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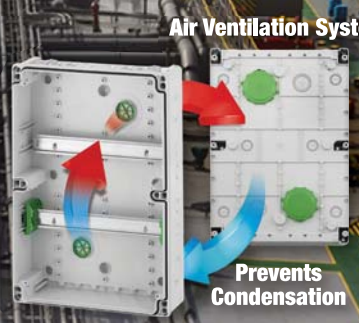

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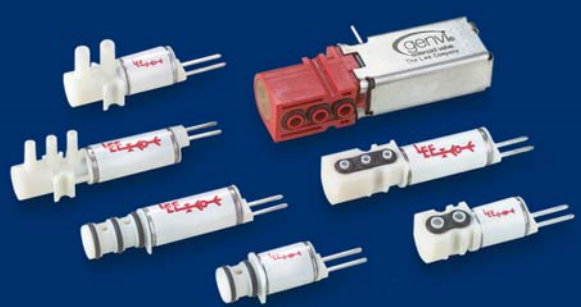

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From the Editor

By Rehana Begg, Editor-in-Chief

Full Automation: **The Path to Lights-Out Production**

SOMETIMES REFERRED TO as lights-sparse or lights-out factories, the concept of a dark factory revolves around the development of fully automated production facilities that run 24/7 without human intervention.

A couple of standout examples: In Japan, FANUC has been running lights-out production since 2001 and today employs lights-out production with the aid of large fleets of robots. In the Netherlands, a Philips plant produces electric razors with a team of 128 robots and just nine human quality assurance workers. And who can ignore Elon Musk's obsession with achieving "alien dreadnought," an in-house term for Musk's ambitions for a hyper-automated Tesla factory?

In this issue, *Machine Design* explores manufacturing automation through the lens of the dark factory. The subtext: Are we there yet?

Think of the work that goes into designing a dark factory as a proxy for a manufacturer's automation maturity model. While automation goals differ for companies based on their level of maturity, the process is highly dependent on computing power, software and networking technologies to speed up assembly, installation, the maintenance of robots and, of course, workers' skill sets.

Automation is helping manufacturers of all sizes carve new working relationships. For the sake of future-proofing, flexibility and sustainability between now and 2030, manufacturers are accelerating adoption. And where business confidence in integrating legacy technology is low, the preference is for partnering and standardized integration, according to a McKinsey survey of 188 industrial automation users and vendors.

Armed with this knowledge while hosting a webinar on the topic, I was only mildly surprised by the coincidence that my guests (representatives from FANUC and Fabco-Air, a Festo company) had a vendor/user relationship. Fabco-Air has practised lights-out processing for about 18 years, in part by shifting from using traditional rotary parts collectors to using robots to collect parts at the end of machines.

Machine Design's technical editor, Sharon Spielman, who tackled the lights-out concept from a supply chain perspective (p. 14), similarly found that the biggest leap that influences an automation implementation is in gaining control over hardware through digitization and emergent tools.

Building capabilities and scaling advanced manufacturing technologies should be a no-regret move. Yet, many companies are stuck in "pilot purgatory," a state in which manufacturers have significant activity underway but their projects don't see bottom-line benefits.

There is a cautionary note for those companies striving to move up the automation stack and aim to be software-defined: Automation for its own sake will imperil best efforts—it's costly, takes a long time to implement and fails to deliver on business objectives.

Successful automation strategies stem instead from good decision-making, and there are definite steps users can take. For best examples, look to the World Economic Forum's Global Lighthouse Network, which currently showcases 132 manufacturers. They lead the way by applying Fourth Industrial Revolution technologies (4IR)—ranging from AI and robotics to cloud computing and big data—to increase productivity, engage workforces, lower emissions and build supply chain resilience.

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Lights-out: Are Fully Automated Facilities the Future?

As with any emerging technology, there are challenges. Part One of this four-part series touches on the chasm between science fiction and reality for the dark-factory concept.

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R&D SPOTLIGHT:

PCB Stator Technology Replaces Bulky Copper Windings

by Rehana Begg, Editor-in-Chief

If the folks at ECM PCB Stator Technology have their say, applications for printed circuit board (PCB) stator motors will replace the bulky copper windings associated with electric motors.

The Massachusetts-based start-up has developed a printed board stator that's smaller than the average motor, achieves efficiencies as high as 96% and requires up to 70% less raw materials to produce.

The design is an improvement over its conventional copper-wound counterparts, stated subject matter experts who gave *Machine Design* a demonstration of the technology at the recent Automate 2023 event in Detroit.

"We've essentially innovated in the electric motor space," said Ethan Frick, director, New Business Development, ECM PCB Stator Technology. "For about 100 years, electric motors have evolved into these extremely bulky copper wire stators. It is the interaction of the copper and the magnets that creates the torque and speed. You need that copper, but it's extremely inefficient to wind it like this. It requires a significant amount of machining tools and design time."

The company also developed a complementary software platform for designing purpose-built PCB stator motors suited to a variety of applications, such as robotics, medical devices or autonomous vehicles. PrintStator enables engineers to rapidly design, model and prototype optimized printed-circuit-board stator motors to exact specifications, said Jake Bright, director of Communications and Investor Relations, ECM PCB Stator Technology.

The start-up recently reported that it was granted additional IP and patents for its use of printed circuit board stators for advanced performance of axial flux, air core machines.

PCB stator technology is proving next-generation electric motors will be customized to exact performance and dimensions for the application.

Asked to sum up the design and unique features of the PCB stator, Frick said, "What we've done is replace the entire [winding] structure with a printed circuit board (PCB). And these printed circuit boards are constructed the same way as circuit boards found in your phone and laptop board.

"We're essentially able to utilize all those existing manufacturing and design tools that are out there to create our motors," he continued. "And we end up with this extremely simple axial flux motor, where you have our copper piece stator in the middle, magnets on either side—and that's all you need."

The only potentially complex thing about this type of motor, said Frick, is the design scheme that goes into these PCB stators. But ECM Chief Scientist Steven Shaw, who received his PhD from the Massachusetts Institute of Technology, came up with a software that automates the design of these motors.

"From robotics to fans to medical pumps and robotic surgery, we're able to plug in torque and speed and voltage, and it will spit out not only a datasheet that gives us build, cost and performance data, but also give us operating conditions under many environments," said Frick. "The data is packaged into a design file, which we can instantly send to that same PCB house that makes your phone PCBs, to print the same day."

Ethan Frick, director, New Business Development, ECM PCB Stator Technology, demonstrates the features of a printed circuit board (PCB) stator motor. *Machine Design*

Frick further pointed out that a disconnect exists between the innovation in electrification and electric motors and engineers often use the wrong motors in their applications. He added that ECM has the capability to design custom electric machines through its PCB stator technology and the company's software optimization platform, PrintStator.

"You come to us and tell us exactly what you need for your underwater submarine propulsion motor, or your exoskeleton shoulder actuator, or your blender motor, and we're going to design something with inherent advantages, a PCB stator that is smaller and lighter," Frick said. "But they're also going to be highly specialized." ■

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BARELY THERE:

Replacing Manual Operations with Lights-out Processes

The concept of lights-out production—streamlining processes with the aid of robotics and automation—doesn't discount the need for people.

by Rehana Begg, Editor-in-Chief

Ambitions for achieving lights-out production have been around for decades. Yet, the number of manufacturers that boast of end-to-end automation—where the facility can operate in the dark for a period of time with minimal or no human supervision—remain the exception to the rule.

Among the early adopters, FANUC, which produces robotics, CNC and motion control, is a stalwart. Back in 2001 the Japanese company made it known that it used lights-out manufacturing techniques. "These were robots making robots, robots making the motors…we're making the CNC controllers, assembling the computer boards," said Jerry Perez, executive director of Global Accounts and manager of Business Development at FANUC Americas.

By one estimate, the factory employs lights-out automation technologies by using robots to build robots at a rate of 50 in a 24-hour shift and can run untended for up to 30 days.

AT A GLANCE:

- Whether the benefits of lights-out automation outweigh the costs depends on the situation. An undeniable benefit, however, is flexibility.
- Athena 3D commissioned Delta Technology, a systems integrator, to develop a turnkey robotic automation system that could keep production going 24/7.
- At Fabco-Air, primary operators at the machining centers have an app on their phones. They can watch their dashboard offsite and know enough about what's going on inside the plant to make a decision.

The foundation for the journey started in the 1980s, estimated Perez. "There's a lot of work that went into making that happen. So, when I hear lights-out-type technologies, I hear journey," he said.

Hot Demand for Automation

The work that goes into lights-out automation is underpinned by what is communicated—between machine and machine and from process to process—and is today well within reach of manufacturers.

"Think of a factory: There are things that people are doing. They're communicating, monitoring different [equipment], and then inspecting and testing those things," said Perez. "For each of those aspects the technologies and devices [and functionality they deploy] didn't necessarily exist 15 years ago, particularly the ones that one could add on and retrofit."

In the past five years, Perez argued, it hasn't become easier, but it is "more doable and more feasible for companies to begin that journey by taking their existing equipment and adding some central devices to get equipment communicating."

Turning the 3D Printing Business Equation on its Head

In one FANUC case study, engineers solved production volume and efficiency concerns for Athena 3D, an additive manufacturing and engineering services provider based in Tempe, Ariz.

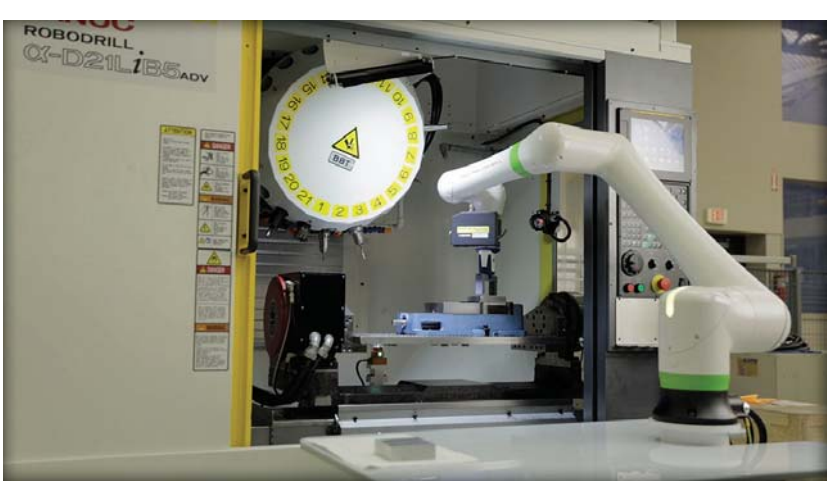
With production volume in mind and to meet demand, the additive manufacturer typically would run multiple 3D printers simultaneously. Once a print run was complete, machines would sit idle because the next job was dependent on having an operator change out the print bed. In some instances, the company would have up to 16 printers to change out manually. Since operators would return to the facility the next day, the lag translated into a significant amount of time and efficiency lost between print runs.

To optimize the use of machines, Athena 3D commissioned Delta Technology, a systems integrator, to develop a turnkey robotic automation system that could keep production going 24/7. The solution allowed the 3D printers to be programmed according to specifications before automatically queuing up the next job. In other words, when one print job is completed in the middle of the night, a FANUC CRX-10iA cobot can remove the print bed, set it on a storage rack and install a clean print bed into the printer. The Application Programming Interface (API) then instructs the printer to start the new job.

Athena 3D's technicians boast of pumping out twice the number of parts and a 40% increase in the use of the technology, noted the case study. Technicians are reassigned to complementary, high-level tasks, such as quality control, maintenance and process management.

Created in 2019, Athena 3D is a relatively new company. The use of a lights-out solution to produce on demand, along with the ability to ramp up production under tighter deadlines, has given the company an edge in record time.

Fabco-Air (and Festo) is aggressively moving to lean, synchronous manufacturing at all facilities. As a way to drive efficiency, the expectation is the company will employ more cobots, especially in assembly operations. *Fabco-Air Inc.*



FANUC has used lights-out manufacturing techniques since 2001. By one estimate, FANUC uses robots to build robots at a rate of 50 in a 24-hour shift and can run untended for up to 30 days. *FANUC*

Unattended Nights and Weekends

Across the manufacturing spectrum, a slow and steady march to full automation has been implemented in varying iterations. Call it what you will—dark factories, lights-sparse factories or crewless cells—the goals for agile automation remain constant: take advantage of new operational efficiencies, reduce errors, accelerate product lifecycles, decrease labor and materials costs, and improve quality.

To achieve these goals, manufacturers turn to advancements in robotics, automation and 5G; innovative processes and operational technology; AI and ML; and VR and AR designed for industrial applications. That's not to say that the highest level of automation is always the best choice; balancing the cost of optimizing existing production systems against the use of advanced technologies can help define an optimal automation strategy in assembly or production lines.

Neither is it a hard-and-fast rule, as analysts tend to suggest, that lights-out automation methods are best suited to simple mass production of a standard product on a set schedule. Fabco-Air is one of those exceptions.

Located in Gainesville, Fla., Fabco-Air Inc. (a Festo company) produces pneumatic actuators and pneumatic control valves, and has used lights-out processing for the past 18 years. What makes this manufacturer unique in their lights-out offering is that they are a custom product, custom solution business. "So much of the product is low volume, high mix," Director of Operations Kevin Cradduck told *Machine Design* during a webinar exploring automation through lights-out manufacturing techniques. "We have a very complex business with a lot of product mix, and that creates very unique challenges, which Fabco-Air has developed a skill set for over the years."

Fabco-Air's use of lights-out technology is on the machining side—in the turning centers, said Cradduck, who joined the company in 2018 and has a finger on the pulse of advancements in technology and synchronous manufacturing

Athena 3D, an additive manufacturing and engineering services provider, commissioned Delta Technology, a systems integrator, to develop a turnkey robotic automation system that could keep production going 24/7. *FANUC*

processes. "We do a lot of machining, and especially a lot of turning. Many of our CNC machine centers are set up during our day shift and proven out. Then, the machines are set up to run all night and produce the components. Actually, they run all night and all weekend."

For the most part, Fabco-Air employs conventional CNC turning centers. The CNC machines are fed by magazine bar feeders, which can load enough material to run fully unattended. Automatic parts collectors then collect the finished parts.

"We've done that well over the years," said Cradduck. "Now, we're really in what I would say is a refinement phase. We're using newer technologies, by moving from traditional rotary parts collectors to now using robots to collect those parts at the end of the machines."

A few advantages have sprung from upgrading the technology. "One is better part protection," said Cradduck. "We don't run the risk of damaging those parts. And another advantage is that we don't have to do secondary operations to clean up while no one's here. So, the robot will collect that part safely and put it in a containment device."

The system also moves the component into parts inspection. "The robot feeds vision systems, and we inspect dimensional parts," said Cradduck. "It does a couple of things: If we have a broken tool, we can feed that information back to the machine and tell it to shut off when it makes bad parts. Or we can decide to continue running that machine. But now we've segregated those parts."

Another advantage is that Fabco-Air can feed that data to a FANUC controller integrated with the machines to automatically do tool offsets and adjust for tool wear while no one's around.

If the potential for reaping benefits has been boosted by IT/OT technology, Cradduck reckons Fabco-Air is still on the learning curve when it comes to applying it. "Go back 15 years or so, when we started, the level of technology that we had were auto dialers on each of our machines," he said. "If there was an error code and the machine would shut down during the night, the poor receiving person would receive an error code, wake up in the middle of the night and come in and turn these machines on. You talk about miserable, right?"

Those times have passed. Cradduck's team, which has an average employee tenure of 25 years, is now collecting data in real time. "It's doing a lot of things for us," he said.

Primary operators at the machining centers have an app on their phones. When they're offsite, they can watch

"So much of the product is low volume, high mix. We have a very complex business with a lot of product mix, and that creates very unique challenges, which Fabco-Air has developed a skill set for over the years."

Fabco-Air Inc. has employed lights-out methods for more than 15 years. As a result, the company refined its offering with short lead times on both custom and off-the-shelf products. *Fabco-Air Inc.*

their dashboard and know enough about what's going on to make a decision. They may then consider whether it is it worth going back into work and correcting this problem.

"There are a number of factors that go into that," said Cradduck. "It may be that the part they're running is getting near the end of the spool, or the machine could only run two more hours. I'm not going to go into work for that. Or, it may be serious."

If employee engagement is one consideration, building out capabilities is another. "The technology is also tying in very nicely with our total predictive maintenance program," said Cradduck. "We're now linking this technology with our software package. Where we see that going is that if there is a lights-out error, it feeds into that software package and sends a notification to our maintenance crew. They can make those same kinds of decisions."

Advancing beyond that, Cradduck envisions the suite of technology will generate enough information to provide a diagnostic map to the maintenance crew. "Let's say they do have to come in after hours, they will already have a diagnostic plan when they come in. They've got that technology in front of them."

Iterative Processes Have Payoffs

Most companies tend to think of lights out as going from where they are today to no lights and no people. The reality is closer to Cradduck's experience—a journey, said Perez, who joined Cradduck as a panelist on the lights-out webinar. "For the most part, you're going to automate what you can and adjust what can be justified now. And it'll be an iterative process."

A logical next step would be to consider technologies that were not available off the shelf years ago but can now be installed to provide feedback from machines, and can re-adjust or calibrate automatically based on the current operation. For instance, sensor technologies can be used to inspect whether enough material was taken off during machining of a part, pointed out Perez.

Festo is aggressively moving to lean, synchronous manufacturing in all of its facilities, according to Cradduck. "And as we do that, we'll probably start to implement more and more cobots, especially in assembly operations where we're doing 'hand-offs.' It continues to drive efficiency."

A general trend Perez has noticed with lights-out technology is that companies are developing off-the-shelf, standard solutions over time. The next iteration of Fabco-Air's journey, he estimated, may require some customization. "To be able to say, 'This went wrong. I need to show this maintenance diagram. But I need to take [a different] maintenance diagram and turn it into software code to automatically tell the machine to do something,' hasn't been done yet," Perez said.

But, among the new technologies available today, it is reasonable to expect the industry to launch such solutions in the coming years, said Perez. "Could we implement that? Yes. Would it take money and time and coders today? Yes. But it could be part of the journey, and maybe Fabco-Air will be the trailblazer."

Cradduck's enthusiasm for his company's next lights-out play is palpable. "We're looking forward to seeing you visit us and Gainseville, Fla.," he tells Perez. ■

Fabco-Air Inc. designed the original Pancake cylinder. The company also designs and manufactures a range of linear slides, actuators, air preparation units and valves. *Fabco-Air Inc.*

Dark Factories:
Science Fiction or Reality?

Has machine design technology matured enough for the concept of a fully automated facility to be more than a pipe dream?

by Sharon Spielman, Technical Editor


Guy Courtin, Tecsys Inc.

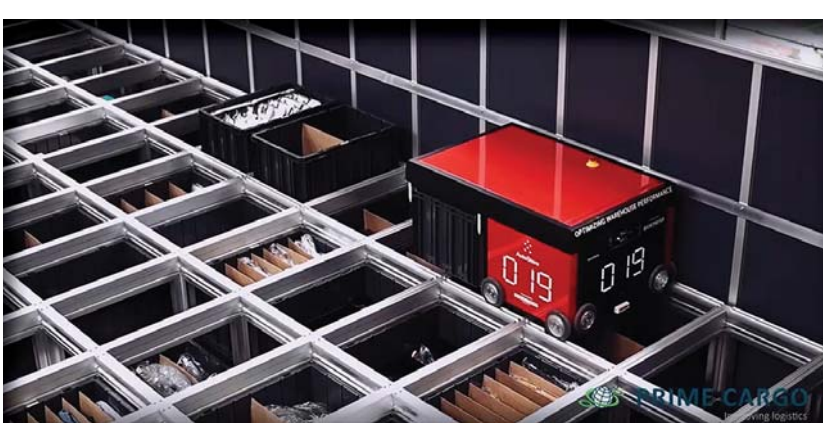
Advancements in automation, robotics, sensors, artificial intelligence and machine learning have led to the potential for self-contained, self-servicing production lines and warehouses. "Lights-out" or "dark" facilities have potential, but is the technology robust and advanced enough for this concept to become a reality?

For a supply chain perspective, *Machine Design* spoke with Guy Courtin *(pictured)*, vice president of Industry and Advanced Technology at digital supply chain solutions company Tecsys Inc. For the last two decades, Courtin has spent time in leadership roles for supply chain solution providers as well as spending time as an industry analyst covering the manufacturing and supply chain space.

While automation is nothing new in the factory—think back to the late 1700s when machines helped produce clothing, Courtin reminds us—today's automation is much more sophisticated and often humans are not needed. Among the benefits of a fully automated dark factory, Courtin says: "Robots don't require breaks or get tired. Conceivably you could run the facility 24/7. Robots don't need heat in the winter or air conditioning in the summer. They don't require lights; they can see in the dark. Certain safety precautions are not necessary…and robots don't go on bathroom breaks or go on strike."

Jobs that are dangerous, repetitive or tedious will benefit the most. "I was recently in a factory building large warehouse automated storage units; there is a considerable amount of welding that needs to be done, [which] was automated," Courtin says. "We have all seen automotive assembly lines where there is an army of robot arms being leveraged to weld, paint, manipulate the cars as they moved down the line. To be able to do this work, you need sophisticated motion and vision to precisely perform these tasks."

When asked how virtual robots can better integrate with existing software and systems, and what role they play in the dark factory concept, Courtin says that with any remotely controlled or



3PL auto store Prime Cargo uses Tecsys Inc.'s warehouse management system to help automate its fulfillment. *Images courtesy of Tecsys Inc.*

autonomous robot, the increased computation power available locally as well as the advances in cloud technology, Wi-Fi, 5G and other communication protocols allow for deeper control of this hardware. "These technologies can make autonomous robotics more of a reality for a dark factory," he says.

Overcoming Technical Challenges

Connectivity is a concern, and it is important to address that aspect to ensure as close to full-time uptime as possible. Courtin reiterates the importance of robust supporting technology: "How stable is your Wi-Fi or 5G network? Do you need to have redundancy within your factory to ensure the systems stay up? If your technology requires on-premises solutions, then you need to ensure you have the right servers within the factory."

As with all technologies, there are limits. "The main limitation I see currently is more associated with cost," Courtin says. "If we had unlimited budgets, then we could have all the robotic toys we wanted. But we have to show some level of ROI."

"Other limits are in some manipulation that humans are still vastly better at. For example, picking items off a warehouse shelf," Courtin says. "We have robotic picking arms, but humans are still much better at this—and more cost-effective."

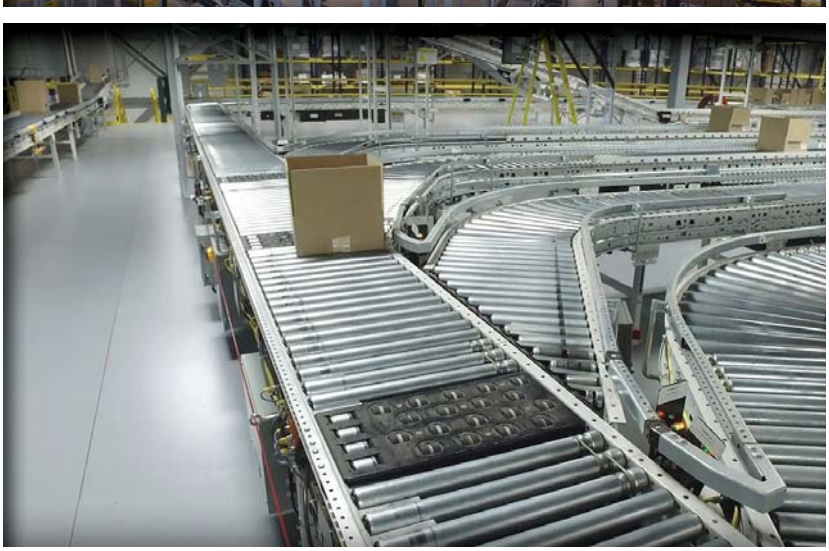
Consider Potential Risks

Courtin reminds us that no technology is without some risk, and one such risk is over-reliance on automation to operate a dark factory. "What happens if there is a power outage or one of the robots goes down?" he asks. "Does this stop my entire process? What are my redundancies when it comes to robotics?"

DKI Logistics integrated the Tecsys Inc. warehouse management system for its automated facility that serves six hospitals in the Jutland region of Denmark.

Another risk to consider is labor strife. He says it is hard to imagine flipping a switch and going from a traditional factory to a fully automated dark factory overnight. "How does labor react when they see more automation? Are there potential issues with labor, unions, etc.? I have seen challenges in selling automation in areas with strong unions as they will oppose such an investment," Courtin notes.

3PL auto store Prime Cargo uses Tecsys Inc.'s warehouse management system to help automate its fulfillment.



Werner Electric uses Tecsys to power its fulfillment operations.

Certain jobs will be lost, he acknowledges, while noting employment should remain steady. "Will certain roles in the factory go away? Absolutely. But others will emerge," he says. "I believe that automation will continue to be complementary to labor…It will certainly replace specific jobs.

"But I think where the chasm is between that sort of science fiction and the reality is there [are] still a tremendous [number] of jobs within these facilities that humans are still better equipped to do and that we still, as humans ourselves, recognize that the humans are better suited to do those jobs," he adds.

Expect Change Management

One of the main areas to focus on, according to Courtin, is how a fully automated facility could potentially impact the rest of the supply chain. "We covered how it will impact labor, but what about other parts of the system?" he says.

"If I increase my throughput in my factory, can my transportation node handle the potential increased volumes of finished goods? Can my suppliers keep up if my production increases two times or three times? I might be optimizing one node of my supply chain, but what is the knock-on effect to the rest of my supply chain?"

In Courtin's dealings with factory and warehouse operators, he says he realized very quickly that some of the processes and procedures are almost ritualistic. So, if a technology as disruptive as robotics is introduced, there will inevitably be change management needs.

From a personnel perspective as well as a process and a flow perspective, Courtin says it must be considered: "You have a system that is…chugging along. Whether it's great or not, it's doing its job. And, also, now you're introducing…a physical machine, a robot, to do something. So that's what I would caution folks."

It does not mean that people should not look at bringing more automation into their facility, he notes, but it does need to be considered. "It's not just bringing a robot in, solve Problem X, increase efficiency … great, done. It's what happens across the whole system," Courtin says.

Parallel Paths for the Future

At the end of the day, a robot is plastic, steel, wires, glass and rubber, Courtin notes. When put together, "mechanically it could do a lot of great things," he says, "but if I don't have some kind of control, some kind of software brain that tells it what to do, then it's just a statue."

Let's look at these parallel paths. "From a mechanical perspective—and I am certainly not a mechanical engineer, so I apologize to offend anybody out there who is—but from a mechanical engineering perspective, I still think there are…tremendous opportunities to push the envelope as to what the physical robots can do," he says, noting manipulation of material, camera technology and visual systems.

He says he sees investments on that track with continuous process improvements.

The biggest leaps that will influence the entire system, however, are around the software, Courtin believes. "How do we leverage things like smarter or artificial intelligence? How do we leverage things such as much more or much more plentiful data?"

Access to more relevant data is the key. How will companies generate and leverage the data? And because these facilities are not based on one technology, they are going to have multiple different hardware and software for multiple different robots. "So, we need some kind of connective tissue that now allows interoperability to happen between all these solutions to make a dark factory feasible, to make a dark warehouse more feasible," Courtin says.

Give Up Control to Gain Control

"All of us software providers, even the integrators and the consultants, we're all trying to become that player that controls all of it. Why? Because if I control all of that, commercially, that puts me in a very strong position," Courtin says.

Of course, each individual node doesn't necessarily want someone else to control what they do. "So, all of a sudden, we have this conflict where…we want to see some kind of hierarchy, we want to see some kind of digital solution that can help integrate and control all this. But each player has to be willing to give up some control to have this happen.

"And I have yet to see that happen across the board. Unless, of course, you go in and someone dictates it, but they do it grudgingly. So…when I look ahead…I think that's what I'm seeing as we continue to evolve and pour resources into it," Courtin says. "And I think that's incredibly exciting." ■

Lights-out Manufacturing: Myths Versus Realities

by Nash Chakraborty & Christian Heck, Siemens Digital Industries Software

Early adopters of lights-out concepts are now learning to scale autonomous production. Siemens' Xcelerator platform is one solution helping manufacturers make headway.

As manufacturing companies consider what the "factory of the future" looks like, autonomous production within a "lights-out" factory seems likely to expand across the industrial spectrum. The concept of a lights-out factory, where the requirements for human activity are so minimal that the facility can operate in the dark, is something of a unicorn: a wonderful idea, but one that is unlikely to materialize any time soon.

That said, the digital and automation technologies needed to make it a reality are now starting to mature, and companies across all industries are being challenged to make products better, faster, cheaper and more sustainably despite supply chain challenges and a shrinking workforce. A dark factory could help not only address sustainability, but also productivity.

Lights-out Factories are Yet to Materialize

It is an ambitious expectation for lights-out production. Traditionally, the type of manufacturing that lends itself to this type of factory is simple mass production on a fixed line layout. As products grow increasingly complex and mass customization/configuration increases the number of potential product variants, implementing a completely dark factory seems to become even more mythical and out of reach.

Although automation and digital manufacturing technologies can help turn the myth into reality, the changes need to be incremental to reap the benefits (especially in brownfield facilities where large capital investments are already in place).

Lights-sparse Factory Floors are More Economically Feasible

According to a Gartner study, by 2025, 60% of manufacturers will have more than two completely lights-out processes in at least one of their facilities. Lights-out manufacturing does not need to be an all-or-nothing proposition. Instead, manufacturers can identify specific processes or areas within a facility where autonomous production is both feasible and valuable. This incremental lights-out implementation, commonly known as lights-sparse implementation, enables manufacturers to balance the return-on-investment (ROI) from automation without the investment typically required for complete transition to a full lights-out factory.

Manufacturing Operations Software is Key to Lights-Sparse Manufacturing

The development and maturity of numerous automated machines and robots, as well as comprehensive and proven manufacturing operations management (MOM) software, is key to creating these lights-out manufacturing cells. New advances in MOM software offerings make it possible to seamlessly orchestrate autonomous production systems through two key capabilities.

The first is the ability to automatically match the operations requirements with the capabilities of the equipment. Software needs to be able to automatically identify available manufacturing resources when a new product is introduced, as well as during an unforeseen shop floor event such as an equipment failure. Second, manufacturing execution, material supply, supply chain and scheduling need to have event-based integration, which will not only ensure the seamless execution of the production process, but also enable continuous optimization and the automated handling of any possible interruptions.

In addition to these key capabilities, MOM software also provides a new user experience. After all, even when talking

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Manufacturing operations management (MOM) software is a key component in orchestrating autonomous production systems. *Siemens*

about lights-out, people will still play an important role in the future of manufacturing. This new user experience contextualizes information from different sources to enable remote decision-making, which could be anything from re-scheduling and re-prioritization of orders to using alternative supplier strategies.

A New Approach to Manufacturing Planning and Machine Engineering

Lights-out manufacturing concepts require a more flexible relationship between product, process and resources than traditional manufacturing. As a result, manufacturing engineers will need to work more abstractly than before, and the way they define constraints will become crucial to leveraging the full potential of an autonomous production system. This, in turn, increases the importance of using simulation early in engineering to support the automated generation and validation of scenarios essential to successful implementation. Adopting this new approach enables the extra level of flexibility and freedom required for the orchestration software to make its own decisions and reach the level of autonomy necessary to turn the lights off.

Use Case: Testing Lights-out Production Concepts in Fürth

AS BOTH A software vendor and a manufacturing company, Siemens recently implemented an autonomous electronic box-built process with a laser, PXI testing, box assembly and final assembly station. All material transportation on the modular shopfloor layout was realized using AGVs. Each station had its own docking stations to load and unload box carriers. Machine loading as well as assembly tasks were realized using universal robots with custom-made end effectors.

Every autonomous cell was equipped with latest PLC technology to realize the defined equipment capabilities, including the handling of incoming and outgoing materials and synchronization with the AGV fleet management system, as well as the safe execution of a specific capability such as "Assemble product variant XYZ." The orchestration of all capabilities, as well as transport, was realized as part of the Siemens Opcenter MES system including an advanced scheduling algorithm for online optimization.

According to a Gartner study, by 2025, 60% of manufacturers will have more than two completely lights-out processes in at least one of their facilities.

Strategic Workforce Planning

As manufacturers begin to implement lights-out concepts, the skill requirements for the workforce will change in three aspects. First, in addition to domain and manufacturing know-how, planning engineers will need to acquire the knowledge required to model abstract constraints and dependencies and use simulation tools for validation in their day-to-day work.

Second, shop floor operators will require knowledge of the latest automation technologies to safely operate autonomous machines and be enabled to extend their capabilities. Machine and solution providers also will need to transition from expert systems with specialized knowledge requirements to user-friendly interfaces to allow quick adaptation and extension of a machine's capability.

This will, for example, include the adaptation of robots, maps for automated guided vehicle (AGV) routes, updating material requirements for new products and more. Leveraging the latest IT and low code programming concepts for different automation engineering tasks can help to enable the broader workforce to contribute to the transition.

Third, job enrichment and continuous learning will help manufacturers stay competitive and profitable in the global economy, as they face an aging workforce and shortages of skilled laborers.

Key Learnings from Fürth

- The experience of the shop floor workforce is critical and must be captured. It is important to include shop floor operations early to digitalize the "institutional knowledge," including information like specific constraints, best practices, typical failure scenarios, etc.
- It all starts with material transparency and intra-plant logistic processes, which require 100% transparency in the material management down to commissioning and preparation in boxes.
- Automated material transportation, including loading and unloading, tends to be slower, so optimized advanced scheduling can compensate for this and get the system into a profitable range.
- An autonomous system requires an abstract machine interface based on a capability state machine, so it is important to involve the machine suppliers early in the process to ensure a uniform shop floor interface.

Autonomous production test area of Siemens electronic factory in Fürth. *Siemens*

Leveraging its learnings from the factory in Fürth, the Siemens Xcelerator portfolio has already implemented fundamental features to support customers throughout their individual journey.

Benefits of Autonomous Production

The main driver for most manufacturers looking into autonomous production concepts is the need to increase productivity, while reducing labor costs despite the associated risk of getting required labor skills at the right time and place to follow changing market demands.

While the autonomous production concepts can address this challenge, it is not their only value. The ability to automatically match and validate every production process of new and existing products—including processes requirements—to available equipment can enable manufacturers to drive important business KPIs such as earlier time-to-market, sustainability and higher resilience.

Additionally, it enables the ability to produce products in different production systems and facilities to support local and sustainable production, as well as a way to compensate for supply chain interruptions. ■

NASH CHAKRABORTY is director of marketing, Digital Manufacturing and CHRISTIAN HECK is technical product manager for Siemens Digital Industries Software.

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Barbara Humpton, president & CEO, Siemens Corporation USA, delivered a keynote talk on "How Digitalization has Transformed Manufacturing—And our Future." *Machine Design*

Automate 2023:

A Robotics & Automation Event Organized Around Market Trends

The A3 trade group highlights how market behavior and new robotic technologies shape the ebb and flow of their event.

by Rehana Begg, Editor-in-Chief

If 2022 was the record year to beat, Automate 2023 has given robotics event organizers an even greater run for their money!

This year's event was the biggest yet, featuring 300,000 square feet of exhibit space, 750 exhibitors and 25,000 attendees, according to Jeff Burnstein, president of event organizer A3 (Association for Advancing Automation). The largest robotics and automation trade group in the world, A3 boasts 1,200 member companies.

"[Automate] has been growing by 45% to 50%, to the point where we're screening for exhibit space this year, and Automate is now going to be an annual show," Burnstein announced at the event held at Huntington Place in Detroit.

Enthusiasm for market growth was similarly reflected in an industry trends

presentation. Alex Shikany, VP, Membership & Business Intelligence, A3, reported that 2022 was a record year in robotics orders, jumping more than 44,000 units for the first time since collecting statistics in the early 1980s.

A3 research, he reminded the audience, is segmented between automotive, which includes OEM and components orders, and non-automotive, which includes life sciences, electronics, metals, plastics and everything that is not bundled under the automotive segment.

"The industry came back from a more historic norm in terms of automotive orders," he said. "The automotive segment really took an upswing [in 2022], and you're going to walk around [the show] and see a lot of automotive applications. One of the things driving this is the route to electrify the supply chain…The move has driven the need for robotics."

Compared to 2022, the start of 2023 revealed a more tempered outlook. North American companies ordered fewer robots in the first quarter of 2023 than for the same period last year. According to

Excellence in Robotics

JEFF BURNSTEIN, PRESIDENT of the Association for Advancing Automation (A3), knows a thing or two about robotics. He was selected as one of two recipients of the prestigious Joseph F. Engelberger Robotics Award, which recognizes excellence in technology development, application, education and leadership. As this year's the Leadership award recipient, Burnstein was recognized for his four decades of commitment and vision at the global automation trade association.

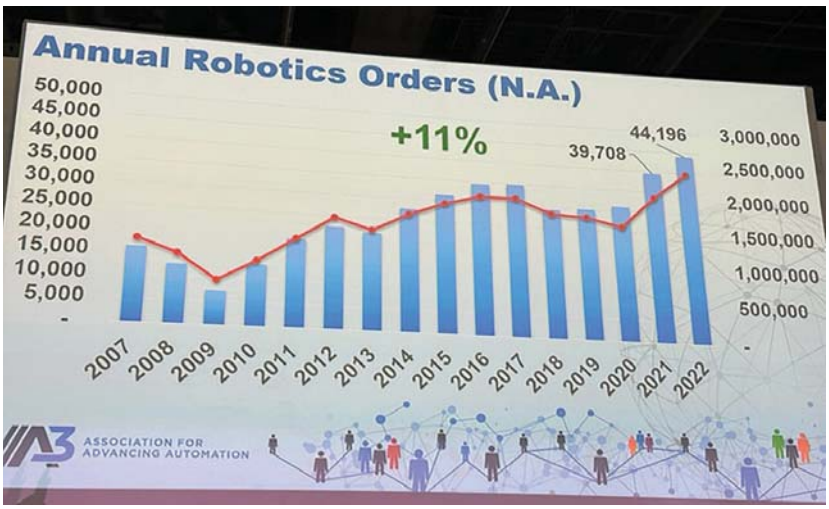
"Winning the Engelberger Robotics Award for Leadership is beyond any accomplishment I could have imagined when I started at the association 40 years ago," said Burnstein. "The award has been described as the 'Nobel Prize of Robotics' for good reason, as it is acknowledged globally as our industry's pinnacle of success. As an English major with no technical background at all, I am living proof that there is a home for anyone in the robotics industry."

The other recipient was Roberta Nelson Shea, global technical compliance officer, Universal Robots. Nelson Shea received the award in the Application category for her outstanding work in the development of industrial robot safety standards in North America and around the world.

A3, companies ordered 9,168 units valued at $597 million in Q1 2023, a 21% drop in total units and a 10% drop in value over the same quarter in 2022.

A3 also stated that automotive customers accounted for 68% of all robot orders in Q1 of 2023, with 5,659 robots purchased. During Q1, non-automotive orders in consumer goods, semiconductor & electronics, plastics & rubber, life sciences/pharmaceutical/biomedical, metals and others purchased 3,519 robots, down 42% over Q1 2022.

Burnstein stated in a press release that inflation and a slowing U.S. economy may have taken a slight toll on robot orders overall, but that the automotive sector continues to fast-track purchase orders as they make the transition to manufacturing electric vehicles.



Alex Shikany, VP, Membership & Business Intelligence, A3, presents an industry outlook at Automate 2023. He said that 2022 was a record year in robotics orders, jumping more than 44,000 units for the first time since collecting statistics in the early 1980s. *Machine Design*

"I don't think automation is about taking away jobs anymore. What we saw recently, is the Congressional Budget Office had released that 0.2% annual increase in labor from 2024 to 2031. And, when you look at that, there's essentially 2.1 million jobs left unfilled. So, it's not about taking jobs anymore. It's about how can you have some continuity in your business to continue to operate at the production levels that you have."

"Non-automotive companies are typically newer to automation and may be waiting to invest more until they've tested recent deployments or see the economy begin to recover," he said.

Add to this the fact that labor shortages continue to be a key risk in the growth of automation. That's all the more reason manufacturers look for ways to handle

ABB's U.S. Robotics Division president, John Bubnikovish, shared insights into the ways automation can offer manufacturers continuity in their operations. *Machine Design*

the "dull, dirty and dangerous" tasks that can be handled by robots, Shikany said.

"I don't think automation is about taking away jobs anymore," said ABB's U.S. Robotics Division president, John Bubnikovish. "What we saw recently, is the Congressional Budget Office had released that 0.2% annual increase in labor from 2024 to 2031. And, when you look at that, there's essentially 2.1 million jobs left unfilled. So, it's not about taking jobs anymore. It's about how can you have some continuity in your business to continue to operate at the production levels that you have.

"[Moreover], how do you expand? And that's where I think the real value from automation comes from nowadays; it's not going to replace workers necessarily. It is that we can't find workers to do these jobs anymore, so we're going to have to automate."

That demand was evident in investments made in AI, motion and vision control, as well as communications and networking solutions that bring together hardware and connected devices into a software environment.

For her part, Barbara Humpton, CEO and president, Siemens Corporation, made the case for using augmented intelligence, or the use of qualitative data sets, to enable the programming of PLCs. "This makes every one of us capable of programming the automation," she said during her keynote. This is no longer out of reach to the people we are going to need to bring it into the workforce. This is the power of the platform."

Siemens is developing a software-enabled controller that is designed to be hardware agnostic. "We know that manufacturing environments everywhere are heterogeneous," Humpton said. "Over the decades we've brought technology from all kinds of suppliers into this working world and we had these solutions working side by side.

"And now the virtual PLC enables us to access that hardware through a software interface. Why would we want to do this? Well, for a couple of reasons. One, we do want to start thinking about hardware as a service."

She explained further that the Siemens Xcelerator open digital transformation platform can enable service technicians to get alerts on their iPhones if equipment needs attention. Technicians would be able to see the diagnostics as they stream through the application interface and then be able to take corrective action. "Think about what this might do for our workforce management," she said.

Humpton's keynote presentation offered an overarching upbeat philosophical message about optimizing for change. "What we've been talking about here is the introduction of technologies. But if you listen closely, what we're really talking about is who we are as people, and how we operate in this world of incredible opportunity.

> *"And the question I've been asking myself, and I hope you'll join me in this quest...to answer this question: Instead of trying to find an optimal state of being, what would it look like if we got our teams to focus on optimizing for being in a state of constant change?"*

"And the question I've been asking myself, and I hope you'll join me in this quest...to answer this question: Instead of trying to find an optimal state of being, what would it look like if we got our teams to focus on optimizing for being in a state of constant change?"

Attendees to Humpton's keynote would have found plenty to mull over on the trade show floor. "There's so much demand for automation, and Automate, we believe, is the leading event for people to learn how to successfully apply these technologies," Burnstein said.

The next Automate will be held from May 6-9, 2024 at McCormick Place, Chicago. ■

Automate 2023 Showcases Process Automation: Coordinators, Orchestrators & Differentiators

End-to-end process orchestration was a principal theme at Automate 2023. *Machine Design* considers seven technologies that enable operators to capitalize on automation.

by Rehana Begg, Editor-in-Chief

This was the year end-to-end process automation made its impression as a dominant theme.

If you asked Jason Waldman what the most observable trend was at Automate 2023, his response would be something like this: "I would reckon that Rockwell Automation's CIO would say, 'AI, AI, AI, AI,' but it definitely is what people are looking for."

As Waldman, a business development manager at Advantech, continues his train of thought, one would realize that he is in effect describing the art and science of beginning-to-end process automation. "It's not just about a robot being able to pick something up over here and put it over here," Waldman said. "It's also about a robot being able to do your inspection to make sure everything is okay.

"It's about a robot being able to pivot where things should be able to go," he continued. "It's about being able to pick items; it's about being able to do the visual inspections…It's making sure robots are smart enough to where you can essentially turn them on and let them run. That, I think, is the biggest trend."

At Automate 2023, the trend was backed by an abundance of emergent virtualizing technologies—from embedded IoT computing and AI, to material removal and calibration, to the latest in vision systems and integration software—all of which work together to scale robotic deployments. Finding a pathway to automation serves a higher ambition to scale up and enable the business to serve customer needs.

Bolster Operational Efficiency

Performance and efficiency are closely related to the goal of end-to-end solutions and services. According to Waldman, it is why Advantech, which bills itself as a provider of Industrial Internet of Things (IoT) hardware and automation technology, partners with software companies "where it makes sense" and helps customers set up equipment right out of the box.

Driving home his point, Waldman pointed to the scalable Valor Mini Workstation. There are three aspects that distinguish the solution, he said. Firstly, the industrial PC can handle complex processes by eliminating the need for frequent recertification, reintegration and replacement associated with commercial workstations. The expected lifespan of a typical industrial PC is around 12 to 18 months, but the Valor Mini offers longevity of up to seven years, Waldman pointed out.

Secondly, Walman said, customers typically can order a SKU from an existing catalog. In contrast, Advantech's workstation sets up a unique SKU number. "We actually give the customer their own SKU number on a configuration for this workstation," explained Waldman. "When they order it, it's a locked revision control; they know that they will receive the same product over and over again." Thirdly, said Waldman, Advantech provides hardware customization options, from CPUs to GPUs to DRAM SSD.

The Valor Mini Workstation measures just 2.2 × 7.9 × 7.9 in. (W × D × H) and expands Advantech's Valor Series. A full-featured Valor Tower is slated for release later this year.

Valor Mini Workstation, released in May 2023, is built to streamline automation processes and has a lifespan of seven years. *Advantech*

Qualitative Visual Inspections Meet Quantitative Data Insights

Where size, speed and accuracy requirements need to be maintained, human vision tends to fall short. Edge learning or AI training can enable manufacturers to maximize throughput. Cognex Corporation, an industrial machine vision company, harnesses these technologies to make vision solutions easier and more marketable to the masses, said Sean St. Peter, territory sales manager, Cognex.

Based in Natick, Mass., Cognex targets logistics and automotive (electric vehicles

and battery-related technology), as well as consumer electronics markets, and strives to reach a customer base that "doesn't have the expertise and know-how to integrate this type of system into their line," according to St. Peter.

The imaging capabilities of the In-Sight 3800 Vision System is embedded with artificial intelligence (AI)-based edge learning technology, as well as traditional rule-based algorithms. Designed for high-speed production lines, it solves tasks with high variability, sets up in minutes with just a handful of training images and offers twice the processing speeds of previous systems.

Cognex specializes in industrial machine vision. The In-Sight 3800 Vision System was designed for high-speed production lines. *Cognex Corporation*

Robot Operations at Scale

Florian Pestoni, CEO and co-founder of InOrbit, guided *Machine Design* through a virtual tour of the company's multi-cloud platform. InOrbit is designed to help robot developers maximize the potential of their robots through expert guidance, advanced software and strategic industry partnerships. The software abstracts the complexity of the hardware to control the autonomous robot's position virtually.

InOrbit uses the term "Software-Defined X" to refer to the process of controlling objects in the physical world. The collaborative, open-source system is built around three personas—engineers, operations and executives—with a focus on the engineering work of building the robotic systems that make everything work and enable operations and other infrastructure to draw benefits from the robot's potential.

Having a platform for managing robot operations (or RobOps) can elevate robotics integration at scale. Pestoni, who co-founded the company headquartered in Mountain View, Calif., explained that InOrbit provides sightlines to robots on the shop floor through secure, real-time analytics and data collection, robot performance monitoring, incident response and root-cause analysis. "With our end-to-end orchestration capabilities, we are revolutionizing the way companies manage and optimize their robot fleets," Pestoni said.

Florian Pestoni, InOrbit CEO and co-founder, explained how the company's multi-cloud platform enables efficient robot operations and provides visibility through secure, real-time analytics and data collection and robot performance monitoring. *Machine Design*

Eliminating Dull, Dirty, Repetitive Processes

In partnership with Applied Automation, ATI industrial Automation and Fer-Robotics, cobot solutions developer Kane Robotics was able to demonstrate GRIT cobots in each booth.

Kane Robotics was founded in 2019 by John Spruce, an executive and entrepreneur who is able to draw from two decades of experience leading large-scale automation projects and engineering and manufacturing services for the aerospace and defense industries.

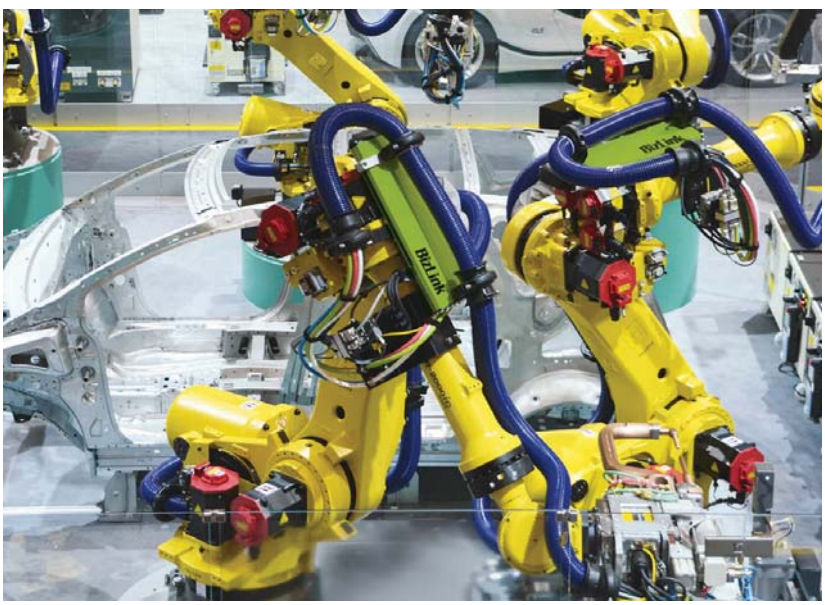
The company developed the first cobot for composites sanding. Kane highlighted its stealth at material removal with demonstrations of its GRIT cobot solutions, including sanding off coatings, grinding welds and polishing metal finishings. These capabilities help manufacturers with removing coating and sanding surfaces for paint preparation or repairs on helicopter main rotor blades, polishing fighter jet canopies, sanding primer from machine components and deburring metal castings.

Kane Robotics' GRIT ST cobot grinding metal industrial parts. *Kane Robotics*

At the ATI Industrial Automation booth, for example, Kane demonstrated how the combined solutions of its GRIT-ST cobot system with ATI's CGV grinder, Universal Robots' UR10e cobot and 3M's Cubitron II abrasive media work together to efficiently and safely grind welds.

Kane Robotics' GRIT ST collaborative robot solution for sanding, grinding and finishing composites, metals and other parts in manufacturing operations.. *Kane Robotics*

> *"If a person's doing it, we can train a cobot to do it. We're not reinventing new processes to automate; we're helping manufacturers move to new tools that will make them more efficient and protect their health."*



BizLink's advintec TCP system can help measure and create an initial tool center point with extreme accuracy and at much cheaper costs. *BizLink*

The company noted that ATI's CGV grinder has built-in compliance so the unit can compensate for irregularities in part surfaces. The grinder's compliance force is adjustable, enabling users to make changes in real-time, and CGV's sensing data allows for process validation. Paired with Kane's GRIT cobot system, the Kane-ATI solution works alongside humans to perform a wide variety of labor-intensive tasks, while avoiding rework and downtime.

"If a person's doing it, we can train a cobot to do it," said Kane Robotics COO Alan Hiken. "We're not reinventing new processes to automate; we're helping manufacturers move to new tools that will make them more efficient and protect their health."

Robot Tool Center Point Calibration

In aerospace applications, where robots are tasked with riveting plane panels together, precision is critical. The robot drills in a specific location, to an exact diameter, and inserts and compresses a rivet. The tool tip's movement needs to be set in relation to the base coordinate system and is achieved more precisely when centered around the very end of the tool or end effector. Even a slight deviation from the original reference point can mean expensive rework or scrapping entire parts.

This is where BizLink's advintec TCP system is useful. The tool was demonstrated on a FANUC CRX cobot with an ATI tool changer. The TCP tool uses a two-channel infrared (880 nm) photoelectric laser sensor pulsed at 2 kHz to calibrate tools and fixtures electronically in up to six dimensions (three axes plus angular rotation around each axis) without touching a robot's end-of-arm tool.

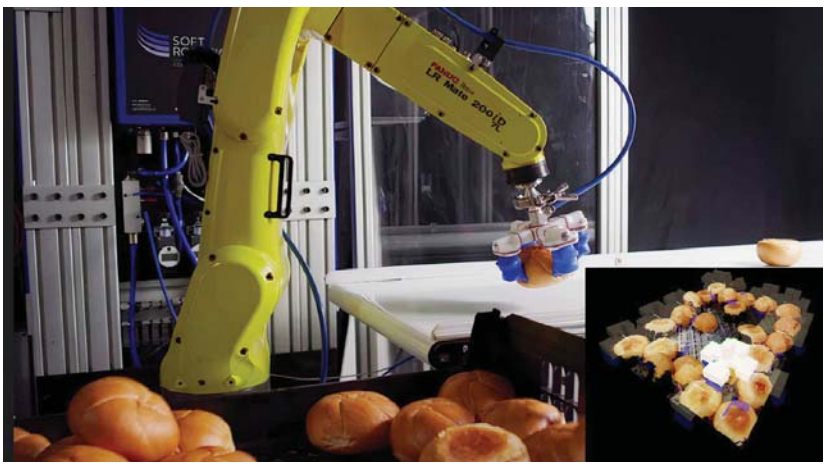
According to BizLink's press release, the system compares the robot's path to the way its main reference moves, records the robot's path, identifies any variations from the original path and establishes that the robot has shifted whenever a process changes or the robot requires calibration.

Soft Grippers and AI Automate Bulk Picking

Soft Robotics showcased its automated food-picking solutions, including the *m*Grip modular gripping system comprised of a suite of configurable soft grippers and controllers, as well as the no-code interface *m*Grip AI that combines 3D vision with robotic grippers and AI software for challenging food automation scenarios. Combining 3D vision, artificial intelligence and soft grasping technologies into an easy-to-integrate, IP69K-rated solution, Soft Robotics highlighted two applications:

- **Case packing sausages from bulk**. 3D bin picking, sorting and orienting packaged sausages at rates of up to 24 picks per minute.

- **Tray packing chicken drumsticks directly from bulk**. Picking, orienting and packaging of raw poultry product from bulk at rates of up to 60 units per minute.



Soft Robotics designs and builds automated high-speed picking solutions using 3D machine vision, artificial intelligence software and proprietary soft-robotic grippers for the food industry. *Soft Robotics Inc.*

Realtime Visual Tracking

FANUC is known for its CNC systems and is popularly associated with bringing high-payload capacity collaborative robots to market. With its North American headquarters in Rochester Hills, Mich., the company can boast 11 cobot models for industrial applications.

FANUC recently introduced the CRX-25*i*A cobot with a 30kg payload capacity, and the CR-35*i*B cobot with a 50kg payload capacity. "We've seen substantial growth in the cobot space, particularly from companies that are new to robotic automation," pointed out Eric Potter, general manager, General Industry and Automotive Segment, FANUC America.

One highlight at Automate was the FANUC R-2000*i*C/165F robot, which uses a FANUC *i*RVision 3DV sensor to locate and pick a wheel from an infeed conveyor. It detects the tilt and rotation angles of a wheel hub on a moving conveyor. A 2D sensor provides visual feedback, enabling the robot to track and load the wheel as the conveyor moves. The action eliminates the need for a stop-station operation.

The robot uses FANUC's FS-250iA Force Sensor and Force Control Software to load the tire, then retracts and waits for the conveyor to stop. Next, the robot uses 3DV to locate and remove the tire from the hub and return it to the infeed conveyor; the cycle then repeats.

Several intelligent products come into play in this demo, including FANUC's realtime visual tracking software, Industrial PC (*i*PC), *i*RVision and Force Control. The 2D *i*RVision tracks the 2D target without the use of encoders and the high-speed FANUC *i*PC processes the information.

"A key customer benefit to this type of tracking is that it can adapt to 2D variances caused by unstable conveyors, as well as adjust to slight speed variations in real time," noted Jennyfer Pina, material handling engineer, General Industries and Automotive Segment, FANUC America. ■

FANUC's demonstration at Automate 2023 featured several intelligent products, such as FANUC's realtime visual tracking software, Industrial PC (iPC), iRVision and Force Control. *FANUC America*

FANUC recently introduced the CRX-25iA cobot with a 30kg payload capacity, and the CR-35iB cobot with a 50kg payload capacity. "We've seen substantial growth in the cobot space, particularly from companies that are new to robotic automation," pointed out Eric Potter, general manager, General Industry and Automotive Segment, FANUC America.

Biomimicry in Medical Device Design

Novel microfluidics technology enable the development of medical device form factors that are easy for patients to use.

by Jeff Morang, Director, Human Factors Engineering, BlackHägen Design

Inspired by nature's ability to manipulate microfluidics, this patient-administered device from PreciHealth was designed with small form factors, making it is easy to use and to carry around. *BlackHägen Design*

Designers and engineers have often looked to the environment and how Mother Nature has accomplished phenomenal design solutions for inspiration over the ages. Perhaps all that is new about this concept is the descriptor, biomimicry.

After all, the concept of the Golden Ratio is a mathematical function of ancient peoples' acute observation of nature. It can be used in design to achieve beauty, balance and harmony. Leonardo di Vinci, for example, would conveniently have a sketch from nature as a reference on the same pages of his innovative concepts.

A more modern example would be the hook-and-loop fastener, commonly known by the brand Velcro. It was invented by a man who noticed burs and brambles clinging to his clothes and dog. Upon closer inspection, under magnification, he found these seed pods to have tiny hooks that engage fibrous materials that presented a structure resembling a loop.

A Source of Inspiration and Guidance

The connection between biomimicry and medical device design may not be as evident for the healthcare industry as it should be, considering how close medical device design is to the organic intimacy of its context for use. One can look at biomimicry from two perspectives—one is inspirational, and the other is design guidance. The latter is literal mimicry, the result of which is referred to as biomimetics: the natural intersection between biology and engineering.

An example of inspirational biomimicry could be the observation that certain animals like tortoises and sharks live much longer than other vertebrate animals, which may reveal clues to an age-related therapy. Guidance-type biomimicry could be examining the evolution and mechanical construct of a ram's skull in the design of a football helmet to understand how rams do not suffer from concussions even with frequent headbutting.

Regardless of the perspective of biomimicry, be it inspirational or guidance, there are opportunities from which medical device designers and engineers can greatly benefit.

A New Regard for Mosquitoes

This case study will demonstrate both types of biomimicry and how they are being applied to current innovative medical products. Starting with inspirational biomimicry, PreciHealth, a startup medical device manufacturer in Switzerland, looked to the mosquito for inspiration. It found the ability of a mosquito to be able to simultaneously acquire blood and deliver its saliva—a strong anticoagulant biochemical—through a very small set of canulae in their proboscis as an opportunity for medical device advancement.

This creature's ability to manage microfluidics inspired the conceptualization and development of ideas around drug delivery and blood collection platforms, especially in wearables and injectable devices. Currently most injectable platforms deliver medication at the milliliter scale, rather than the microliter scale, like a mosquito's transactions.

The first step was to develop technology that mechanically managed microfluidics in a repeatable, extremely precise manner. It was no surprise then, given the Swiss culture, that PreciHealth initially demonstrated the precision of the new technology in the form of a novel type of wristwatch. The commercialization of these watches by the parent company, PreciFlex/HYT, proved the microfluidic precision and enabled the application of the company's technology into medical devices.

The first application of this technology, inspired by nature's adept ability to manipulate microfluidics, was in the design of a combination device for the delivery of epinephrine. At the time, current solutions were challenged by two issues. First was the size. An EpiPen can measure 6 in. in length each, and the patient is required to have two of them. The second issue is how readily it can be used incorrectly and end up injecting the user's thumb.

However, the novel microfluidics technology enabled the development of a very small device, about the size of a key fob, with safety features and a more intuitive user interface included. In addition, its smaller form factor better accommodated the requirement for patients to carry two of the devices. ■

Editor's note: A longer version of this article can be found at machinedesign.com/21265727.

FAQ

Incorporating High Power Relays into Solar Power Applications

With the proliferation of the use of solar power systems throughout the country, designers need components that are right for each segment of the system. Understanding what is required and what is available is key to designing a quality system.

Q1: How are relays used in solar power applications?

Solar power is considered a photovoltaic generator and is comprised of one or more solar panels along with an AC grid inverter that is interconnected with the public power grid. These systems may also include batteries for storing solar energy and a battery charger that is integrated with the AC inverter. These systems can vary in size from rooftop systems to utility-scale generation plants.

Q2: How is the DC voltage created from a solar power system converted to AC voltage?

Direct current voltage generated by solar panels is converted into alternation current through the AC converter. This voltage is either fed into the power grid or collected by receivers that are connected directly to the system. The inverter provides voltage to the connected AC receivers from the solar power system batteries or the power grid and allows it to be redirected directly from the AC grid input to the inverter output. If the absorbed energy by the receivers is greater than the energy supplied by the solar power system batteries, the DC/AC converter works in bypass mode, switching to power from the public grid.

Q3: Where are high-power relays incorporated into a solar power system?

High-power electromagnetic relays used in solar power systems have two main purposes. Relays are used on the DC side to switch DC voltage generated by the photovoltaic cells off and on. On the AC side of the system, high-power relays are used to connect or disconnect the entire system from the power grid (see Figure 1).

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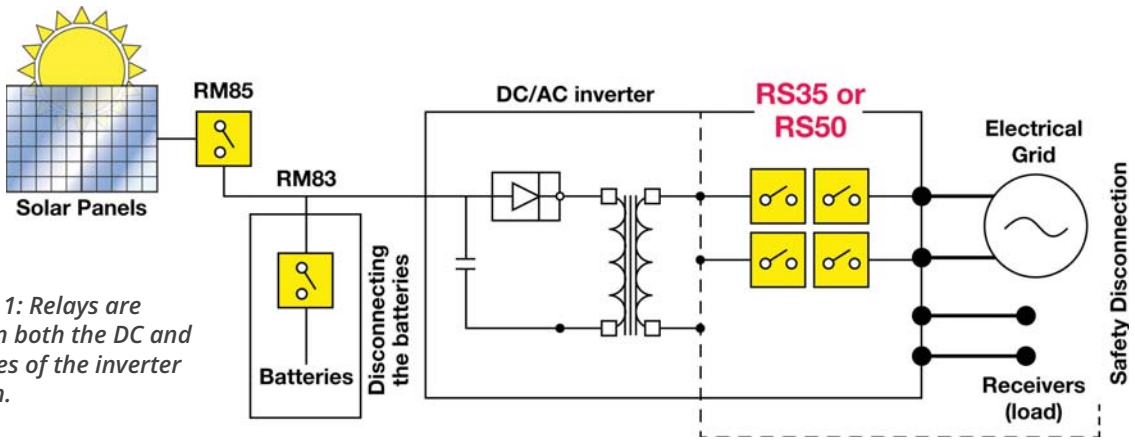

Figure 1: Relays are used in both the DC and AC sides of the inverter system.

Q4: Are there special requirements for relays used in solar power systems?

Any time there is a supply of energy to the public grid, it is susceptible to special requirements relating to the relays being incorporated. Some important requirements include a minimum contact gap of 1.5mm, a minimum open contact dielectric strength of 2500 V rms, low holding power for the coil and a wide temperature rating.

Q5: What is meant by an "automatic system"?

An automatic system refers to safety regulations. A solar power system must be equipped with an automatic system that disconnects the generator from the AC power grid for safety reasons. This protection circuitry is often built into the DC/AC inverter. Two-pole relays are used so that each contact disconnects a separate line during emergencies—the single-phase line and the neutral line in a single-phase application and two phases in a two phase application. Two contacts connected in series are required for each line. The separation of the circuit is therefore carried out by two two-contact high-power relays.

Q6: What relays are recommended for this type of application?

Altech has partnered with Relpol to provide high-power relays for these applications. Their RS35, RS50, and RS80 relays are specifically designed in accordance with the requirements of many safety standards, including the DIN VDE 0126-1-1, to fulfill the needs of users. The RS35 relay, with a switching power rating of 8750 VA, is intended for smaller solar power systems such as those installed in single-family homes. The RS50 relay, with a switching power rating of 12,500 VA and the RS80 with a switching power of 20,000 VA are designed for larger industrial systems (see Figure 2).

Figure 2: The RS35 and RS50 high-power relays for solar power systems are designed in accordance with the requirements of DIN VDE 0126-1-1.

Q7: Is relay power consumption an important factor in solar power applications?

Yes, that is one of the most important elements To ensure the highest efficiency of the inverter, the power relay components must have the lowest possible power consumption possible. That is why the RS35/RS50 high power relays are equipped with coils that are rated for only 0.4 Watts of power consumption. Heat emission is also significantly reduced by decreasing the supply voltage of the relay coils after activation. For example, for a relay with a 12V coil, the minimum supply voltage used during continuous operation can be as low as 5V. This means that power consumption is only 85

mW, which translates into high efficiency for the entire device.

Q8: Are their relays available for printed circuit board use?

Yes, the RS35, RS50, and RS80 relays are designed for PCB mounting. In addition to the RS type relays, Altech supplies many other varieties of relays. For example, the company offers the RUC relay line specifically for printed circuit board designs—with a contact gap of 3mm. These relays are available in both 2NO and 3NO configurations, which allows them to be used in three- phase designs in addition to single- and two-phase systems.

Q9: What high-power relays are available for DC voltage disconnection?

An array of products are available for all areas of solar power systems, including disconnecting the voltage generated by assemblies of the photovoltaic cells such as on the DC side of the inverter. Disconnecting the system on the DC side is often required for safety reasons—in the event of a failure—as well as during service inspections or for test and measurement purposes. Altech also offers relays for this purpose. Their RM83 and RM85 offer an increased contact gap ideal for these applications (see Figure 3). The relays can also be used to disconnect the battery system or be used in the equipment that calibrates the angle of inclination of the solar panels.

Figure 3: A wide variety of power relays for the solar power industry are available, including Altech's RM83 and RM85 used for DC voltage disconnect.

Q10: What other applications might require high-power relays?

Power relays are a versatile component used in a wide variety of industries, including industrial automation and home automation, tele-communications systems, lighting and safety monitoring, automotive electronics, computer systems, battery testing equipment, elevators, and numerous industrial control applications. High-power relays have become key components in many circuits for a variety of safety reasons, including protecting humans as well as protecting other electrical or electronic equipment.

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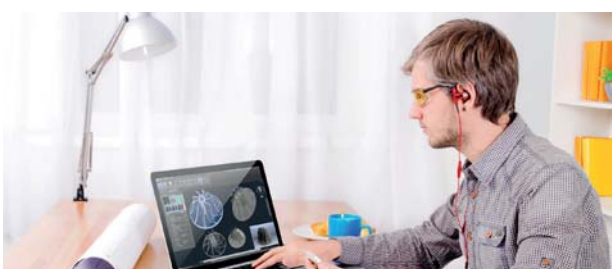

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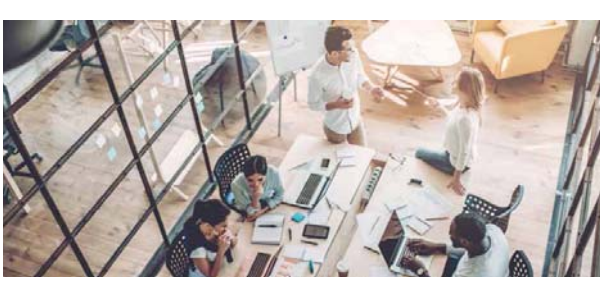

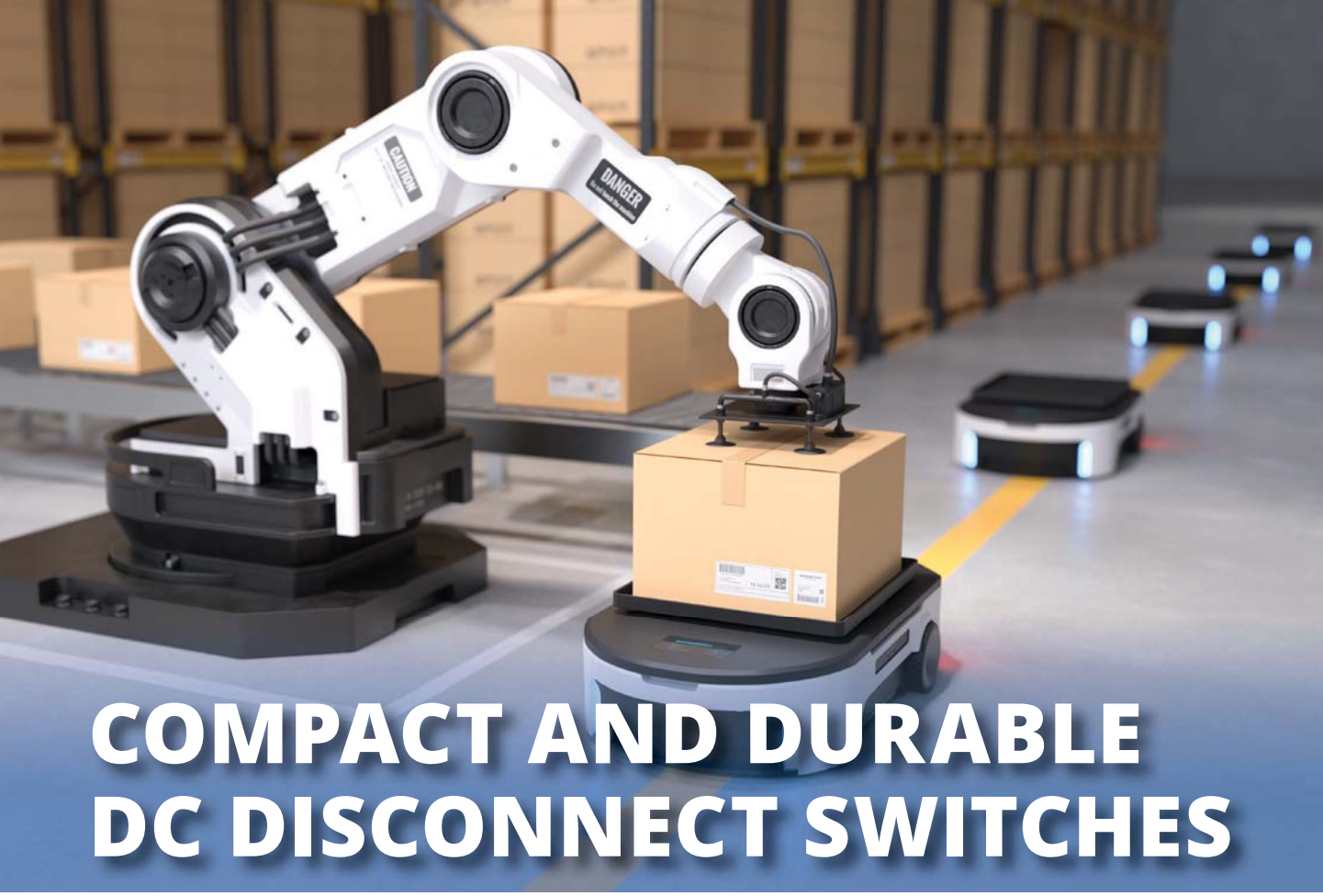

COMPACT AND DURABLE DC DISCONNECT SWITCHES

With a number of challenges concerning the design, manufacturing, and delivery of all types of electrical components, it is important for companies to design new products with a full understanding of customer needs and market realities. Disconnect switches are such a key component to most applications that the proper design along with assured deliveries is essential.

Robots, battery powered transports, and portable lab equipment are being used on the factory floor and in the laboratory, which means they are in close proximity to humans. An AC disconnect switch separates the inverter from the electrical grid, while a DC disconnect switch separates the equipment from the DC source. In the past disconnect switches were mounted to walls and or electrical cabinets where they are available for emergency use. With smaller and smaller real estate like that of a small robot, the disconnect switch is often panel mounted close to the device.

Disconnect switches are used to keep equipment and people safe. They must be properly installed so that incoming power can be quickly shut off whenever necessary. Most equipment being manufactured today must be equipped with a disconnect switch for safety purposes. Their purpose is to shut off incoming power from your equipment or device.

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The primary reasons you might use a disconnect switch include local or federal requirements and codes, the threat of product waste or system damage during an equipment breakdown if power is left on, or in the even that a human gets into a position where they can be harmed.

Engineered Products

The markets have changed, the availability of materials has changed, and the needs of manufacturers have changed—and continue to change. Design teams need to focus on present needs as well as future challenges. Every component has to be reviewed, evaluated, and designed to meet the present and future needs of the customer.

When it came to designing the new disconnect switch line offered by Altech, a range of features were considered. With the increases in supply struggles, the aim was to use materials that were easy to acquire and use, as well as those that will be available for many years into the future. Plus, design features were focused on manufacturability using the latest automation tools.

The switch bodies are produced from high-grade plastics able to handle most harsh environments. The tough bodies can operate within a wide temperature range, are shock resistant, and chemical resistant. Internally, the design team focused on the quality of the contacts. Silver plated contacts and rivets are used throughout to assure long life cycles while providing better conductivity.

Designated as the LSF series, these disconnect switches are the only DC switches available in the compact frame size that are dual rated for AC/DC. The switches are available to mount in multiple ways, including with an integrated base and DIN-rail mounting, and a separate RT version with integrated door mounting and side panel mounting. The RT devices are provided with rear facing terminals for ease of installation. For electrical box installations, the mounting versions depend on the needs of the user. One option is an extended handle application where the shaft sticks out beyond the electrical box for easy access and interlocks with an external handle so that the box cannot be opened until power is turned off (see Figure 1). This dual rated switch represents the “only” DC switch in this small of a frame—36mm (W) x 71mm (H) x 46mm (D)—without integrated switching knob and panel mount tabs).

The extended handle application uses a long shaft that sticks out beyond the electrical box for easy access.

Another option is the panel mount. Usually installed in a side panel, this option requires users to drill a small 22.5mm hole into their panel which will accommodate the rear-mounted disconnect switch (see Figure 2).

A knob is then attached to the front of the panel for easy access. The panel mount version is typically used for applications where the user requires a local disconnect for total power, or a local disconnect used to remove power from a portion of a particular piece of equipment without shutting the entire system down. Both of these mounting options for the disconnect switches have only three parts, unlike most other products on the market that have multiple parts and can be complex to install.

Figure 2: The panel mount option for the LSF series disconnect switch is easy to install.

The LSF series disconnect switches are designed to be compact for use in a wide variety of applications. They are available in 16A, 30A, and 40A versions. They all offer UL 60947-4-1 certification. An important design feature is that the switch make/break operation is independent from the operator's actual turning speed. Hence, the actuator arm has nothing to do with changing the state of the switch. The internal design of the switch is spring loaded so that DC current cannot arc and burn up the contacts after multiple uses. Once the switch gets to a certain point, it snaps into place and cannot be backed off. Unlike AC switches where you can "tease" it open or closed without harming the internal functionality of the switch, DC switches must take arcing into consideration.

Assuring Quality and Delivery

Automation, when done properly has been shown to increase efficiencies in production, as well as assure that quality is maintained throughout an entire line of products being manufactured. When using readily available materials, and a reduced number of component parts, further efficiencies can be obtained. Manufacturing lines do not have to slow due to supply issues. These factors are even more important when it comes to products such as disconnect switches that have such a wide user base.

The reality of supply chain challenges facing today's manufacturers on multiple levels have been taken under consideration during the entire concept and design of Altech's LSF disconnect switches. The design specifically incorporated only materials that were safe from becoming obsolete and leaving customers unable to fulfill their application needs. By combining multiple levels of evaluation and analysis, the company was able to guaranty delivery times, eliminating the supply chain issues other companies struggle with daily. Everything from concept through design through manufacturing has been reviewed and purposefully streamlined for easy of manufacturing as well as delivery.

ABB Robotics Adds Four Energy-Saving Models to Lineup

ABB Robotics has added four models to its line of large robots. These robots allow for payloads of 150-310 kg. The robots' modular design provides 22 variants from which customers can choose to ensure they pick the best solution for their application needs. Eleven of these variants come with ABB's LeanID DressPack, which eliminates swinging cables and supports off-line programming. Key features of the robots include reach that ranges from 2.5 m to 3.2 m, sustainable production energy savings up to 20%, high motion control accuracy, suitability for complex tasks and repeatability with a minimum of 0.03 mm deviation.

ABB ROBOTICS

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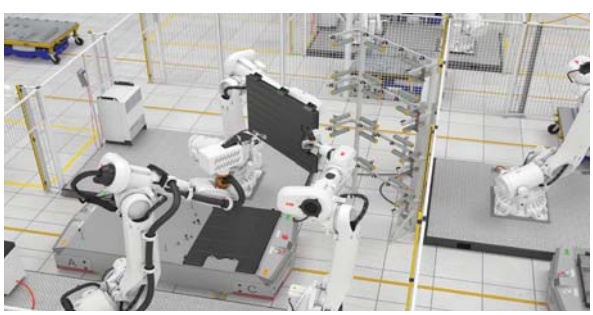

Siemens SINAMICS G220 Adjustable-Speed Drive is Designed for Digitalization

The Siemens SINAMICS G220 multipurpose adjustable-speed drive uses built-in Clean Power technology to reduce harmonics by up to 97% without an AC line reactor or DC choke. It is the first drive to join the company's Xcelerator portfolio, a business platform for digitalization. Key features of the SINAMICS G220 drive include space and operational efficiency, the ability to be set up quickly, an IIoT module, hardware-based SIL 3 functional safety requirements and a range of modular and flexible hardware options.

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Gearing up at Automate 2023: Schaeffler Showcases Latest Components for Robotics

by **Rehana Begg,** Editor-in-Chief

AS THE DEMAND for AI-driven solutions in the robotics industry rises, so does the strain on the hardware.

For companies like Schaeffler, the opportunity to bring new system components—precision gearboxes, pivot bearing supports, drive motors, sensors as well as the robotic 7th axis—to Automate 2023 was invaluable.

A relative newcomer to the robotics space, the company first entered the arena around 2018. That's when Nicolai Haemmerle, vice president, Business Field Robotics, Schaeffler, and his colleague, the regional CTO, realized the hype building around cobots.

"In Tokyo, you could go to a café and have a cobot make coffee, and that was a great thing to experience," Haemmerle said. "And we thought, why don't we actually give it a shot? We've got the technology and the market is growing rapidly, especially on the cobot side. More and more applications are being conquered by sensor technology. We also see a lot of opportunities because Schaeffler has 75 plants globally."

Haemmerle characterized the idea to expand into the robotics and automation market as "genius" because Schaeffler has avoided adding any additional components to the system.

"We use the existing components of the mechanical gear and apply the sensor directly into the gear," Haemmerle explained. "We use the flex spline with the strain wave gear and apply the sensor structure directly onto the flange by coating layers onto it. We etch out the sensor structure using a laser and that way we're actually able to apply the laser sensor directly in the gear box.

"We don't add any additional design space or any additional parts, and we have a high stiffness, which is important for our customers," he continues. "We don't reduce the torsional stiffness, and we have the highest accuracy of the sensor signals. It's a win-win for all of us. And overall, the market response has been amazing."

Sensors Make the Difference

The opportunity to answer the market's call for solutions can be addressed through the development and integration of sensor technology. In this respect, Schaeffler's sensor-based components can be viewed from two topics, said Haemmerle.

The first is in the sensor design itself. "What we have done is we've actually merged multiple sensors inside the system," explained Haemmerle, who flew in from Germany to be at the Detroit show. "And these are read out by two completely separate software clusters, one being a deep learning algorithm." Engineers use the data to evaluate the mechanical effects from the gear itself and filter it, he said.An additional input is that each gearbox is trained on an end-of-line test at the point of manufacturing. "Basically, the algorithm is trained over the entire torque range of different revolutions. That is adapted specifically for the gear set, with the right tolerance, and so that we can always ensure that we have the maximum accuracy readout."

1.


2.


3.

1. Gregory Falco, communications and branding specialist, and Nicolai Haemmerle, vice president, Business Field Robotics, Schaeffler, were on hand to answer questions about the company's lineup of high-precision planetary gearboxes and strain wave gear set. *Schaeffler* **2. Schaeffler's Precise Silent Constant (PSC) series planetary gear units that exhibit virtually no torsional backlash. 3. Heavy-duty RT1-T strain wave gear with integrated torque sensor system featuring Schaeffler's proprietary sensory coating.**

The second software cluster serves as a redundancy test. "It's just standard, basic software tests that validate if the AI algorithm is actually working correctly, to confirm whether signals are valid, and so we can process it and send it out to the interface of our customer," he said.

The following components were highlighted at Automate:

PSC Series precision planetary gear units. These ultra-precision planetary gear sets are for a range of industrial automation and robotics applications. PSC stands for Precise (the highest precision available on the market), Silent (the lowest noise level) and Constant (a constant level of precision during the application period). Traditional gear drives exhibit torsional backlash that increases with wear.

RT1 and RT2 precision strain wave gear sets. Schaeffler is now offering two series of precision strain wave gears for industrial automation and lightweight robotics applications. Encompassing five sizes, Schaeffler's standard-duty RT2-series strain wave gears cover about 80% of normal cobot applications.

Designed for high-torque applications up to 900 Nm, Schaeffler's heavy-duty RT1 gear units are currently offered in four sizes. The low weight and compact design make them ideal for use in cobots. ■

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