how it's collected, stored, accessed and analyzed.

Digital transformation is a journey, and there are many unique routes to successful outcomes. Companies in the same vertical—with similar revenue, headcount and organizational structure—often take very different approaches. But one thing many industrial leaders in digital transformation have in common, and perhaps the most surprising characteristic of the digital age, is that they're all talking openly about their digital transformations, and this information sharing is having a positive impact.

A shift in mindset

Technology has historically been considered a source of competitive advantage in the process manufacturing industries. While a company's home-grown solutions are typically proprietary intellectual property, a rise in publicly available data storage, infrastructure, analytics tools and open-source algorithms has differentiated between competitive advantage and simply embracing new technology. As industrial companies navigate these new technologies together, there's much to learn about what they're using, what it's enabling, and how it fits in their overall data strategy.

Intra-industry tech sharing offers many potential benefits, the first of which is understanding which of the tools available have had proven success in a particular vertical. Given the large number of data storage and analytics offerings available today, this can be an important steppingstone in honing the list of technologies to a manageable number for evaluation.

Another opportunity for intra- and cross-industry collaboration is verification that a particular solution meets the cybersecurity and regulatory requirements of other companies in

PREDICTIVE MAINTENANCE AND OTHER ANALYTICS ENDEAVORS

Figure 1: At the "AWS for Industrial Web Day," chemicals manufacturer Covestro shared how it's working with Seeq, OSIsoft and Amazon Web Services to lower barriers to data and analytics toolsets for its global workforce.

the industry. For example, a pharmaceutical manufacturer may be more receptive to a new technology if it's already undergone validation by some of their peers. For technologies where system integrators and other service providers are crucial or helpful, these conversations can also help whittle down the list of possible partners.

Platforms for digital discussion

There are several different avenues for sharing digital strategies and learning among end users. Each offers different levels of audience engagement to learn, discuss and collaborate.

Events and tradeshows can be an excellent opportunity to learn how others in your industry are leveraging digital applications, platforms and technology partners to drive operational excellence. One example of this was the recent participation by global chemical manufacturer Covestro and Seeq Corp. in Amazon Web Services' "AWS for Industrial Web Day." Covestro, a leader in digitization in the chemical vertical, launched an initiative called process data analysis and visualization (ProDAVis) to provide all employees at its sites worldwide with the data access and analytics toolsets required to achieve successful digital transformation.

At AWS for Industrial Web Day, Covestro presented a compelling story about how their partnerships with technology companies OSIsoft, Seeq and AWS tie into their ProDAVis initiative. This forum also gave them the ability to showcase how each of the different technologies worked together. Workflow integration among applications was demonstrated, and the strengths and weaknesses of each application were highlighted. The presentation closed with a broadly applicable industry use case—monitoring heat exchanger fouling via data-driven models—and a demonstration of how digital technologies were used to transform data into actionable insights (Figure 1).

Another way manufacturing companies are sharing their digital strategies is by engaging with IT and OT analyst firms. These engagements can take the form of event presentations, webinars, case studies, industry reports and other avenues. The output can provide compelling evidence of digital success for peers exploring potential solutions.

For example, Duke Energy, a leader in developing innovative wind and solar energy solutions, presented at the February 2020 ARC Industrial Forum, highlighting how they were using Seeq digital technologies to predict wind turbine failures.

Turbine failures result in reduced power generation from renewable sources, requiring make-up from fossil fuel resources like coal and natural gas to keep the grid stable. An understanding of when turbine failures are likely to occur allows wind energy producers to proactively take turbines down for maintenance and spread their production potential across remaining resources, reducing reliance on fossil fuels and improving sustainability.

Presentations like this one from Duke Energy are critical to providing analysts with real-world applications of the industrial solutions they use and evaluate. This context helps ensure technology evaluations and solution selection guides are accurate and useful for other industry players.

One of the most interactive platforms for digital technology sharing across verticals is the user group. Given that these events are centered around a particular technology solution, the focus is less on solution selection, and more on technology platform integration and use case application.

In 2020, Seeq held user groups for major process industry verticals like chemicals, pharmaceuticals, oil and gas and utilities. The agenda for these events is comprised of a combination of customer presentations, vendor roadmap discussions and breakout sessions for peer-to-peer interaction.

Customer presentations range from high-level digital strategy within an organization, to nitty gritty use case solutions, to common industry problems. Attendees leave the sessions feeling energized about new possibilities for their technology solutions, and many expand their professional networks of peers and advisors.

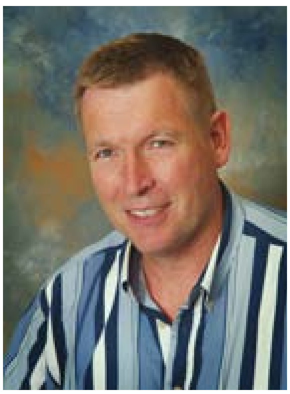
Digital transformation is enabled by technology, but many end users don't see these initiatives as proprietary intellectual property, but as information to be shared among peers. This openness helps advance efforts throughout the process industries by creating a new feedback channel for organizations as they continue their digital transformation journeys. ∞

Behind the byline

Allison Buenemann is an industry principal at Seeq Corporation. She has a process engineering background with a B.S. in chemical engineering from Purdue University and an MBA from Louisiana State University. Buenemann has over six years of experience working for and with chemical manufacturers to solve high value business problems leveraging time series data. As a senior analytics engineer with Seeq, she was a demonstrated customer advocate, leveraging her process engineering experience to aid in new customer acquisition, use case development and enterprise adoption. She enjoys monitoring the rapidly changing trends surrounding digital transformation in the chemical industry and translating them into product requirements for Seeq.

Retaining robustness for 'Etherbus'

Some key fieldbus functionalities should be preserved in field Ethernet implementations



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"The site had effectively tested and demonstrated a valuable feature of two-wire fieldbus—the controls could ride through a host system *faux pas* without the process being adversely affected."

THE factory had issued a recommendation to flash an earlier generation of fieldbus interface cards, also known as H1 cards. Like many microprocessor-based devices (home routers and smart phones, for example), a flash involves installing new firmware in the appliance, so named because, while it's software, it's more immutable than your smartphone apps. You may have noticed these tasks invariably mean the device goes offline and reboots after the new image is installed. But in this case, the systems specialist failed to notice the H1 card in question was not redundant, and once the process was started, it couldn't be reversed. What would happen to the control valves on the affected segments?

There was some indigestion for the minutes it took for the H1 card to come back online, but to everyone's relief nothing dire happened—the valves' default behavior was to hold last position and when the card was once again fully functional, the associated loops picked up where they'd left off. Measurements and final control elements effectively never went offline. While field power was maintained over its two-wire communications network, valves held and measurement devices continued measuring, awaiting the host system to send or request an update. The site had effectively tested and demonstrated a valuable feature of two-wire fieldbus—the controls could ride through a host system *faux pas* without the process being adversely affected.

It was not unknown for a DCS or PLC to allow some manner of configurable behavior for its conventional I/O, but it was found to have some disastrous results when such a configuration was poorly understood. Scary consequences, like a fuel gas valve remaining open when its temperature controller was no longer getting updates, persuaded many end users to simply default to all I/O going to the shelf or to a no-power state. Bumpless initial conditions recovery from a loss of communications from the host was also uncertain—no one was really sure the recovery would be smooth.

Bumpless recovery from a communications loss was solved by fieldbus, which employed mode shedding and recovery for many of its connected function blocks, especially those connecting to final control elements. Setpoints to an output block and feedback from it included messages buried in its status—the other characteristic of a digital fieldbus signal besides its numerical value. This facilitated a smooth re-initialization of the controller.

So at least three important and valuable aspects of two-wire fieldbus were demonstrated by the unplanned experiment: 1) field power to devices was maintained despite the absence of a functioning interface; 2) field devices had configurable behavior upon loss of communications, which contributed to overall control system robustness; and 3) provisions existed in the protocol to ensure bumpless initialization on resumption of communications. In our eagerness to extend Ethernet to the field, we should ensure such properties of fieldbus are maintained.

It's not uncommon to employ media redundancy for traditional Ethernet when employed in applications requiring high availability, like process controls. It's interesting to contemplate how frequently there's a demand to switch to the backup network. Ring topologies are not as easy to deploy, and special hardware is needed to facilitate a switch to the backup or reverse path. The network appliance needed to make the ring reverse may itself needs to be redundant. Is it? Is it hot-swappable? Indeed, with field Ethernet networks, our concerns shift from the media itself to the many active devices and transducers needed to make it function. The media may remain unbroken, but the copper-to-fiber converter—or the non-redundant power supply supporting it—may fail.

Achieving fieldbus-like fault tolerance for two-wire Ethernet should likewise focus on its most vulnerable components. I would argue it isn't the media (two-wire twisted pair copper) but the switches and power supplies through which we might connect dozens of field devices. "Etherbus" field devices need to ride out network disruptions in a manner that permits recovery without adversely impacting the process we're monitoring and controlling. Like old H1 fieldbus, thoughtful accommodations for fault tolerance, robustness and bumpless recovery from most network faults are critical for adoption. ∞

Wireless lessons for wired networks

Knowing one's assets is the first step in managing them—and securing them, too

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"Almost everyone who does a first scan of their system, especially a wired system, finds something they didn't know was there and, in many cases, consuming significant bandwidth."

THE most important aspect of asset management is the starting point: awareness of what assets you have. This is especially true when the assets connect to your networks, as they're also potential cybersecurity vulnerabilities.

Because you can only respond to something about which you're aware, checking and managing the assets themselves is also the first step in the cybersecurity chain. In other words, knowing who and what is connected to your system allows you to determine what's connected that shouldn't be.

Fortunately, there are many tools available that can passively scan your wired and wireless networks on a regular basis to find all the connected devices. That information can then be compared against a database of what should be there, and issue alerts about any discrepancies. Almost everyone who does a first scan of their system, especially a wired system, finds something they didn't know was there and, in many cases, consuming significant bandwidth.

Similar tools are available to watch overall network health for changes in traffic patterns, and report the same over a standard interface, so proper actions can be taken before an event grows into an incident.

Compared to fixed networks, wireless networks offer some additional tools to effectively manage assets that can move, potentially transferring across access points or between physical networks. Because of these unique challenges, wireless sensor networks (WSN) tend to have more, basic, built-in security features, as well as tools to keep track of moving assets. These include:

- IEEE 802.15.4 radio networks and specific protocols;
- AES-128 encryption for all communications within the network and the gateway;
- Individual device session keys to ensure end-to-end message authenticity, data integrity, receipt validation and secrecy (non eavesdropping by other devices in the mesh network) through data encryption; and
- Hop-by-hop cyclic redundancy check (CRC) and message integrity code (MIC) calculations to ensure message authentication and verification of the source and receiver of communications.

The above list reflects tools from a wireless perspective, but the same reasoning holds for all digital assets, particularly if they're able to communicate with one another via an RS-232/ RS-485 serial connection, or a digital protocol such as one of the fieldbuses on which devices tend to “auto-negotiate” to announce their presence on a network, or a HART device that fires up once power is added.

I understand work is being done through a dedicated ISA-99 Working Group as well as some of the fieldbus consortia to address security vulnerabilities at the wireless and wired field sensor level. More on these developments when they're published.

The larger and more difficult asset management challenge is with IEEE 802.11 (Wi-Fi) devices as they seem to be everywhere. Being so prevalent means these devices are constantly moving in and out of different hotspots, and have the potential to connect to plant networks as well.

Both 802.11 and 802.15.4 employ the clear channel assessment (CCA) technique, which means they listen to the channel to make sure there are no ongoing transmissions before starting to send. This prevents collisions, but it also has the effect that if you're using a software-based network monitoring tool, you may not capture the true total picture.

Cybersecurity is a constantly changing landscape. However, not knowing what you're trying to manage compounds the problem. Asset management not only keeps an inventory of networked equipment, but it also provides information on the nature of each device and its capabilities, from which it's possible to infer expected behaviors under different conditions. Knowing what you have where is also an important step in being able to respond and react when something requiring intervention does occur.

“When it comes to security,” it’s often said, “asset awareness is the first step to a solution.” ∞

Emerson takes controlling interest in AspenTech

New combined software unit to include OSI Inc. and Geological Simulation Software divisions

EMERSON (www.emerson.com) and Aspen Technology (www.aspentech.com) reported Oct.11 they've agreed to have Emerson purchase 55% of AspenTech for about $11 billion in cash and stock. AspenTech will be combined with Emerson's OSI Inc. and Geological Simulation Software businesses, and together they'll create a "new AspenTech" that will be a "highly diversified, high-performance industrial software leader with greater scale, capabilities and technologies" and "support the entire lifecycle of complex operations across a range of verticals, including design, engineering, operations, maintenance and asset optimization."

The new company will enable Emerson to realize synergies and accelerate its software strategy, and give it a platform and flexibility to strategically deploy capital for growth through continued investment and mergers and acquisitions (M&A). It will also retain the AspenTech name, but will be fully consolidated into Emerson's financials, and is expected to be accretive to adjusted earnings per share (EPS) after the first year.

"We saw an attractive opportunity to accelerate our software strategy to capitalize on the rapidly evolving industrial software landscape and advance Emerson's high value portfolio journey," said Lal Karsanbhai, president and CEO of Emerson. "Our customers are increasingly seeking partners to help realize stronger performance as they automate workflows in their facilities to optimize operations. New AspenTech will become an engine for both acquisition and organic growth."

Antonio Pietri, president and CEO of AspenTech, who will lead the new company, adds, "This transaction enables us to advance our position as a premier, highly diversified industrial software leader poised for growth, strong financial performance and a vehicle to drive software acquisitions, while providing immediate cash value to AspenTech shareholders. The new AspenTech will benefit from a larger, more diverse market, which we'll be able to serve with a comprehensive software portfolio, expanded global sales channel and an even stronger balance sheet reinforced by Emerson. This transaction also expands our ability to support customers' global sustainability ambitions."

Once the purchase is complete, the new AspenTech will have more than 3,700 employees, and is expected to achieve $1.1 billion in revenues for fiscal year (FY) 2022, double-digit annual growth in spending through 2026, and attract software talent. Other benefits of the new firm will include:

- Software portfolio that spans the full asset lifecycle, such as industrial AI and asset optimization with Emerson's grid modernization technology, advanced distribution management systems and geological simulation software.
- Joining OSI and Geological Simulation Software will let AspenTech expand into new, high-growth markets. For example, OSI will let AspenTech to develop its transmission and distribution offering to support power grid modernization and reliability.
- Increased collaboration and revenue for OSI and Geological Simulation Software by moving to token and subscription business models, and increased technology sharing and innovation between Emerson and AspenTech's 1,400 software engineers.
- Strong cash flow generation that will allow AspenTech to drive increased innovation and growth.
- Strong platform for future M&As in the consolidating industrial software industry. The new company's expanded solution set, broader global footprint and larger installed base will let it access a wider range of acquisition and investment targets across industries, products and geographies.

Schneider Electric turns dilemmas into opportunities

Disruptions due to COVID-19, climate change, accelerating technologies and aging demographics have many process engineers wondering where to turn. Luckily, Nathalie Marcotte, president of process automation at Schneider Electric, and Michael Martinez, EcoStruxure Foxboro DCS leader at Schneider Electric, have decades of experience with evolving technologies and automation strategies, which they discussed online during Innovation Talks: 2021 Foxboro and Triconex User Groups in mid-September.

"Universal automation will enable us to be ready for the next generation of industry," said Martinez. Marcotte added, "This is all about what this technology does for our clients."

The pair agreed the pandemic has accelerated automation programs, including quicker adoption of automated processes, more remote and unmanned operations. "The fear of digital has been relieved," explained Marcotte, who detailed how this new confidence is enabling greater resilience in industrial initiatives and the supply chains that fuel them.

Marcotte referenced a biodiesel customer that asked Schneider Electric to help it meet new sustainability goals and enhance its digital integration and automation capabilities—all within a cramped, brownfield environment. The user implemented Schneider Electric's EcoStruxure stack and other solutions, and the result was a 15% reduction in capex, quicker project delivery and the ability to meet aggressive sustainability goals. "And, we were able to accomplish this, powered by digital, in a fully virtual environment during COVID," added Marcotte.

In a separate presentation, Martinez reported how Schneider Electric's long-proven EcoStruxure Foxboro DCS works with its

EcoStruxure Automation Expert software, which is a new cornerstone of the EcoStruxure ecosystem.

"EcoStruxure Automation Expert is part of our decentralized approach to native operations technology (OT) and information technology (IT) integration that we're calling Universal Automation," added Martinez. "Our vision is for it to be an app store for automation that provides plug-and-produce automation software that's decoupled from hardware. It also complies with the IEC 61499 standard for using function blocks for process measurements and control systems, and is designed to make operations more agile, reduce how much software is needed, and make process applications more cybersecure."

For complete coverage of Schneider Electric's Innovation Days, visit www.controlglobal.com/articles/2021/schneider-innovation-talks-2021

Inductive stages 2nd online event

Undaunted by having to attend remotely due to the pandemic, more than 2,500 visitors crowded virtually into Inductive Automation's second online, ninth overall and largest-ever Inductive Community Conference (ICC) on Sept. 21-22. The always close-knit community, united in their devotion to web-based Ignition HMI/SCADA software and its accessories, remotely experienced 40 live and prerecorded conference sessions, 10 demonstrations from 23 exhibitors and distributors, and 15 user presentations in its Discovery Gallery. Each exemplified how Inductive's longtime "easy, fun affordable" motto was joined by the event's "smarter, faster, stronger" theme.

"Inductive Automation's success can be traced to addressing the pain points I faced as a system integrator. Without that experience, I wouldn't know how to run a company like this," said Steve Hechtmann, founder and CEO of Inductive Automation, during ICC 2021's keynote address. "It starts with a foundation of being up to your eyeballs in a project; working 18-hour days under trying circumstances; and having the attitude that no one's going home until a solution works. Without that, what's the vision? If it's just money, that's a pretty low form of motivation. This is why our Ignition Exchange community is collaborative and collegial, and has enthusiasm and passion."

For example, Ignition Exchange members create, post and share resources, which others can download and uses—elevating everyone's capabilities. Ignition's open technology stack lets the company and its community listen to each other, improve their software more efficiently, and also enable programs like Inductive University program that provides free, open, online training. More recently, the company launched its University Engagement program, which gives Ignition software to dozens of universities.

"We've grown faster, smarter and more responsive to customers' needs through our continuous improvement process, which never stops cycling through our entire company, improving the weakest areas, and moving on to the next," said Hectmann. "It was hard when recent world events forced us to become a remote-first company. I had my doubts when we first switched to remote workflows, but they were unfounded because we didn't miss a beat, and in the long run it's made us more efficient."

Firebrand award winners

The 15 end-user projects featured in the ICC Discovery Gallery included four winners of Inductive's Firebrand Awards. Cox reported these projects included:

- Ginko Bioworks expansion of its automation capability to meet demand for more diagnostic and DNA sequencing test sample preparation during the COVID-19 pandemic. Ignition was implemented at the center of the company's facility, where it works with 50 PLCs, lab equipment, quality and vision systems. The software helps extract process data and meaningful test results, even as the lab's systems and equipment change layouts on a daily basis.
- BHP built a mining asset and infrastructure monitoring application for Minerals Australia's remote operations center, which uses Ignition to provide data via a modern server-based interface and a zero-install environment that's mobile-device friendly and has Industrial Internet of Things (IIoT) connections. The application monitors more than 30 sites, 20 network domains, tens of thousands of devices, and about 9,000 data points.
- Incat, a builder of high-speed catamaran ferries in Hobart, Tazmania, recently worked with Cromarty on a ship management system, which uses Ignition and its unlimited licensing to provide simple graphics throughout a vessel, and quickly highlight any abnormal situations. This application is fully redundant, and includes more than 100,000 tags, 5,000 alarms and 10 clients.
- CPM Beta Raven helped automate feed processing at Smithfield's hog production facility in Milford, Utah. Its feed mill previously relied on pushbuttons, relays and physical labor, so adding an Ignition-based system enabled it to improve ingredient and recipe accuracy, boost production results, establish inventory alarms and alerts, and perform loadout, historian and data analysis functions.

To view ICC 2021's online sessions, visit and register at https://icc.inductiveautomation.com/register

OPC, FDT partner on data visualization specification

FDT Group (www.fdtgroup.org) and OPC Foundation announced Oct. 1 their memberships have approved updating the FDT/OPC Unified Architecture (UA) companion specification (CS). This launches what they report is the only protocol-agnostic, server-level, universal device information (DI) model for process and discrete manufacturing, and empowers next-generation, open automation FDT architectures. The updated FDT/OPC UA CS unifies data for IT and OT users and processes, while enabling the transmission of uniform, real-time process, network and device information for any OPC UA client in an enterprise.

To download a copy of FDT OPC UA CS, visit www.fdtgroup.org/resource/fdt-opc-ua-information-model-for-fdt3

SIGNALS AND INDICATORS

- **Emerson** (www.emerson.com) announced Sept. 30 that it's agreed with hydrogen solutions provider **BayoTech Inc.** (www.bayotech.us) to accelerate the delivery of hydrogen worldwide. Emerson will deliver advanced automation technologies, software and products to enable BayoTech to build hundreds of hydrogen units to produce cleaner, lower-cost hydrogen. BayoTech's modular hydrogen generation units produce up to 1,000 kilograms per day.
- Under a contract with plant builder **SMS Group** (www.sms-group.com), **ABB** (www.abb.com) reported Sept.29 that two of its electromagnetic brake systems (EMBR) will be installed on two compact strip production (CSP) casters at **Tata Steel Ltd.**'s (www.tatasteel.com) flagship plant in Jamshedpur, India. ABB will also supply DCS800 DC drives, dry type transformers, water cooling systems, commissioning services and metallurgical performance evaluations.
- **Copia Automation** (www.copia.io) announced Oct. 5 that it's secured a Series A investment of $14.2 million to bring modern DevOps to coding PLCs to improve efficiency and reliability, and maximize uptime of automation systems. Copia adds its product enables robust Git-based source control with direct support for PLC programming environments by Siemens, Rockwell Automation and Codesys. All files are centrally stored with their history recorded, so users know when and why a change was made.
- **The International Society of Automation** (www.ISA.org) has recognized Jack Nehlig, president of **Phoenix Contact USA** (www.phoenixcontact.com), as the recipient of its 2021 Excellence in Leadership award, which recognizes an individual who has made significant contributions to the industry and/or profession to advance automation. Nehlig was nominated for the award by Brad Carlberg, PE, CSE, president of ISA's Richland, Wash., section, who praised him "for working with the Open Process Automation Forum (OPAF) and driving the development of an open PLC."
- **Newark** (www.newark.com), an Avnet company and electronics distributor, introduced Oct. 7 configuration-based solutions with data acquisition software and hardware from **National Instruments** (www.ni.com) coupled with sensors from **Omega Engineering** (www.omega.com). These solutions reduce the need to research system compatibility, saving users time and money in temperature monitoring, reliability testing and product-lifecycle evaluation.

Module type package aids interoperability

Control's monthly resources guide complements MTP feature article on p 58

MTP WEBPAGES AT NAMUR

NAMUR's website includes several webpages with useful information about MTP, including "Automaton modular plants" with links to an overview about MTP and a one-page flowchart. The website also has a "WG 1.12 Modules/Plug-and-Produce" page that details the organization's activities, goals and advantages of modularizing with MTP. It also includes a link to an abstract of NAMUR's NE 148 recommendation on "Automation requirements relating to modularization of process plants." They're at www.namur.net/en/work-areas-and-project-groups/wa-1-project-planning-and-construction/wg-112-modules/plug-and-produce.html. NAMUR also presented a 15-minute video, "Drivers for plug-and-play concepts" by Michael Krauss of NAMUR at ARC Industry Forum 2019 at www.youtube.com/watch?v=jFzTamzmxB4

NAMUR
www.namur.net

EASIER COMMISSIONING

This four minute video, "INVITE and Festo show efficient commissioning of modular plants applying the MTP approach," shows how a proof of concept uses standardized formats for data exchange in engineering and production ensure that individual production modules can be integrated into higher-level automation systems regardless of the manufacturer. It's at www.youtube.com/watch?v=ADYvrAMhjMY. The company also presented a 30-minute video, "ACHEMA Pulse 2021: Modular production with MTP" by Alexander Kehl and Valentin Buleac at www.youtube.com/watch?v=DL521GVoWDc

FESTO
www.fresto.com

MODULES IN NOA CONTEXT

This 20-page report, "Process Industrie 4.0: the age of modular production," and four-page flyer, "Process Industrie 4.0: future production is modular and open," cover the concepts of modular production, and present flowcharts about MTP and the NAMUR Open Architecture (NOA), and how they achieve greater interoperability. They're at www.zvei.org/en/press-media/publications/status-report-modular-production-on-the-doorstep-to-market-launch and at www.zvei.org/fileadmin/user_upload/Themen/Industrie_4.0/Modulare_Produktion/HM_2020_digital_days_Sonderschau_Modulare_Produktion_final.pdf

ZVEI
www.zvei.org

INTEGRATING MODULES AND SOFTWARE

This 11-minute video, "How to easily integrate equipment using MTP technology—product demo," covers how MTP (NAMUR 148) interface specification standard and software can make it easier to integrate process equipment, such as Emerson's DeltaV DCS and PACSystems AMS, and their applicable data objects and control logic. It's at www.emerson.com/en-us/automation/control-and-safety-systems/module-type-package

EMERSON
www.emerson.com

TWINCAT FOR MTP PROCESS

This eight-page whitepaper, "TwinCAT for the process industry: MTP," defines MTP, and shows how it can be applied in a variety of process applications, such as dosing, reacting, mixing and filtration. It also covers module engineering, and how to integrate MTP into TwinCat communication protocol. It's at www.beckhoff.com/media/downloads/information-media/beckhoff_mtp_d.pdf. The company also offers a 14-minute video, "TwinCAT MTP: standardized interfaces for modular systems," on the same topic at www.youtube.com/watch?v=xcxcRzZAwB4

BECKHOFF
www.beckhoff.com

TWO VIDEOS AND A GUIDE

These two two-minute videos, "Module Type Package—the way to a modular system" and "Interview: Module Type Package," present computer animations and a live interview at a recent SPS/IPC/Drives show about the advantages of using MTP in manufacturing. They're at www.youtube.com/watch?v=y6oNUXMQeMc and at www.youtube.com/watch?v=-ut6BkVBoBs. Wago also links to its eight-page guide, "Module Type Package (MTP)—the way to a modular system" at www.wago.com/us/digitalization/adaptability

WAGO
www.wago.com

MODULES FOLLOW FUNCTIONS

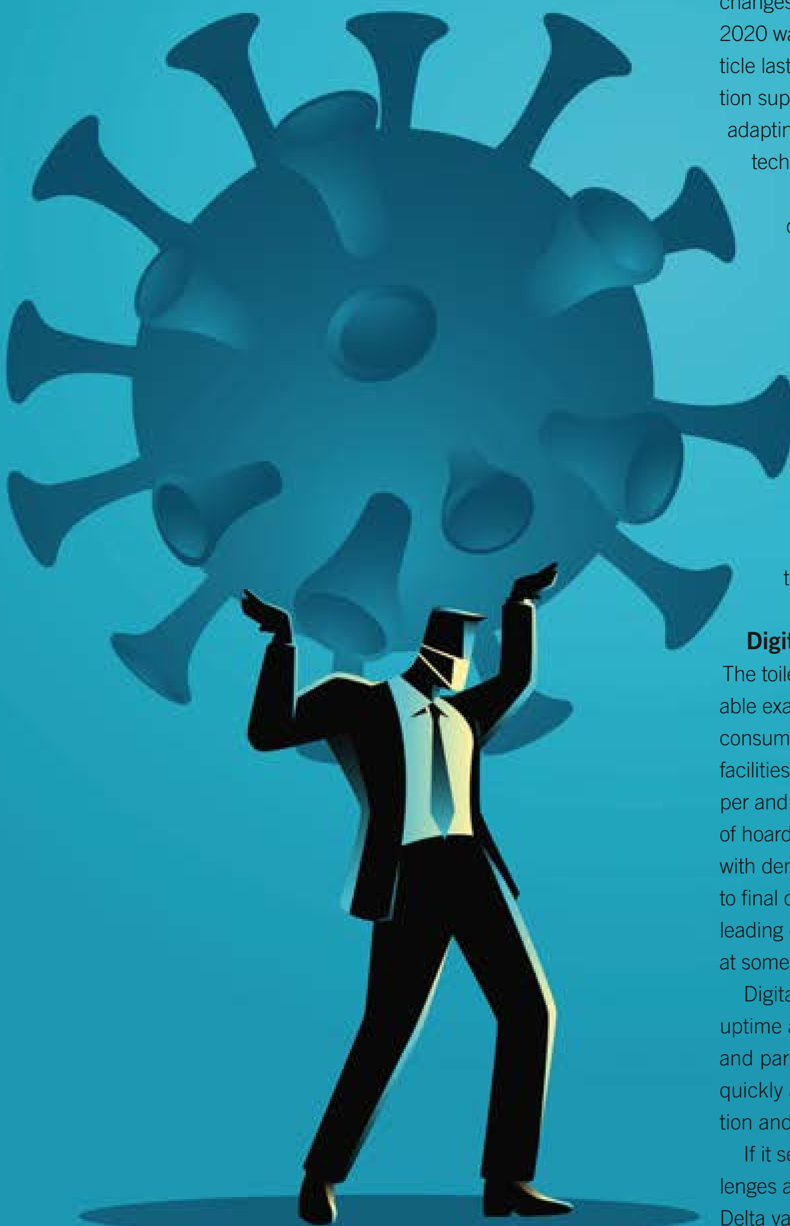
This six-page whitepaper, "Process module engineering," covers the function-based architectures of modular plants, and how MTP modules are developed. It's at www.controlglobal.com/assets/knowledge_centers/abb/assets/2010/Modular-Process-Plants.pdf. ABB also presents a three-minute video, "What is modular automation?" at www.youtube.com/watch?v=8aM7ZNZ5w9E s

ABB
www.abb.com

[Editor's note: see "MTP more than sum of parts" feature article on page 58]

If you know of any tools and resources we didn't include, send them to ControlMagazine@Putman.net with "Resource" in the subject line, and we'll add them to the website.

Rising to recover



The Top 50 global and North American automation suppliers keep rising to meet COVID-19, but the challenge isn't over yet

by Larry O'Brien, Allen Avery, Florian Güldner, Chantal Polsonetti and Sharada Prahladrao

THE COVID-19 pandemic is probably the greatest test of resilience the automation market has ever faced. It's changed how and where companies spend their money and the fundamental nature of work in the manufacturing sector, and many of these changes will last long after the pandemic subsides. We knew 2020 was going to be a challenging year when we wrote this article last year, but the Top 50 global and North American automation suppliers faced up to the challenges of COVID-19 by quickly adapting to changing market dynamics and capitalizing on new technologies that help end users become more resilient.

The primary enabler behind this improved resilience is digitalization. The Top 50 suppliers continue to expand their offerings for Industrial Internet of Things (IIoT) computing, cloud computing, virtualization, containerization and the entire suite of technologies that fall under the IIoT umbrella. At ARC, we've always promoted the idea that technology shouldn't be embraced for its own sake, but rather as an enabler for achieving operational excellence and improving returns on investment and assets. Many end users saw COVID-19 as the catalyst for creation acceleration and implementing digitalization efforts because there was simply no other way for them to adapt to the many challenges posed by the pandemic.

Digitalization cures vulnerable supply chains

The toilet paper shortage during COVID-19 is an easy and relatable example of the value of digitalization to manufacturers and consumers. The pandemic resulted in many empty offices and facilities, which resulted in a drop in demand for institutional paper and sharp rise in demand for residential paper. All discussion of hoarding aside, the paper producers largely couldn't keep up with demand because the entire supply chain from raw materials to final distribution wasn't agile enough. It's no accident that many leading digital transformation programs recently put into place are at some of the world's leading paper manufacturers.

Digital transformation directly affects agility, product quality, uptime and more. Opportunities and challenges arise quickly, and participants have to adapt and capitalize on them just as quickly and effectively. This is the ultimate promise of digitalization and the definition of resilience.

If it seems like everything is happening at once, it is. The challenges aren't over yet, as the more recent surge in COVID-19's Delta variant shows us. Other challenges loom, many of which

Top 50 Global Automation Vendors

2020 Worldwide Revenue (US$ millions)

1	Siemens	$12,025
2	ABB	$11,175
3	Emerson	$10,995
4	Schneider Electric	$6,636
5	Rockwell Automation	$6,211
6	Fortive	$3,773
7	Honeywell	$3,587
8	Mitsubishi Electric	$3,304
9	Yokogawa Electric	$3,257
10	Festo	$3,241
11	Omron	$3,211
12	Endress+Hauser	$2,941
13	Ametek EIG	$2,925
14	Phoenix Contact	$2,739
15	IMI	$1,961
16	Sick AG	$1,940
17	MKS Instruments	$1,900
18	Advantech	$1,755
19	Spectris	$1,724
20	GE	$1,466
21	Baker Hughes	$1,336
22	National Instruments	$1,287
23	Technip FMC	$1,286
24	Roper Technologies	$1,254
25	Fanuc	$1,233
26	Mettler-Toledo	$1,225
27	Wika	$1,170
28	IFM	$1,142
29	Wago	$1,120
30	Teledyne Instruments	$1,095
31	Aveva	$1,058
32	Flowserve	$1,058
33	Yaskawa	$1,052
34	Belden	$1,047
35	Beckhoff	$1,031
36	Thermo Fisher Scientific	$947
37	Weidmuller	$904
38	Harting	$866
39	azbil Group (Yamatake)	$856
40	Lenze	$826
41	Hitachi	$810
42	Eaton	$759
43	Fuji Electric	$758
44	Turck	$751
45	Bosch Rexroth	$745
46	Pepperl+Fuchs	$742
47	Samson	$689
48	Horiba	$658
49	Neles (Metso)	$657
50	Krohne	$638
Total		**$115,767**

Top 50 North American Automation Vendors

2020 North American Revenue (US$ millions)

1	Emerson	$5,267
2	Rockwell Automation	$3,723
3	ABB	$2,168
4	Fortive	$2,168
5	Schneider Electric	$1,659
6	Ametek EIG	$1,483
7	Siemens	$1,083
8	MKS Instruments	$1,059
9	Honeywell	$880
10	Teledyne Instruments	$788
11	Belden	$607
12	IMI	$588
13	Roper Technologies	$549
14	Spectris	$534
15	Advantech	$513
16	National Instruments	$492
17	Festo	$486
18	GE	$482
19	Thermo Fisher Scientific	$478
20	Mettler-Toledo	$474
21	Wika	$468
22	Flowserve	$430
23	Baker Hughes	$408
24	Endress+Hauser	$392
25	TechnipFMC	$386
26	Aveva	$342
27	Eaton	$333
28	Sick AG	$301
29	Omron	$249
30	Aspen Technology	$243
31	OSIsoft	$235
32	Turck	$227
33	Neles (Metso)	$191
34	Yokogawa Electric	$183
35	Yaskawa	$173
36	IFM	$171
37	Wago	$143
38	Mitsubishi Electric	$138
39	Phoenix Contact	$133
40	MTS	$131
41	Weidmuller	$127
42	Toshiba	$122
43	Parker	$112
44	Badger Meter	$107
45	Valmet	$96
46	Harting	$90
47	Horiba	$90
48	Beckhoff	$89
49	Pepperl+Fuchs	$88
50	Lenze	$87
Total		**$31,765**

are outgrowths of the pandemic. The supply chain has become particularly vulnerable. The silicon shortage has created numerous challenges for just about everybody in manufacturing. Cyberattacks have shut down ports, assembly lines and water treatment plants. The increasing pace of climate change and changing nature of the hydrocarbons industry are creating renewed momentum for renewable energy, and resulting in the “mass electrification” of many applications and technologies that previously relied on more hydrocarbon-based sources of power. Reimplementation of lockdowns changes consumer demand quickly.

COVID-19’s impact on the workforce is also accelerating adoption of many new technologies we mentioned last year. End users are on a path to autonomous operations, and the drive to improve the safety of work environments is resulting in changes in everything from control room design to shift management and the cybersecurity of remote workers. Remote work isn’t just for cubicle farms anymore. More operations personnel are performing their duties offsite, so access to sensitive plant and production information must be done remotely and securely. End users are escalating the use of remote access to reduce field visits, enable remote personnel, and provide remote troubleshooting and training.

Consolidated revenues for the top 26 automation suppliers tracked by ARC contracted by over $8 billion between 2019 and 2020, but the suppliers became more agile and the market is already making a substantial recovery into the first half of 2021.

Challenging traditional suppliers

The Top 50 suppliers have done an admirable job of addressing the challenges brought on by COVID-19. Keep in mind that the suppliers themselves were already on a path to digitalization when the pandemic struck. Probably their biggest challenge was articulating the value proposition of digitalization to their customers, but COVID-19 provided ample impetus for customers to adopt IoT technologies and speed up their digitalization programs. While the automation suppliers of the world may start to look more like Google, Amazon Web Services (AWS) or Microsoft, don’t expect the latter to replace the former any time soon. The automation suppliers continue to take the new technologies offered by the IT suppliers, and put together solutions that are tailored for specific manufacturing applications. Plus, they still have plenty of their own technology and service expertise to offer. End users are also using digitalization and digital transformation to gain insight and visibility into supplier performance, inventories and other metrics.

The application-specific nature of the engineered systems in manufacturing applications, and their extreme real-time, mission-critical nature will always be the distinguishing factor for the world of operations technology (OT). The deep expertise in these unique applications will continue to be a key differentiator for automation suppliers, regardless of which new technology they use. If you don’t understand the problems faced by OT, you can’t use information technology (IT) as a magic wand to create solutions. This is why we don’t see major changes in the list of suppliers year after year—nobody has stepped in to successfully challenge them.

Companies like Google and Microsoft are also referred to as "hyperscalers" because they can offer cloud, networking and Internet services on massive scales. While the hyperscalers probably won’t replace the leading automation suppliers in the near future, hyperscalers are responding to the importance of the IIoT edge in fulfilling their value proposition by extending their reach into lower tiers of the architecture. Hyperscalers are extending their reach, not only in search of data, but also in pursuit of executing analytics, artificial intelligence/machine learning (AI/ML), augmented reality/virtual reality (AR/VR) and similar applications at the edge. Microsoft Azure IoT Edge, AWS Greengrass, and Google Cloud IoT Edge represent just some of the edge initiatives by enterprise cloud providers. Concurrent with the descent of the hyperscalers is the adoption of cloud-native and open-source technologies that offer numerous advantages in design, management and scalability. Numerous industry activities are pursuing specific aspects of IIoT, ranging from the Industrial Internet Consortium's (IIC) testbeds to open-source efforts such as Eclipse, EdgeX Foundry and LF Edge.

Plenty of end users still want to solve their own problems, and are looking at these new technologies as enablers for easier development of their own solutions. They're developing and deploying digital twins, high-fidelity simulations and more advanced cybersecurity organizations, and demanding more open and modular systems that are immune from the development cycles of the large suppliers, such as the new specifications offered by the Open Process Automation Forum (OPAF).

Automation and its associated work processes, from engineering and design to operations and maintenance, also remain burdened by needless complexity. Again, digitalization is providing solutions in the form of better integration between engineering and process automation applications, late-binding concepts, virtualization and containers, and software-defined networking. Technologies like procedural automation and bulk automation of manual tasks are increasingly being deployed to free up remaining personnel to focus on value-added tasks.

Coming out of the COVID-19 recession

The worldwide and North American automation markets almost universally declined in 2020 due to COVID-19. By April 2020, more than 80% of flights were restricted, cargo capacity was down, airlines and rental car companies reduced their fleets, and West Texas Intermediate Crude hit less than $37 per barrel. Consolidated revenues for the top 26 automation suppliers tracked by ARC contracted by over $8 billion between 2019 and 2020. But, as we’ve already mentioned, the suppliers themselves became more agile, and the market is already making a substantial recovery into the first half of 2021.

Among other things we do at ARC, we track the quarterly revenue growth of automation suppliers that publicly report their results. While we can't present those results to you here, we can tell you that the automation market rose by 17% in the first quarter of 2021. Almost all automation companies recovered or saw good growth in mid to high single-digit ranges in the first quarter. In 2Q21, almost all the automation companies continued on their recovery path, with some experiencing double-digit growth rates. Constant demand for automation products has helped the market grow at a much faster pace compared with 1Q21. Many of the recent supplier results show extremely strong growth in orders, but this doesn't immediately translate to increased shipments and revenues, and we should expect constrained growth in revenues vs. orders moving forward.

Chip shortage burdens manufacturers

Despite promises of capacity expansion and new projects, the microprocessor chip shortage continues unabated, and according to many sources it's getting worse. The impact of COVID-19 rippled through the silicon supply chain just as it did other industries. As the automotive industry was making a V-shaped recovery in the summer of 2020, the chip shortage was looming just a few months in the future, and it hasn't gone away. While automotive is facing the brunt of the shortage with projected chip-related losses at $210 billion in 2021, it's also hit the market for PCs, smartphones, GPUs, consumer electronics, smartphones and just about anything that requires a chip, including automation products and systems.

Again, the sensitivity and complexity of supply chains are a major force behind this shortage. According to semicondcutor.org, there are 50 points across the semiconductor value chain where one region holds more than 65% global market share. All of these points on the supply chain are single points of failure, which could easily be disrupted by natural disasters, pandemic shutdowns or other events.

For machine as well as automation companies, this is an extremely tough situation because their market power is often smaller compared to large automotive and consumer electronics manufacturers. The challenge for industrial users is the often-small batch sizes of semiconductors ordered because

OEMs and automation vendors often have small unit numbers shipped. On the other hand, smaller batch sizes and the less just-in-time nature of the value chain also enable OEMs and automation companies to be more flexible. Still, according to the German engineering association, VDMA, selected OEMs weren't able to deliver machinery due to the chip shortage. Looking at market shares, we'd expect that the larger the company, the more it can use its purchasing power to overcome the shortage.

In early 2021, a spokesman from the automotive industry estimated the chip shortage will be gone by the second half of the year. At present, it's still ongoing, and looking back to 2020, we can ask ourselves if investments in a more diversified and adaptable value chain will come. For example, Bosch invested in a large semiconductor factory in Dresden, Germany. The current outlook is that the shortage will last through 2021, and will most likely follow us into 2022. Many of the suppliers we speak to expect the shortage to continue through the end of 2022, given the current average 58-week lead time for all types of components like ASICs, CPUs and even metal. Intel corroborates this, warning that the worst is yet to come in the second half of 2021, and temporary shortages may remain for one to two years.

Semiconductor production is complicated and requires significant capital expenditures. This means it will take time, and many semiconductor companies will think twice before taking the money to ramp up capacity. After all, they operate in a market full of natural monopolies and higher prices mean higher margins.

Open Process Automation

The Open Process Automation Standard (O-PAS) continues to move forward with its vision of a standards-based, open, secure and interoperable process control architecture, which lets end users preserve their existing investments, while simultaneously enabling them to move forward with new investments in technologies and applications. A significant milestone was achieved in May of this year, when Version 2.1 of the O-PAS standard was published. Where possible and applicable, O-PAS embraces existing industry standards for industrial automation systems. These documents are publicly available on the OpenGroup's website for the Open Process Automarton Forum (www.opengroup.org/opaf), where industry feedback on O-PAS is encouraged.

Another key event in terms of testing the utility of this standard is the Interoperability Workshop (PlugFest) planned for later in 2021. Currently, O-PAS Version 3 is being drafted and the themes are: application portability (Part 8), distributed control node (DCN) physical platform (Part 7), and orchestration, which OPAF members sometimes call “systemness.”

Business ecosystem building in OPAF

The Business Working Group within OPAF focuses on building a business ecosystem using the standard. The first version of the OPA Business Guide was published in 2019, and the team is working on Version 2.0. This guide provides valuable information about business scenarios across various industry verticals, stakeholder roles in the O-PAS ecosystem, conformance, certification and contracting processes. OPAF is working with other standards organizations and industry associations, such as the OPC Foundation, NAMUR, CSIA, ISA, etc. O-PAS already has a certification policy process that was published in February 2020. OPAF is also in discussions with multiple O-PAS verification labs, and the first wave of the certification process is expected to become operational in the first quarter of 2022.

Increasing importance of cybersecurity

OT cybersecurity strategies with basic, passive defenses may have been enough for yesterday's basic malware attacks, but they can't protect companies against today's threats. OT systems also need advanced defenses to protect systems from sophisticated attacks, like the recent Triton and SolarWinds incidents. Such attacks may target specific operations to achieve political and espionage goals. These attackers have the resources and funds to research companies fully, identify exploitable security weaknesses, penetrate defenses with a variety of surreptitious techniques (spear phishing, supply chain downloads, etc), and develop complex malware to accomplish their goals.

Ransomware attacks on industrial companies, such as the one that disrupted Colonial Pipeline's operations, are increasing at a frightening pace. One recent research report noted that almost one-third are launched against industrial companies because cyber-criminals recognize that the incredible costs of downtime can encourage ransom payments. Organizations that provide critical infrastructure, like power, water and transportation, also face external pressures to rapidly restore operations. While the focus of many of these attacks has been limited to IT, there's every reason to expect eventual movement into connected OT systems. Thriving cyber black markets will also increase the number of such attacks and raise the risks for industrial companies. In this environment, cybersecurity is no longer an afterthought.

Consequently, virtually all suppliers are increasing their investments in their own cybersecurity solutions, investing in or acquiring OT-level cybersecurity suppliers, and strengthening their partnerships. There's still plenty of room for consolidation in the realm of OT level cybersecurity suppliers, which number in the hundreds. Many of these suppliers will make attractive acquisition targets for the automation suppliers in the future. With the increasing adoption of IIoT, cybersecurity technologies and approaches from the IT world are also being adopted at the OT level. Many of the more IT-centric cybersecurity suppliers are strengthening and expanding their offerings for OT applications. ∞

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When the heat is on, help your pressure transmitters keep their cool

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IDEALLY, a pressure transmitter is installed with the sensing element as close to the process as possible. Short impulse lines allow for the fastest dynamic response. But many industrial processes run at elevated temperatures and heat transfer by radiant, conductive or ambient paths can damage a transmitter's wetted materials or, more commonly, shorten the life of its electronic components. So, when process temperatures climb above 220°F, it's time to consider protective solutions that increase transmitter life and preserve process uptime without sacrificing responsiveness.

To learn about the range of solutions designed to facilitate safe and accurate pressure measurement at high temperatures, *Control* sat down with Doug Greaves, U.S. product manager, temperature and pressure, ABB Measurement & Analytics.

Q: Since heat transfer depends on proximity to the heat source, isn't mounting the transmitter further away and using longer impulse lines a logical and easy first step?

A: Most standard transmitters like the ABB 266DSH DP (differential pressure) and 266HSH Gauge are connected to the process via impulse tubing. Thoughtfully planning the path of the tubing can be a cost-effective way to extend transmitter service life without special seals, gaskets or material considerations.

Follow these recommendations when planning for a high-temperature application:

- While some distance is recommended, keep in mind that too much distance can dampen dynamic response.
- Note that impulse lines act as cooling fins, effectively reducing temperatures 150 °F per foot in common ambient conditions.
- Each impulse line should lead to a dead end, meaning no leaky connections and tightly closed instrument manifold valves. Sustained flow of hot medium to the transmitter effectively negates any coooling advantage gained by distance.
- In most cases, if the pipe is insulated, the transmitter should not be.
- Generally recommended impulse line sizing for lengths up to 50-ft is ¼ in. to 3/8 in. for water/steam/dry gas and ½ in. to 1 in. for wet gases/oil/viscous and dirty liquids. Beyond 50 feet, increase impulse line size to ½ in. and 1 in. to 2 in., respectively.
- When multiple impulse lines exist for the same measurement point (e.g., DP, redundant P), run lines together to maintain equivalent temperatures and try to keep each line the same overall length.
- In cryogenic applications, impulse lines work in the opposite direction, effectively warming process fluids before reaching the transmitter.

Q: When using impulse lines for differential pressure-based tank level measurement, what are the considerations between dry leg and wet leg installations?

A: It really depends on the process medium. Does cooling the headspace gas never, sometimes or always result in condensate? If normal is "no" or "some," a dry leg impulse line can likely do the job. If condensate is normally expected, use a wet leg impulse line instead, where the headspace impulse line is kept full of liquid to a fixed height. Both options, however, come with maintenance considerations. A dry leg will require a collection pot that's periodically drained, while a wet leg will require liquid level to be maintained at a known height and protected from freezing by heat tracing or compatible antifreeze additions.

Steam is a specific case where wet legs are commonly used, with condensate expected between the transmitter and process. Sometimes condensate pots are used to make sure impulse line condensate isn't boiled off during high demand loads, particularly with superheated steam.

Another typical application in power and steam generation is boiler drum level measurement. ABB 266CSH Multivariable with active level calculation can compensate for DP drum level due to both wet leg condensate density changes caused by temperature fluctuations as well as real-time water and steam densities in the boiler based on the measured static pressure and onboard steam tables.

Q: What about blockages in impulse lines?

A: In an ideal case, mount the transmitter to allow the impulse line a 10% slope back to the process. This will allow liquid to drain or gas to vent back to the main process line, depending on the defined normal condition.

Continuous purging is a time-tested method to keep lines clear, but maintenance and operating costs across a plant can be prohibitive. Alternatively, ABB 266 Series transmitters come standard with a Plugged Impulse Line Detection (PILD) feature that can be trained to the high-frequency signature of the normal background pressure, and signal a diagnostic alarm to the operator if it detects a change in the signature indicating a blockage.

Q: The cost of installing impulse lines—and keeping them clear—is certain to add up, and failure to do could be unsafe or cause a shutdown. Are there other options?

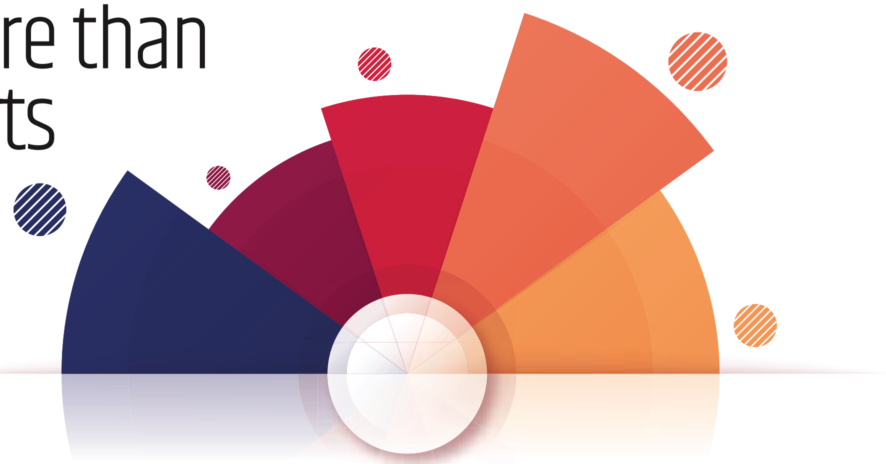
Remote diaphragm seal pressure transmitters such as the ABB 266DRH (shown here with WirelessHART antenna) facilitate the responsive, accurate pressure measurement of high temperature streams without the safety or maintenance implications of traditional impulse lines.

A: Remote seals, specifically all-welded seals, remove the wet/dry leg decision as well as the need to install and maintain impulse lines in high temperature applications. Consider an ABB 266 Series transmitter complete with S26 remote seals like a doctor with a stethoscope. The measurement is taken directly at the process and transmitted back to the sensor. In the case of the remote seal, the pressure is conveyed through fill fluid. In high temperature processes, the key consideration is specifying a compatible fill fluid based on the highest temperature at the lowest pressure that will be encountered, such as during a cleaning cycle. Compare these conditions to the vapor pressure curve of the fill fluid to make sure it won't boil behind the sensing diaphragm.

ABB transmitters with remote seals can also be direct or remote mounted to the process. When remote capillaries are used, it's best to keep them as short as possible and of equal length to minimize response time. And because ABB seals are designed in-house, our experts can also engineer custom solutions like cooling extenders, or use special materials for constructing the wetted elements.

In some colder ambient conditions, heat tracing on the capillaries and a heated enclosure may be necessary to maintain fast response times. Another option for improving the response times of hot processes in cold environments are "electronic" remote seals. In this configuration, which we call a Digital Diaphragm Seal, an 266HSH and 266HRH are electronically coupled to produce a DP output. Often used for level applications, this approach removes the need for lengthy capillary legs; response effects are eliminated, and larger tap-to-tap dimensions are possible. ∞

Modularity more than the sum of parts



Module Type Package (MTP) standardizes device descriptions and process interactions to streamline programming and production

by Jim Montague

IT'S a bad idea to glue Legos or other building blocks together because you can't take them apart, reassemble and rebuild, or create something new and different later. To avoid similar restrictions, discrete manufacturers have been seeking less constrained devices, and developing more modular equipment and production lines for years—but lately process users are seeking the same flexibility and advantages.

Module Type Package (MTP) is a standardized, non-proprietary way of describing process automation modules from individual components up to production skids, which lets them work with other modules, and fit more easily into larger applications. These common, shared definitions of basic capabilities, interfaces and services reportedly let MTP modules plug-and-play with other compliant devices and systems. This can save huge amounts of time and labor that's usually spent on programming, configuration, data conversion, networking and getting non-interoperable devices to work together.

"MTP can save up to 50% on the engineering effort required to build process plants, including skids and package systems," says Axel Haller, global segment manager for specialty chemicals and life sciences at ABB (www.abb.com), and chair of the MTP working groups at ZVEI (www.zvei.org), the Electro and Digital Industry Association. "Users can do a proof of concept (PoC) by contacting their suppliers, adapt it to their processes, and see the benefits for themselves. This is possible because MTP is agnostic and independent, so any five modules can connect to five different PLCs or DCSs. Because they're all using the same language, MTP can also help a supplier with a specific PLC or DCS link to others without having to do as much reconfiguring, or spend as much on fees for optional modules. Easier connections with MTP can also help suppliers protect their intellectual property."

Pieces in the playset

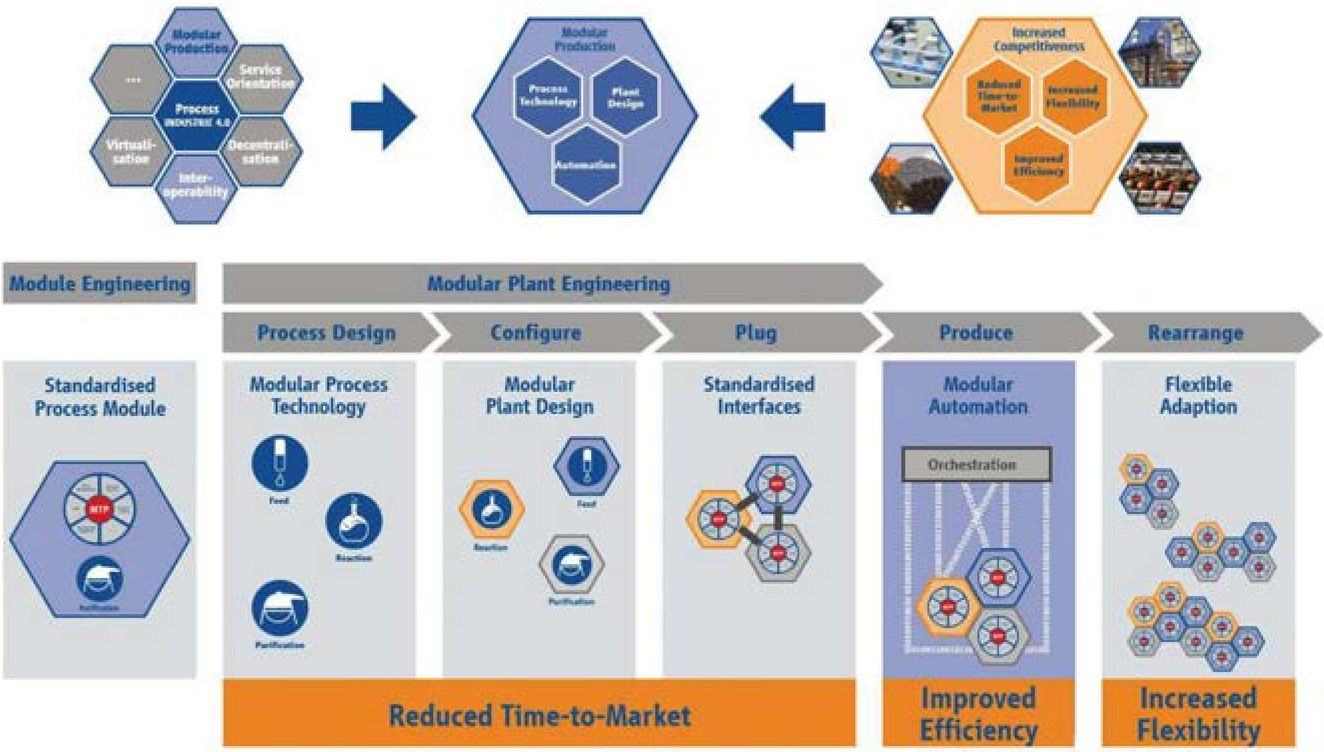
Presently under development, the MTP standard effort was started in 2014 by the NAMUR (www.namur.net/en) association of process industry end-user companies, which drafts recommendations with help from ZVEI and other groups and suppliers. NAMUR reports that MTP is designed to use intelligent equipment modules for production, improve flexibility and increase efficiency, enable package unit integration, allow quick and easy adoption of new processes, fulfill individual users requirements, cut engineering and automation costs for plant conversion, and reduce time-to-market for products.

"MTP consists of standardized descriptions of a process module's functions, which can be used like a mouse driver to integrate mixers, reactors, heaters, distillation units and other devices with their controls and other modules," says Dr. Jens Bernshausen, PLC and process control technology manager at Bayer (www.bayer.com), and plug-and-produce working group leader at NAMUR. "The engineering workflow for MTP begins with making sure each standardized module has its own control capability, and using AutomationML (AML) data format and OPC UA networking to coordinate between modules. MTP is technically and vendor neutral, so its five main aspects of process control, HMI, maintenance and diagnostics, alarm management, and safety and security can be employed or not by each user. For instance, they can move static and dynamic data for their HMI from a PLC to their DCS within MTP's service-based architecture."

Jesse Hill, process industry manager at Beckhoff (www.beckhoff.com), adds that MTP allows secure interoperability between automation systems from different vendors, and eases development because users can employ modules from suppliers that know its production best. "Because each MTP module has its own controller, it can import HMI designs and other data into the controller to make an MTP file, which it can export to other systems, orchestration and higher-level controllers," says Hill. "MTP is a way to take engineering and programs from a module or library, and integrate them into a DCS. For example, an MTP file can integrate HMI screens into a DCS, which reduces programming because they don't have to be recreated every time. This is using IT-based strategies that have been available for a long time."

Timeline and schedule

Bernshausen reports that NAMUR, ZVEI and their joint working groups are writing a German national standard for MTP, entitled



MTP ENABLES MODULAR PRODUCTION

Figure 1: Module Type Package (MTP) consists of common, standardized, non-proprietary definitions of process automation components and services, which lets devices from different suppliers communicate, plug-and-play, fit more easily into larger process applications, and potentially save huge amounts of time and labor on design, engineering, configuration and maintenance. Source: NAMUR and ZVEI

VDI/VDE/NAMUR Guideline 2658 (www.vdi.de/en/home/vdi-standards/details/vdivdenamur-2658-blatt-1-automation-engineering-of-modular-systems-in-the-process-industry-general-concept-and-interfaces). So far, they completed and published three sections, including basic concepts and interface definitions, descriptions and modeling of HMI to process equipment assemblies, and interfaces and libraries for basic object types. The draft of the fourth section, services for process control equipment assemblies, is being reviewed, and is expected to publish late this year or in early 2022. Several suppliers plan to release MTP products as soon as the fourth section is approved. Sections for standardizing 10 more functions are in the works, including monitoring and diagnostics, safety and cybersecurity.

The organization is also integrating MTP with its NAMUR Open Architecture (NOA) for adding and monitoring sensors, and reducing PLC workloads by using a second channel to deliver applicable data directly to Industrial Internet of Things (IIoT) devices and cloud-computing services. Finally, NAMUR also plans to get MTP adopted as an International Electrotechnical Commission (www.IEC.ch) standard, entitled IEC65E/663/NP, "Automating engineering of modular plants."

"The working groups are determining how MTP modules should do maintenance and diagnostics, alarm management, and safety and security," says Bernshausen. "Using MTP modules lets users go from spending a month or more designing, integrating and configuring a skid or package system to doing it in just a few days. Plus, MTP isn't just useful for new devices and greenfield applications, but it can also upgrade existing equipment and brownfield processes. For example, it's possible to add modular components to a steam unit, and use MTP to integrate them more easily, which can also enable equipment leasing or buying steam or other production on a subscription basis."

To deliver MTP's potential benefits, Bernshausen adds that users should ask vendors for more modular, standardized and pre-tested products, and specify MTP for them. "It used to take a lot of time to design and configure a skid or other equipment. Users ordered pre-engineered packages and automation systems, which might not interoperate when they tried to integrate them," says Bernshausen. "Now, MTP lets users employ the best controls and other devices available from each supplier, and be more certain they'll work together."

Moving to modular

"Many processes and batches are getting smaller, more numerous, and have more varied specifications, so process engineers want to standardize their individual production units, such as mixers, fermenters and skids, and combine new plants made of these standardized modules, so they can gain flexibility and reduce costs," says Dr. Eckhard Roos, head of industry segment and key account management for the process industries at Festo (www.festo.com). "MTP and standardized modules can also help users test new processes, and handle them as they also become more numerous."

While its origins and methods can be traced to the well-known S88 batch standard, Roos reports that MTP is based on NAMUR NE 148 and its main recommendation that each module possess its own PLC to control its sensors, I/O points, actuators and other components, be able to act on them and connect to upstream and downstream modules, such as SCADA systems and DCS, and integrate these standardized modules with the least effort.

To enable a device as an MTP module and link it with a SCADA system, Roos explains its engineering process needs to be defined by having its supplier provide the data needed for it to be represented in the larger SCADA environment. This includes number of devices, where it's located in the interface, what its colors mean and other relevant details. To connect modules and services with a DCS, MTP is loaded into its orchestration layer, where it can provide services, properties of services and interfaces. "If everyone follows this standard, then OEMs can pick any PLC for the equipment they build, and their data can be represented immediately in the system those devices join," says Roos. "We can now connect a Festo PLC to an ABB or other SCADA systems, and it's easy to make those links with little effort. In the past, the PLC, SCADA and other devices came from one supplier, and if they didn't, there were connection and performance problems.

Roos adds that NAMUR's working groups overcame these traditional interoperability problems by getting everyone at the same table, and defining the data sets needed to represent MTP modules in SCADA, DCS and other supervisory systems. They agreed to use AML as the way to get data for graphics to supervisory systems, and agreed to use OPC UA for communicating between runtime operating systems. "This lets OEMs choose what they want for automation, encourages existing suppliers to join, so they don't lose business, and lets new suppliers come in, too," says Roos. "MTP and standardizing on AML also means OEMs don't have to know how to program every type of PLC, and can instead learn just one, which is less complex, cuts costs, and is easier to maintain and fix."

Charlie Norz, automation product manager at Wago (www.wago.com) reports it used to be an engineering feat and very time consuming to get a DCS and its orchestration architecture to show the operations of individual equipment and add new ones. "System integrators and OEMs had to coordinate with their DCS supplier, and exchange memory locations, diagrams and screens, and secure P&IDs to be recreated in the HMIs, which could take hundreds of hours," says Norz. "Now, they can use MTP to export files to a DCS more easily, which can show how graphics should look, share memory locations, and automatically provide required look and feel. MTP can save many hours by automatically drawing the data that needs to be shown on an HMI. For instance, a typical water/wastewater facility may have four possible suppliers, but following MTP makes it easier for them to pick the equipment that best suits their needs. MTP makes controls more readily available because its modules interface with the orchestration later."

Norz reports that Wago has added MTP function block libraries to its eCockpit PLC software, so users can export AML files to their DCS, or let suppliers add MTP to the controls in the products they're providing to others. "For instance, a hot water system manufacturer may have a memory location for a start/stop function handling temperature measurements or flow rates, and MTP can expose that information to the orchestration system and the DCS can use it. This flexibility saves time compared to the rigid and manual methods of the past, but MTP also helps users maintain their processes by making it easier pull, replace and integrate new devices."

Proof in pilot projects

While MTP hasn't been launched in mainstream production applications—at least none that have been disclosed—it's been proven in several modular PoCs and pilot projects.

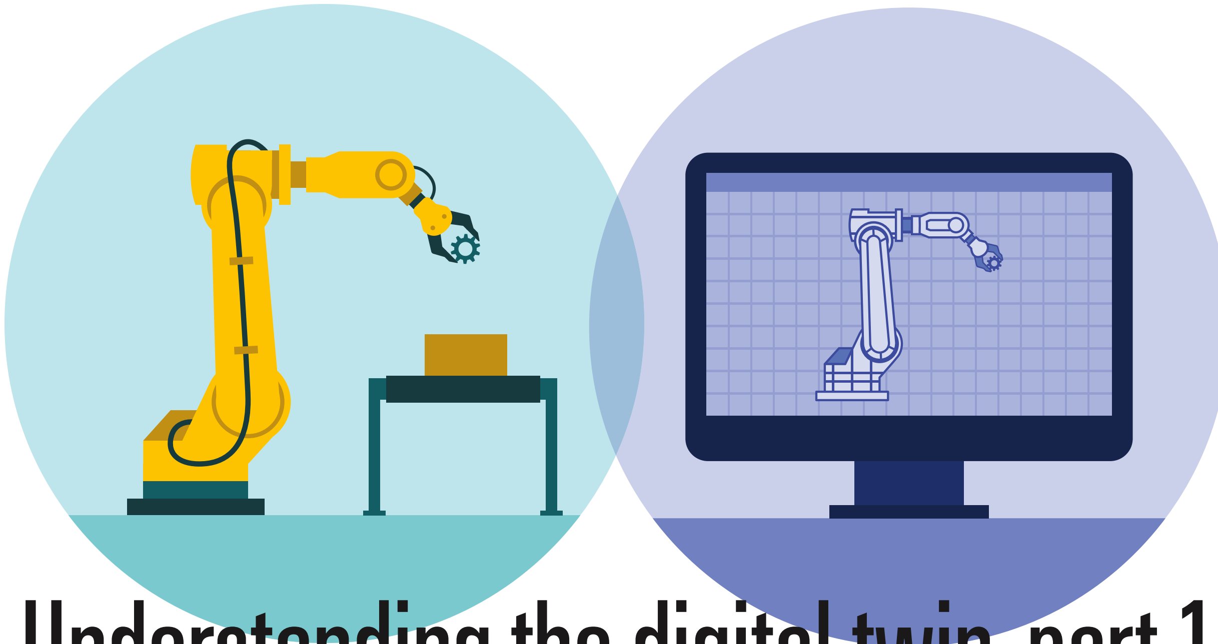
Evonik (evonik.com) recently implemented MTP modules in three projects. The first pilot is a modular, lab-based plant at its facility in Marl, Germany. It includes components from ABB, Wago and Orca, which were successfully used to start up an orchestration prototype, provide fast exchangeability, and use MTP to streamline development of HMI, alarm management, runtime communications and services.

The second is a PoC involving module orchestration via IIoT that's is also at Marl. It integrates components and software from Phoenix Contact and PTC, including its ThingWorx IIoT platform, which can reportedly fulfill the technical requirements of the process orchestration later (POL) for MTP use cases. It's also expected to enable easy integration of added functions, such as access to engineering and operations data, PIMS and SAP.

Located at Evonik Singapore, the third pilot uses MTP to integrate refrigeration units from Engie for synthetic amino acids into a DCS. It employs devices and software from Yokogawa for plant automation, as well as Siemens for module automation and operations. It was successfully implemented in 2019.

Similarly, the "invite" project is a modular plant developed by Bayer, Siemens and Festo that's commissioned and functioning. It integrates modules with Siemens' MTP-ready PCS neo AS and S7 PLCs networked with Profibus DP and Profinet, as well as Festo PLCs serving as MTP modules networked by OPC UA. ∞

[Editor's note: for videos and other supporting materials, see the resources guide "MTP aids interoperabilty" on page 48.]



Understanding the digital twin, part 1

What makes a digital twin different from a mathematical model, and what sorts of jobs they can do?

BY R. RUSSELL RHINEHART

"WHEN I use a word, it means whatever I want it to mean."

So began Louise Wright and Stuart Davidson in their recent article, "How to tell the difference between a model and a digital twin."[1] Indeed, the words spoken by Lewis Carroll's Humpty Dumpty in *Alice's Adventures through the Looking Glass* might well be applied to any number of marketing campaigns discussing this latest, most fashionable moniker for a virtual representation of an actual phenomena. "Digital twin is currently a term applied in a wide variety of ways," Wright and Davison continued, their message being that clarity of meaning is essential. Excessive marketing hype and one-upmanship name-dropping distorts a term, which leads to disillusionment about the concept, which leads to underutilization of a good thing.

This article is the first in a three-part series seeking to clarify what a digital twin means in the chemical process industries (CPI), how models and twins are used, and some techniques that can convert a model to a twin.

Model types

The term model also has many meanings. It could be a small-scale replica of an object used for dimensional analysis testing (such as for hull design of ships in a tow-tank) or entertainment (such as a train garden layout) or design (such as a tabletop replica of a chemical plant layout to visualize spatial relations). However, in the context of digital twins, the term model means a mathematical model that's been converted to digital code, which is used to mimic or simulate the response of the full-scale object. In the digital twin context, "full-scale" and "digital simulator" are key attributes for the model meaning.

We commonly use empirical, generic dynamic models in control, such as a first-order plus deadtime (FOPDT) model that's fit to process data to approximate the process response. These models are useful for tuning controllers and setting up feedforward and dynamic compensators. These and similar models (ARMA, SOPDT) have functional forms matching a predefined behavior. But just because we can get the model to comfortably approximate the process data doesn't mean the process behaves like the model. For instance, a high-order process with zero delay can be fit with a FOPDT model. That doesn't mean there's a delay in the process. In these cases, model coefficients don't have fidelity to the process, although they do have mechanistic meaning within the approximating model.

In a digital twin, model coefficients should represent a full-scale process attribute, such as equipment size, catalyst reactivity, valve characteristic, etc. There should be fidelity of the model coefficient to one property of the full-scale process.

We also use finite impulse response (FIR) models in model predictive control (MPC), neural-network models in soft sensors and inferential measurements, simple power-series (polynomial) models, and dimensionless variables in quantifying variable correlation. These are mathematically flexible models which don't express a predefined functionality. Because of this, they're often termed "model-free" methods of representing a process. Many such approaches are in the toolkits associated with data analytics and machine learning. And again, although they're useful for discovering relationships, they don't seek mechanistic fidelity to the process. The coefficients in generic empirical models are adjusted to mimic what the data expresses, but coefficients in the model don't correspond to physical or chemical properties or dimensions of the process.

Contrasting empirical models, phenomenological (first-principles, mechanistic) models seek to express the human understanding of the cause-and-effect mechanisms of an object. They're based on material and energy balances, and use appropriate models of thermodynamic, kinetic, friction losses and other constitutive relations. Phenomenological models have mechanistic fidelity to the input/output (I/O) relations of the object, which permits them to extrapolate to new conditions. Coefficients in the model have a direct match to process sizes, object properties and behaviors. Phenomenological models are useful for exploring the impact of changes on the object properties and responses. Seeking fidelity of the model to the process, digital twins would prefer to use phenomenological, not generic empirical models.

In an extreme, rigorous phenomenological models seek perfection in representing every detail and nuance of the object with the most perfect of models. Although the ideal gas law may be fully functional for use in a particular model, a rigorous "show-off" approach might be to include the Benedict-Web-Rubin-Stirling or a Virial Equation of State, just because it's most advanced. Tempering a sense of ultimate scientific perfection, the fidelity sought in a practicable model should be appropriate to the functional use of the model in the given application.

This means that, instead of using the partial differential equation that would be the "right" way to model the distributed temperature of fluid in a heat exchanger, the modeler could choose to approximate that truth with a FOPDT model in which time-constant and delay values are mechanistically scaled to flow rate. The inclusion of some empirical models may be pragmatic.

Although phenomenological models are preferred, the models desired in a digital twin will seek to balance perfection with sufficiency, to have fidelity to the requirements of the application that use the model, not necessarily to represent an ultimate in modeling perfection.

An object of the model

The "object" being modeled could be a mechanical device, chemical process, electronic device, building, distribution system, aircraft, communication system, etc. Although the object could be a single control valve, it could also be all devices within that control loop (current-to-pressure, or i/p, wireless connection, actuator, etc) including their features (stiction, digital discrimination, dropped messages, etc). The object could also be the heat exchanger, including its associated instrument system, or the distillation column with that heat exchanger, or the separation process unit containing the column, as well as tanks and startup and safety items, or some larger assembly. The object doesn't need to be a single entity; it could be the composite of many interacting objects.

The object can also be a batch or continuous process.

Model uses

The use of models isn't new in the CPIs. Simulators using mathematical models of objects are essential for design, fault detection, performance analysis, knowledge development, process improvement, training, process optimization and many other human initiatives. Phenomenological models can be used in model predictive control and as inferential measurements. When the engineering and operational staff understand the process through phenomenological models, they'll better understand cause-and-effect relations, and be better at troubleshooting and process improvement.

The rationale to use phenomenological models (and digital twins) is to actualize all those potential benefits.

What's new about twins?

Digital twins are simulators based on models. So what makes them different from a model-based simulator?

Following the guide of Wright and Davidsont, the digital twin of an object entails:

- a phenomenologically-grounded digital simulator of the full-scale object,
- an evolving set of data relating to the object, and
- a means of frequently updating or adjusting the model in accordance with the data.

We're familiar with Item 1, simulators based on phenomenological models of the full-scale object. We commonly use both textbook type models of units and software providers' simulation packages for process design and many other modeling applications.

Item 1 is a model. Items 2 and 3 differentiate a model from a twin.

Item 2 represents data from the real world that's used to adapt, adjust or update the model. In chemical processes, this data could be related to reconfiguration changes, such as piping paths, taking a parallel unit offline for maintenance, shifting a raw material supply source that changes its character, lowering tank levels to meet end-of-year inventory desires, and others. The data from the process could also relate to attributes that change in time, such as catalyst reactivity, heat transfer fouling, tray efficiency, or fluid friction losses in a pipe system. The data is called an evolving data set, meaning data is continually (or at least frequently) acquired, and reflects properties of the object that are ever-changing.

Item 3 indicates that the model is adapted to retain fidelity to the real object. "Frequently updating" means the model is continually updated (or at least frequently enough to keep the twin locally true to the object). This could mean model objects are rearranged to match process reconfigurations, that model constituency relations are changed to best match the data (the ideal gas law could be replaced with a Van der Waals model if data shows it should), or that model coefficient values are adjusted to make the models best match the data (such as product yield, tray efficiency or inline flow restriction).

This digital twin concept already is familiar in the CPIs. It's not uncommon to “calibrate” phenomenological models or process simulators, so they match the actual process behaviors. Then the models can better represent constrained conditions, operating possibility, optimum setpoints and KPIs in general. Calibrated models are more accurate. If you calibrate simulators with recent plant data, then you're creating digital twins.

Outside the CPIs, in manufactured products (compressors, refrigeration units, cell phones, cars, etc), the in-use data from an object can be related to conditions of use and degradation of that object. The Internet of Things (IoT), in turn, can provide real-time access to data from onboard sensors. The twin is then a common phenomenological model that's adjusted with data from the object, and can be used for situation monitoring.

For the chemical process operator, access to data from the process has long been available through local area networks (LAN) and digital control systems. Here, digital twinning, recalibration of models to match the process, is no longer a groundbreaking concept. However, for manufactured products, access to onboard data from remote objects is relatively new. The concept of a digital twin may be more newsworthy in that context.

Classically, however, chemical plants were built with the minimum investment in instrumentation necessary to effect adequate safety and control. To achieve a true digital twin, more sensors, sensors with greater precision, and techniques for data validation (such as voting, data reconciliation and inferential sensors) will likely be needed to permit valid model recalibration.

Process simulators and control

Simulators for chemical process design use steady-state models of continuous process units, or end-of-batch models, and are fully adequate for many design, optimization and analysis purposes. Increasingly, simulation software providers are offering dynamic simulators of process units that include emulations of controllers. These can be very helpful in exploring the transient behaviors in response to startup, transitions and disturbances. However, as McMillan, et al.[2] point out, the controllers provided in process simulations are often primitive. The process simulators may not include advanced regulatory control options, nonlinear characteristics of installed valves, or data processing features and digitization characteristics of a controller. Those authors suggest that a digital twin should include dynamics, controllers, and any structure of the control system that might affect I/O relations. Preferentially, a dynamic simulator of the object would be connected to either a real controller or a twin of it to have the control aspects represented in the digital twin of the combined process-controller system.

Twin functionality

The intended use of a digital twin (or a model) will define essential properties that the model needs to express. For instance, if the digital twin is going to be used for supervisory setpoint economic optimization or scheduling, then steady state models that adapt to process characteristics and associated operational constraints may be fully adequate.

However, if the purpose is to explore or tune control strategies, the models of sub-objects should include their dynamic response. Further, to test control strategies and to quantify goodness of control metrics, stochastic (ever-changing) inputs to the model should include the vagaries of environmental disturbances (such as ambient conditions and raw material variation), operational uncertainties (such as mixed-feed compositions, instrument noise, reactivity, fouling and other process attributes that change in time). These stochastic inputs can be created with auto-regressive moving-average (ARMA) models that mimic the real-world experience of both the variability and persistence[3]. These models could then be used to define setpoint values that are comfortably away from specifications, so that variation doesn't create safety or product violations.

Generating stochastic input values

A recommended way to generate stochastic inputs is to consider that they're first-order responses to disturbances. In Equation (1), the variable x represents the first-order influence on a process from a disturbance d, with a first-order time constant of τ:

$$\tau\frac{dx}{dt} + x = d, \quad x(t=0) + x_0 \qquad (1)$$

Analytically, the solution can be converted to an incrementally updated new time sample by Euler's explicit method.

$$x_{new} = \lambda d_{new} + (1-\lambda)\, x_{prior} \qquad (2)$$

Where:

$$\lambda = 1 - e^{-\Delta t/\tau} \qquad (3)$$

Here, Δt is the simulation time step, or sample-to-sample time interval. If the influence, *d*, is not a constant, but continually changes, then the new *x*-value is influenced by the new *d*-value.

If d_{new} is modeled as randomly changing in a Gaussian manner with a mean of 0, and variance of σ_d, then it can be modeled using the Box-Muller[4] formula:

$$d_{new} = \sigma_d \sqrt{-21n\,(r_1)}\;\; sin\,(2\pi r_2) \qquad (4)$$

where r_1 and r_2 are independent random numbers uniformly distributed on an interval from 0 to 1 (your standard random number generator). Then, the first-order persistence driven by $NID(0,\sigma)$ noise and averaging about a value of x_{base} can be is modeled as:

$$x_{new} = \lambda\,[\, x_{base} + \sigma_d \sqrt{-21n\,(r_1)}\;\; sin\,(2\pi r_2)] + (1-\lambda)\, x_{prior} \qquad (5)$$

In creating a simulation with a stochastic influence, the user would choose a time-constant for the persistence that is reasonable for the effects considered, and a σ_x-value that would make the disturbance have a reasonable variability. At each sampling, Equation (5) would provide that stochastic value for the variable *x*. The stochastic variable could represent barometric pressure, ambient heat load, raw material composition, or any such ever-changing influence or process character. In its first use, the value for x_{prior} in Equation (5) should be initialized with a characteristic value, such as x_{base}.

How should one choose values for λ and σ_d? First consider the time-constant, τ in Equation (1). It represents the time-constant of the persistence of a particular influence. Roughly, $\tau \approx 1/3$ of the lifetime of a persisting event (because the solution to the first-order differential equation indicates that after 3 time-constants, *x* has finished 95% of its change toward *d*). So, if you considered that the shadow of a cloud persists for 6 minutes, then the time-constant value is about 2 minutes. Once you choose a τ-value that matches your experience with nature, and decide a time interval for the numerical simulation, Δt, calculate λ from Equation (3).

To determine the value for σ_d, propagate variance in Equation (5). The result is Equation (6). Use your choice of σ_x (and λ, which is dependent on your choices for Δt and τ) to determine the value for σ_d:

$$\sigma_d = \sigma_x \sqrt{\frac{2-\lambda}{\lambda}} \qquad (6)$$

Choose a value for σ_x, the resulting variability on the *x*-variable. To do this, choose a range of fluctuation of the disturbance. You should have a feel for what is reasonable to expect for the situation you're simulating. For instance, if it's barometric pressure, the normal local range of low to high might be 29 to 31 inches of mercury; if outside temperature in the summer, it might be from 70 to 95 °F; or if catalyst activity coefficient, it might be from 0.50 to 0.85. The disturbance value is expected to wander within those extremes. Using the range, R, as

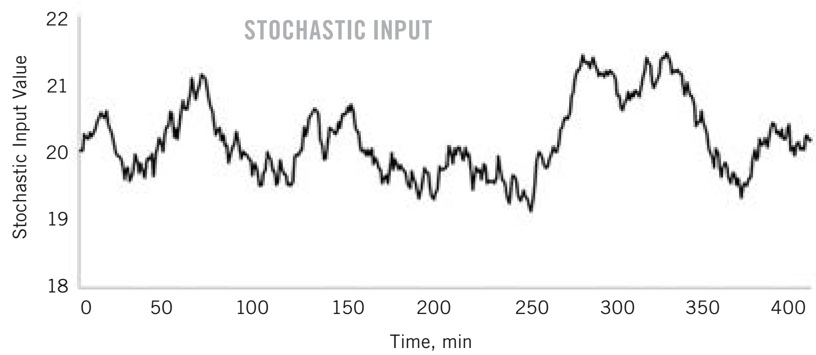
$$R = HIGH - LOW \qquad (7)$$

And the standard deviation, σ_x, as approximately one-fifth of the range, then

$$\sigma_d = \frac{R}{5} \sqrt{\frac{2-\lambda}{\lambda}} \qquad (8)$$

As a summary, to generate stochastic inputs for dynamic simulators, choose a time constant for persistence of events and a range of the disturbance variable. Use Equation (3) to calculate λ, then Equation (8) to calculate σ_d. Then, at each simulation time interval, use Equation (5) to determine the stochastic input.

Figure 1 is an illustration of one 400-min realization of a stochastic variable calculated as above. The time-constant is 40 min, the nominal value is 20, and the range is 3 units. In this one illustration, notice that the variable averages about its nominal value of 20, and the difference between the high and low values is nearly 3. From a period between 150 and 275, the value is below the average, indicating a persistence of 275 -150=125 min, which is about three times the 40 min time-constant. Some persistence values are shorter, some longer.



STOCHASTIC INFLUENCE CALCULATION

Figure 1: As detailed in the accompanying article, stochastic influences can be approximated using estimates of proces nominal values, range and time-constant.

Key takeaways

A digital twin is a simulator that is frequently calibrated with data from its object. Preferentially, the models in the simulator are phenomenological. The twin seeks adequate fidelity to the aspects of the object that are functionally important. It doesn't seek perfection in what it uses for constituent relations, nor to model aspects that are irrelevant to the application utility of the simulator.

Having a digital twin permits offline exploration of design changes, structuring controllers, economic optimization within constrained conditions, hazard analysis, predictive maintenance, training, and many applications.

Using frequently recalibrated models may be nothing new to you as a process operator. But for some, especially related to manufactured products, the

> The twin seeks adequate fidelity to the aspects that are important. It does not seek perfection.

concept of twinning each individual object in use, from its individual data, for individual analysis seems to be relatively new. Such applications may be shaping the news.

Effective twinning in the CPIs may require additional process instrumentation and data verification and correction techniques to have the valid feedback needed to recalibrate models.

The model type, the features in the model should be appropriate to the model use. If, for instance, to test controllers, the twin should include the vagaries of input and ambient disturbances, equipment attributes and operational conditions. ∞

[This article consists of three parts. Parts 2 and 3 of this series will be published in the November and December 2021 issues of Control*. This first part was on the utility of using models, what sort of models there could be, benefits and disadvantages for them when used as a digital twin. The second part will discuss methods for both initial and on-line model adaptation. And the third part will be about tempering the adaptation of the model coefficients when in response to noise and spurious signals.]*

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Russ Rhinehart started his career in the process industry. After 13 years and rising to engineering supervision, he transferred to a 31-year academic career. Now "retired," he enjoys coaching professionals through books, articles, short courses and postings at his website www.r3eda.com.

To cascade or not to cascade?

Sometimes it makes sense to spring for a feedforward approach

This column is moderated by Béla Lipták (http://belaliptakpe.com/), automation and safety consultant and editor of the Instrument and Automation Engineers' Handbook (IAEH). If you have an automation-related question for this column, write to liptakbela@aol.com.

Q: **I've been reading articles in *Control* magazine and at ControlGlobal.com for awhile now and they've been very helpful. I was wondering if your team will respond to the following technical question:**

Do set criteria exist for determining whether to break regulatory cascades when choosing manipulated variables for advanced process control? For example, manipulating steam flow setpoint instead of the temperature controller setpoint, whose output normally writes to the steam flow setpoint. I'm thinking that if a temperature control (TC) loop (or other master loop) has a time constant greater than 10 minutes, could a one-minute model predictive control (MPC) controller optimize better with the faster slave loop than with the slower master loop? I've run across this issue recently, and I'm not sure of all the considerations that should be considered.

Thank you in advance for the response!

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A1: The main advantage of cascade control is that disturbances that occur in the secondary loop are corrected there, and aren't allowed to upset the primary loop. For example if you take the steam heater shown in Figure 1, the existence of a pressure (secondary) loop prevents the effects of steam pressure changes from upsetting the temperature control (primary) loop because the pressure regulator (secondary) keeps the pressure constant (plus corrects for valve sticking or non-linearity). Naturally, the secondary loop must be much faster (usually 10 times faster), so the primary never sees these disturbances. In the "pneumatic age," I used only the simple and cheap pressure regulator shown in Figure 1, as the secondary loop and the clients were always happy with the result, as long as the secondary was much faster than the primary loop.

Conventional cascade is still a feedback configuration, so it still gets upset by load variations (changes in hot water demand). When that occurs, a temperature error must develop in the primary loop before correction is started. Therefore, in critical heater applications, I spend the money on a feedforward cascade system (Figure 2), which doesn't wait for an error to develop in the process fluid temperature control loop, but takes action as soon as the process load (T_2) changes to match it with the steam flow (W_S), according to the heat and material balance equation (process model) in the figure.

Figure 3 illustrates the difference in the response to load changes of a feedback and a feedforward system.

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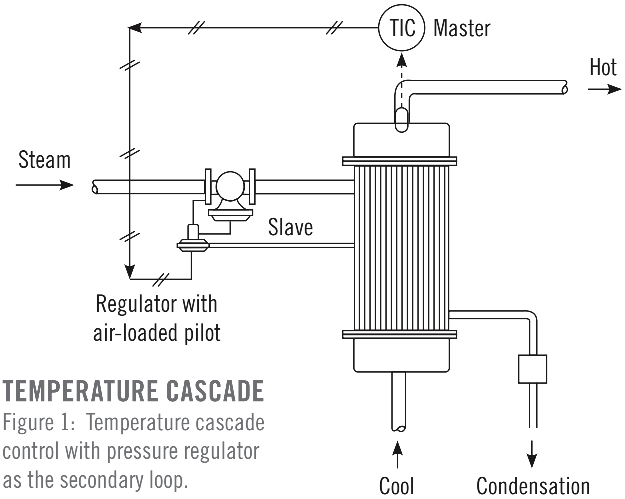
A2: Operators often don't understand cascade control. They want to take more direct action, so they break the cascade by putting the primary in Manual and operate the secondary in Auto, or sometimes put both primary and secondary in Manual, and take over the steam flow control valve directly by manipulating the secondary Output. This is understandable but it's a sign that the control has failed.

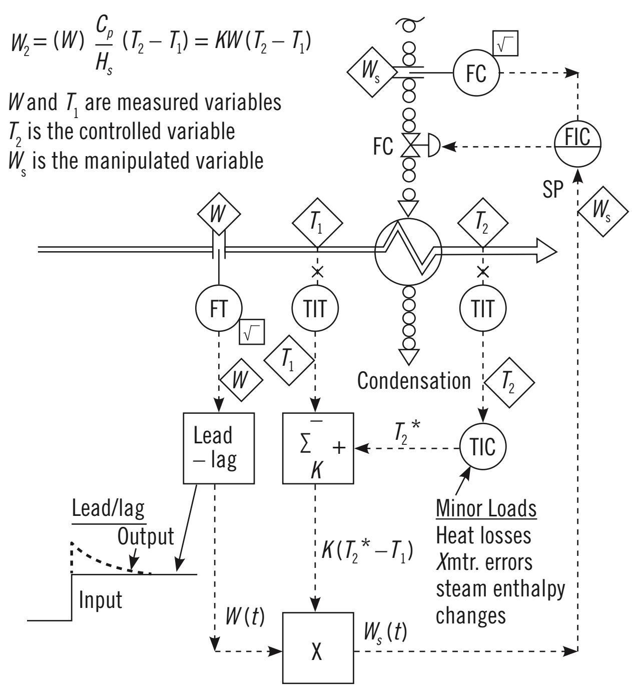
The most frequent problem is that the conventional temperature-to-steam flow cascade is implemented on a heat exchanger with an inherent transport time delay. The process fluid is almost always routed through the tubes of the shell and tube heat exchanger, often making several passes. The dead time between a temperature change on the fluid entering the exchanger and its exit, where the temperature is measured, may often be measured in minutes. You can't optimally tune a PID controller—cascade or not—for this condition. Often a Smith-Predictor can be configured to remove the deadtime from the control action, but that's a crude solution. The best solution is to build a feed-forward, model-based control loop using a first-principles model derived from heat and material balances.

The rationale is to control the flow of steam needed to raise the fluid temperature when it's needed, not just wait for it to be out of control due to the time lag of the heat exchanger. Hopefully,



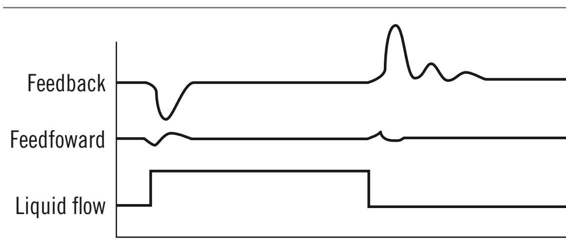
TEMPERATURE CASCADE

Figure 1: Temperature cascade control with pressure regulator as the secondary loop.



FEEDFORWARD-CORRECTED CASCADE

Figure 2: Steam heater controlling the critical temperature of a process fluid flow (W), using feedforward-corrected cascade control.



FEEDFORWARD VS. FEEDBACK FOR FLOW UPSETS

Figure 3: The upsets caused by load (liquid flow) changes in time are much reduced if feedback control is replaced by feedforward.

if this cascade is done correctly, the operator will no longer feel the need to break the cascade.

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A3: The question you raise is a good one, and it doesn't always get the attention it deserves. The regulatory control strategy can have a significant effect on the overall performance of the MPC. A common decision is whether to keep or incorporate a cascade such as a TC to FC. Due to the faster execution in the DCS or PLC (often one second or less), a cascade will normally provide better disturbance rejection capability than the MPC. It will also allow a greater turndown ratio of the MPC, allowing reliable MPC control over a wider range of throughputs. A TC cascade is normally retained on heaters, reactors and distillation columns, or added if one is not in place. For distillation columns, a TC will normally be used if a temperature control point can be found that correlates well with a composition controlled variable (CV) in the MPC. Manipulation of dual-ended temperature controls would be avoided with MPC, with only one temperature controller selected as an manipulated variable (MV) for the MPC. The exception to using a TC can be if the flow controller is a better MV for controlling against a frequently encountered constraint.

Additional information on this topic can be found in the MPC chapter of the *Process/Industrial Instruments and Controls Handbook,* 6th Edition, edited by Gregory K. McMillan and P. Hunter Vegas.

I normally don't find that the MPC can control the temperature more tightly due in part to the slower execution period of the MPC. Executing the MPC faster can help, but the MPC will still be controlling multiple control variables simultaneously, which can make MPC tuning more challenging. Note that tuning is normally required of the TC to get proper setpoint and disturbance response.

Some argue for MPC manipulating the FC instead of the TC to get the advantage of decoupling. In my experience, keeping the TC still wins. Decoupling doesn't perform well with high purity columns. Also, the simpler structure of the control matrix with a TC for distillation composition control will be robust for modeling errors and allow a greater throughput turndown ratio.

The main reason for considering manipulation of the FC is constraints, namely if the constraint variable is primarily a function of the flow, rather than the TC. An argument for manipulating flow might be if there are multiple, significant disturbance variables that the TC has trouble rejecting, but these could also be feedforward variables in the regulatory control system.

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Improved accuracy, detection methods, protections and other innovations let analyzers reach new levels

CHEMILUMINESCENCE GAS DETECTION

Built to detect ultra-low concentrations of NOx emissions in combustion applications, Rosemount X-Stream enhanced XE-CLD process gas analyzer has fast response times and the widest available, user-selectable NOx measurement ranges from 0-5 parts-per-million (ppm) to 10,000 ppm. It uses chemiluminescence detection (CLD) with a thermoelectrically cooled, solid-state detector to ensure stable measurements and longer operating life. It also eliminates the need for vacuum pumps often used in CLD instruments.

EMERSON
Emerson.com/RosemountXECLD

DIGITAL ANALYZER DISPLAYS AND SENDS DATA

OMR 700 is a digital process analyzer and recorder. It displays inputs on its touchscreen as lines, bar graphs or numeric values, and its colors are settable for each channel. OMR 700's data can be saved and sent to a PC for analysis with bundled software. Input channels can expand from four to 96. It's also programmable, and can measure temperature, humidity, pressure, pH, load and level. OMR 700 accepts thermocouples, RTDs, voltage, current inputs. Relay, analog and digital output cards are available.

BRISTOL INSRUMENTS
877-866-8500; www.bristolinstruments.com/data-recorder.html

MEASURE DENSITY OF AGGRESSIVE ACIDS

Density Cell measurement system is weather-tight and explosion-proof, has no moving parts, and is virtually wear-free. Users can choose from density cells with Tantalum media contact parts, as well as Hastelloy c-276, Carpenter 20, s316L stainless steel and other alloys. Density Cell calculates density at a reference temperature, and uses the process value to calculate specific gravity, Baumé or percent concentration. It uses unique vibratory principles to provide continuous measurement at online process conditions.

DYNATROL, DIVISION OF AUTOMATION PRODUCTS INC.
800-231-2062; www.dynatrolusa.com

ACCURATE SPECTROSCOPY, 24/7 CONNECTIVITY

Kaiser Raman Rxn embedded spectroscopy analyzers feature intuitive Raman RunTime embedded control software. Their latest portfolio includes Raman Rxn2 and Rxn4 base analyzer models. They collect in situ measurements, enabling real-time monitoring, optimization and control, and perform self-monitoring and self-diagnostics. Kaiser Raman embedded analyzers can be configured with 532, 785, or 1,000 nanometer excitation wavelengths, which let them measure up to four channels.

KAISER OPTICAL SYSTEMS, DIVISION OF ENDRESS+HAUSER
https://eh.digital/3qrMbuu

AUTOMATED, LAB-ACCURATE FOR 20 PARAMETERS

Ketos Shield is a smart water management system that provides lab-accurate results for more than 20 parameters in one, modular, microwave-sized unit. It's patented, proprietary robotic process maps samples to appropriate methodologies, and delivers results in 30-60 seconds. Ketos Shield is also fully automated with 0% data drift, and doesn't require manual cleaning, calibration or maintenance on a daily or weekly basis. Ketos Shield is coupled with cloud-based, analytics software, and is available on a subscription basis.

KETOS INC.
www.ketos.co

INFRARED AND CROSS-STACK LASER

Continuous emission monitoring system (CEMS) and process monitoring gas analyzers provide infrared and cross-stack laser process analysis for compliant CEMS and process applications. Multi-component infrared analyzers are available for up to five gases, including CO, CO_2, NOx and SOx, methane and oxygen. Their advanced technologies are suited for oil and gas, chemical, petrochemical and power applications. Specialized models are also available for automobile and heat-treatment emissions applications.

FUJI ELECTRIC
americas.fujielectric.com/process-analyzers

SMART TURBIDITY, CHLORINE SENSOR

Sencom 4.0 four-wire, smart sensor platform, which includes the FLX402T analyzer that can simultaneously measure multiple parameters, has added turbidity and chlorine measurement and analysis to its pH, conductivity and 4-20mA inputs for water quality applications. Its multi-input function lets it flexibly connect up to two sensors at once. FLX402T also has an intuitive touchscreen with a clear display and user-friendly indication with eight languages.

YOKOGAWA

www.yokogawa.com/solutions/products-platforms/process-analyzers/liquid-analyzers/smart-digital-sensor/turbidity-chlorine-sencom-platform

AIR MONITOR REPLACES SENSORS

MBGAS3000-CH single-cell, FT-IR analyzer integrates into air-monitoring systems with up to 48 sample points, including permeation tube for calibration/validation. It's fast and capable of simultaneously measuring multiple acid, organic, amino and hydrogenated gases at ppm to ppb levels. With its more than 20-year diode laser, non-hydroscopic optics, no external PC and more than three-year source, MBGAS3000 runs continuously with minimal maintenance.

MEASUREMENT & ANALYTICS DIVISION, ABB INC.

800-858-3847; new.abb.com/products/measurement-products/analytical/original-equipment-manufacturer/mbgas-3000

FAST-RESPONSE FLUE GAS MEASUREMENT

Thermox WDG-V is a flue gas analyzer intended to optimize combustion control and process safety through the flue gas measurements of excess oxygen (O_2), combustibles ($CO+H_2$), and hydrocarbons (CH_4+). WDG-V mounts directly onto the process flange by using a close-coupled extractive design, and it delivers fast responses in flue gases up to 1,648 °C (3,000 °F). It's ideal for a wide range of markets, including hydrocarbon processing, metals and mining, and power and steam generation.

AMETEK PROCESS INSTRUMENTS

412-828-9040; info.ametekpi.com/combustion

MONITOR TOC, CONDUCTIVITY OR OZONE

RecordLOC is an easy-to-use, audit-ready, multi-language system designed to monitor Mettler Toledo TOC, conductivity and/or ozone sensors at an Alcoa-compliant level. RecordLOC data integrity package provides comprehensive, encrypted audit trails that are clearly legible, and delivers accurate records to comply with FDA regimes for water quality. This in-process control system ensures data integrity that's trustworthy and equivalent to paper records.

METTLER-TOLEDO PROCESS ANALYTICS

800-352-8763; www.mt.com/RecordLOC-Control

MODULAR POWER FOR ONE TO THREE PHASES

WM20AV63H is a modular power analyzer meter from Carlo Gavazzi for single-, two- and three-phase systems. It consists of a maximum of three components, including a main unit that displays measurements on an LCD, and manages two alarms and two accessory modules—one with digital outputs and the other for communication. The digital output module associates alarms with static or relay outputs and/or transmits pulses proportional to energy consumption.

NEWARK

www,newark.com

NON-CONTACT VOLT METERS WITH ANALYTICS

377 FC and 378 FC non-contact voltage, true-RMS AC/DC, clamp meters simultaneously measure and display current and voltage, and eliminate test leads with Field-Sense technology, so users don't have to risk touching live wires. Accurate voltage and current measurements are delivered through the clamp jaw. Fluke Connect software lets users remotely log, trend and monitor measurements. These clamp meters come with an iFlex flexible current probe that can measure AC current as high as 2,500 A, even in tight spaces.

FLUKE CORP.

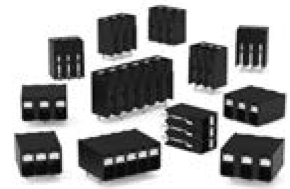
www.fluke.com/en-us/product/electrical-testing/clamp-meters/378-fc

EXPLOSION-PROOF SAFETY DEVICES

IDEM hazardous area safety devices include tongue interlock safety, safety limit and safety cable-pull switches. They provide functions similar to their general-purpose counterparts, but offer explosion-proof switching in hazardous areas, and are made with ATEX Exd IIC T6 certified, explosion-proof contact blocks encapsulated to contain explosions and prevent ignition of hazardous materials. The general-purpose safety cable-pull switches are extended to allow for emergency cable lengths up to 250 meters. Both lines have a one-year warranty.

AUTOMATIONDIRECT
www.automationdirect.com/hazardous-area-devices

PANEL FEED-THROUGH IN TIGHT SPOTS



2086 Series PCB terminal blocks for panel feed-through and tight spaces feature Push-In Cage Clamp spring-pressure connection for inserting solid and ferruled conductors, with the added convenience of pushbutton operation. The series has more than 256 variants, and lets users choose between pin spacing (3.5 or 5 mm), side or top wire entry angle, double inline or staggered pinning for higher voltages with nominal current, as well as through-hole or surface mounting. 2086s are available with two to 12 poles, accepting 24-14 AWG wire sizes.

WAGO
www.wago.com/us/2086-series

TOUCH DISPLAYS AND MEMBRANE KEYPADS

High-contrast capacitive touch displays and membrane keypads for industrial housings are integrated flush into their fronts. They include high-resolution, graphic-capable, 2.4-in., color displays with or without touch functions, and are available for ICS, ME-IO, and UCS enclosure families. Display/touch combinations up to 7 in. are available for the UCSs. Due to their larger size, these displays can visualize more complex processes. A 0.96-in. display is also available for narrow, 2.5-mm ICSs. A web-based configurator allows custom-positioned displays.

PHOENIX CONTACT
www.phoenixcontact.com/us-displays

FLUE GAS FLOWMETER EARNS TÜV AMS/QAL1

MT100 multipoint flue gas flowmeters with thermal dispersion flow sensing have earned TÜV certification for AMS/QAL1 continuous emissions monitoring (CEMS), and comply with EN15267-3 with QAL1 and EN14181(2015). MT100 uses one to eight flow-rate sensing points, and can measure hot, moist, aggressive and dirty flue gases up to 454 °C (850 °F), and measure flow rates over a wide range from 0.07 to 305 NMPS (0.25 to 1,000 SFPS) with 100:1 turndown and with accuracy of ±1.75% of reading and ±0.5% of full scale.

FLUID COMPONENTS INTERNATIONAL (FCI) LTD.
760-744-6950; www.fluidcomponents.com

LOW-VOLTAGE, SEVERE-DUTY AC MOTORS

Simotics SD 200 low-voltage, severe-duty AC motors have gained 75-800 hp outputs, feature 444-5013 cast iron frames for operating in 460 V and 575 V ranges, and meet or exceed NEMA Premium MG1 Table 12-12 efficiencies. They also offer IP56 ingress protection, encoders, brakes, blowers and other options. A unique offset rotor bar provides improved efficiency, while larger bars and end rings reduce resistance. For insulation, Class-H non-hygroscopic system with NEMA Class B temperature rise provides extra thermal life.

SIEMENS
http://usa.siemens.com/simotics-sd200

LEAD, COPPER ANALYZERS FOR WATER QUALITY

S80-T80 lead (Pb) and copper (Cu) analyzers verify treated water quality, and let users comply with EPA lead, copper and electrical/electronic effluent rules and EU RoHS directives. S80-T80 Pb measures lead over a 2.0 to 20,700 ppm range at a pH level of 4-8 over a 32-176 °F (0-80 °C) temperature range with a 10-sec T90 response time. S80-T80 Cu sensor operates over a 1.0 ppb to 6,300 pm range at a pH level of 2-4 over a 32-176 °F (0-80 °C) temperature range with a 10-sec T90 response time. Each uses its T80 transmitter to upload sensor data.

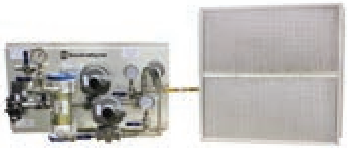
ELECTRO-CHEMICAL DEVICES (ECD)
800-729-1333; www.ecdi.com

IP65/67-RATED, COMPACT CONTROL

C7015 ultra-compact industrial PC (IPC) integrates fanless machine control into harsh production environments with PC-based machine control and IP65/67 components. This Microsoft Azure-certified and AWS-qualified edge device is suited for decentralized installation and provides multi-core computing. C7015 measures just 85 x 167 x 43 mm, and is appropriate for automation, visualization and communications applications. Its integrated EtherCAT P connection and mounting plate enables sensor/actuator connections via IP67-protected EPP modules.

BECKHOFF
www.beckhoff.com

FLAMELESS METHANE DESTRUCTION



EnviroDyne methane destruction unit converts vented or fugitive methane gas emissions to water vapor and carbon dioxide at a rate of 90% or higher without using a flame, which lets it run safely in otherwise hazardous locations. EnviroDyne consists of just two modules: 300 stainless-steel converter and gas train with no moving parts. Following initial start-up via electric power, it runs continuously when supplied with air and clean fuel. It's also CSA C/US-certified for use in Class I, Div. 1 & 2 hazardous areas, and meets Temperature Code T2C.

THERMON GROUP HOLDINGS INC.
www.thermon.com

WIRELESS LEVELING FOR CHEMICAL VAPORS

ParallelPro is a leveling tool with wireless and a field-serviceable battery for use in chemical vapor deposition (CVD) processes and process control in equipment requiring precise parallelism. It measures offset distance, parallelism and temperature, and transmits via Bluetooth to any tablet running an app that also saves and analyzes calibration data. The interface lets users customize display units and calibration parameters. The battery pack is designed for vacuum environments, and provides safe, extended life and many charge cycles.

KAMAN PRECISION PRODUCTS INC.
800-552-6267; www.kamansensors.com/product/kaman-parallelpro

EQUIPMENT & MATERIALS

AD INDEX

The concealed PID revealed, part 2

Five key informational objectives of the ISA 5.9 technical report

GREG MCMILLAN

Gregory K. McMillan captures the wisdom of talented leaders in process control, and adds his perspective based on more than 50 years of experience, cartoons by Ted Williams, and (web-only) Top 10 lists. Find more of Greg's conceptual and principle-based knowledge in his Control Talk blog. Greg welcomes comments and column suggestions at ControlTalk@putman.net

GREG: Last month, we introduced you to the motivation and signals for a proportional-integral-derivative (PID) controller to do what can be an incredible job of providing basic and advanced regulatory control. There is unfortunately a considerable lack of understanding of what the PID can do and should do, complicated by confusion from academia, suppliers and users not being on the same page. The key to spreading the beneficial knowledge gained over decades is to get the leading experts in industrial applications to document their knowledge, and develop consistent terminology and essential concise explanations of functionality in the ISA 5.9 PID Algorithms and Performance Technical Report. Here we begin to get to the heart of the matter by having one of the experts who wrote the section on PID Algorithms explain the informational objectives he sought to resolve and the resulting knowledge gained.

Peter Morgan, what are points of confusion that you resolved in the PID Algorithms section?

PETER: While the PID algorithm in its various forms has been the workhorse of virtually all closed-loop control applications for nearly a century, the fact that there's been no standard convention for naming each of the algorithm forms has led to confusion and sometimes heated debate, when the adopted form name suggests the property of the algorithm. A good example of the latter is the common use of the form name “non-interacting” for the parallel algorithm. This name, suggesting the behavior of the algorithm, for gain, reset and derivative parameter adjustments, rightly expresses the behavior of the algorithm from a time domain perspective, but not from a frequency domain perspective, when, if gain is adjusted, the phase shift across the controller changes at a given frequency, requiring compensating adjustment in reset and derivative parameters during the tuning process.

In my own experience, due to the inconsistency in the naming convention adopted by vendors, I was never confident about which form I was selecting, unless I was able to verify it by reference to the PID equation provided in vendor documentation. The only exception was the parallel form, when it's offered as an option, since it unambiguously defines the structure.

One of the earliest activities of the ISA 5.9 Committee was to survey members and review vendor documentation to determine the range of form names adopted by vendors and practitioners. This activity soon gave evidence to the bewildering variety of names used in describing the PID form offered by vendors or favored by users. For example, for the parallel algorithm alone, some of the names in common use are parallel, ideal parallel, non-interacting, independent, gain independent and independent gains form. ISA 5.9 establishes an unambiguous naming convention for the three PID position forms, namely: parallel, standard and series PID forms.

The report illustrates and distinguishes the characteristics of each PID form with reference to the frequency response characteristics. This approach is not common, but it's the most illustrative in my opinion of the characteristics of the PID algorithm, and provides the foundation for control loop tuning.

Benefitting from the collaboration of committee members with collectively many decades of experience and enquiry, the report shines light on many of the features of the PID algorithm not previously found in one reference document. Below are listed five of the key additional benefits the report is intended to provide.

1. *Adds to the understanding of common features.* The standard brings together in one place a description of the common features such as output tracking, integral tracking, process variable (PV) tracking and feedforward, with typical applications described. As PV tracking is commonly misapplied, the standard provides guidance for its selection.
2. *Provides insight regarding the effect of sampling on PID loop performance.* Since contemporary PID controllers are typically imple-

mented digitally, the implications of sampling are discussed and recommendations made for selection of sampling interval (also known as execution interval). When early distributed digital control systems (DCSs) allowed for the implementation of only a small number of PID loops per controller with fixed sampling interval, a basis for reasoned selection of sampling interval was hardly required.

However, with contemporary control systems offering user configurable PID execution interval and the number of loops configurable only limited by processor capacity to execute the algorithms, some judgment is required in selecting the execution interval for each loop, so that the controller`s ability to complete all required tasks isn't compromised. The report illustrates the effect of sampling on PID loop behavior and provides practical guidance for the selection of PID execution interval based on loop target response times.

3. *Demystifies digital implementation.* The report provides practical guidance for the digital implementation of the PID algorithm. Although, this may be of passing interest to those implementing well-tried algorithms on a familiar platform, the report provides an uncommon and valuable resource for modelling realistic digital PID controllers.

4. *Adds to the understanding of provisions to prevent integral windup and the behavior and impact of specific implementations of anti-reset windup.* Although contemporary control systems implement logic to prevent integral windup at the PID controller when output limits and (typically) external limits are reached, the output may leave the limit when there is a reversal in actuating error in one implementation, while in another it may leave the limit when the error is less than that obtained when the limit was reached. While all methods avoid any latency in action due to integral windup, it's important that the user recognize the behavior and its cause, so an alternative implementation or additional logic can be implemented to provide the desired result. The report describes the behavior for common implementations of PID and provides examples that can meet specific control objectives.

5. *Reintroduces integral action through filtered positive feedback as a practical and beneficial alternative to conventional PID implementations, especially when external reset feedback is applied.* Integral action by the application of filtered positive feedback is a legacy of early pneumatic controllers that few vendors have sought to benefit from in contemporary digital control systems. The PID algorithm section of the report reintroduces the method, describing its characteristics and implementation, and the benefits with respect to the algorithm's inherent property of preventing integral windup without additional logic. A variation of the implementation using external-reset feedback is noted to bring further benefit in accounting for external limits and lost motion. The report is expected to encourage the use of this implementation of PID when it's available as an option, and encourage system suppliers to offer the method as an option.

In general and to summarize, the report is expected to benefit system vendors, users and researchers in avoiding ambiguity in identifying PID form, in the understanding of common PID characteristics and available features, and (for the researcher in particular) in providing practical digital implementations that facilitate the modelling of real-world PID controllers for dynamic studies.

On a personal note, serving on the ISA 5.9 committee provided me with the opportunity to collaborate with a number of experienced, enthusiastic and, not least of all, generous practitioners in the field, an experience that's been inspirational and challenged some of my own ideas. ∞

Seek out the online version of this article on ControlGlobal.com for more on ISA 5.9 algorithms and the Top 10 ways they can improve your personal and technical life.

Roadside attractions

Scanning for giant mascots can be practice for spotting digitalization trends

JIM MONTAGUE
Executive Editor
jmontague@putman.net

"Once digitalized technologies succeed, reach critical mass, become ubiquitous and are always-on, they also fade into the background—like landmarks ignored by those living nearby."

ALL the big topics are supposed to be journeys, rather than destinations. Cybersecurity, wireless, Internet, cloud and edge computing and other forms of digitalization are also enormous in scope, so it's hard to wrap the average brain around them and their jurisdictions. So, maybe labeling them as continuous trips makes them feel less overwhelming. Fair enough. It always helps to break huge jobs into approachable chunks.

Likewise, on long road trips through regions of often mind-numbing sameness, drivers and passengers begin to scan for unusual geological features and man-made novelties to break up the monotony. Music, radio and audio books can help. But after awhile, even billboards can be as visually diverting as an oasis with cold drinks is hydrating. Knowing this, some of the best remedies are put up by locals well-aware of the mental hunger for novelty. Hence, the inexplicably welcome presence of giant Paul Bunyans and other mascots, reptile zoos, the Corn Palace, small liberals arts colleges and other tourist traps. Though not always exactly on the up-and-up and sometimes downright sketchy, these diversions can break up otherwise monotonous landscapes.

Of course, in the process control field and most other industries and businesses, the equivalent of the trackless wastes is the truly endless "talking a lot, but not saying anything" of vague exhortations, which are worse but seem more socially acceptable than saying, "I don't know anything useful." As always, talk is so cheap and plentiful, and the vast majority of it is ego-boosting puffery.

Consequently, the process control versions of refreshing roadside attractions take the form of the intriguing twists and turns in how the details of its huge digitalization topics are revealed as they evolve. For instance, it was interesting to watch the digital industrial protocols like Modbus, DeviceNet, Profibus, HART and Foundation jockey for position years ago, until they all ended up running on Ethernet.

I remember many experts saying that low-cost Ethernet wasn't rugged and deterministic enough for plants floors, and now it's everywhere on all of them, and is adding Ethernet-Advanced Physical Layer (APL) to take it even further. Same goes for cheap, generic silicon boards like Raspberry Pi, Arduino and others that are usually viewed as too fragile and unreliable for process control and manufacturing, but are quickly adding power ratings and other protections, and pushing into industry just like Ethernet did before them.

Similarly, I used to wonder whether controls and software for process or discrete applications would take over both sides of the automation realm. However, I don't wonder anymore because machines and discrete production lines appear to be quicker and maybe better-suited to adopting IT-based software and methodologies.

For example, the ANSI/ISA-88 batch standard started defining functions and phases for discrete batch applications, but everyone apparently loved its organization principles so much that they all adopted its methods, including process users who simply defined the endpoint of their batches as infinite. Likewise, the IEC 61131-3 programming standard for PLCs originated on the discrete side, but lately users on all side appear to be employing it. Even the new Module Type Package (MTP) standard from NAMUR for modular process applications uses Automation Markup Language (AML), which appears to be similar to the PackML standard for packaging machines and the MTConnect standard for linking machining centers.

Ironically, once digitalized technologies succeed, reach critical mass, take over, become ubiquitous and are always-on, they become seamless and mostly invisible, just like OPC UA, Ethernet and wireless. No one tries to put together individual stories about software, networking, electricity or why the sky is blue. They're all just huge facts that everyone accepts. Similar to attractions and landmarks that are ignored by those living nearby, they fade into the background. And the search for smaller problems, diversions and useful fixes revs up again, and the journey turns out to have been be a roundtrip. ∞


The Plant Floor in Your Pocket
Get an overview of your process at a glance.
Control your SCADA with a swipe.
Ignition
Perspective
See the live demo now.
Scan this QR code with your phone
or visit demo.ia.io/industry