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50 years of robotics

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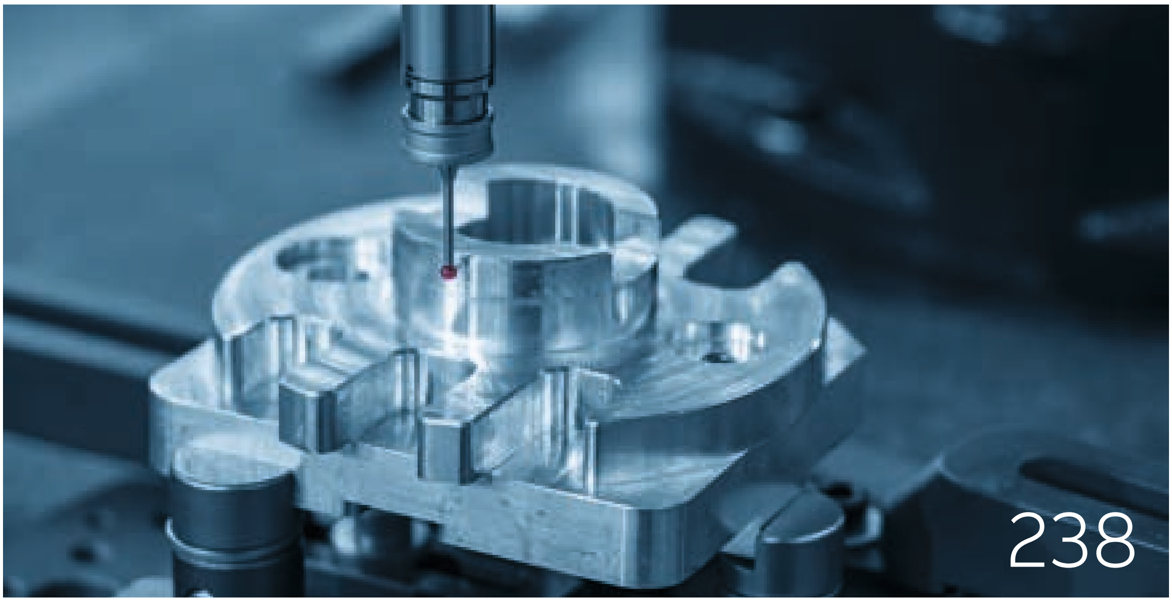
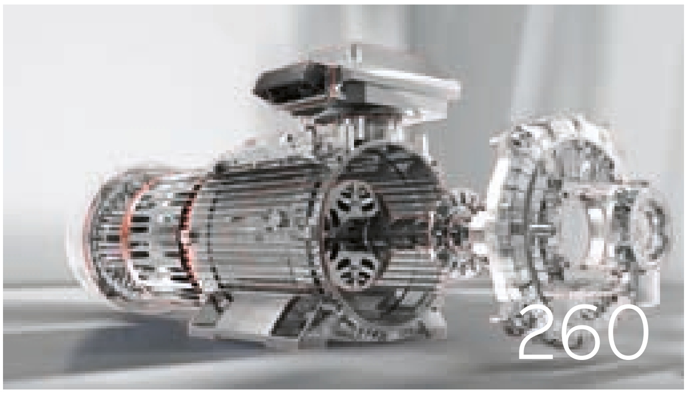


Down to a human hair



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50 years of robotics

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Buzzword Demystifier

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EDITORIAL

50 years of robotics

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Dear Reader,

Fifty years ago, we revolutionized manufacturing by introducing the IRB 6, a robot that changed industries forever. That spirit of game-changing innovation still defines ABB today.

Imagine a robot whose path error is smaller than the width of a human hair - that's what ABB's new GoFa™ can achieve. Or picture a programming environment that not only makes more of a robot's kinematic capabilities, but seamlessly integrates AI and vision systems. ABB's new Omnicore™ control architecture reduces a robot's cycle time by up to 25 percent, while at the same time introducing intuitive simplicity to robot programming and reducing energy consumption. Just think how such innovations can help industries outrun - leaner and cleaner.

Discover these innovations and more in this edition of ABB Review.

Enjoy your reading,

Morten Wierod
Chief Executive Officer, ABB Group

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Andreas Moglestue
Chief Editor

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FAQS

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Signing up using the subscription form linked on the left will assure you receive ABB's new Innovation and Technology Newsletter. As from 2025, new editions of ABB Review will be announced in this newsletter, and published on the Innovation and Technology Hub.

What is the Innovation and Technology Hub?
The Innovation and Technology Hub is a web hub presenting ABB's innovation, technology and R&D activities. The hub will be updated with new material approximately every two weeks. New content will also be announced in the newsletter.
Hub content includes:

- ABB Review (two editions per year).
- Web stories on technology and innovation (a new story circa every two weeks). These articles will typically be shorter and less technical than ABB Review articles.
- Interviews.
- Case studies.
- Selected white papers and scientific publications.

What will the future ABB Review be like?
ABB Review is being retained as a standalone publication, maintaining the same levels of quality, depth and style that have become its hallmarks over its 111 years of publication. Content will continue to be selected by the ABB Review Editorial Board, which includes many of ABB's senior technology leaders. There will, however, be a reduction in the frequency of publication, languages, and the number of articles. From 2025 there will be circa six articles per edition and two editions per year. Publication will be in English only. This edition of ABB Review is the last to appear in the old format.

Will ABB Review still be available in print?
Yes, the company will continue to offer the print edition as an option. Readers signing up to the Innovation and Technology Newsletter will later receive a survey in which they can express their preference to receive the print edition. Please note that production of print copies is limited and possibly not all requests can be honored.

What will happen to the German and Chinese editions of ABB Review?
Up until the present edition, ABB Review is published in English, German and Chinese. From issue 01/2025, only an English edition will be provided.

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Why is a new registration necessary?
ABB is launching a Innovation and Technology Hub and embedding ABB Review within this. Re-subscription is required to ensure transparency regarding what readers have subscribed for.

Who can subscribe to the Innovation and Technology Newsletter?
Subscription is open to anybody and is free of charge.

What is ABB Review?
In continuous publication since 1914, ABB Review is one of the world's longest running technical journals. This is its 907th edition. The journal prides itself on its accuracy and objectivity, speaking "from engineer to engineer". ABB Review is provided free of charge to those with an interest in ABB's technology and objectives.

The objective of ABB Review is to showcase to ABB's customers the latest research results of ABB's more than $1 billion annual R&D investment, innovative solutions and achievements, in an objective, permanent, trustworthy and precise way.

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In 1974, ABB produced the world's first all-electric industrial robot.

50 years of industrial robot hardware and software innovation followed.

ABB's robot innovations help solve global challenges.

A JOURNEY THROUGH INNOVATION

50 years of ABB industrial robots

In 1974, ABB (then ASEA) installed the world's first electrically driven industrial robots. Throughout the half-century that followed, the company has stood the forefront of the robotics industry, delivering a continuous stream of innovation that fundamentally changed the industrial landscape.

In mid-2024, ABB launched its latest industrial robotics innovation – the new version of the OmniCore™ controller platform. With best-in-class motion control, reduced energy usage and future-proofing through built-in digital connectivity, this new product helps customers step over the threshold into a new era of efficient manufacturing powered by artificial intelligence (AI).

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The IRB 6 set standards with its small footprint, speed of movement and positioning accuracy.

But OmniCore is just the latest chapter in a story that goes back 50 years to ABB's initial foray into industrial robotics with the IRB 6, the first

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BJÖRN WEICHBRODT – THE FATHER OF THE ELECTRIC ROBOT

In 1971, ASEA (the "A" in the later ABB) hired the Swedish engineer Björn Weichbrodt, who was fascinated by the idea of using microprocessors in robots. Weichbrodt and his team developed an industrial robot with a microprocessor control and electric drive – the famous IRB 6. This robot played a groundbreaking role in a decade marked by economic challenges and the associated need to automate and make manufacturing processes more efficient.

The compact IRB 6 is characterized by its five axes that allow it to perform complex movements and handle various tasks such as welding, material handling and painting. Using a microcomputer to control the robot was a significant innovation at the time and enabled more precise and flexible control. The IRB 6's success marked the beginning of ABB's long-standing commitment to advancing robotic technology and such is the elegance of the IRB 6 design that its basic shape is echoed in the design of ABB's robots today.

Closely linked to the success story of the IRB 6 is the first customer and user: Magnusson, a Swedish manufacturer of stainless steel pipes. In 1974, Magnusson's first IRB 6 went into operation. By 1976, three more robots followed and the this quartet served for over 30 years. This factory became one of the first in the world to operate around the clock, seven days a week.

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01 Björn Weichbrodt – the father of the electric robot.

01a Björn Weichbrodt and the IRB6.

all-electric industrial robot →01. This 6 kg-capacity device was unique, not only in its drive system but also in its anthropomorphic configuration and use of a microprocessor-based control system. The IRB 6 set standards with its small footprint, speed of movement and positioning accuracy. This new generation of electric drive robots opened up new applications – arc welding, for example – for which the clunkier hydraulic machines available at the time were unsuited.

Despite the initial success of the IRB 6 in finer tasks, beefier applications, such as spot welding, remained in the hands of hydraulic robots until 1975 and the introduction of the IRB 60, designed for loads of up to 60 kg. The first IRB 60 was used by the Swedish car manufacturer Saab for spot-welding car bodies. The final demise of the hydraulic spot welding robot came in 1982, when ASEA introduced the IRB 90, with its six axes and supply lines for water, air and electricity integrated into the arm.

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The final demise of the hydraulic spot welding robot came in 1982, when ASEA introduced the IRB 90.

Paint your wagon

The 1980s ushered in two world-changing trends: digitalization and globalization. As traditional economic powerhouses came under pressure from emerging economies in Asia that emphasized efficiency and quality, digital technology began to revolutionize robotics and automation, offering a way for developed countries to rein in costs and regain competitiveness.

These factors added impetus to the evolution of industrial robots, especially for painting automobiles – an application that had thus far evaded electric robots. Accordingly, in 1988, ASEA brought the TR 5000 onto the market. Initially, only intrinsically safe hydraulic drives had been used for painting robots, but the TR 5000 met all safety requirements while bringing higher speeds, better accuracy and finer electronic control. ABB's success story in the field of paint robots continues to this day.

The IRB 2000 – the second generation is founded

The IRB 2000, introduced in 1986, represented a significant further development in robot mechanics →02. This second-generation robot had a load capacity of 10 kg, recoilless gears for improved spatial kinematics and AC motors. AC motors offer higher torque, are more compact, and require less maintenance because they are brushless and have a longer lifespan.

Accelerating innovation: even higher speeds

The first industrial robots mimicked the human arm, which presents a moment of inertia challenge when high speed is needed – in packaging or handling small parts, for example. Accordingly, ASEA brought out the suspended-arm-design IRB 300 and IRB 1000. The 2 G acceleration achieved by these robots was, however, too slow for some applications. For this reason, in 1998, ABB introduced the IRB 340 FlexPicker, which achieved an acceleration of 10 G and an astonishing 150 handling operations per minute →03. The current FlexPacker™, the IRB 390, is a ground-breaking innovation in Delta Robot technology.

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The ABB robotics family tree has flourished over the years, with dozens of variants and models to suit all situations.

Doing the heavy lifting

Flexibility and adaptability are constantly called for by industrial robot users, so in 1991, ABB met these demands head-on with the heavy-duty (150 kg capacity) IRB 6000. Aimed primarily at spot welding and large component handling, the IRB 6000 was built on a modular concept with a range of base, arm and wrist modules to meet every user's needs. The IRB 6000 was also highly cost-competitive through its lean design, with 60 percent fewer parts than the IRB 90. It was ABB's most successful spot-welding robot, with

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02 Exhibits in the ASEA Historical Collections in Västerås, Sweden. From left: IRB 6, IRB 60, IRB 2000, IRB 3000, S3 control cabinet (for IRB 2000 and IRB 3000).

many large multi-robot orders from leading car manufacturers.

The ABB robotics family tree has continued to flourish over the years, with dozens of variants and models to suit all situations – clean rooms, biological labs, dusty factories, etc. – now available. Recently, a new branch of the family tree has grown that contains ABB's collaborative robots, cobots – more of which shortly →04.

Evolution, expansion and RobotStudio®
The IRB 6 had a single 8-bit Intel 8008 microprocessor to support programming, interfaces and control. Programming and operating the robot required trained specialists. It would be fair to say that things have changed a lot, and swiftly, since. The rapid evolution in ABB robotics included, for example, the teach pendant, which had a joystick for direct, intuitive control and positioning of the robot axes; the tool center point (TCP) concept, which facilitated better kinetic precision; and the ASEA Robot Programming Language which made programming and setup more accessible and faster for both experienced and novice users. A very significant breakthrough, though, came with RobotStudio →05.

RobotStudio is a powerful simulation and offline programming software that allows users to create, simulate, and optimize robotic applications in a virtual environment before deploying them in the real world. The new RobotStudio Cloud enables individuals and teams to collaborate in real time on robot cell designs from anywhere in the world, on any device.

The cobots arrive: GoFa™ and SWIFTI™
In recent years, the robotics industry has witnessed the arrival of cobots, designed to work alongside humans in a shared, unprotected workspace. ABB has been a key player in this transformation with its 2015 YuMi cobot. YuMi has been swiftly followed by cobots such as GoFa and SWIFTI. These two robots combine advanced safety features, intuitive programming and high-performance capabilities, enabling safe and efficient human-robot collaboration. GoFa and SWIFTI are used in healthcare and life sciences laboratories for tasks such as sample handling, analysis and drug discovery, enhancing throughput and accuracy while reducing human error.

GoFa is designed for tasks involving high payloads and longer reach. Crucially, its simple interface and easy setup allow businesses to integrate automation quickly and efficiently, even without prior robotics experience. The newest GoFa models, the GoFa 10 and 12, can handle payloads up to 10 and 12 kg, respectively, and TCP speeds of up to 2 m/s with only 0.02 mm deviation. The GoFa 10's 1.62 m reach makes it ideal for palletizing. In 2021, GoFa's groundbreaking design won the Red Dot "Best of the Best" award, reserved for the most aesthetically appealing, functional, smart, or innovative design. YuMi won the same award a decade earlier.

In 2021, GoFa's groundbreaking design won the Red Dot "Best of the Best" award. YuMi won the same award a decade earlier.

SWIFTI is tailored for high-speed operations that require precise and agile movements. Its ability to work safely alongside humans without protective barriers opens up new possibilities for automation in environments where space and flexibility are critical.

Responding to the growing diversification of automation applications, ABB also launched its ABB Robotics Ecosystem program. Bringing together third-party accessories such as

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03 The IRB 390 FlexPacker won the Red Dot award in 2022.

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04 The ABB Cobot family.

grippers, cameras and customized software compatible with the ABB portfolio, including the new GoFa cobots, the program lets users easily leverage innovation from across the fast-growing ABB Robotics world.

ABB expands modular large robot portfolio
ABB Robotics is continuing the expansion of its modular large robot portfolio with the introduction of the new IRB 7710 and IRB 7720 →06. These new robots, combined with the recently launched IRB 5710 to IRB 5720 and IRB 6710 to IRB 6740 series, offer a combined total of 46 different variants capable of handling payloads between 70 kg and 620 kg to give customers a new level of flexibility, greater choice and higher performance in their operations.

Powered by OmniCore, the new robots achieve class-leading motion control, with path accuracy down to 0.6 mm, even with multiple robots running at high speeds of up to 1,600 mm/s and moving payloads of up to 620 kg. Customers can also benefit from an up to 25 percent reduction in cycle times, further enhancing productivity and quality. In the automotive industry, the all-new IRB 7710 with the latest OmniCore controller will boost the production output of robotic press lines from 12 to 15 strokes per minute to produce 900 parts per hour. Furthermore, in the construction sector, the new robots will support the growth in modular assembly as they are capable of constructing steel building frames and finishing surfaces with speed and high quality.

Transforming logistics and construction
The logistics industry has greatly benefited from ABB's robotics solutions, particularly in the face of growing e-commerce demands and labor shortages. Robots are employed in warehouses for picking, packing, sorting and palletizing goods, ensuring faster and more accurate order fulfillment. The flexibility and scalability of ABB robots allow businesses to adapt to changing market demands and optimize their supply chain operations.

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Powered by OmniCore, the new robots achieve class-leading motion control with path accuracy down to 0.6 mm.

ROBOTSTUDIO

One of the most significant innovations in ABB robotics technology was RobotStudio.

RobotStudio revolutionized how robot systems are designed and tested by using a digital copy of an automation project. This approach significantly reduces downtime and enhances productivity by enabling engineers to perfect their processes without interrupting production. RobotStudio's intuitive interface and comprehensive tools make it accessible to users of all skill levels, democratizing access to advanced robotic programming and simulation. The adoption of virtual- and augmented-reality technologies enabled system integrators and end manufacturers to visualize how a robot would work on the factory floor without stopping production. RobotStudio is utilized by thousands of robot users around the world.

The main driver behind RobotStudio received recognition for their vision and leadership in the field when, at the 2022 International Symposium on Robotics in Munich, Germany, they were awarded the Engelberger Robotics Award. This award is named after Joseph F. Engelberger, the founding force behind industrial robotics.

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05 RobotStudio.

Visual SLAM and natural-language programming (NLP)
ABB's commitment to innovation is exemplified by its integration of AI technologies, such as Visual SLAM and NLP, into its robotic systems.

Visual SLAM enables robots to navigate and map their environment in real time using visual data from cameras and sensors. This ability lets the robot operate autonomously in dynamic and unstructured environments. Visual SLAM came to ABB via the acquisition of Swiss startup Sevensense, which was previously part of ABB Robotics' Innovation Challenge, underlining the importance of reaching out beyond company boundaries to find the very best technology partners.

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Robotic technology is helping the construction industry overcome significant challenges.

NLP represents a significant leap in making robotics more accessible and user-friendly. ABB simplifies the interaction between humans and machines by allowing users to program robots using natural-language commands, reducing the need for specialized programming skills. This democratization of robotics technology opens up new possibilities, especially for small and medium-sized enterprises, to adopt automation.

Shaping tomorrow's factories
Over the past 50 years, ABB has consistently pushed the boundaries of what is possible with industrial robotics. From the groundbreaking IRB 6 to sophisticated cobots like GoFa and SWIFTI, ABB's innovations have transformed industries and improved operational efficiencies across the board. Integrating advanced

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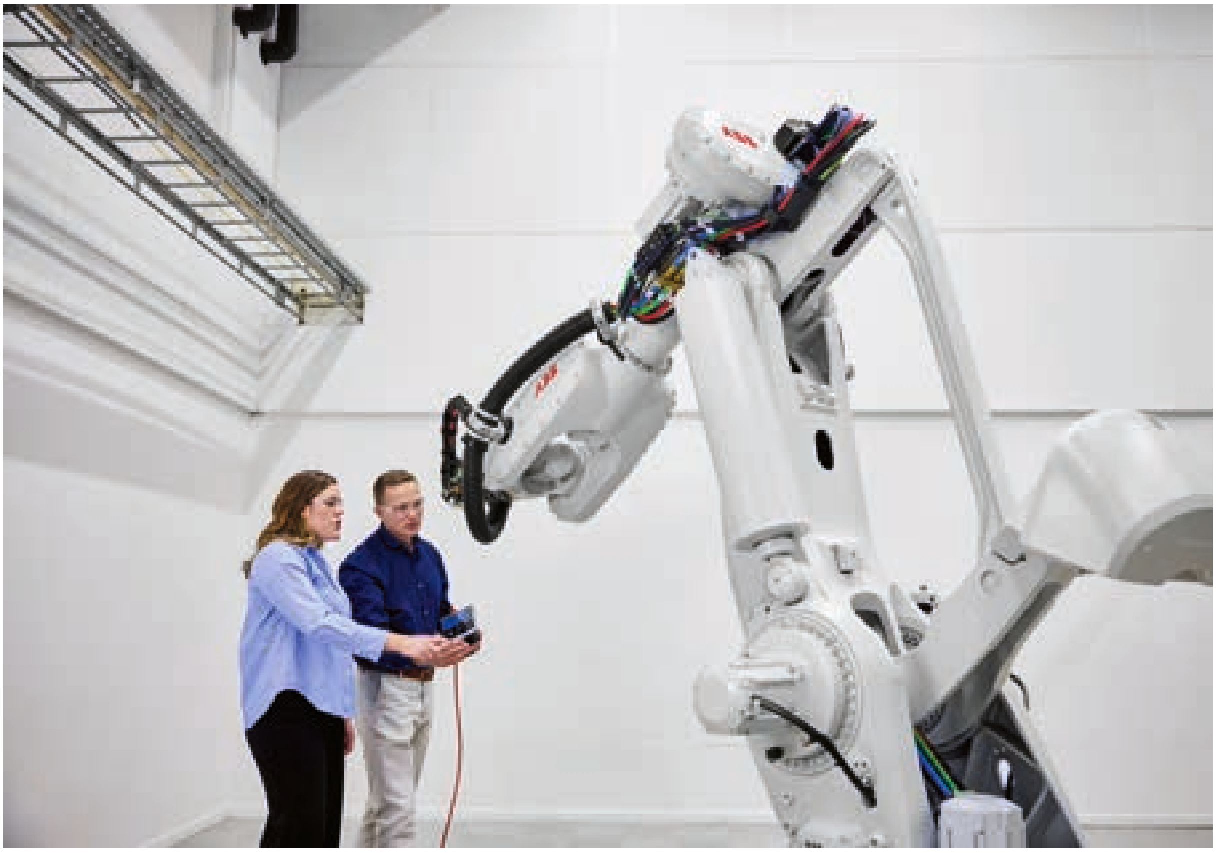
Further information

For further information, please go to https://campaign-ra.abb.com/l/961042/2024-07-05/5sf33j



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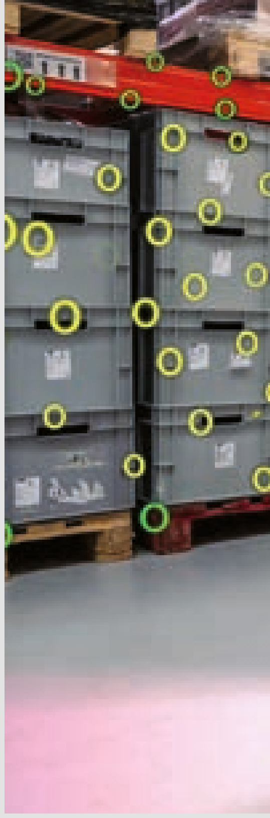
06 The IRB 7710 and IRB 7720 offer up to 25 percent reduction in cycle times.

technologies such as Visual SLAM and NLP continues to drive the evolution of adaptable, accessible and efficient robotics.

ABB's industrial robots are poised to play an even more significant role in addressing global challenges such as labor shortages, sustainability and the need for high-precision automation in critical sectors like healthcare and logistics. The legacy of ABB's robotics journey is a testament to the company's unwavering commitment to innovation, excellence and the continuous improvement of industrial processes worldwide. •



AN INTERVIEW WITH MARC SEGURA

New frontiers for robotics and AI

Artificial intelligence (AI) is making robots more accessible to more people and businesses. The AI transition will make robots more approachable and bring them to a broader audience, leading to new job prospects while helping alleviate labor and skills shortages. Marc Segura explains.

AR ABB Review (AR): Marc, AI seems to be opening up new frontiers in many technologies. Is it affecting ABB's robotics?

MS Marc Segura (MS): It sure is! This coming year, we will see a growing focus on the critical role of AI in our robotics business. From mobile robots and cobots to enabling new robotic applications in new sectors and creating new opportunities for people to learn and develop, these emerging frontiers for AI are redefining the future of industrial robotics.

AR So, will AI drive new levels of autonomy in robotic applications?

MS In a word, "yes." AI is enhancing everything from robots' ability to grip, pick and place to their ability to map and navigate dynamic environments. AI gives our autonomous mobile robots – called AMRs – unprecedented speed, accuracy, and payload-carrying ability, enabling them to take on more tasks in settings like flexible factories, warehouses, logistics centers, and laboratories.

AI-enabled mobile robots can transform sectors like discrete manufacturing, logistics and laboratories. Robots equipped with ABB's new visual simultaneous localization and mapping technology, for example, have advanced mapping and navigation skills, granting new levels of autonomy while significantly reducing the infrastructure needed. This paves the way for a shift from linear production lines to dynamic networks, creating significant efficiencies and taking on dull, dirty and dangerous tasks to enable workers to take up more rewarding jobs.

AR So AI will see robots enter new sectors?

MS The potential offered by AI-enabled robotics is influencing sectors far beyond manufacturing and is expected to bring substantial efficiency improvements to more dynamic environments, such as healthcare, life sciences and retail. For example, we have a dedicated healthcare research team in the United States that works

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With AI making programming easier, education can shift towards how robots can assist humans more effectively.

with hospitals and laboratories to develop non-surgical medical technologies. We are working to introduce industrial-level efficiency in laboratories and enable researchers to focus on more mission-critical tasks. We've also created a robotic neutralizing antibody testing system that is much quicker and safer than manual testing .

Another example is the construction industry, where AI-powered robotics can literally make a material contribution to boosting productivity, enhancing safety and sustainable construction

The tasks robots are required to do are becoming more sophisticated.

AI can enhance robots' ability to navigate, grip, pick and place.

ABB's AI-powered robots boost productivity and spur growth.

practices while spurring growth. This industry faces worker shortages, safety concerns, stagnant productivity, etc. Abilities such as the enhanced recognition and decision-making offered by AI, coupled with advances in collaborative robots, enable safe deployment alongside workers. These advances also let robots perform key tasks such as bricklaying, modular assembly and 3-D printing with greater precision and speed, all while contributing to more sustainable construction by lowering emissions, such as by concrete mixing on site. On-site assembly reduces the amount of material that has to be delivered. ABB is also working with several leading universities to co-develop new automated construction technologies. These universities include ETH Zurich, where we support research and have helped establish the world's first laboratory for collaborative robotic digital fabrication in architecture.

AR Will AI offer new opportunities for education and working with robots?

MS Absolutely. We are closing the automation skills gap and making robots more accessible to more people and businesses. With AI making programming easier through lead-through and even natural language, education can shift towards how robots can assist humans more effectively rather than just teaching programming skills. This transition will make robots more approachable and bring them to a broader audience, leading to new job prospects while helping alleviate labor and skills shortages. ABB has, for example, launched a complete robot training package for students that includes an easy-to-use GoFa collaborative robot cell, 56 hours of teaching materials and a globally recognized STEM certification.

Marc Segura
President of the
ABB Robotics Division

A shortage of people with the skills needed to program and support robots has long been a hurdle to the uptake of robotic automation, especially in small- to medium-sized manufacturing companies. We will see this increasingly being alleviated as advances in generative AI lower the barriers to automation. Developments in natural language programming, powered by AI, in which workers can verbally instruct a robot in its task, will create a new dynamic in human-robot interactions.

AR Marc, thank you for giving us that fascinating insight into the latest developments in robotics. •

UNPARALLELED PATH- AND ABSOLUTE ACCURACY FOR ROBOTS

Down to a human hair

Motion performance is a key differentiator in robotics applications. By introducing GoFa™ Ultra Accuracy, ABB advances path and absolute positioning accuracy beyond existing limits. The newly created potential for robotic automation solutions allows high-precision applications that were previously impossible.

Industrial processes require robots and controllers to achieve improved accuracy.

GoFa Ultra Accuracy enables high performance in the entire workspace.

A reduction of **50 %** in absolute path error, or to **< 0.1 mm,** is achieved.

—
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Silke Klose
Former ABB employee

The trend toward product miniaturization, the ability to program offline yet deploy in real-world scenarios, as well as the need to meet ever tighter application requirements in robot automation is essential for a variety of industrial processes that require accuracy. In electronics manufacturing, high component density, multiple layering and small components require care in assembly. In gluing applications for example, a robot typically handles a work piece as large as a smart phone, a tablet or a laptop. The gluing nozzle usually has an inner diameter of 0.6 mm; the glue profile is shaped like a semicircle (height of 0.5 ~ 1 mm and a width of 0.8 ~ 1.8 mm). Thus, gluing as well as tasks such as cutting, sealing, additive manufacturing, surface inspection, and metrology require robots and robot controllers to achieve very high accuracy, both in terms of absolute positioning and path tracking.

Enter, GoFa Ultra Accuracy which is built on ABB's TrueMove® concept, providing control for high path accuracy for robots since the 1990s, and on Absolute Accuracy, an ABB calibration option that enables high absolute positioning accuracy. Experimental results demonstrate that GoFa Ultra Accuracy achieves path errors < 0.1 mm, the average width of a human hair. Currently, ABB is integrating this feature into the GoFa™ collaborative robot line to push the limits of robot accuracy further than previously possible.

What is accuracy anyway?
The term accuracy conjures up exactitude and determinism for most people. And yet, ironically, accuracy can often be a somewhat fuzzy term in many technical situations despite the precise definitions found in DIN EN ISO 9283 [1]. In the context of this article, it is critical to distinguish between repeatability, absolute accuracy, and path accuracy, which are often confused. While repeatability can be interpreted as the ability to hit the same spot, or target repeatedly, accuracy refers to how precisely a given target can be hit. This difference is easily understood and visualized →01.

Regarding robotic applications, industrial robots typically excel at very high repeatability, between a range of 0.01 mm and 0.1 mm depending on the model – a key to their success in automation processes. For example, GoFa achieves a repeatability of 0.02 mm – the best among collaborative robots. However, without special capabilities that will be detailed throughout this article, the accuracy of such robotic manipulators is not as high as for repeatability.

Delving further, there is a need to distinguish between absolute- and path accuracy. As visualized in →02, absolute accuracy refers to the capability of reaching programmed targets in space accurately – a key property for robotic tasks such as spot welding, where ever a path must be followed without touching the work piece. In contrast, path accuracy refers to how accurately a prescribed geometry that connects two targets (ie, a path) can be tracked – a key property for continuous robotic tasks such as gluing, sealing, or 3D printing. In reality, industrial robots need to complete automation tasks with high absolute– and path accuracy.

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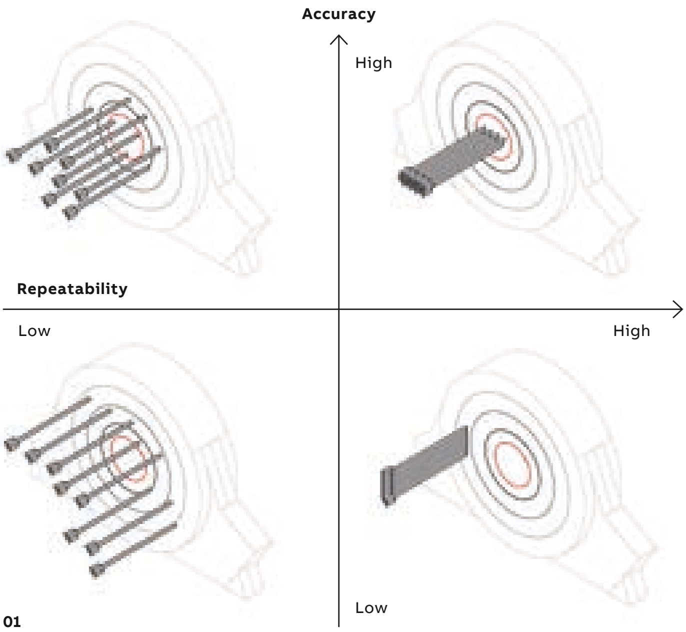
In electronics manufacturing, component density, layering and small components require precision for assembly.

State-of-the-art accuracy and the challenges
Nowadays, thanks to the application of high-resolution position sensing on the gearbox input-side and advanced model-based controls,



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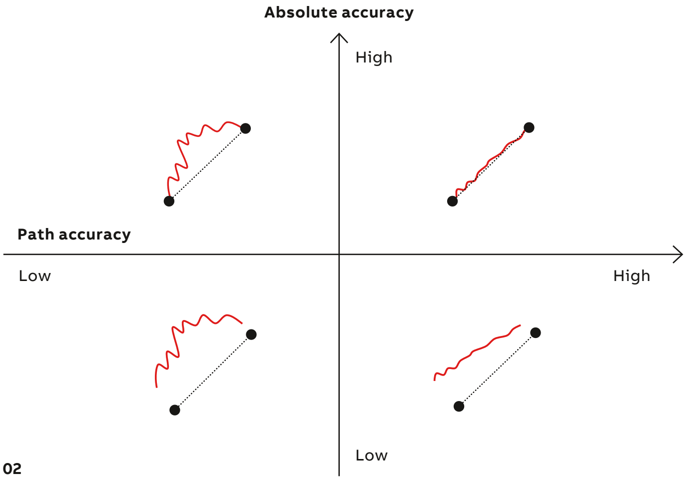

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01 The distinctness of accuracy and repeatability are illustrated. Serial chain manipulators typically provide very high repeatability but are limited in accuracy if no special measures are taken.

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02 Absolute accuracy and path accuracy are easily differentiated in this visualization. Absolute accuracy describes how well programmed points in space can be met while path accuracy is related to how well a geometry connecting two targets can be tracked.

articulated robots achieve very high repeatability (eg, ± 0.01 mm for an ABB IRB 1100-4/0.58). When it comes to absolute positioning accuracy however, the difference between a virtual, or ideal, robot and a real robot can be between 8 and 15 mm (depending on the robot model). This discrepancy is due to the resultant errors generated during establishment of the zero positions of position sensors in response to the kinematic tolerances in link lengths and mechanical assembly, as well as to deflections in the robot structure due to load [2,3].

Deflections due to load constitute the structural compliance within the gearboxes, as well as in the bearings and links. Thankfully, algorithms are now available that can identify such modeling errors (referred to as absolute accuracy calibration). With their absolute accuracy option, ABB currently offers a solution that not only identifies the modeling error in the individual robot at hand, but also employs the calibrated model to compensate for the negative effects described above. As a result, maximum absolute positioning errors can typically be reduced to < 1 mm, although exact error values are dependent on the individual robot [4].

Compliance within the mechanical structure poses a major challenge in terms of path accuracy. Not only does compliance induce flexible modes that result in vibrations and oscillations once excited, but the resultant oscillations cannot be traced down to an individual robot joint generally but affect the entire arm due to inertial couplings [5]. Moreover, the reduction gears that are used in each joint to transform the high speed and low torque output of the electrical motors into reasonable ranges for robotic manipulation induce additional challenges. Such specific effects include periodic transmission errors, non-linear stiffness characteristics, hysteresis [6,7], and friction [8,9]. To tackle those challenges, ABB developed the TrueMove concept in the 1990s: This ABB hallmark product ensures that high path accuracy is achieved by means of advanced motion control [10].

Introducing GoFa Ultra Accuracy feature
Thanks to the absolute accuracy option and TrueMove, the starting point for taking both absolute and path accuracy beyond the level currently achieved is simple: increase the breadth of information available and used to eliminate disturbances and diminish error. But how can this be accomplished?

To achieve both accuracy objectives, it is crucial to recognize that the gearbox is one of the major sources of modeling errors and inaccuracies. These modeling uncertainties directly impact accuracy, just as in conventional robot control systems, where only the position of the motor (ie, at gearbox input side) is measured and used

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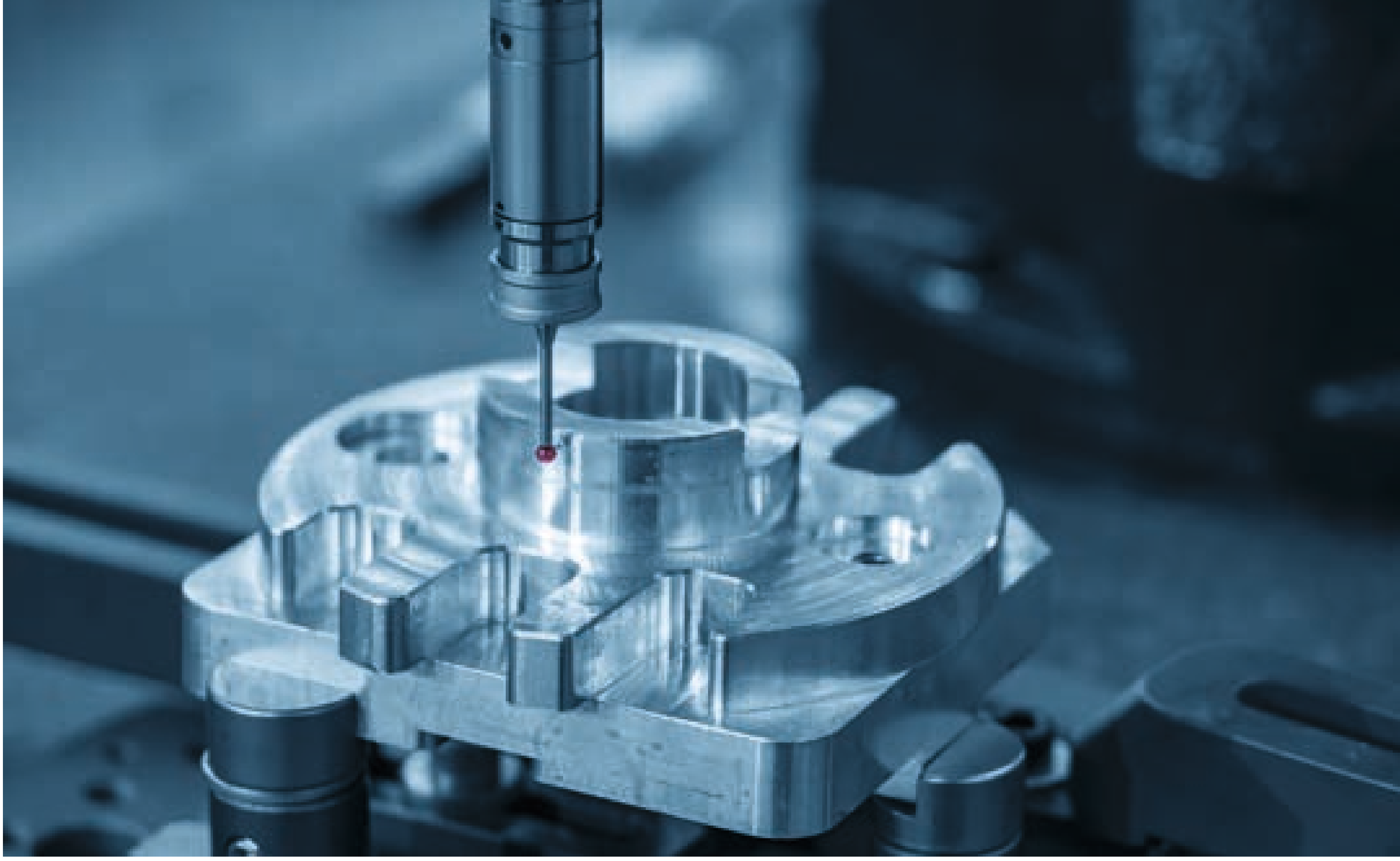
GoFa Ultra Accuracy employs arm-side information in the servo loops and uses conventional measurements.

for feedback controls [11]. The basic, yet innovative, idea behind GoFa Ultra Accuracy is not only to use such conventional measurements, but to also employ arm-side information in the servo loops →03. This added functionality improves the controller's ability to reject disturbances and uncertainties introduced by the gearboxes, as well as disturbances that originate externally



(such as from process forces). At first glance, use of measurements at the gearbox output (ie, “after” one of the main sources of uncertainty) would seem to be a natural way to improve accuracy compared to use of conventional motor-side instrumentation. Despite this, application of such a concept results in the physical distribution of actuation and sensing with dynamic and, or compliant elements in between. Such non-collocated problems, however pose significant challenges to control systems in general and control of robots specifically →04, which have, until recently, seemed intractable [11,12,13]. New promising progress from academia brings a solution within the realm of possibility [14,15,16]. By developing an improved understanding of the gearboxes and measurement systems, and by integrating such capacity with ABB’s advanced model-based controls, ABB’s GoFa Ultra Accuracy runs stably with high performance within the robot’s complete workspace, covering its full payload- and speed-range despite the challenges arising from non-collocation →04.

Absolute accuracy results

The process of calibrating a robot to achieve high absolute accuracy relies on moving the robot to several programmed calibration targets. The nominal position of the robot tool center point (TCP) is compared to the actual position measured by an appropriate 3D measurement system (typically a laser tracker). The actual calibration step then aims to minimize the difference between the measured TCP positions and the TCP positions of the calibrated model. Once a calibrated model has

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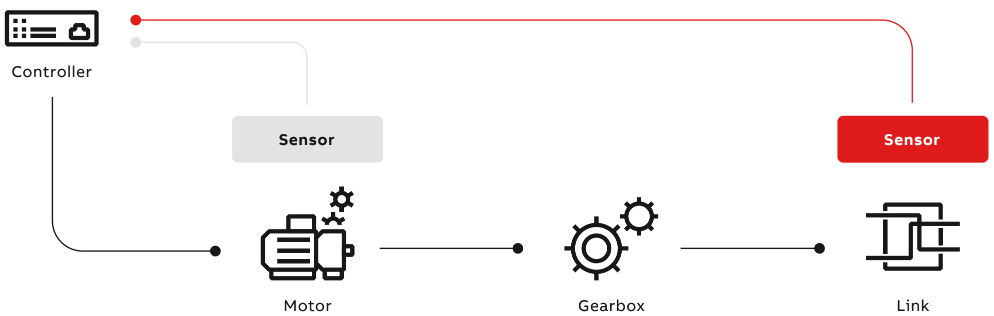
03 Concept overview for GoFa Ultra Accuracy shows that for each joint of the robot the conventional scheme’s feedback information from the gearbox input-side to the controller (gray) is augmented by information from the gearbox output-side (red).



03

MODELLING OF ROBOTIC JOINT DYNAMICS

The essential dynamics of a robotic joint can be modelled as a system consisting of two rotational inertias representing motor- and the reflected output inertia, which are coupled by a torsional spring representing the finite-stiffness gearbox [11]. The governing differential equations can be derived as

$$J_{out}\ddot{q}_{out} = k_T\left(\frac{q_{in}}{i_g} - q_{out}\right) + d_T\left(\frac{\dot{q}_{in}}{i_g} - \dot{q}_{out}\right) + \tau_{d,out},$$

$$J_{in}\ddot{q}_{in} + d_{in}\dot{q}_{in} = \tau_{mot} - \frac{k_T}{i_g}\left(\frac{q_{in}}{i_g} - q_{out}\right) - \frac{d_T}{i_g}\left(\frac{\dot{q}_{in}}{i_g} - \dot{q}_{out}\right) \quad (1)$$

Where, q_{in} and q_{out} are the positions at the gearbox input- and output-side, respectively. Corresponding speeds are denoted by by $\dot{q}\,in$ and $\dot{q}_{out}$, and J_{in} and J_{out} representing inertias. The gearbox is characterized by the reduction ratio i_g, the torsional stiffness k_T, and torsional damping d_T. The motor-side dynamics is driven by motor torque τ_{mot} and friction is modeled as $d_{in}\,\dot{q}_{in}$, where d_{in} is the coefficient of viscous friction. In the output-side dynamics, an external disturbance $\tau_{(d,out)}$ is included, which can eg, describe a process force acting on the TCP of the robot. Note that in the general case of a multiple-degree-of-freedom system, dynamic couplings exist among the joints that are neglected in the simplified model shown in (1).

State-of-the-art motion control systems typically use a cascaded feedback control structure [11]. The inner speed loop uses a proportional-integral controller that produces motor torque τ_{mot} as a function of the speed error according to:

$$\tau_{mot} = K_v\left(\dot{q}_{in,ref} - \dot{q}_{in}\right) + K_i \int \dot{q}_{in,ref} - \dot{q}_{in}. \quad (2)$$

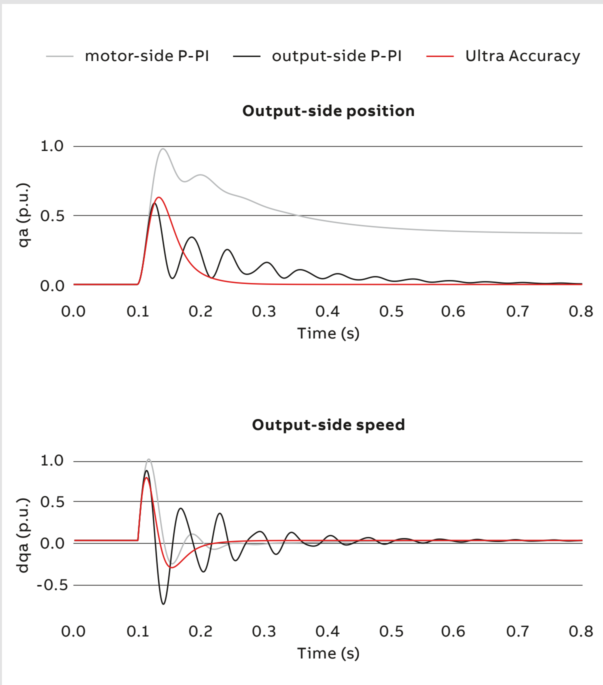
Where, $\dot{q}_{in,ref}$ is the reference value for the input-sided speed, which is in turn the output of the outer-loop position controller. Commonly, a proportional controller is used in the outer loop, ie:

$$\dot{q}_{in,ref} = K_p\left(q_{in,ref} - q_{in}\right). \quad (3)$$

With proper tuning of the controller parameters K_p, K_v, and K_i, the conventional motor-side feedback control cascade can achieve decent disturbance rejection →04a: Upon an output-side disturbance step, the controller is able to dampen the resulting oscillations and converge to a steady state within 0.5 seconds. The downside of this approach is that feedback loops are closed solely based on motor-side information. As a result, a steady-state error remains under output-side disturbances, negatively impacting accuracy.

Due to the problem of non-collocation [11,12,13], the intuitive idea of re-using the same cascaded control structure consisting of (2) and (3) but feeding it with output-side position q_{out} and $\dot{q}_{out}$ fails. While this process can remove the steady-state error and thus achieves superior static accuracy, the output-side P-PI cascade comes with notably worse oscillation damping and is generally prone to instability. Note that this is a structural issue that cannot be remedied by controller tuning.

Applying ABB's GoFa Ultra Accuracy solution to the example case results in superior vibration damping, faster decay to a steady-state, and the ability to achieve zero steady-state error.



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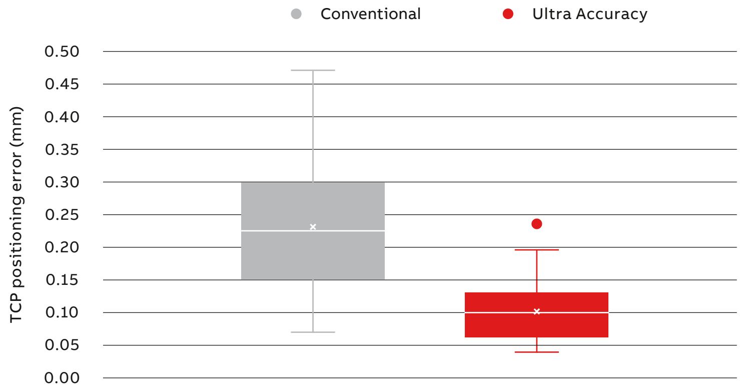
been obtained, the model is used to calculate compensation parameters that are then applied to each Cartesian position programmed by the user. To validate the calibration and compensation parameters the individual robot is moved to a set of 50 additional targets with compensation activated. While an absolute positioning error of 0.23 mm (average) and 0.47 mm (maximum) is achieved on an ABB GoFa™ 5 robot running motion control with conventional motor-side position sensing, superior absolute accuracy is achieved by performing calibration



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04 Modelling of robotic joint dynamics.

04a The output-side disturbance step response of a single robot joint compares the different control approaches of a conventional motor-side P-PI cascade (gray) and output-side P-PI cascade control (black) and the GoFa Ultra Accuracy solution (red) which achieves zero steady-state error.

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05 Absolute accuracy validation demonstrates the 50 percent reduction achieved by activating GoFa Ultra Accuracy compared to conventional control alone. Note that values are for individual robots and may differ slightly for other individuals of the same type.

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06 2D path accuracy results show that serial chain manipulators with conventional motor-side controls reach their limits in terms of path accuracy (gray plot), while GoFa Ultra Accuracy, reduces path errors (red plot).

on the same robot while GoFa Ultra Accuracy is activated →05: In the latter case, absolute positioning errors are reduced by 50 percent, to only 0.10 mm, the width of a human hair, and from a maximum error of only 0.23 mm – phenomenal results →05.

Path accuracy results

To quantify path accuracy, ABB focused on the non-trivial task of separating absolute positioning errors from path errors. To isolate the latter, the motion along small, programmed shapes was performed, where the measurements of the TCP position, obtained by a high-performance laser tracker system (Leica AT 960), are expressed relative to the center of the respective shape. In this way, the impact of absolute positioning errors is minimized and an evaluation of the path errors can be conducted.

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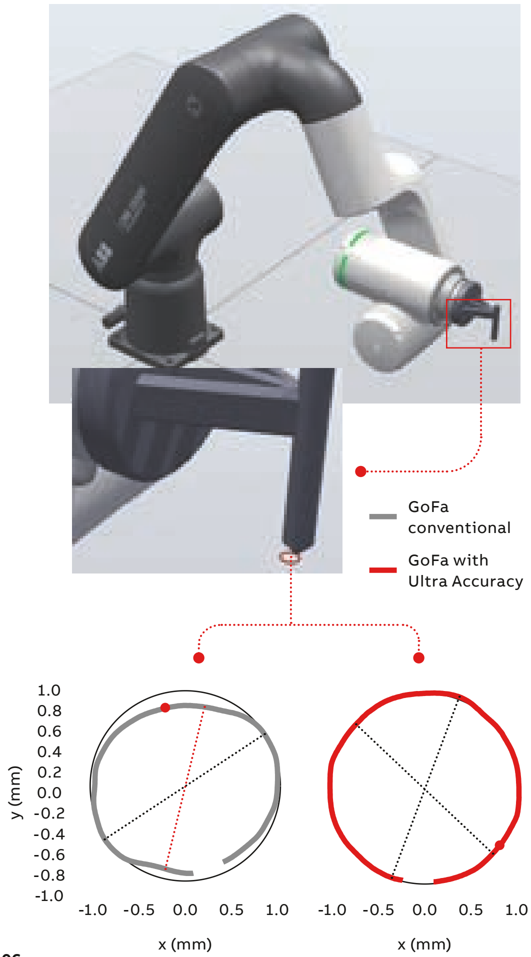
GoFa Ultra Accuracy reduced absolute positioning error by 50 percent, or only 0.10 mm, the width of a human hair.

The two dimensional (2D) path accuracy evaluation results for a GoFa collaborative robot compare Ultra Accuracy with conventional instrumentation (ie, motor-side position only) →06. Here, it becomes apparent during execution of a circular motion that a very small radius of only 1 mm poses a significant challenge to serial chain manipulators: in other words, the limits of their capabilities, in terms of path accuracy, are reached. The addition of the GoFa Ultra Accuracy feature provides for a notable improvement in path accuracy.

In a second experiment to examine path accuracy in 2D and three dimensions (3D), a small rectangular path (10 mm x 2 mm) was executed. As →07 shows, the path accuracy improvement achieved by implementing GoFa Ultra Accuracy in 3D was significant: Path errors were achieved below 0.1 mm for speeds up to 80 mm/s. The 2D path errors were even smaller.

Applied example results

As mentioned above, absolute positioning errors and path errors are superimposed in actual applications. Ultimately though, what matters is that task completion is ensured at the required quality specifications. In terms of robot motion accuracy, this boils down to moving the TCP along a path that is specified along a physical work piece. This process requires the additional calibration of the tool (to precisely determine the position of the TCP relative to the robot flange) and the work object (to precisely determine the position of the work piece relative to the robot base). Those two application-related calibration steps can be automated, with easy-to-use functionality that are available in ABB's RobotStudio® Machining PowerPac [17]. By using



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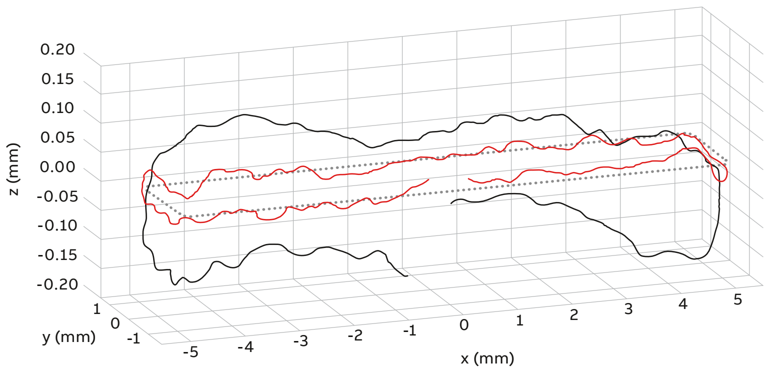

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07 3D path accuracy result of a small rectangle (10 mm by 2 mm), show the improvement achieved with Ultra Accuracy (red) activated compared to conventional control (black).

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08 ABB's hallmark challenge taken to the microscale. With a spacing of 2.2 mm between the "cans", GoFa Ultra Accuracy enables the movement of a sensitive touch probe with a diameter of 2.0 mm in between the "cans" along a complex path including TCP reorientation.

a robot calibrated for absolute accuracy, running GoFa Ultra Accuracy to push the limits of both absolute positioning and path accuracy, and conducting tool and work object calibration as described above, it is possible to achieve a vastly improved level of offline programming: Complex paths can be programmed in ABB's RobotStudio® and executed on real robots with very tight tolerances with respect to the physical work pieces.

ABB's OmniCore Challenge, launched in June 2024, uses the OmniCore™ automation platform to achieve a precision of 0.6 mm with multiple robots (IRB1300) at maximum speeds of 1600 mm/s, thanks to MultiMove®. This new challenge is based on a prominent showcase of ABB's superior motion control performance

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Application-related calibration can be automated with functionality in ABB's RobotStudio® Machining Power Pac.

enabled by QuickMove® for short cycle times and TrueMove® for path accuracy. Significantly, ABB's R&D revisited motion control performance at the microscale with GoFa Ultra Accuracy →08. The spacing between the "cans" has been reduced to 2.2 mm, while the diameter of the touch

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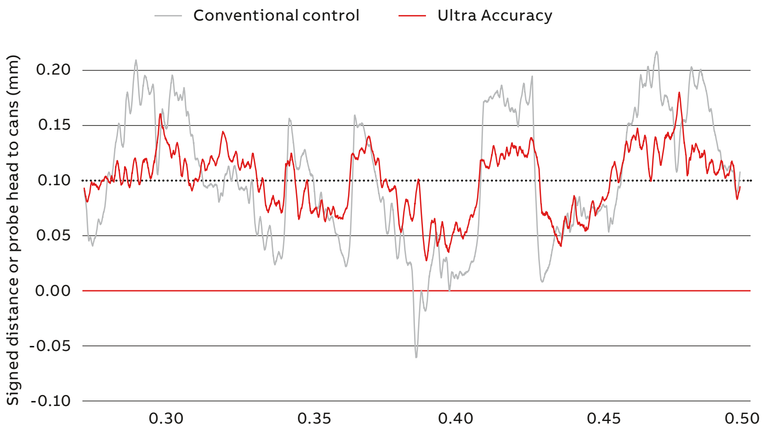
Watch the OmniCore Challenge – Redefining the future of robotic capabilities.



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09 Measurement of signed distance of probe head to cans taken to the microscale. Using conventional control (gray), the signed distance becomes negative – a collision of the probe with the cans occurs. In contrast, GoFa Ultra Accuracy (red) allows movement through the can gaps without impact.

probe moving along the path is 2.0 mm – leaving only a 0.1 mm margin on either side →08. The measurement results obtained by a laser tracker →09 reveal that the path error using conventional motion control exceeds the available tolerance margin. The results show the signed distance of the probe head to any of the cans →09. Ideally (ie, if the TCP perfectly follows the programmed path), the distance should always be 0.1 mm as indicated by the dashed black line in →09. Using conventional control, a signed distance smaller than 0 mm occurs – the probe touches one of the cans. In contrast, the error achieved using GoFa Ultra Accuracy remains well within 0.1 mm on either side of the path. This remarkable result means that the probe can be moved in between the cans without touching them as the signed distance in →09 never becomes negative. Moreover, the same holds true even if the TCP is re-oriented while in motion.

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Based on the remarkable test results, GoFa Ultra Accuracy is being developed for release in ABB's collaborative robot line.

The future of robot accuracy is at hand
Based on the phenomenal real-world test results, ABB's exciting new feature GoFa Ultra Accuracy is being developed for release in ABB's GoFa collaborative robot line. By improving robot motion performance, ABB can offer a high accuracy robot to the market, thereby opening the door for higher-precision applications.
In this way, ABB helps manufacturers meet superior operational performance, improve productivity and effectively create products to exact specifications. •

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Further information

Learn with ABB: Are accuracy, precision and repeatability the same thing? Measurement made easy blog, 2023-04-26

OMNICORE – THE NEXT-GENERATION ROBOTICS CONTROL PLATFORM

More with OmniCore™

01

ABB's OmniCore is a new robotics control architecture that integrates ABB's complete range of robot hardware and software →01. This automation platform is faster, more precise and more sustainable than existing solutions and will empower, enhance and futureproof businesses.

Peter Fixell
ABB Robotics
Västerås, Sweden

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It is fitting that in the year ABB celebrates 50 years in the industrial robot business, the company announced a step change in industrial robotics technology with its new platform, OmniCore. The OmniCore platform powers ABB's extensive robot portfolio, providing futureproof, scalable control to automate almost any imaginable application with the industry's broadest robotics offering.

What is OmniCore and how did it come about?
OmniCore is founded on ABB's long experience in industrial robotics. In 1974, the company (as ASEA, the "A" in the later fusion with Brown Boveri to form ABB) pioneered the industrial robot with its IRB 6 (see article "50 years of ABB industrial robots" on page 228). This very successful product became a template for many designs created in the following decades.

Gradually, the robotics portfolio was expanded to meet the needs of multiple industries and present a product palette – including autonomous mobile robots, collaborative robots (cobots), industrial robots and machine automation solutions – that covered the needs of the entire value chain.

The platform increases business productivity and flexibility.

OmniCore is a unifying, modular and futureproof control architecture.

OmniCore can empower, enhance and futureproof businesses.

02

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01 The OmniCore family.

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02 RobotStudio.

The software supporting ABB's robots continuously evolved with the hardware. One significant product was RobotStudio®, introduced in 1998, which revolutionized programming and opened the door to interaction with ABB's robots without the need for specialist programming skills. RobotStudio is a powerful simulation and offline programming software that allows users to create, simulate and optimize robotic applications in a virtual environment before real-world deployment →02. RobotStudio Cloud now enables individuals and teams around the globe to collaborate in real time on robot cell designs.

The latest software advances include the exploitation of the newest artificial intelligence (AI) techniques to build an integrated mechatronics offer that meets demand from more industry sectors. ABB has been integrating AI into software for over a decade and across ABB there are currently over 100 AI-enabled solutions under active development.

Most applications today use analytical AI, including machine learning. Combined with vision systems, this type of AI can enable automated quality checking (20 times faster than a human)

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The latest software advances include AI techniques to build an integrated mechatronics offer for more industry sectors.

or give, for example, the ABB Item Picker the ability to recognize new objects and learn how to handle them (picking up to 1,400 unsorted items per hour is now possible).

AI is enhancing everything from a robot's ability to grip, pick and place to their ability to map

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03 OmniCore simplifies the integration and management of multiple robots.

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04 The ABB value architecture for robotics.

and navigate dynamic environments, improving speed, accuracy and payload-carrying ability, thus enabling them to take on more tasks in a multiplicity of settings.

Complexity simplified by OmniCore
As a result of 50 years of incessant innovation, ABB's robots are more accessible, more capable, more flexible and more mobile than ever before. They are able to work together and with humans to take on more tasks in more places, handling the jobs that people are no longer available to do and enabling workers to take on more rewarding roles.

However, the inescapable reality is that more technology can create more complexity for operators. That is why the simplification OmniCore delivers is an important milestone in ABB's journey towards a new era of intelligent automation.

Put simply, OmniCore is an intelligent automation platform, realized in hardware and software, that is faster, more precise and more sustainable than comparable solutions. These attributes can empower, enhance and futureproof businesses. The platform is a step change to a modular and

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futureproof control architecture that will fully integrate AI, sensors, and cloud- and edge-computing systems to create advanced and autonomous robotic applications. OmniCore makes it much easier to integrate and manage multiple robots in an automated system, which provides customers with greater simplicity and flexibility →03.

These latter aspects are critical because, for ABB's customers, automation is a strategic requirement as they seek greater flexibility, simplicity and efficiency in response to the global megatrends of labor shortages, uncertainty in supply chains and the need to operate more sustainably. Concerns over labor shortages, for instance, are well-founded. For example, 75 percent of European companies currently struggle to find professionals with the necessary skills – from traditional manufacturing skills, such as welding, to labor-intensive operations, such as logistics and fulfillment [1]. Further, forecasts suggest that 2.1 million manufacturing jobs will be unfilled in the United States by 2030 [2].

OmniCore helps solve these many issues because through ABB's development of advanced mechatronics, AI and vision systems, robots are more accessible, more capable, more flexible and more mobile than ever. But increasingly, they must also work seamlessly together and with people to take on more tasks in more places. This is the basic reason why ABB developed OmniCore, a new milestone in the company´s 50-year history in robotics. OmniCore is a unique, single control architecture – one platform and one language that integrates ABB´s complete range of leading hardware and software.

Critically, OmniCore lowers the barriers to automation through ease of use and opens new possibilities for businesses of all sizes.

The ABB value architecture

OmniCore is at the top of what ABB calls its value architecture. A key building block in this architecture is RobotWare – the robotic operating system that offers more avenues for value creation, be it through its RAPID language, intuitive Wizard Easy Programming or AI-built skills →04. RobotStudio, described above, as a tool to simulate systems, is another important block.

Poetry in motion

OmniCore's class-leading motion control delivers robot path accuracy of under 0.6 mm (the width of a grain of sand), with multiple robots running at speeds of up to 1,600 mm per second. This performance creates new automation opportunities in precision areas such as arc welding, mobile phone display assembly, gluing and laser cutting. Overall, OmniCore enables robots to operate up to 25 percent faster and with twice the accuracy than under the previous IRC5 controller →05. This is beneficial in, for example, press tending in the automotive industry, where performance has improved from 12 to 15 strokes per minute to produce up to 900 parts per hour. Motion control can be combined with force and sensor control, enabling applications that have physical contact and can follow and track – allowing, for example, the placement of doors on a car body as it moves down an assembly line.

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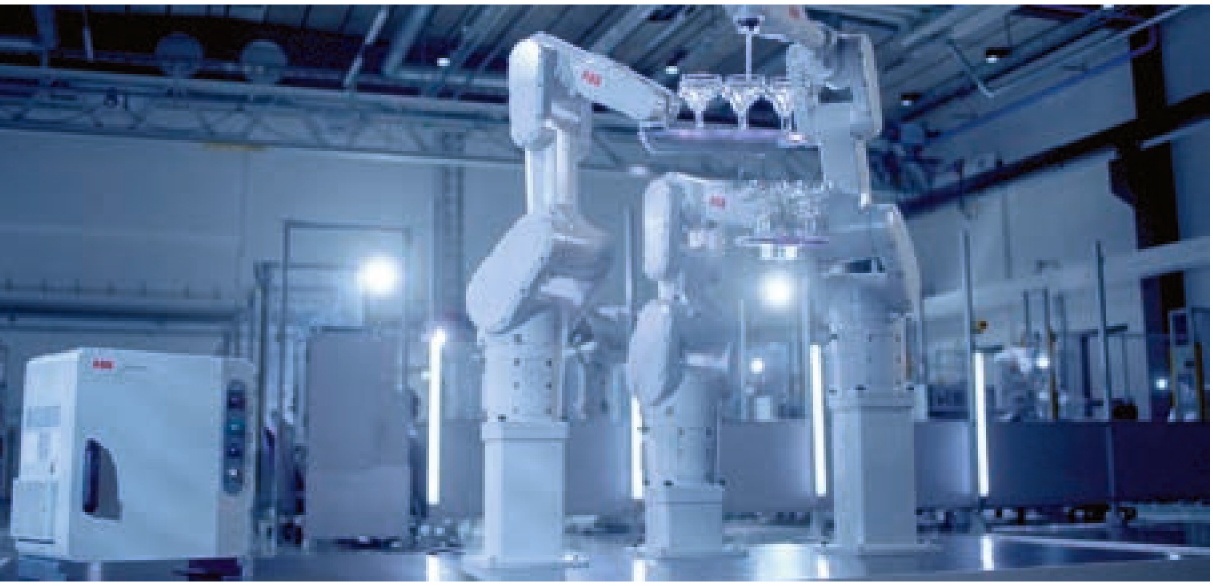
OmniCore's class-leading motion delivers robot path accuracy of under 0.6 mm – the width of a grain of sand.

OmniCore is open to all major robotics communication protocols, allowing simple integration of peripherals, such as sensors, cameras, or conveyors.

The single OmniCore management interface allows non-experts intuitive control of the interplay of robots in a system so they can be given



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05 OmniCore enables robots to work faster than before.

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06 Online and in-class training prepares engineers to work with OmniCore in the field.

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07 OmniCore allows robots to collaborate on repetitive jobs and free up skilled workers for other tasks.

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Watch the OmniCore Challenge – Redefining the future of robotic capabilities.

new skills. Here, the focus is on critical areas where recruitment of skilled workers is difficult – for example, in welding.

Sustainability attainability
Along with the challenges for businesses today of disruption and uncertainty in supply chains, there is also mounting pressure to produce more sustainably.

OmniCore enables a robot to reduce its energy consumption by up to 20 percent compared to when it runs under ABB's IRC5 controller. In addition, energy is saved through regenerative braking: The kinetic motion energy from braking the robot is collected and fed back to the factory's power grid. No external equipment is required for this as the base design includes

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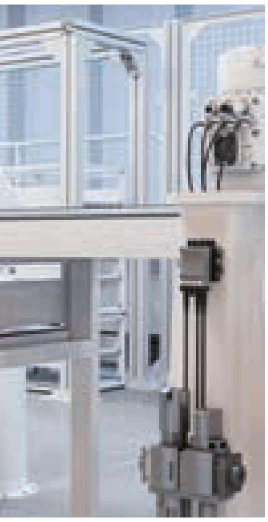
Kinetic motion energy from braking the robot is collected and fed back to the factory's power grid.

everything needed. This eliminates the need for external energy storage equipment, saving money, space and time.

OmniCore comes with the latest technology for power conversion from AC to DC, which means less energy is lost through heat. This benefit reduces not only primary energy consumption but also means that energy requirements for

Further information

Learn more about ABB Robotics 50 years on LinkedIn, X, Facebook and Instagram or head to the landing page for all the latest news and updates.



cooling are decreased. Moreover, automatic path planning can save up to an additional 30 percent of the energy consumed in operations by identifying the most energy-efficient robotic movements.

All these measures help businesses reach their sustainability targets.

Engineering support and training

OmniCore pioneers software for ease of use in individual robots – from wizard programming to the latest AI-powered learning – to open the door to working with ABB robots without needing specialist programming skills.

The platform comes with 15 pre-engineered applications covering everything from spot welding to high-speed alignment, machining and integrated vision, reducing commissioning time from weeks to days. It also supports more than 100 safety configurations, meeting the needs of different use cases while making safety configurations easier to implement than ever before.

To support the transition from IRC5 to OmniCore and OmniCore operation in general, ABB provides free online training. In addition, ABB offers more detailed in-class training in 40 training centers around the world to support those who want to gain deeper knowledge →06.

Although the IRC5 controller will be phased out in June 2026, ABB will continue to support IRC5 customers with spare parts and service through the remaining lifetime of their robots. With upgrade and refurbishment programs, there is no limit to how long ABB can support the customer to keep their production up and running.

Robot vision

OmniCore is built on a scalable, modular control architecture that offers a wide array of functions to create almost any application imaginable, making it suitable for businesses embracing automation in existing and new segments, such as biotechnology and construction, amongst many others. With over 1,000 hardware and software features, customers can design, operate, maintain and optimize operations easily. This is enabled by software features that include ABB's Absolute Accuracy, PickMaster® Twin and hardware options such as vision systems and fieldbuses.

OmniCore opens the door to the entire ABB robotics portfolio of hardware and software in any combination under a single control platform, offering endless possibilities for customers and more avenues for value creation. This platform bundles more value than any other robotics controller, delivering motion control and safety and adding the best in cyber security, connectivity, sensor integration and AI processing.

ABB's vision is for workplaces where integrated, AI-enabled autonomous robots undertake repetitive, dull and dangerous tasks, bridging skills gaps and allowing people to perform more fulfilling jobs →07. Generative AI, which is designed to create or generate new content from large learning models, is a game changer. The day cannot be far off when a user will be able to simply verbally instruct a robot and have it ask questions in return to enable it to complete the required task.

As ABB celebrates its 50th anniversary in robotics, OmniCore offers a springboard for many more industry breakthroughs.

As ABB celebrates its 50th anniversary in robotics, OmniCore offers a springboard for many more industry breakthroughs, empowering customers across all sectors to meet the challenges ahead. •

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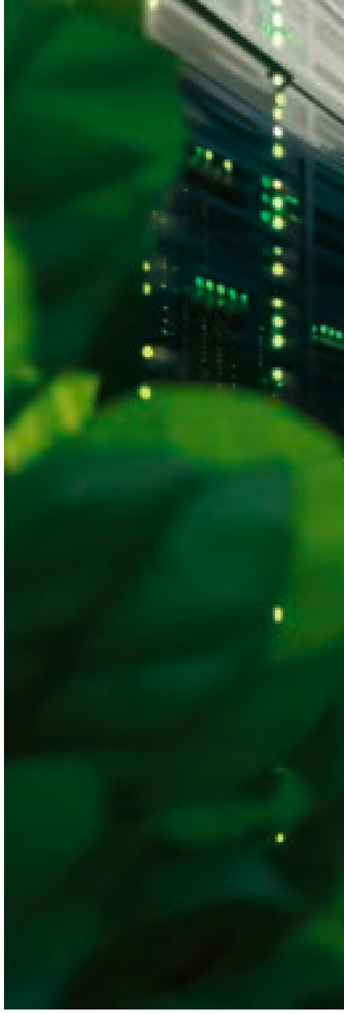

SUSTAINABILITY OF ARTIFICIAL INTELLIGENCE MODELS

How green is the machine?

Understanding the factors that affect the carbon footprint of computation could help decision makers in the process industries to reduce their CO_2 emissions. Taking a theoretical and experimental approach, ABB explores this topic and provides advice on how to make AI models greener.

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Artificial intelligence (AI), specifically machine learning (ML), has infiltrated everyday life. Neural networks (NN), which are multi-layered deep learning models, provide facial recognition capabilities for added mobile phone security or convert human speech into commands for smart home applications. This rapid progress is becoming increasingly relevant for process industries with applications ranging from the interpretation of infrared images of machinery [1] to the analysis of production-related data and more [2]. Clearly, the promise of this potential ignites competition to improve performance leading to ever larger AI models that are trained for longer, thereby generating worrisome secondary effects: more energy is consumed and more CO_2 is emitted [3,4,5] – less than laudable ramifications considering the current climate crisis.

Dilemmas and goals
It would appear that carbon footprint goals must be sacrificed for the performance enhancement generated by AI models. But, is this necessarily so? At first glance, studies that have evaluated this tenet have focused on high-performance language- or image processing models such as GPT-3, a deep, a neural network model with 175B parameters that provides human-like texts. This large language model (LLM) required 1’287 MWh for training, which corresponds to 552 t of CO_2 – the annual emission of 276 medium-sized cars [4]. Though not yet disclosed, the footprint for GPT-4 will probably be much larger. Still, other high-performance AI models

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Ever larger AI models, trained for longer, generate worrisome secondary effects such as higher energy consumption.

are associated with a smaller carbon footprint; some investigators have even suggested that the scope of the problem has been exaggerated [6]. Such discrepancies make AI providers unsure about the carbon footprint of their specific model or how to reduce it. Decision makers in the process industries face an additional challenge: models are typically much smaller in scale than the high-performance models discussed in the literature. Are emissions in these cases even relevant? In this paper, ABB aims to give

What is the environmental impact of the computational needs of AI?

ABB's framework explains the carbon drivers of models.

The carbon footprint of process automation models was found to be negligible.

engineers, managers, and others guidance so they understand the impact that individual AI models have on the environment. Specifically, ABB examines the literature to create a comprehensive framework to explain the various carbon drivers over the entire AI model lifecycle and offers advice about reducing those drivers [7]. Based on experimental data, ABB also tests the validity of literature recommendations to provide guidance for reducing the carbon footprint and energy consumption of AI models, eg, the use of transfer learning models. Moreover, the carbon footprint of process industry-relevant AI models is computed and discussed.

State-of-the-art AI carbon footprint

While theoretical models from the literature estimate the carbon impact of a new AI model based on architecture (layer types and size), training and usage [4,5,8,9], it is difficult to determine which metric drives the footprint [5,10]. Contrastingly, the carbon footprint of ML models can easily be measured using software tools to record the impact of development or use via carbon accounting. Some tools use metrics, eg, training time, energy mix, and hardware information [8,11], while others, eg, energyusage or CodeCarbon, integrate directly with the ML code [6,12,13,14]. Other tools compute central processing unit (CPU) power usage, estimate graphics processing unit (GPU) runs, compare hardware type [12,15,16] and determine the carbon impact of image recognition models [17].

Despite the significance of this research, two study gaps loom: First, studies are either too generic or focus on specific unrelated domains, eg, images [17,16] or LLMs [3,4,5], with unknown relevance to process industry data since industry models are specific and use small data sets. Second, carbon calculation models are not standardized and specific lifecycle steps are often omitted [18]. To close these gaps ABB empirically evaluated the carbon footprint and created a model for all AI life cycle phases.

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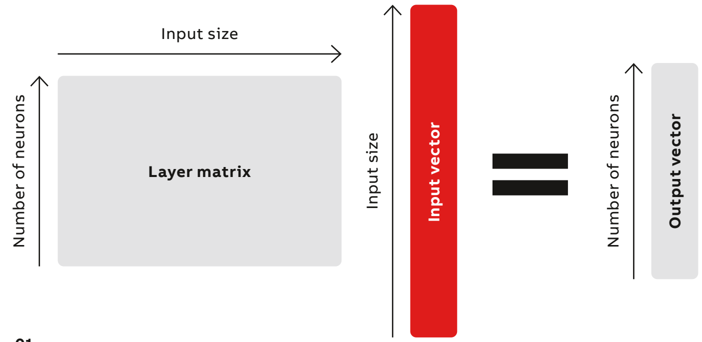
ABB examines the literature to create a framework to explain the carbon drivers over the entire AI model's lifecycle.



01

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01 Inference of a single layer expressed as a matrix multiplication – a simple case. For a layer, a matrix multiplication and a simple activation function eg, (ReLU), are applied. Activation function omitted for clarity.

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02 The experimental comparison of transfer learning MNIST model results to the dedicated MNIST model results in relation to energy use.

Deep model's carbon footprint
The carbon footprint (CO_2eq) of NNs depends on how much energy is used (in kWh) and the carbon intensity (in lbs/kWh) of the energy source. The carbon intensity of Chat GTP-3 (1'214'400 lbs CO_2eq) [4], Gopher (851'200 lbs CO_2eq) [18], and NAS (626'155 lbs CO_2eq) [9] are unsurprisingly high. Contrastingly, the carbon footprint of other high-performing models is much lower, such as BERTbase (1'438 lbs. CO_2eq) [9]. Such disparities suggest that the factors that impact a high-performance model's carbon footprint require more scrutiny.

Examining AI lifecycle phases – inference
To explain the impact of AI models on carbon footprint, ABB holistically modeled all life cycle phases [4,5]:

- model architecture search (MAS) – the design stage
- model training – for training the model with data
- inference – the usage stage

Because inference operations are executed during all phases, they are described first. Essentially, inference (which is estimated to cause between 80 and 90 percent of a model's total energy use [4]) can be defined as the computation of a mathematical formula expressed through a series of learned parameters that transforms an input vector into the correct output vector, eg, an image, time series, predicted value, etc. The mathematical operations for a standard NN dense layer consist of a matrix multiplication and application of a simple activation function to the result →01. Layer output acts as input for the next layer leading to a series of matrix multiplications, thereby consuming energy. The amount of inference energy used depends on: model architecture (M), ie, layer types, order, and size; and type and quantity of processing units (PT) eg, CPUs, GPUs, and tensor processing units (TPUs). The overhead imposed by the power usage effectiveness (PUE) of the datacenter also has an impact [19]. Thus, the energy cost I of an inference can be described as:

$$I = F(M, PT) \cdot PUE \quad (1)$$

Approximating f is challenging mainly due to different hardware implementations, memory access [13,9,21] and the use of specialized layers. Thus, simple substitutes for M such as the number of trainable parameters [20] are problematic [10]. Nonetheless, measurement-based estimates of I can be used to calculate the total life cycle carbon footprint of a model. Both PT and PUE can be optimized by choosing efficient data centers and/or hardware. For example, a GPU is 10 times more efficient than a CPU; a TPU is 4 to 8 times more efficient than a GPU [8]. Although the PUE of a datacenter might be unavailable, those centers located in colder regions generally consume less energy than those situated in warmer regions [22]. Selecting a low-carbon M can also reduce energy use without sacrificing performance [20,12,14]. To reduce model size suggested techniques are pruning, adding sparsity, quantization, or knowledge distillation [4, 23,24]. For DNNs [6], computation effort can be reduced by factors 5–10 [4]; for convolutional neural networks (CNNs) – a feature engineering NN – by a factor of 40 [20].

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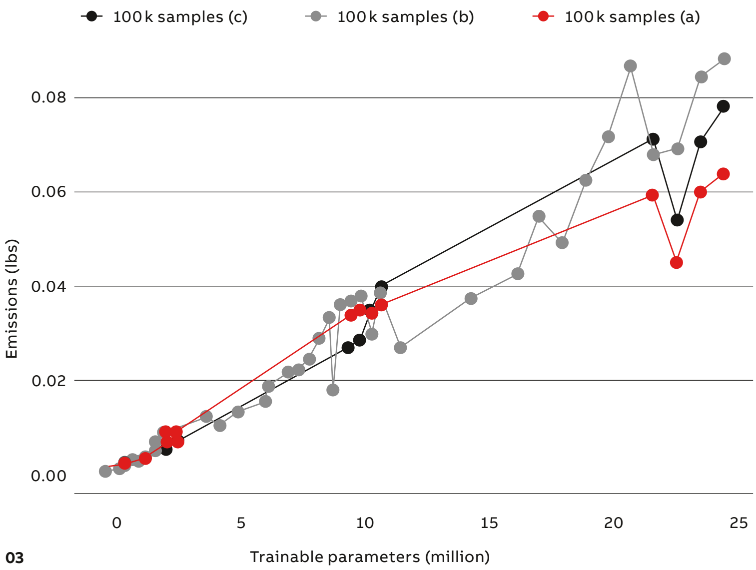
The impact of AI on carbon footprint is modeled for each life cycle phase: model architecture search, training and usage.

The training phase
Energy use during a model's training phase depends on training duration and number of processors used [4]. Three factors act as drivers: The energy cost of a single inference (I), the size of the training data set (D) and the number of epochs (E) used to optimize the model weights.

Experiment	Energy use
MNIST-exception transfer learning	0.451 kWh
Dedicated MNIST model	0.005 kWh

02



03

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03 Here, layer size was varied between 25 and 100 nodes and the number of layers ranged from 10 to 170. The models were trained for 10 epochs with 100'000 samples. Except for an odd dent at the end, the growth seems almost linear.

Overhead[1] is expressed as a constant θ.

$$T \propto E \cdot D \cdot I \cdot \theta \qquad (2)$$

Where, *PUE*, and number and type of processors are considered within the value for I. It follows that training energy can be reduced, theoretically, through transfer learning – the reuse of a pre-trained model on a new problem – as it reduces E and D [4,5,8].

The MAS phase
Notably, different model architectures used for the same task can vary in accuracy. For this reason, many architectures are trained during MAS and the best one is chosen for the final training phase. While performance is the optimization criterion of choice, energy consumption could be used as an additional criterion.

The cost at this stage (CT) is proportional to two factors [5]: The cost of training, T, and the number of times hyperparameters are tuned (H). Some of T's components, ie, I, E, and D, might vary for each tuning step resulting in different values of T for each tuning step.

$$CT \propto \sum_{n=1}^{H} T_h \qquad (3)$$

Choice of MAS is critical because the more often Hs are tuned, the more energy is used. Interestingly, in terms of energy used, a random search is better than a systematic grid search, which compares many similar architectures [8]. It follows from equation iii that transfer learning could reduce MAS or even eliminate it [4].

Life cycle energy use and carbon footprint
The total life cycle energy use depends on the energy cost of all life cycle phases: CT, T, I; and the expected number of inference calls (e):

$$E_{life} = CT + T + I \cdot e \qquad (4)$$

The CO_2eq is determined by multiplying (4) with the carbon emission factor (EF):

$$CO_2eq = E_{life} \cdot EF \qquad (5)$$

EF varies greatly depending on the energy source used. For example, EF ranged from 20g CO_2eq/kWh in Quebec, to 736.6g CO_2eq/kWh in Iowa in 2019 [8]. Evidently, the easiest way to reduce CO_2eq is to choose the right location [4].

By taking into account the carbon footprint at each ML life cycle stage as determined in the previous sections, the resulting consolidated framework provides a reasonable estimate of a DNN model's carbon footprint[2].

Experimental conditions
To empirically test framework assumptions about the carbon footprint of models with different properties, ABB conducted a series of experiments[3]. The code (Keras/ Python) was tested on a PC with a GeForce RTX 2080 Ti GPU and 32 GB RAM. ABB assumed the energy mix of Germany and used the CodeCarbon tool, which uses a carbon intensity of 365.5 g/kWh for its calculations.

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ABB's results confirm that smaller models use less energy than larger ones, especially if the model properties are similar.

Testing set size, epochs, and pretrained model use
To test if set size and epoch number increase energy use, ABB conducted two experiments:
1 H was fixed for a model and the number of training samples was increased.
2 The number of epochs was increased for two models of different sizes: 100 and 50 layers of size 25.

The results confirm that energy use linearly increases with increasing number of training samples. Similarly, increasing epoch size results

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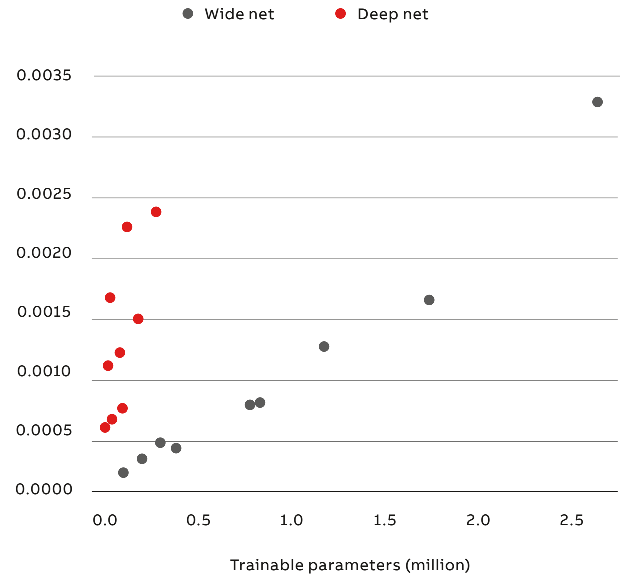
Footnotes

[1] There is significant overhead for the loss function and back propagation step, which is included in the calculation as its use has been validated in experiments.

[2] The framework ignores static energy consumption and original hardware production [13] and in contrast to some studies sacrifices accuracy to focus on ease-of-use.

[3] Model performance was not considered in the experiments. Carbon optimization and performance optimization interfere with each other but are not a direct trade-off.



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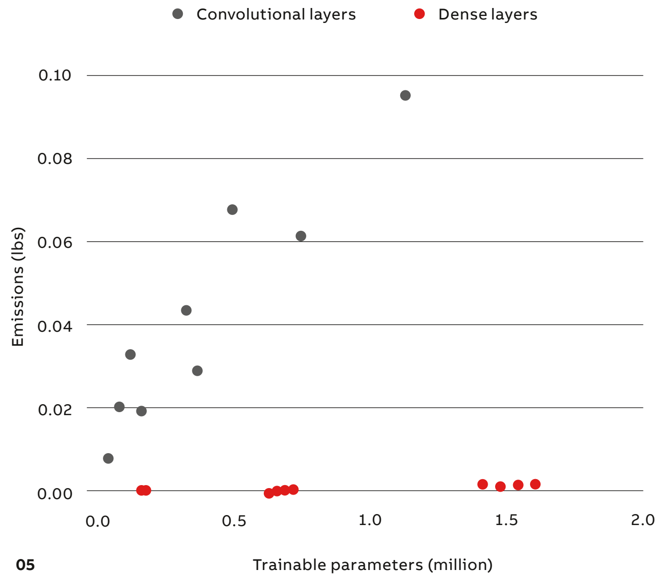

05

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04 The energy footprint of varying shapes – 10 epochs with 100k samples with 100 values is displayed.

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05 The energy consumption related to the trainable parameters of different layer types, ie, convolutional layers and dense layers (the simplest type) are displayed.

in a linear growth of emissions, thereby demonstrating the vital importance of both factors. While these results seem to confirm the value of pretrained models to reduce energy consumption [4,5,8], ABB's experiments indicate that pretrained models bear the risk of using oversized

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ABB's tested process automation-relevant models have a negligible carbon footprint, yet perform well.

and therefore inefficient models. A pretrained model can be fine-tuned for a fraction of the cost that training the same architecture would require when trained from scratch [26]. However, using a dedicated (smaller) architecture for a problem can be even more energy-efficient. For example, in an experiment with MNIST classification, a dedicated model needed only a tiny fraction of the energy used for a fine-tuned Xception model of comparable performance →02.

Testing the impact of model size
Generally, larger models require more energy than smaller ones, especially if the model properties are similar. ABB's experimental results confirm this statement →03. They also support the literature in rejecting the number of trainable parameters as a carbon driver.

In one test, ABB compared wide and narrow models with the same number of trainable parameters and observed great divergence in energy used →04. In deep learning, it is notable that the energy consumption of nets with many small layers, "deep nets", is much higher than for "wide" nets of the same size (fewer layers yet more nodes per layer). Nevertheless, depth is far better than width at increasing expressive power of an NN [27].

To assess the impact of layer type [20], ABB compared two groups of models: a series of wide models with dense layers, and a series of similarly shaped convolutional layers (where the

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This article is a condensed and edited version of: "Estimating the sustainability of AI Models: Based on theoretical models and experimental data" in ATP magazine, vol. 66 no. 3 March 2024.

Read the original article here:

	ECOD [28]	DeepSVDD [29]	BLOOM (Benchmark) [18]
Trainable parameters	N/A	3,202,048	1.79×10^9
Training data	60 MB	60 MB	1.6 TB
Training time	<1 min	11 min	1×10^6 h
Training carbon footprint	0.000027 lbs	0,00012 lbs	661’387 lbs

06

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06 An overview of typical industrial models. Data about a less intensive LLM (BLOOM) is added for comparison. Good performance levels are indicated. The industrial models seen in the literature are on a similar scale.

“width” is represented by the number of filters). The results show that purely convolutional models consume significantly more energy than do dense models →05. Thus, trainable parameters are a basic indicator of energy use, but only if the models compared share many properties ie, shape and type of layers.

Implications for AI models in process industry
While the consolidated framework presented and the experimental results can help users and decision-makers to reduce model carbon footprints, the question arises: Are these findings even applicable to process industry-relevant models? Certainly, vast quantities of industrial data are produced, thanks to distributed control systems (DCS) indicating that NN models could be useful. Unfortunately, significantly less data is available for training because most of this data is unlabeled. Less available data means less training time and lower energy costs. But, is this positive, or not? Crucially, such a scenario implies lower performance and, yet smaller AI models with a specific use case and good feature engineering do perform well indicating that performance might not need to be sacrificed.

To evaluate the carbon footprint of small models, ABB chose to evaluate two literature examples →06: a non-deep anomaly detection algorithm (ECOD) [28] and a deep anomaly detection model, Deep Support Vector Data Description

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As large deep models enter the industrial domain, ABB’s results will help engineers and managers to make better decisions.

(DeepSVDD) [29]. Both models were trained on data from an angular sensor used for condition monitoring. Not only do both models perform well in the test, their carbon footprints are negligible even when compared to an efficient LLM such as BLOOM →06.

These results suggest that further actions to reduce the carbon footprint of such process

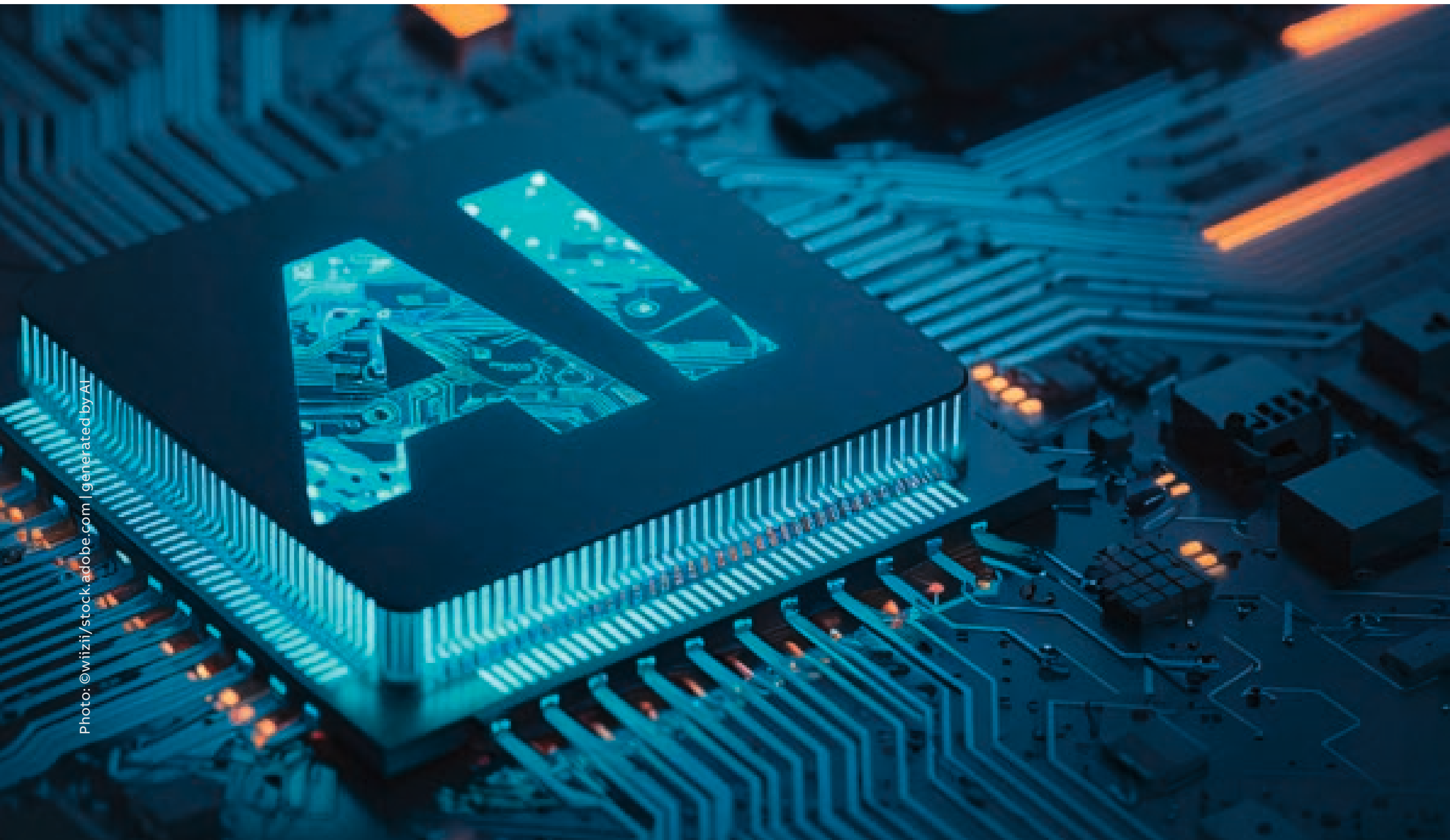

Photo: ©wiizii/stock.adobe.com | generated by AI automation-relevant models is currently unnecessary. Nonetheless, the explosive growth of LLMs, eg, GPT 4.0, strongly indicates that large deep models will enter the industrial domain soon. When this happens, the consolidated framework and experimental findings discussed in this paper will help engineers and managers make better decisions about the design, deployment, and use of their models in terms of carbon footprint. •

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GAME-CHANGING ENERGY EFFICIENCY FOR MW-SCALE MOTORS

MV Titanium

The pioneering MV Titanium concept optimizes the complete electromechanical powertrain as one seamless unit to offer transformative savings of up to 40 percent for energy-intensive sectors.

Only
10 to 15 %
of larger motors are VSD-controlled.

MV Titanium puts the entire powertrain into one speed-controllable unit.

MV Titanium offers savings of up to 40 % for energy-intensive users.

Large medium-voltage (MV) motor-driven components such as pumps, fans and compressors account for around 10 percent of the world's electricity consumption. This statistic makes energy efficiency a crucial objective for heavy industries such as power generation, renewables, chemical processing, mining or cement production as they transition towards low-carbon or zero-carbon operations.

Highly efficient speed-controlled motors using variable-speed drives (VSDs) have gained significant traction in smaller, low-voltage applications, as well as in larger, MV systems where speed control is essential – for example, in propulsion motor applications. However, larger motors, particularly in the 1 to 5 MW range, that are typically used for pumps, fans, and compressors lag behind, with only 10 to 15 percent currently controlled by a VSD. This can be attributed to initial cost and complexity.

ABB has addressed this challenge with a game-changing holistic concept – MV Titanium. MV Titanium is the world's first speed-controlled MV motor in the 1 to 5 MW range in a single, easy-to-specify and simple-to-install package.

The MV Titanium concept is a response to the main hurdles to installing a drive with a large motor – not just the upfront cost of a separate drive unit but also the cost, complication and commissioning of the associated electrical house (e-house), transformers, switchgear and cabling. These factors multiply capital costs and ramp up installation complexity, particularly at existing sites with limited space.

The concept uses a state-of-the-art multiphase induction motor and stacked polyphase bridge (SPB) multi-level control, designed together as a single electromechanical system. This cost-effective approach also enhances control, monitoring and connectivity capabilities. To simplify deployment, setup and commissioning are completed during factory testing. This approach enables the motor to be delivered as a single pre-configured solution.

MV Titanium is ideal for new installations or retrofitting existing direct-on-line (DOL) motors. With energy savings of up to 40 percent, the potential for reductions in energy costs and CO_2 emissions is significant. To put this potential in perspective, upgrading the global installed base of some one million large motors would save as much energy as 1,000 coal-fired power stations output.

Beyond its technical innovation, this large-motor concept signifies a major step change toward a more sustainable future. MV Titanium sets the industry firmly on the path to transitioning the vast installed base of large, fixed-speed motors to high efficiency and full electrical control. •

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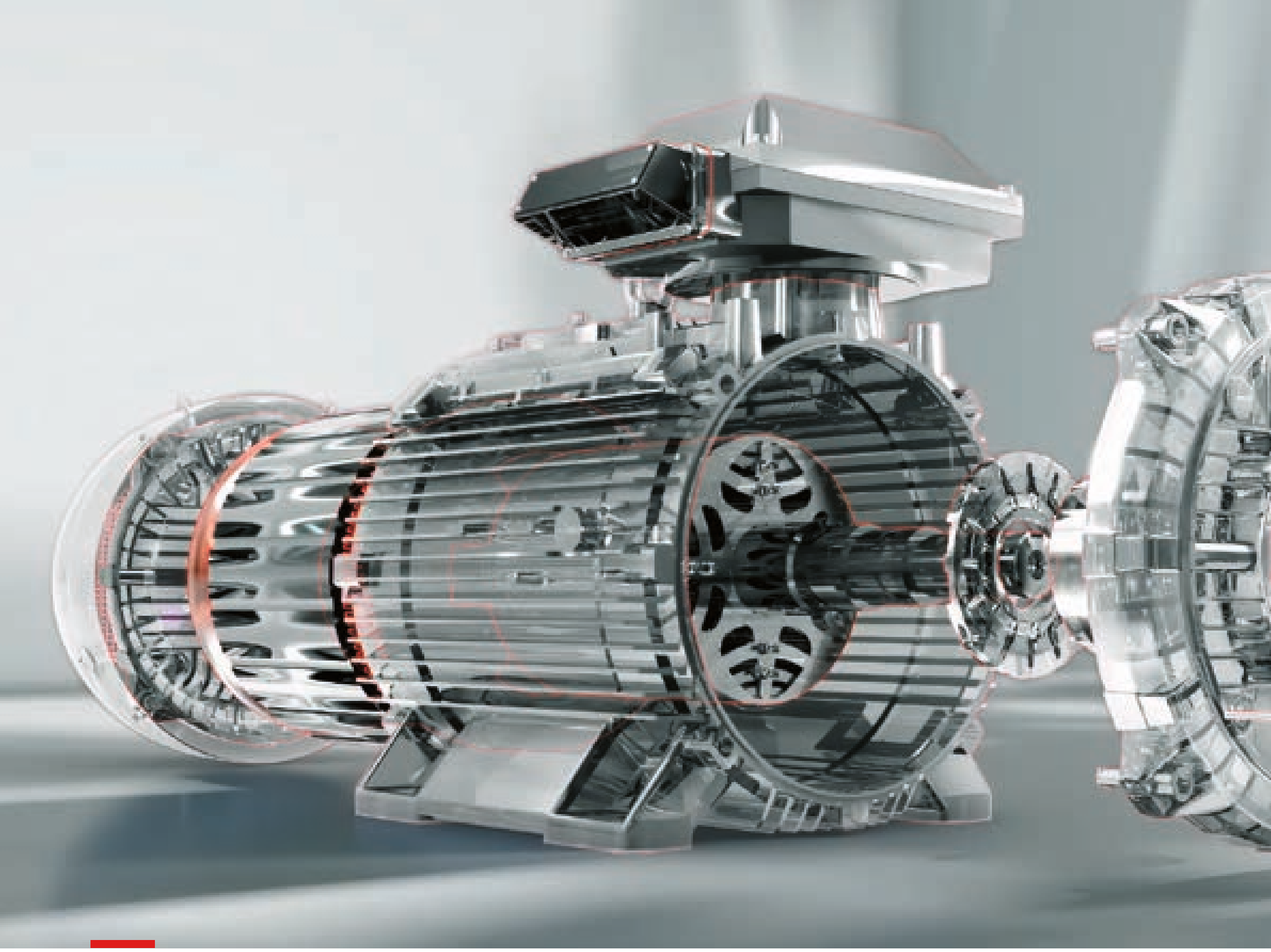

SYNRM ELECTRIC MOTORS WITH UNPRECEDENTED ENERGY EFFICIENCY

Motor power

ABB is the first manufacturer to reach IE6 hyper-efficiency in a magnet-free synchronous reluctance motor (SynRM).

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Because they generally work away in the background, unseen in daily life, the sheer quantity of electric motors needed to run society and the energy they consume is often overlooked. In fact, electric motors consume one-third of all electricity consumed globally. Low-voltage industrial motors are leading energy consumers, especially in the chemical, air separation, oil and gas, and energy industries, as well as in the water and wastewater treatment, metal and mining, and pulp and paper segments. The global consumption of electric energy by electric motors is dominated by just four major motor applications: compressors (32 percent), mechanical movement (30 percent), pumps (19 percent), and fans (19 percent) [1].

In 2019, ABB raised the bar for energy efficiency with its IE5 synchronous reluctance (SynRM) motor →01. This motor delivers ultra-premium IE5 energy efficiency, which is currently the

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Motion generated by electric motors accounts for one-third of all electricity consumed globally.

Electric motors consume around a third of all electricity produced.

ABB's SynRM is the first motor to reach IE6 hyper-efficiency.

Simple, no rare-earth metals and

20 %

reduction in energy losses vs IE5.

highest level defined by the International Electrotechnical Commission (IEC). SynRM motors are characterized by high energy efficiency, reliability and low maintenance needs.

ABB is the first manufacturer to reach IE6 hyper-efficiency in a magnet-free design. This advancement is a significant step towards addressing the energy consumption challenges in the various industrial sectors mentioned above, offering a promising future of enhanced energy efficiency.

The launch of the IE6 SynRM is the latest testament to the rapid progress of the well-proven SynRM technology, which ABB pioneered in 2011. This technology has advanced so swiftly that it has outpaced the evolution of official industry-wide standards or definitions. However, so far, each higher IE efficiency class has demonstrated 20 percent lower energy losses than the previous one and ABB has continued this approach with the IE6 SynRM, reaffirming its technological leadership in the industry.

Reduced energy costs and increased productivity

These motors will appeal to innovative customers who want to futureproof their fleet by adopting the highest level of energy efficiency commercially available. Early adopters of IE6 hyper-efficiency motors will reap the benefits of reduced energy costs and increased productivity while moving ahead of current sustainability targets.

Motor-driven systems in industrial facilities are major users of electricity and, therefore, maximizing their efficiency offers huge potential to cut emissions and help meet climate change targets. Using new magnet-free SynRM motors, reaching efficiency levels anticipated for future IE6 definitions will also take energy savings to the next level. Because the IE6 SynRM is the same size as the equivalent IE3 induction motor, it is an easy replacement for legacy motors. That makes it possible for customers to upgrade to modern, high-efficiency products to futureproof their operations in a world of fluctuating energy costs. This compatibility also simplifies spare part provision and maintenance.

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With the IE6 SynRM, ABB has set a new benchmark with a motor that reaches the anticipated hyper-efficiency level.

ABB's wide range of SynRM motors has set the benchmark for magnet-free design. Their efficiency has progressed from IE4 to the IE5 versions, which were launched in 2019. IE6 is the next logical step that demonstrates the capability and technical superiority of SynRM technology.

Performance and simplicity

SynRM combines the performance of permanent magnet (PM) motors with the simplicity and service-friendliness of induction motors to achieve the highest levels of energy efficiency that ensure a short payback time. The rotor has neither magnets nor windings and suffers virtually no power losses. The design also requires no rare earth metals and offers a high level of usability due to the wide availability of suitable VSDs to provide the required control capabilities.

IE6 SynRMs offer 20 percent lower energy losses than comparable IE5 motors, so CO_2 emissions are reduced. Constant, quadratic torque with high efficiency delivers fast, precise control. ABB

—

SynRMs offer 20 percent lower energy losses than comparable IE5 motors, so CO_2 emissions are reduced.

IE6 SynRMs deliver full torque from zero speed and give excellent partial-load efficiency. Their low rotor inertia allows precision movement and speed control that is very accurate due to the synchronous nature of the motor. This quiet motor is ideal for driving pumps, fans, compressors, etc., in any industrial application →02.

SynRM technology also offers much lower winding and bearing temperatures than traditional motors. These lower operating temperatures have multiple benefits – including longer insulation life and longer bearing greasing intervals and lifetime. Lower bearing temperatures are important because bearing failures cause many unplanned motor outages.

The ABB EcoSolutions™ portfolio
ABB SynRM motors are part of the ABB EcoSolutions product portfolio that enables customers and partners to make more sustainable choices by providing enhanced transparency about each product's circularity value and environmental impact. This comprehensive collection of information ensures informed and responsible decision-making. Products within the ABB EcoSolutions portfolio comply with a set of key

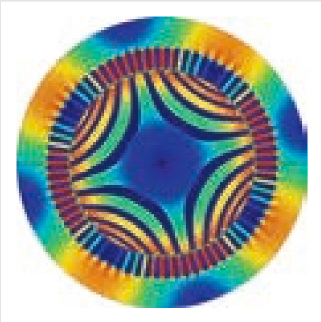
WHAT IS A SYNRM?

SynRMs work on a well-known and very elegant principle. But only since the recent rise of sophisticated variable-speed drive (VSD) control has it been possible to exploit these super-efficient electrical machines fully.

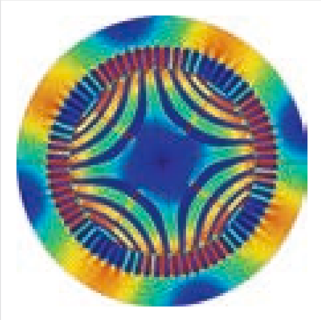
In a SynRM, the rotor is designed to produce the smallest possible magnetic reluctance (the resistance to the flow of a magnetic field) in one direction and the highest reluctance in the direction perpendicular. The VSD steers the stator field so it "rotates" around the motor. The rotor's directionally unequal magnetic reluctance properties cause it to rotate with the field and at the same frequency →01a-b.

SynRM technology combines the performance of the permanent magnet motor with the simplicity and service-friendliness of the induction motor. SynRMs do not feature rare-earth-based components like permanent magnets. The rotor has neither magnets nor windings and suffers virtually no power losses. Maintenance is as straightforward as with induction motors because there are no magnetic forces in the rotor.

ABB pioneered SynRM technology in 2011 with an IE4 efficiency class. In 2019, ABB introduced the IE5 SynRM ultra-premium efficiency motor and recently extended the portfolio with an Increased safety version for hazardous industries as well as a liquid-cooled design for demanding applications in harsh environments, such as food and beverage, rubber and plastic production, and marine. Now, ABB has taken SynRM technology to the next level by offering hyper-efficient IE6 models.



01a



01b

01

—
01 What is a SynRM?

01a No load.

01b Load applied.

02

02 Pumping is just one of many applications where the IE6 SynRM will improve performance.

03

03 The IE6 SynRM offers users a path to improve sustainability.

performance indicators defined in ABB's circularity framework and carry an external, third-party verified environmental product declaration – ISO 14025 Type III [2].

Motoring ahead

In motors, ABB makes a point of having the right solution for any industrial need to respond to market demands for higher output, better efficiency, longer service intervals and footprint reduction. ABB believes that IE6 SynRM technology – which exceeds by far the minimum efficiency performance standards put in place by all major industrialized regions – provides the basis for sustainable efficiency of low-voltage motors into the future →03.

Magnet-free SynRM motors are just one element of ABB's comprehensive premium portfolio of high-performance motors that incorporates over 140 years of domain expertise to ensure maximum reliability combined with a commitment to sustainability. Recognizing that a single technology does not answer all customer needs, ABB aims to master all motor technologies. That is why, in addition to SynRM, ABB can also achieve the anticipated levels for future IE6 efficiency

ABB believes that IE6 SynRM technology is the basis for sustainable efficiency of low-voltage motors into the future.

with PM and permanent magnet-assisted-SynRM (PMA-SynRM) technology – a hybrid technology that pairs the SynRM design with a PM "boost." This extension offers the right solution based on a comprehensive range of hyper-efficient technology building blocks to meet every segment- and application-specific need. •

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ENERGY-EFFICIENT MOTOR-INVERTER COMBINATION

One-two combo

A new package from ABB, featuring the first 3-level inverter for electric buses, enables greater lifespan and significant efficiency gains.

David Segbers
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The market for electric buses is growing at 14 % annually. Electric buses are here to stay.

A new inverter/motor combination features the first three-level inverter for a bus.

75 %
lower motor harmonic losses save energy and reduce heat.

Buses are on the move. With ever more people living in urban areas, growing environmental concerns and a steadily increasing number of governments committing to zero emission targets, is it any wonder that the global electric bus market is growing at a compound annual growth rate (CAGR) of 14.5 percent and is expected to be worth over $ 48 billion by 2030 [1]?

In view of these trends, ABB has developed and launched an energy-efficient inverter and motor →01–02 package for electric buses that features the first 3-level inverter to reach the ebus market [2]. Designed to work in perfect harmony, the motor and inverter enable greater lifespan and significant efficiency gains with up to 12 percent less motor losses on typical drive cycles compared to previous 2-level inverters. The package marks a significant leap forward in cleaner, more sustainable transportation options.

Compared to conventional 2-level inverters, the HES580 3-level inverter achieves a substantial reduction of up to 75 percent in motor harmonic losses, significantly minimizing heat dissipation and maximizing energy conservation →03. By reducing the effects of harmonics and minimizing stress on motor windings, this advanced technology offers sustained performance and longevity of the entire electric drivetrain.

Additionally, the AMXE250 motor stands out as a compact, permanent magnet synchronous powerhouse designed for high-efficiency propulsion. The motor also offers high torque density for improved dynamic performance, as well as quieter operation for increased passenger comfort. The inverter and motor are designed to offer flexibility, allowing them to be placed further away from each other, thus providing bus builders with space optimization options. With its easy parameter setting, commissioning, and start-up capabilities, the package can be swiftly installed. •

—

The 3-level architecture reduces harmonic effects and minimizes stress on motor windings, thus enhancing performance.

A FIRST IN INVERTER ARCHITECTURE

Unlike 2-level inverters, which switch between two voltage levels (DC+ and DC-), 3-level inverters such as the HES580 introduce a third voltage level – neutral →**03a**. This addition effectively halves the voltage step during each switching operation →**03b**, resulting in reduced current ripple and subsequently lower harmonic losses. Consequently, the AMXE250 motor operates with enhanced efficiency, delivering greater performance across diverse driving conditions →**03c** and →**03d**.

—

03 A first in inverter architecture.

03a The HES580 introduces a third voltage level – neutral – not found in 2-level inverters.

03b Compared to a 2-level inverter, the HES580 halves the voltage steps.

03c As a result of the previous advantages, the HES580 generates more power, more efficiently, from the same motor.

03d An evaluation of the pluses and minuses of 3-level topology reveals that it offers best-in-class overall efficiency.

01

02

—

01 Compared to conventional 2-level inverters, the HES580 achieves a substantial reduction of up to 75 percent in motor harmonic losses.

—

02 The AMXE250 is a compact, permanent magnet synchronous motor designed for high-efficiency propulsion.

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[2] ABB. ABB launches energy-efficient motor and inverter package for electric buses. Available: https://new.abb.com/news/detail/116119/abb-launches-energy-efficient-motor-and-inverter-package-for-electric-buses. Accessed July 3, 2024

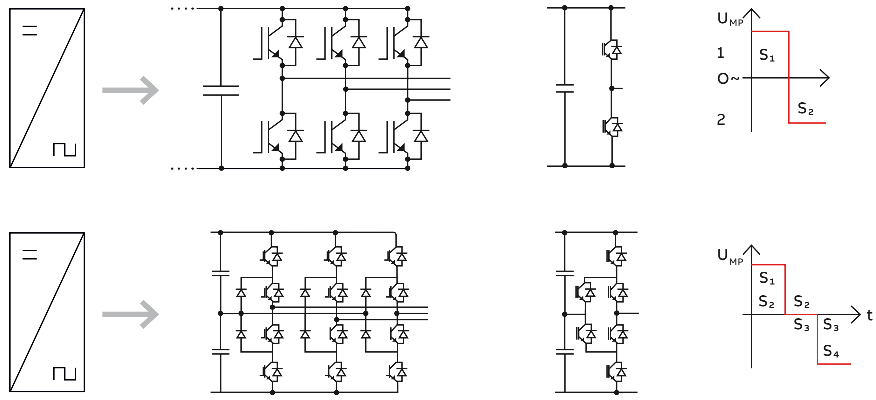
[3] https://truckandbusbuilder.com/article/2024/01/08/use-of-3-level-topology-inverter-to-boost-electric-motor-efficiency-in-buses-says-abb Accessed October 18, 2024

2-level topology:

- 850 Vdc
- 1.2 kV IGBT

3-level topology:

- 850 Vdc
- 0.8 kV IGBT

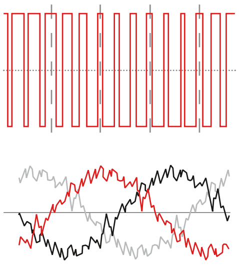


03a

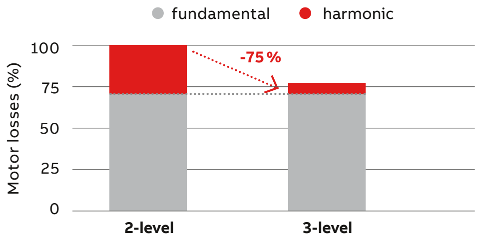
3-level advantages
... on motor losses

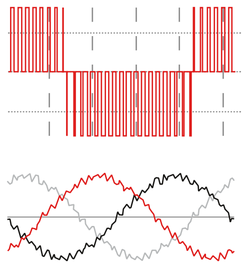
The voltage steps are halved from a 2-level inverter to a 3-level inverter

- Harmonic motor losses will decrease from 100 % to ~25 %
- Harmonic losses are 15 %–35 % of fundamental motor losses (sinus losses) which remain constant



2-level waveforms



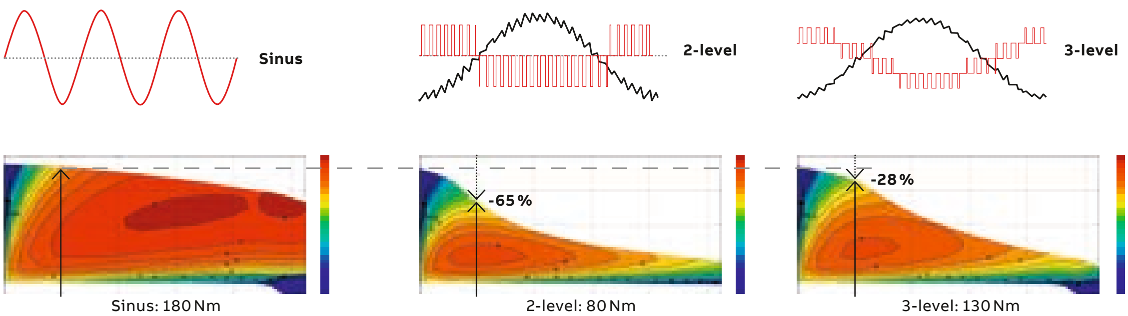


3-level waveforms

3-level drives produces 75 % less harmonic losses in the motor compared to a 2-level topology.

03b

Efficiency maps: How much power can I get out of the motor?
All limits calculated with maximum temperatures: winding max: 175 °C / magnet max. 150 °C

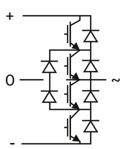


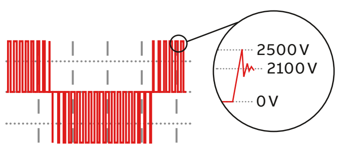
“Sinus” values stated in the datasheet | **Only 45 % power compared to the sinus** | **63 % more power compared to 2-level**

The 3-level converter can draw 63 % more power than a 2-level converter out of the same motor.

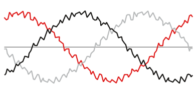
03c

3-level topology





3-level inverter output voltage waveform



Pros

- More Power out of the same electrical machine
- Increased efficiency due to reduction in motor harmonic losses
- Less voltage stress on motor insulation
- Reduces risk of motor bearing currents through to reduced common mode voltage
- Inherent fault tolerances

Cons

- more complex circuit
- Physical size of the circuit
- More conduction losses in the semiconductors

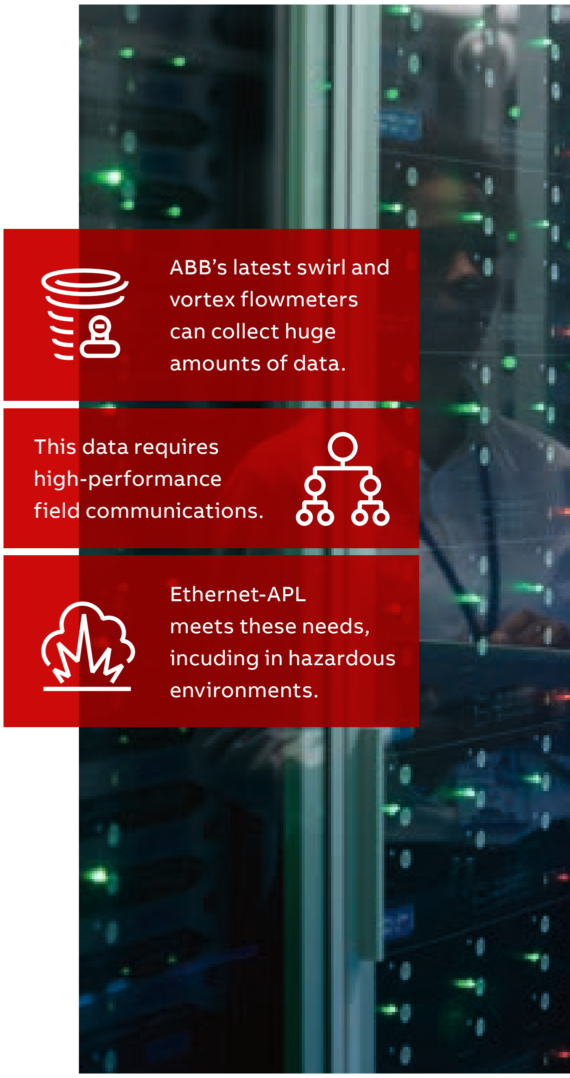
but this will be overcompensated by reduced switching losses of the semiconductor and reduced harmonic losses in the motor

A 3-level topology is the motor friendliest drive ... and the best-in-class for the overall efficiency of the drive system.

03d

ETHERNET-APL-ENABLED FLOWMETERS

Tapping data pipelines



New possibilities for digital collection and analysis of data in the chemical, oil & gas and hydrogen processing industries are now on the horizon thanks to the introduction of Ethernet-APL to ABB's industry-leading SwirlMaster and VortexMaster flowmeters. An innovative communications technology, Ethernet-APL not only eliminates the risk of sparking in hazardous conditions but offers a readily scalable solution for connecting vast numbers of devices in the field to a control system.

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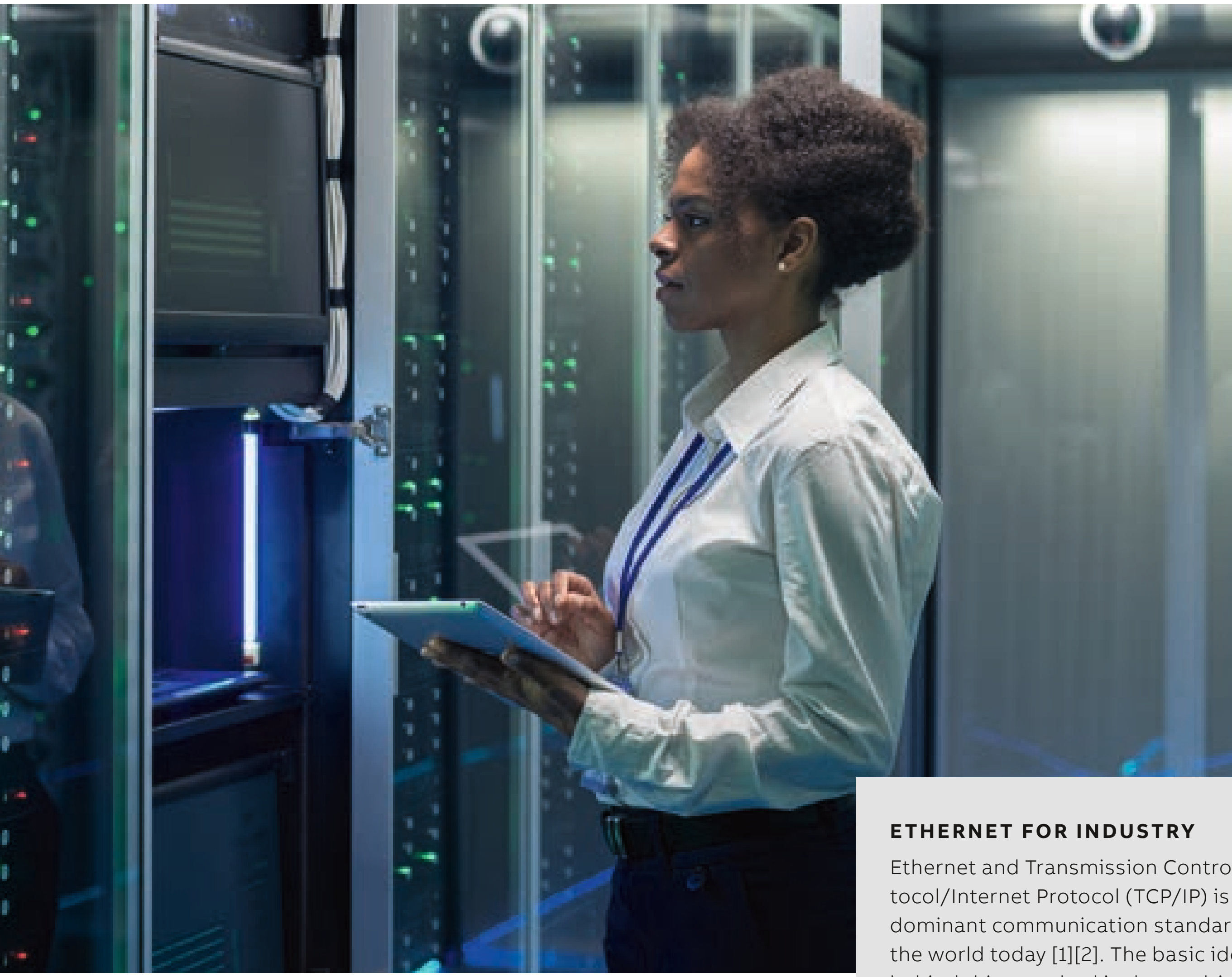
Ethernet cables are familiar to just about everyone who uses a computer. They provide high-speed wired connectivity to local area networks, metropolitan area networks and wide area networks. However, until recently, such cables could not be used at the field level in factories that have potentially hazardous conditions. To overcome this obstacle, ABB, in cooperation with a group of leading process industry suppliers and international standards organizations, has developed a solution in which intrinsic safety is fully integrated, including a profile that limits supply voltage and current, thus eliminating the risk of sparking.

Working with suppliers, ABB has developed a solution that limits supply voltage and current, thus eliminating the risk of sparking.

Improving operational efficiency
Known as Ethernet Advanced Physical Layer (APL), the solution offers enhanced data rates of up to 10 Mbps, a shielded two-wire connection for carrying power and data safely over the same cable, and cable lengths of up to 1,000 meters. The technology thus opens new possibilities for digital collection and analysis of data in chemical, oil & gas and hydrogen industry processes →01–03.

Ethernet-APL's innovative communication technology can help manufacturing companies improve their operational efficiency by providing a high-speed channel for process data as well as configuration and diagnostic information. It



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01 Ethernet is increasingly connecting the worlds of information and operation technology.

furthermore offers a readily scalable solution for connecting devices in the field to a control system and enables simplified networking with

—
Ethernet-APL provides a high-speed channel for process data as well as configuration and diagnostic information

all instruments in a plant, as well as opening new opportunities for process optimization by utilizing valuable data that was previously locked away.

With these advantages in mind, ABB has added this innovation to its well-known FSS450 SwirlMaster and FSV450 VortexMaster

01

ETHERNET FOR INDUSTRY

Ethernet and Transmission Control Protocol/Internet Protocol (TCP/IP) is the dominant communication standard in the world today [1][2]. The basic idea behind this standard is that multiple computers have access to it and can send data at any time. Widely used in domestic and commercial settings, Ethernet is now finding growing use in industrial measurement applications, connecting the worlds of information and operation technology.

As a 'plug and play' technology, Ethernet is easy to set up. Compared to other protocols, it allows the use of more common, commercially available, electrical components, thus helping to future proof systems and keep costs down by providing access to many sources of supply. It also offers several other benefits. Multiple protocols and applications share the same infrastructure. Eliminating gateways and protocol converters enables seamless communication, thus lowering the cost and complexity of getting data from where it is generated to where it is needed, while at the same time providing high reliability, low signal loss and high-speed functionality.

A WIDE RANGE OF BENEFITS

Similar to Power over Ethernet (PoE) [1], Ethernet-APL offers several benefits. At a basic level it omits the need for a separate DC power infrastructure, providing power and communications via the same cable. And thanks to its use of standard fieldbus cables, no special tools are required. Installation reliability is also increased as centralized power enables back-up solutions with uninterruptible power supply systems. In addition, devices can be remotely powered down via the APL switch during periods of low usage or for security and safety reasons. There is also no need for additional electrical outlets or for running different cables.

02

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02 A wide range of benefits.

flowmeters →04, giving them Ethernet-APL connectivity and allowing all the benefits of high-speed field data transmission with none of the safety drawbacks. The technology also saves on costs and complexity since it removes previous limitations on cable length, which made it difficult to establish communication networks across large industrial facilities. ABB's swirl and vortex flowmeters are the first instruments to have received Ethernet-APL certification from the FieldComm Group. This certification assures superior product quality for process instrumentation, and reliable interoperability throughout industrial communication networks.

—
ABB's swirl and vortex flowmeters are the first instruments to receive Ethernet-APL certification from the FieldComm Group.

Swirl and vortex flowmeters, which are among the industry's most widely used flowmeters, measure both volume flow and temperature, as well as mass flow and energy flow by tracking key inputs such as pressure. In addition, the devices make it possible for industrial companies to easily and remotely access device health status and maintenance data, thus obtaining valuable diagnostic information.

New possibilities for predictive maintenance
ABB's unique swirl technology also offers the benefits of minimal installation requirements and superior measurement precision. In addition to supporting the widely adopted FDI standard for configuration, the devices are easily configurable with the integrated web interface – no tools, drivers, or specialized software are required. The screen layout is responsive, adapting automatically to computer screens, tablets, and smart phones.

With the ability to measure volumetric, mass and energy flow, as well as process temperature, the swirl and vortex flowmeters with Ethernet-APL open new possibilities for operators to make operational decisions and carry out predictive maintenance based on real-time data, thus significantly reducing potential errors and downtime.

By enabling fast access to an expanded array of process and device data, Ethernet-APL also offers benefits for plant operators facing the challenge of gathering data from potentially hundreds or even thousands of devices when combined with ABB's Ability™ SmartMaster suite. SmartMaster is an asset performance management platform that enables fast troubleshooting, remote diagnostics, non-invasive process analytics, and many other possibilities by combining operational data, engineering data, and IT services. ABB plans to integrate Ethernet-APL technology into all its instruments and is already in the process of doing so. •

03

04

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03 ABB's Advanced Physical Layer (APL) brings the benefits of Ethernet to the peocess industry.

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04 Outfitted with Ethernet-APL, ABB's Swirl and Vortex flowmeters can safely, easily and remotely provide real-time data on the health of processes.

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References

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AUTOMATION ENGINEERING WITH THE ASSET ADMINISTRATION SHELL

Automating automation engineering

Designing oil and gas or energy plants is a complex, multidisciplinary and multi-organization process involving many documents and a vast quantity of data. A collaborative study with Equinor shows how Industry 4.0, particularly asset administration shells (AASs), speed up and simplify design work.

Designing O&G or energy plants involves a vast quantity of data.

Asset administration shells speed up and simplify design work.

A seamless end-to-end engineering and commissioning workflow emerges.

Photo: ©Tanakorn/stock.adobe.com

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The complex, multidisciplinary and multi-organizational nature of plants in the oil and gas and energy sectors presents unique engineering design challenges. In particular, orchestrating many drawings and diagrams, tables, text-like control narratives and other documents can lead to considerable complications. Fortunately, Industry 4.0 – along with modular and model-based automation engineering concepts – can ease cross-organizational information exchanges and data format and semantics interoperability. To demonstrate how these approaches can lead to a continuous engineering workflow in the sectors mentioned, a collaborative study between Equinor – an energy major based in Norway – and ABB was conducted in 2023. The main goals of the study were to:

- Understand what engineering data needs to be exchanged between involved organizations.
- Outline how this data will be represented as an Industry 4.0 AAS.

AAS is a vital concept for implementing a digital twin – ie, a digital model of a physical product, system, or process – for industrial applications →01. AAS is a universal information model that can be accessed throughout an industrial asset's lifecycle.

HOW AAS IMPLEMENTS THE DIGITAL TWIN

The AAS concept, a cornerstone of Industry 4.0, is governed by Industrial Digital Twin Association (IDTA) working groups and is available as the international standard IEC 63278 as well as a set of IDTA specifications. The AAS specifies a technology-neutral information model that can be mapped to and accessed via different IT protocols and technologies. In a nutshell, the AAS is attached to a physical or virtual asset and structures the asset-related information into so-called submodels, eg, to represent technical data relating to a device. These submodels are independent, use-case-specific containers for the actual "payload" of the AAS – eg, properties or files. The IDTA governs the creation of the submodel templates (there are currently over 80) from different industrial verticals, ranging from device purchasing through descriptions during plant design up to service and lifecycle events during the operational phase of the plant.

Technically, the AAS can be accessed and exchanged as a file or using request-response interfaces (so-called RESTful APIs with a JSON payload).

01

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01 How AAS implements the digital twin.

Automation engineering and modular automation

Along with Industry 4.0 technology, modular production plants are an additional efficiency driver for plant engineering. Here, standardized interfaces are the critical elements for success: Based on a standardized description of process module interfaces, type-specific module-type packages (MTPs), instance-specific intelligent modules and process equipment assemblies (PEAs) can be integrated into a supervisory control system – the process orchestration layer (POL), which might be implemented as part of the distributed control system (DCS). These items form the basis of the modular automation. MTPs, for instance, enable seamless PEA integration and reduce engineering effort and commissioning time.

—
The AAS is a vital concept for implementing a digital twin for industrial applications.

Further, a shift to off-site prefabrication of large conventional plant modules has driven the modular automation concept of the function module (FM) [1]. Compared to standardized MTPs, FMs provide several advantages for conventional plants – such as the ability to deploy the control logic of multiple logical modules in one physical controller.

These topics form the basis of the collaborative study between Equinor and ABB to explore MTP/FM and AAS synergies during plant engineering regarding automated workflow and the usage of AAS infrastructure [2].

Workflow steps and information models

An overview of the cross-organizational workflow created for the study shows which information needs to be exchanged and how this information can be represented as AAS content – eg, as potential submodels or submodel templates →02.

The AAS-solution strategy for the workflow is to generate AASs (and connected assets) as early as possible in the design process – ie, in step 1 – and

—

"As our strategic long-term partner, ABB was able to deliver a state-of-the-art demonstrator to showcase the application of Industry 4.0 technologies in the energy domain. We appreciate the open and unique collaboration opportunity to increase engineering efficiency and quality of delivered projects."

Anders Bjørsvik, Senior Advisor, Automation, Equinor ASA

add submodels and submodel elements to these in the consecutive steps [3]. The following discussion outlines the most important steps of AAS and asset creation.

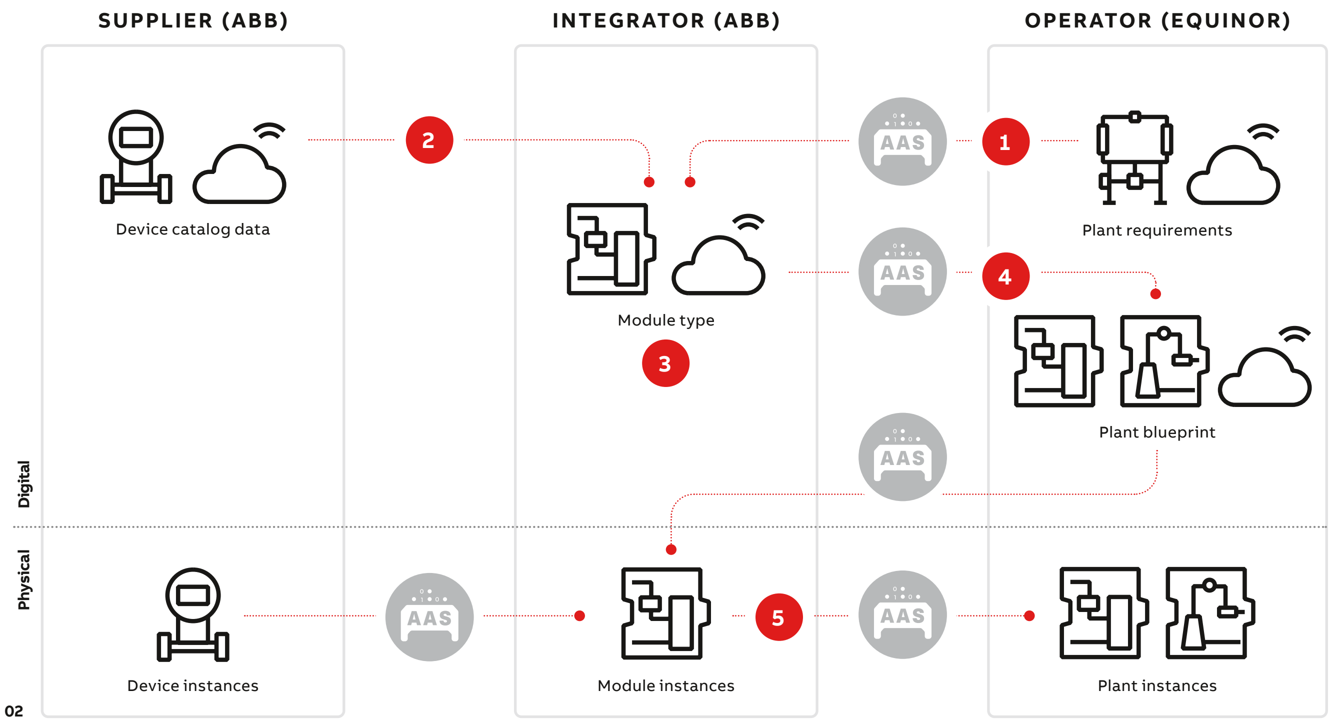
Requirements exchange (step 1)
The initial step of the workflow is the handover of plant requirements from the plant operator to the integrator. These requirements are typically represented as abstract diagrams, eg, process flow diagrams (PFDs), supplemented by a detailed process description written in human-readable language. For the scope of this study, a process segment consisting of a heater, gas treatment and separation system was modeled in Equinor's PFD modeling tool, MIMIR. The process segment was loosely based on a real-world asset of Equinor, both in terms of plant topology and tag names.

A PFD design base is especially useful for handling high-level service abstractions required by the modular automation methodology. Well defined high-level services (eg, heating or filtering) are a foundation of the demonstrated modular engineering workflow.

The container in the PFD modeling tool holds different aspects of the specified system – such as the functional and locational aspects of the physical plant elements. Each aspect is structured hierarchically to break down the system into subparts →03–04.

A crucial component for maintaining a continuous digital thread throughout each aspect of the engineered system is the creation and preservation of identifiers for the system and its individual elements. In the case of the diagrams in Equinor's PFD modeling tool, unique internationalized resource identifiers (IRIs) are created for elements of the diagram and represent asset identities used within the AAS domain.

An AAS representing the whole MIMIR project is created that contains the following submodels (compare with the left column of →05):



—
02 An example engineering workflow.

—
03 A MIMIR diagram showing a functional breakdown of a plant containing a separation and a gas treatment system with further subcomponents.

—
04 Cross-element connections between subcomponents of the separation system showing mass flow, electrical connection, etc.

—
05 Three AASs representing hierarchical elements of a MIMIR project instance (representation using AAS-GUI tool from Eclipse BaSyx™).

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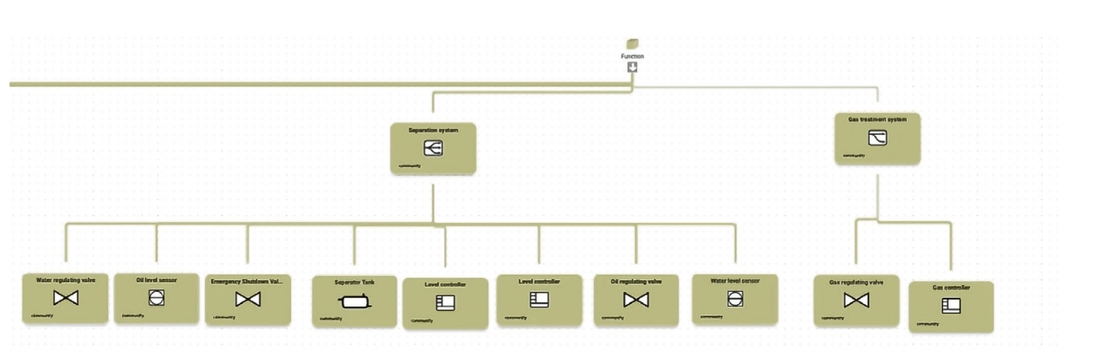
06 A high-level representation of device-type AAS containing, among others, OPC UA Nodeset files corresponding to the OPC UA information model of device instances.



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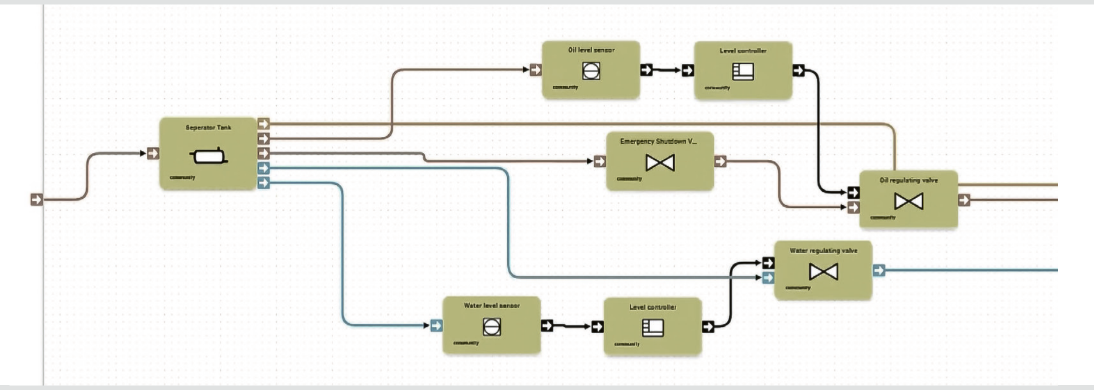

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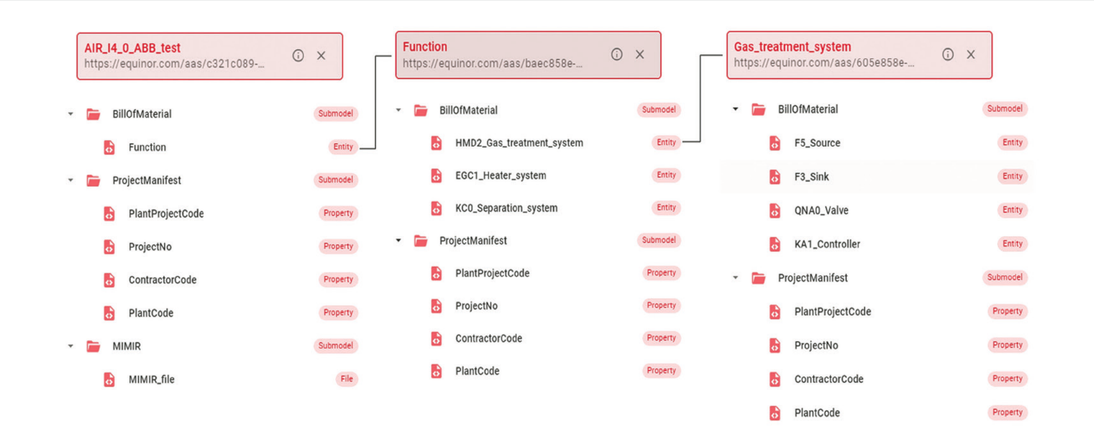

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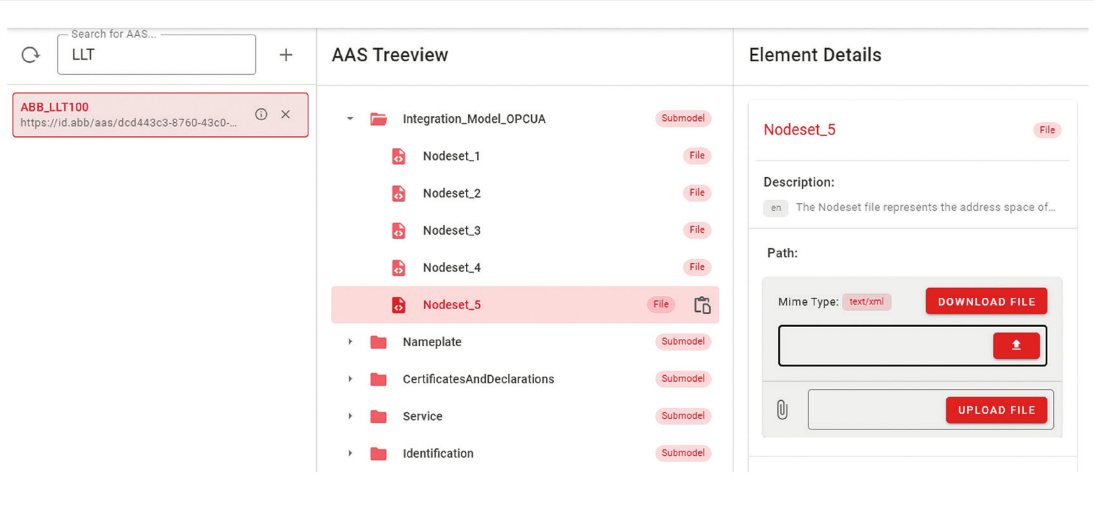

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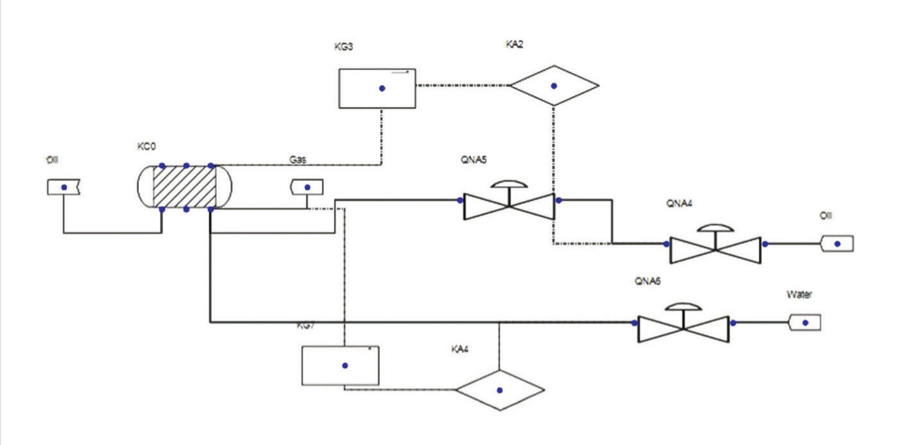

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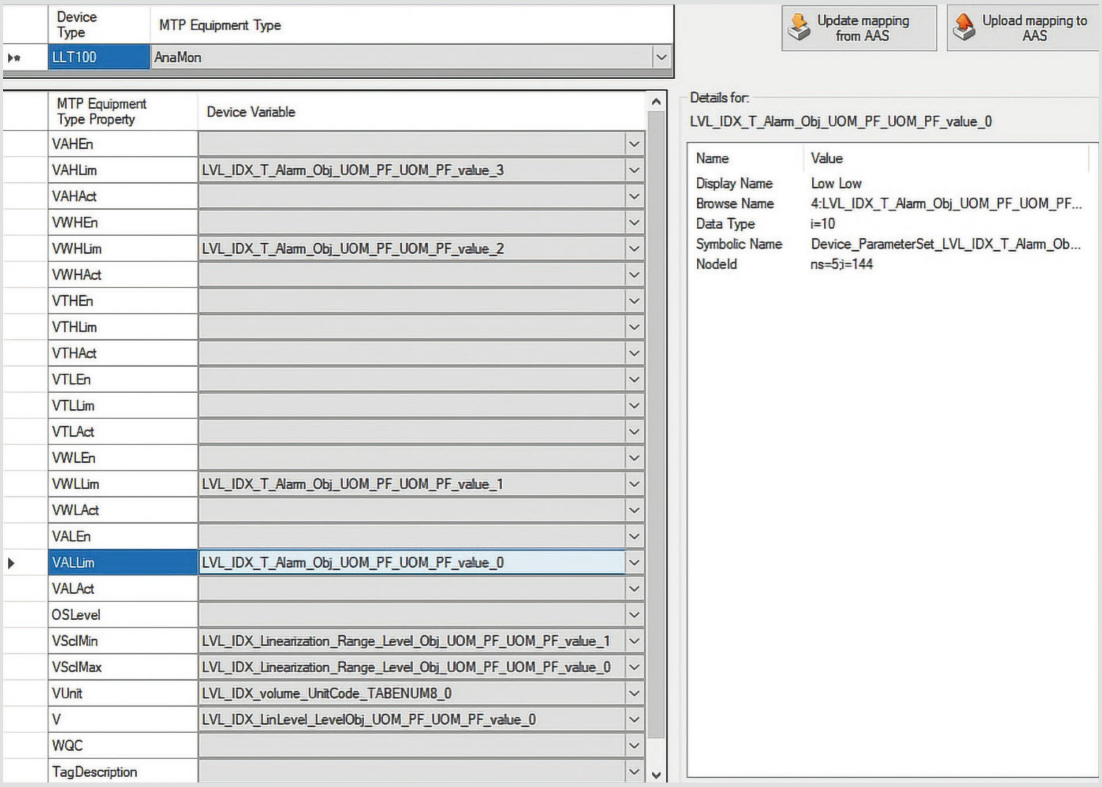

08

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07 Preliminary module HMI for the separation system generated from the MIMIR template.

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08 Mapping of OPC UA PA-DIM variables obtained from the AAS submodel to MTP/FM block abstractions.

- MIMIR submodel: contains the MIMIR file as a file submodel element.
- Project manifest submodel: contains meta-information about the project related to the specification, such as plant project code.
- Bill of material submodel: the standardized IDTA submodel contains the hierarchical breakdown of elements within the MIMIR project.

Exchange of device type information (step 2)
The next workflow step involves exchanging device type information (actually, catalog information) between device vendors and the engineering company. In the prototype implementation, an AAS of a device type was used that contained, among other things, submodels from the IDTA describing technical specifications and contact information related to the particular device type [4].

A further extension of this submodel set from the prestudy is a proposal to include a submodel containing OPC UA Nodeset files, which represent the information model of the future device's OPC UA server to be installed in the physical plant →06.

Engineering of the system parts (step 3)
In the next step of the cross-organizational engineering workflow, MTP module engineering

is taken as a proxy for various parts of the final plant. Additionally, FMs [1] can be used for modular-like automation of physically monolithic plants.

Instead of reusing existing module definitions from module vendors, new FM definitions (and a corresponding MTP submodel) are generated from the requirements provided by the operator in the form of a MIMIR system definition. To achieve this goal, the prototype modular engineering tool was extended to:

- Import MIMIR files and corresponding assets from AAS type 2 servers via a RESTful API.
- Process MIMIR files using a custom MIMIR file parser to map functional entities, such as the separation system, and MIMIR assets, such as valves or vessels, into the corresponding MTP library objects.

Tag names are inherited from the MIMIR specification. Element placement automatically generates the preliminary human-machine interface (HMI) layout of the FM →07. The placement and connection topology of the elements correspond to the layout in →04.

In a subsequent step, additional equipment – laser level or flow transmitters, etc. – can now be added to the module type definition. Here, the AASs of the device types from the previous step play an important role.

To use the device type within the MTP module or FM package, a mapping between the information model of the device (eg, PA-DIM, a manufacturer-independent information model with a structured hierarchy for standardized data access for devices) and the library element of MTP needs to be performed. Here, one makes use of the OPC UA Nodeset files supplied along with the device type →08. The mapping (right-hand side of →08) is also stored within the AAS of the device and can be reused over multiple projects.

Design review and commit to design (step 4)
The prototype used an MQTT event broker (a message coordinator) and distributed AAS registries to carry out change events between the organizations involved. Furthermore, a distributed version control system allowed for the review and sign-off of snapshots of the whole system – ie, all relevant AASs and submodels.

Plant commissioning and preparation for operations (step 5)
In this step, the types of modules (FMs or MTPs) are instantiated and interconnected to build the final plant topology. The study uses the ABB orchestration designer tool to create instances from existing MTPs or FMs out of FM definitions. Separator instances are constructed using FM extensions (configuration options, alarm filtering, etc), while the oil heater uses a standard compliant MTP definition.

A smooth workflow
The study implemented a realistic cross-company information workflow during the engineering process. It showed how different standardized and proprietary information models can be interlinked and extended over the lifecycle of the plant and its components. Furthermore, the viability of cross-standard interfaces – eg, referencing from an AAS submodel to OPC UA elements – was proven. This enables the concept of "bring your own model," allowing the linking and the re-use of different digital models within an Industry 4.0 workflow, thus assuring the security of digitalization investments.

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The study created an end-to-end engineering and commissioning workflow with no significant technical roadblocks.

The importance of asset identity preservation along the engineering lifecycle should be emphasized. While this matter appears trivial for existing physical devices, the identification of engineering entities such as piping and instrumentation diagrams and their elements is challenging.

The most significant achievement of this collaborative study between Equinor and ABB was the creation of an end-to-end engineering and commissioning workflow with no significant technical roadblocks. The work gives valuable insights for both automation and Industry 4.0 communities and might be used as a blueprint for other industry-lead evaluations of Industry 4.0 applications in practice. •

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SENSITIVE DETECTION BY REINJECTION

High-precision gas measurements

An ABB research project has successfully employed an optical reinjection technique to construct a high-precision analyzer for the simultaneous measurement of methane and ethane. The method also significantly reduces false positive errors and improves the ethane-peak detection rate.

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Oil and gas infrastructure is a significant source of emissions of methane and ethane, both of which are greenhouse gases. These emissions occur throughout oil and gas production processes, from extraction to transportation, due to unintentional leaks and intentional venting. Such releases not only intensify climate change – methane has a global warming potential more than 80 times that of carbon dioxide (CO_2) over 20 years (GWP-20) – but also represent a significant loss of valuable resources. These considerations make efficient methane and ethane leak detection systems indispensable.

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Methane's GWP-20 is over 80 times that of CO_2, making efficient methane and ethane leak detection indispensable.

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01 ABB has a range of products that detect gas leaks, such as the ABB Ability™ MobileGuard™ shown here. An optical reinjection technique improves methane and ethane detection precision.

Such systems must be capable of rapidly identifying and locating leaks and providing operators with high-accuracy real-time data. By meeting these requirements, the risks associated with gas transport and storage can be mitigated, the environment and public safety protected and regulatory compliance ensured.

Why simultaneous detection of methane and ethane is important

The simultaneous detection and quantification of methane and ethane is essential in determining the origin of these gases. Biogenic methane is derived from natural sources such as wetlands,

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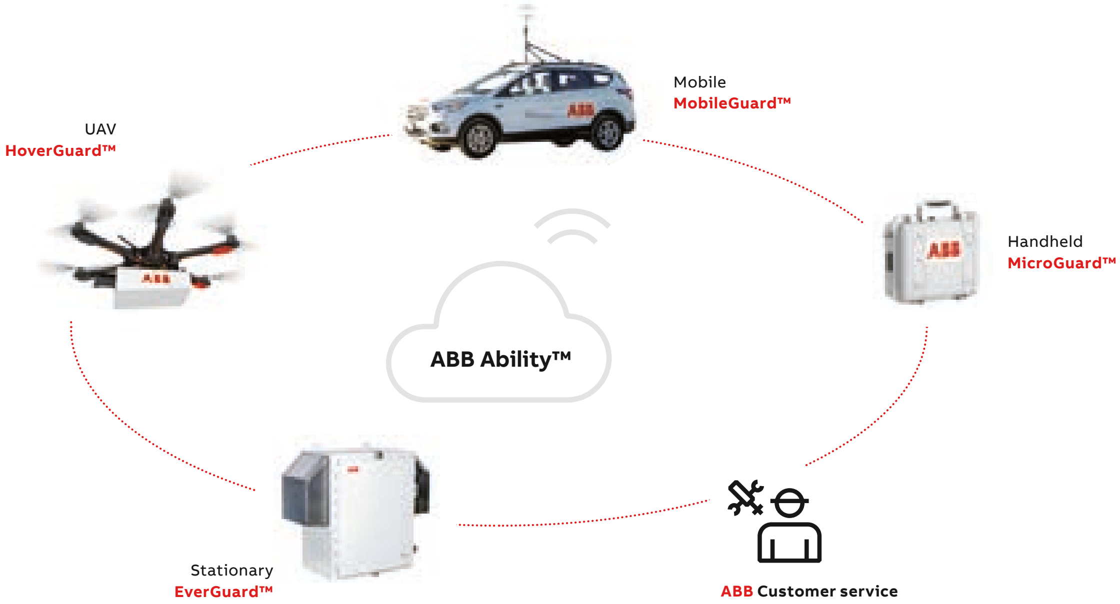
ABB is the first and only company offering four different solutions for detecting, finding, quantifying, and mapping leaks.

while thermogenic methane is produced from fossil fuels. In contrast, ethane is almost exclusively generated from fossil fuels. Therefore, a higher-than-expected ratio of ethane to methane can indicate that the methane emissions primarily originate from fossil-fuel sources rather than natural sources →01. A simultaneous measurement of both gases can determine this ratio.

Off-axis but on-target

ABB provides a wide range of gas analyzers based on unique and proprietary off-axis integrated cavity output spectroscopy (OA-ICOS) technology. OA-ICOS represents the fourth generation of cavity-enhanced tunable diode laser absorption spectroscopy (TDLAS). This technology has revolutionized the detection and quantification of gases. More specifically for natural gas leak detection, the laser-based analyzers offered by ABB can be deployed quickly to identify and quantify gas leaks in the field. ABB is the first and only company offering four different solutions for detecting, finding, quantifying and mapping leaks of natural gas while driving, walking, flying or stationary →02.

These ABB gas analyzers are based on so-called non-mode-matched optical cavities, in which only a very small amount of the laser light enters the cavity to interact with the gas sample. The research project described here aims to increase



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02 ABB Ability™ mobile gas leak detection system family.

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03 The ABB GLA231 series of analyzers provides highly sensitive and accurate measurements of gases such as HF, HCl and NH_3.

the amount of light entering the cavity – and thus available for measurement purposes – by using an optical reinjection technique. The reinjection arrangement will:

- Replace costly high-power laser sources with cost-effective and low-power alternatives
- Enhance the signal-to-noise ratio, improving instrument precision to expand the sales volume and available market
- Enable use of higher reflectivity cavity mirrors, thus increasing the optical path length and thus measurement sensitivity
- Tolerate a wider range of mirror reflectivity values, thus increasing allowable mirror manufacturing margins.

Simulate, design, build and test
The development and realization of optical reinjection in an OA-ICOS analyzer was carried out in several steps. Firstly, ABB developed an optical simulation tool to establish optimal and feasible configurations. Secondly, the team designed and set up an interband cascade laser (ICL)-based OA-ICOS analyzer that demonstrated optical reinjection. The ICL produces the wavelengths of interest for the spectroscopic examination of the gases of interest. The demonstrator is based on a commercially available ABB GLA231 series analyzer →03, in which key elements such as the laser source, the photodetector, the cavity mirrors, the collection lens and the reinjection optics, were replaced by custom versions appropriate to the aims of the project.

Various optical reinjection scenarios suggested by the simulations were experimentally investigated and verified. Measurements of precision, accuracy, linearity and cross-interferences for methane, ethane and water were performed

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The optical reinjection technique can be applied to the whole ABB OA-ICOS platform for various applications.

with and without optical reinjection. Although the optical reinjection technique is implemented in the methane/ethane OA-ICOS gas analyzer in this project, it can be applied to the whole ABB OA-ICOS platform for various applications.

Three mirrors and a cavity
The OA-ICOS analyzer with an optical reinjection system consists of an ICL laser source coupled to

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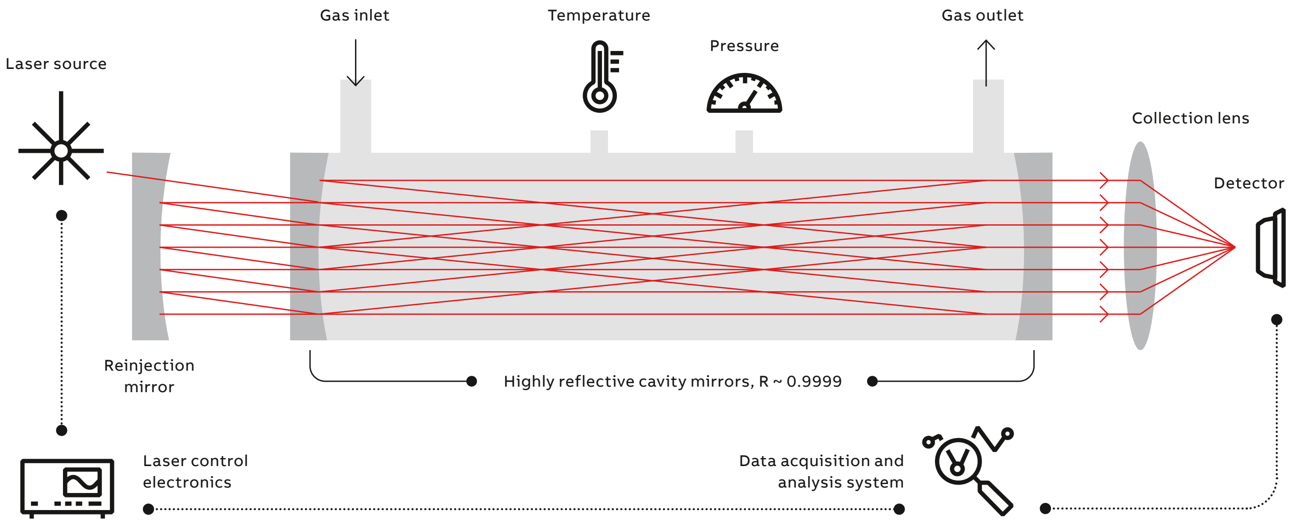

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04 OA-ICOS analyzer schematic.

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05 Optical configuration.

05a 3-D layout in Zemax.

05b Side-view of the layout. All the key components are included in the simulation.

an optical cavity with two high-reflectivity mirrors, a photodetector to measure and monitor the signal, the laser control electronics, the data acquisition and processing system and a reinjection mirror →04.

Initially, the laser beam passes through a small hole in the reinjection mirror and enters the first cavity mirror. The interior of the "exit" side of this mirror is highly reflective (99.99 percent) so most of the light is reflected internally, back towards the reinjection mirror, where it is reflected back to the cavity mirror. Since this three-mirror configuration is optically stable, this process repeats itself continuously. Only about 0.01 percent of the available light enters the cavity at each pass. The light that does enter the cavity 'bounces' between the cavity mirrors in an off-axis manner. A small fraction of the light leaks out through the rear cavity mirror, giving rise to the ICOS signal that indicates the concentrations of the various gases present in the cell. The output light is then focused onto a photodetector with a suitable collection lens. The gas sample is pumped continuously through the cavity using a vacuum pump and the pressure inside the cavity is controlled and measured. The temperature inside the cavity is measured with a temperature sensor.

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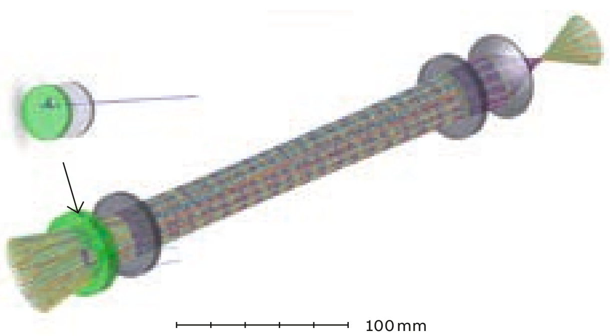
The optical system must be carefully designed, particularly with regard to the reinjection mirror.

The optical system must be carefully designed, particularly with regard to the reinjection mirror. Further, given the space limitations of the final product, the dimensions of the reinjection setup are critical. To design an appropriate optical reinjection setup, ABB used an optical simulation software called Zemax that integrates all the features required to conceptualize, design, optimize,



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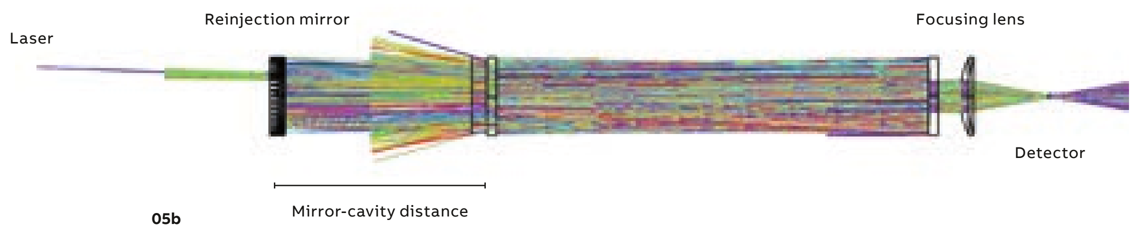

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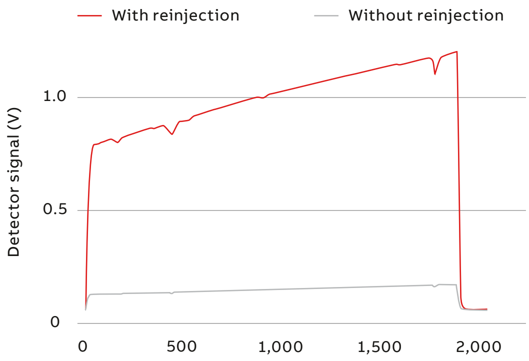
06 Measurement of ambient air in the laboratory.

06a Comparison of detector signal with and without optical reinjection.

06b Comparison of the detector signal of optimized optical reinjection and optimized standard ICOS.

06c Comparison of the detector signal of optimized optical reinjection and maximized optical reinjection.



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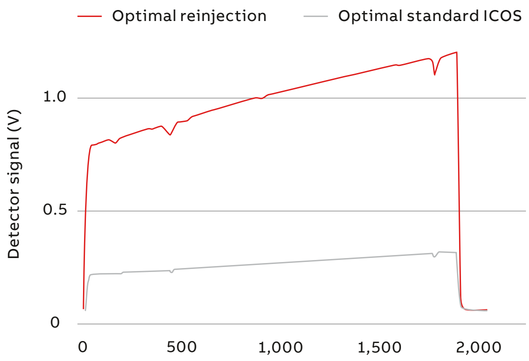

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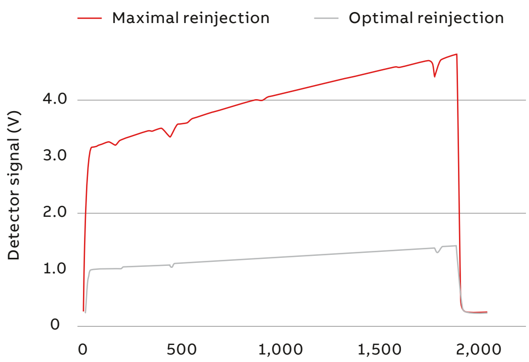

06c

analyze and document any optical system. Zemax is widely used in the optics industry as a standard design tool.

The simulation and experimental setup are configured identically, having the same mirror curvatures, clear apertures, reinjection mirror hole size and offset, beam diameter and divergence, collection lens surfaces and detector size →05. The efficiency of optical reinjection is related to the position of the hole, the distance between the reinjection mirror and the cavity, the curvature of the reinjection mirror and the incident angles of the laser beam. In the end, ABB experimentally tested and verified six reinjection mirrors with various cavity-mirror distances.

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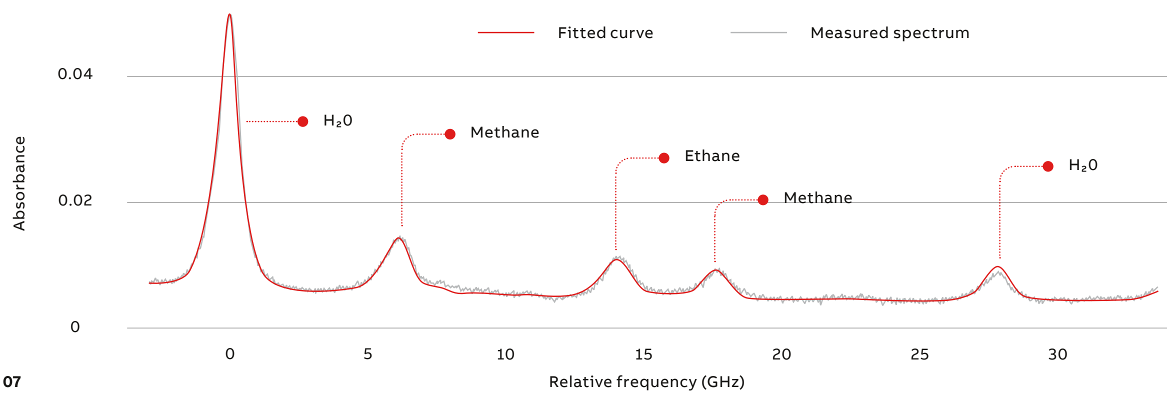
The enhancement of the signal amplitude is around a factor of four with optical reinjection.

A spectrum of results

→06a compares the signal with and without optical reinjection (by simply removing the reinjection mirror and keeping the laser alignment unchanged). Here, the alignment of the standard ICOS system may not be optimal in terms of signal amplitude and the signal-to-noise ratio. The comparison results after re-optimizing the standard ICOS (without the reinjection mirror) by adjusting the laser beam direction are shown in →06b. The enhancement of the signal amplitude is around a factor of four with optical reinjection. However, as shown in the optical simulation, more reinjection power is expected and can be obtained by further tweaking the incident angle



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07 Absorbance spectra from the measurement in ambient air. The absorption peaks from three species are indicated. The absorbance spectra act as a spectral fingerprint, unique for each gas species.

of the laser beam →06c, though this significantly increases optical noise.

The concentration of the gas samples and the measurement precision for a given period can be obtained by fitting the spectra. First, the measured time-dependent transmission spectra must be turned into frequency-dependent absorbance spectra. A physics model is then fitted to the recorded spectra, using species-specific spectral data from the HITRAN database (a molecular spectroscopic library) as input. The proportionality between the area of the fitted line shape and the directly measured parameters (ie, gas temperature and pressure) allows direct inference of the gas concentration. →07 shows the absorbance spectra measured in ambient air, where the absorption from methane, ethane and water vapor can be observed. In the case of optimized optical reinjection (upper curve in →06b), the demonstrator is capable of reporting methane and ethane concentrations in ambient air continuously with a precision of 10 parts-per-billion (ppb) for methane and 15 parts-per-trillion (ppt) for ethane over one second of measurement time.

Reinjection perfection?
Various optical reinjection configurations have been simulated, set up, optimized and characterized to construct a mid-IR OA-ICOS analyzer for the simultaneous measurement of trace-level methane and ethane. Compared to incumbent methods, the precision achieved for the ethane measurement is enhanced by three orders of magnitude as a result of employing optical reinjection, a new laser source and optimization of

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Compared to incumbent methods, the precision achieved for ethane measurement is three orders of magnitude better.

the mirror and detector. With this high precision, the discrimination between thermogenic and biogenic sources in the field can be improved significantly. Based on gas dispersion simulations, the leak attribution accuracy can be improved to nearly 98 percent across all the simulated leak rates and conditions. This improvement reduces the time surveyors spend investigating biogenic emissions, allowing them to focus on actual natural gas emissions, thus enhancing the safety of natural gas grids. In addition, optical reinjection can be leveraged for the entire ABB ICOS product platform to improve overall performance on applications requiring high gas measurement sensitivity. •

PRESSDUCTOR'S 70TH BIRTHDAY

Perfect pressure

The development in the 1950s of Pressductor sensor technology opened the door to a new level of manufacturing quality. Since then, the accurate and stable measurement of force, tension, pressure and torque in a range of industries has ushered in a world of virtually flawless materials. Today, this technology is paying new dividends as it provides vast amounts of data from which ever more manufacturing knowledge can be gleaned.

A Pressductor uses magnetoelasticity to measure force.

The first Pressductor roll force meter was installed in a cold rolling mill in **1954.**

Pressductors see widespread use in the metals and paper industry.

From automobiles to machine tools and from paper products to plastics, consumers and businesses expect metal strip made of steel or other metals and flexible webs made of paper or plastics to be flawlessly smooth, consistent, and of uniform thickness. Although we now take these characteristics for granted, meeting these expectations has never been easy. Over the years, various technologies evolved for the measurement of force, tension and torque in industrial applications. But in the early 1950s, in response to increasingly demanding industrial requirements, Dr. Orvar Dahle, a researcher at ASEA, which later became part of ABB, developed a new torque sensor, Torductor®, and a force sensor, Pressductor® by successfully applying the magneto-elastic effect →01 [1].

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The introduction of Pressductor® technology led to a revolution in the measurement of force, tension, pressure and torque.

The introduction of Pressductor® technology based on this effect led to a revolution in the accurate and stable measurement of force, tension, pressure and torque in the harsh environments encountered in heavy industries. The first Pressductor roll force meter was installed in a cold rolling mill in 1954 and the first patent for Pressductor technology was granted in Sweden the same year. Since then, ABB has launched a number of new products covering a range of applications, such as strip/web tension measurement, weighing, torque measurement and flatness measurement and control.

A major step for this technology came in 1960 when General Electric ordered 12 Pressductor® load cells (1,600 t) for installation on a 132-inch finishing mill at U.S. Steel's Geneva, Utah facilities, a few miles south of Salt Lake City. Since then, the success of Pressductor® technology has remained unbroken. Over the years, ABB has delivered some 20,000 roll force load cells to rolling mills around the world.

The launch of the roll force load cell was followed by the development of strip tension measurement systems, such as the Large Pillowblock system for cold strip mills and processing lines. Web tension measurement systems, on the other hand, were designed to help improve production in industries such as paper, board, printing, plastics, rubber and textiles – all with a view to ensuring uninterrupted manufacturing quality.

In response to the special requirements of web tension measurement, ABB engineered a range of web tension load cells tailored to meet these requirements. Notably, the PillowBlock type load cells have, for many years, been customers' preferred solution for tension measurement in paper mills.

Like all ABB load cells based on robust Pressductor® technology, PillowBlock load cells are characterized by their accuracy, durability and long-term reliability. To date, the company has supplied well over 100,000 Pressductor® load cells, about half of which are PillowBlock load cells.

Stressometer®: a flatness measurement and control system

The 1960s also saw steadily increasing customer demand in the metals industry for a measurement system that would enable improved

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> The Stressometer® system measures and controls flatness, analyzes and stores flatness data, and presents related information.

flatness control in rolled steel, aluminum and copper flat products. Automatic gauge control had helped rolling mill operators achieve closer thickness tolerances, but the problem with strip flatness had persisted. In 1967, following a request from Alcan in Ontario, Canada, a prototype system to measure strip flatness, called Stressometer®, was installed there. Following comprehensive tests, the Stressometer flatness system allowed Alcan to substantially improve the flatness of a cold rolled aluminum strip by providing frequent, accurate and reliable flatness measurement data.

The Stressometer® system measures and controls flatness, analyzes and stores flatness data →02a-c, and presents data in clear, informative displays. Its features include parallel flatness measurement, accurate flatness control from the start of the rolling process, and minimum maintenance for lowest lifecycle cost.

In addition to the obvious benefit of controlled and improved sheet flatness, the Stressometer® system has contributed to increased productivity and yield →03. Today, ABB has an installed base of over 1,300 systems and 1,700 measuring rolls delivered.

Torque measurement – Torductor®-S
ABB's Torductor® torque meter was originally developed in the 1950s to measure the torque of pulpwood grinder shafts and propeller shafts in

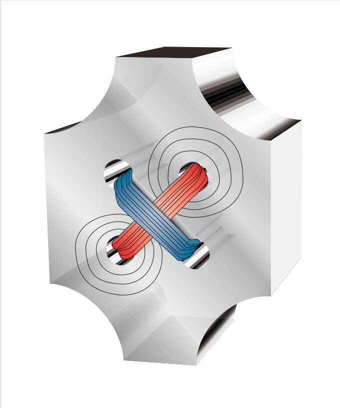
01 The magnetic properties of a ferro-magnetic material are influenced by the mechanical forces acting on it.

01a No coupling exists between a sensor's windings as long as no load is applied.

01b If a mechanical force is applied to the sensor, a voltage is induced in the secondary winding.

MAGNETO-ELASTICITY INSIDE

According to the magneto-elastic effect, the magnetic properties of a ferro-magnetic material are influenced by the mechanical forces acting on it [1]. ABB's Pressductor® sensor was originally produced from a number of laminations of a specially developed electro-steel material, bonded to one another to form a solid block. Today, most sensors are made from a solid machined block. A typical sensor has four holes through which two windings pass at right angles to each other. One of these serves as the primary winding and the other one as the secondary winding. No coupling exists between the two windings as long as there is no load acting on the sensor. If a mechanical force is applied to the sensor, the permeability of the material in terms of magnetic flux is changed in such a way that a voltage is induced in the secondary winding. The induced voltage is proportional to the applied force up to a given value. A Millmate roll force load cell, for example, may contain up to 1,500 sensor elements.



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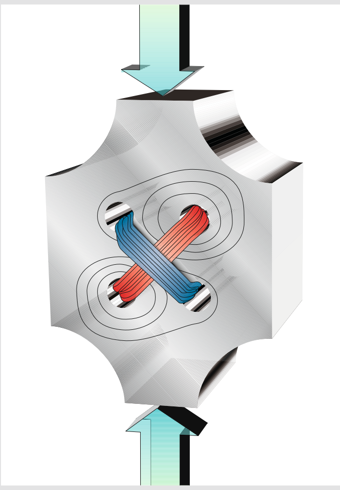

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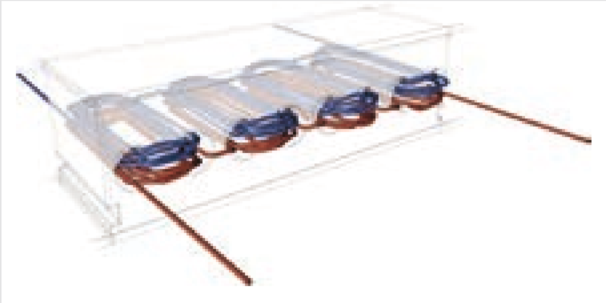
INSIDE STRESSOMETER

ABB's Stressometer family of solid flatness measuring rolls for cold rolling mills recently introduced its newest member, the Stressometer low-force sensor [2]. Based on the electro-magnetic principle for force measurement, the system's innovative Pressductor transducer is used in rolling mills to measure roll force, strip tension and strip flatness.

Basically, the transducer produces a signal in response to changes in an electromagnetic field whenever it is subjected to mechanical force. Unlike other flatness measurement principles, physical movement is not required for signal generation.

Essentially, two windings of copper wire around a steel core combine to provide a measurement signal. An electromagnetic field is created by continuously feeding an alternating current to one of the windings. The field is positioned in such a way that there is no magnetic coupling between the windings when the transducer is unstressed. But when the transducer is subjected to a force, the magnetic field pattern changes. A portion of the field induces an AC voltage in the second winding that is directly proportional to the force applied to the transducer. This voltage – a comparatively strong transducer signal – is converted by the system into a flatness output.

Offering unsurpassed parallel resolution due to low force spread, the system is exceptionally reliable, with a mean time between failures of more than 20 years. It also offers long term stability since its sensors do not lose sensitivity over time, thus eliminating the need for onsite calibration.



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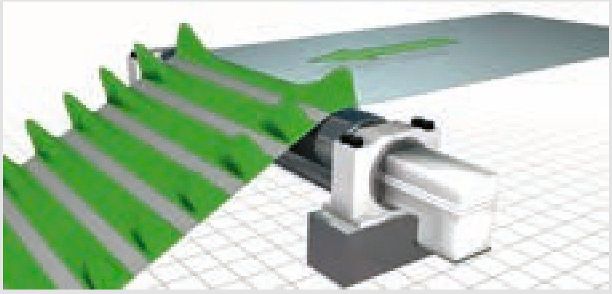

02c

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02 Inside Stressometer.

02a Pressductor transducer principle.

02b Roll with four rows of Pressductor transducers.

02c Stressometer measures force distribution on a roll. Using strip tension, width and thickness, the stress distribution in a strip can be calculated. When the E-module (Young's modulus of elasticity) is inserted, the (un) flatness distribution is achieved in units of thickness.

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Torductor®-S opened new markets for direct torque measurement, including the automotive and aerospace industries.

large ships. Although thousands of units were delivered, this solution had two major weaknesses: It could only be used on very large shafts and was unable to measure instant torque.

These weaknesses were overcome in the form of a true non-contact and rugged torque sensor without moving parts. Known as Torductor®-S, it opened new and diverse markets for direct torque measurement, including the automotive and aerospace industries, industrial tools and machines, and bicycles. Since the sensor is part of the load-carrying shaft, the torque it measures is the true transmitted torque, and a high output signal ensures integrity against electrical or magnetic interference from the surroundings. Therefore, in the case of vehicle engines, the actual torque measured can be used to lower emissions and improve engine performance.

Cylmate®: Diesel engine performance monitoring

In the early 1970s, ABB introduced its Cyldet sensor for the continuous monitoring of combustion pressure in large diesel engines, such as those on many ships. In 2001 the company released a substantially improved version of the

STRESSOMETER KEY DEVELOPMENTS

1967 World's first flatness system delivered to Alcan Kingston, Canada
1970 Improved measurement resolution: 52 mm zone width from 84 mm
1976 First microprocessor-based system (Intel 8080)
1977 World's first digital closed-loop flatness control (Kobe Steel, Japan)
1980 World's first flatness control system for a cluster mill (Outokumpu)
1982 Resolution improved further: 26 mm from 52 mm
1989 Digital color-graphic human-machine interface (HMI)
1989 World's first flatness control based on actuator models
1990 New technology for measurement of strip width and edge position – MSS (Millmate strip scanner)
1993 Measurement and compensation for strip temperature in steel applications
1994 New transducer and roll for foil applications
1998 World's first HMI based on a Web browser for industrial applications
2002 Seamless roll for surface-critical applications
2006 Predictive flatness control
2007 Foil roll with 26 mm resolution
2011 World's first Stressometer installation for hot rolling of aluminum
2011 Flatness control with automatic process identification
2013 Optimal coordinated control through ESVD for cluster mills
2014 Introduction of HSS (High Speed Steel) rings to replace compound rings.
2014 Introduction of DTU (Digital Transmission Unit) to replace the analog STU (Signal Transmission Unit)
2017 World's first Stressometer for steel hot rolling, and release of fully digital Stressometer version 9.0
2024 New foil sensor for low force applications

03

sensor together with a new measuring system. Known as the Cylmate diesel engine performance monitoring system, the system is designed for diesel engines running at low speeds, such as those on ships →04 [1]. The quality of its data translates into optimized reliability, availability and efficiency for propulsion machinery; as a result, ship owners benefit from significantly reduced fuel consumption and maintenance costs, as well as compliance with environmental standards. The same applies to today's Torductor – Torductor Marine – which is installed on a ship's propeller shaft, making it possible to run a ship considerably more fuel efficiently.

Current situation
ABB products based on magneto-elastic technology have been extremely successful in the metals industry, and particularly in flat rolling mills.

Stressometer has long been the predominant flatness system among the world's cold rolling mills.

Stressometer, for instance, has long been the predominant flatness system among the world's cold rolling mills and is the "secret sauce" behind countless everyday consumer and industrial products →05. Today, the Stressometer is used for all types of metals – from carbon steel and stainless steel to copper and aluminum – from thicknesses of 12 mm and downwards and can even measure flatness in foil with a thickness of a few thousandths of a millimeter.

One of the key events in Stressometer's history has been the introduction of its Digital Transmission Unit (DTU), which was launched in 2014. The unit makes it possible to contactlessly transmit measurement signals from a Stressometer roll, as well as contactlessly supply sensors with power. The DTU's introduction has meant that the need for maintenance has been eliminated.

The Stressometer is also fast. Its maximum speed is 4,000 revolutions per minute. Based on the most common roll diameter, this is equivalent to a strip speed of 4,000 meters per minute.

When it comes to dimensions – the widest Stressometer roll that has so far been delivered has a width of nine meters and was installed in

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03 Stressometer key developments.

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04 Data generated by ABB's Cylmate diesel engine performance monitoring system improves onboard propulsion system efficiency and reliability.

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05 An industrial process hidden inside everyday life.

2012 at Holmen Paper in Bråviken, Sweden. It was the very first delivery of a Stressometer to the paper industry and its measuring technology has proven to be ideal for paper applications. The narrowest roll thus far was installed at ILNOR SpA outside Venice and is used in the rolling of brass-, bronze- and copper strips for delivery to vehicle and electronics companies.

Future trends
What does the future hold for Stressometer and other ABB magneto-elastic technology products? First of all, demand for rolled products is set to remain strong. Standards of living are improving,

—
Stressometer has a maximum speed of 4,000 revolutions per minute.

resulting in increased demand for, for instance, vehicles and white goods, all of which depend on rolled products and thus measurement and control of roll force, strip thickness, tension and flatness.

At the same time, there are a lot of old rolling mills in operation. To remain competitive, they will need to modernize or rebuild to comply with increasingly stringent environmental requirements. Furthermore, requirements for more efficient vehicles will drive demand for aluminum.

Last but not least, technological developments, above all in the electronics and software segments, are proceeding at great speed. Cloud solutions, learning systems and AI are becoming increasingly important. Combining these trends with ever-growing use of automation, it becomes clear that all forms of manufacturing will demand increasingly precise measurement data and analyses of that data – demands that Stressometer technology, which is already at the cutting edge of flatness process optimization, is well equipped to meet. •

AN INDUSTRIAL PROCESS HIDDEN INSIDE EVERYDAY LIFE

Vehicles
Stressometer measures flatness regardless of which metal is used in the manufacture of the metal strip. Today the Ford F-150 is the bestselling car in the USA. The vehicles have become lighter and more fuel-efficient than their predecessors thanks to the aluminum strip used in their manufacture.

Razors and shavers
The Stressometer does not distinguish between electric shavers and manual razors – they both require the greatest possible flatness of steel, with tolerances of a few thousandths of a millimeter.

Printed matter
Offset technology needs printing plates that are originally completely flat. Any unevenness will otherwise be visible on the cover of the book.

White goods…
Refrigerators, freezers, stoves and microwave ovens are examples of white goods where cold rolled strips are used and where the correct flatness is essential.

…and much more
Cold rolled sheet metal is also used for building facades, roofs, draining boards, coins, Venetian blinds, cylinder head gaskets, hearing aids, cables, heat exchangers, coolers, solar panels and superconductors – just a few examples of where ABB Force Measurement Pressductor technology enables manufacture of flawless surfaces.

05

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[1| M. Ottosson, 50 years of Pressductor®: Force measurement technology. *ABB Review* 03/2004, pp. 45–49

[2] ABB. ABB Stressometer systems ver 9 FSA. 2019. Available: https://search.abb.com/library/Download.aspx?DocumentID=3BSE025058R0401&LanguageCode=en&DocumentPartId=001&Action=Launch Accessed September 5, 2024

100 YEARS OF THE MINIATURE CIRCUIT BREAKER

Breaking a century

It has been 100 years since Hugo Stotz developed the first miniature circuit breaker (MCB). His company has long been part of ABB and the MCB has benefitted from many decades of technological advances. The evolution of the MCB is a story of innovation and progress.

—
01 Hugo Stotz at his shop in Mannheim, 1904.

100 years ago, Hugo Stotz patented the first miniature circuit breaker.

MCBs can now be integrated digitally into smart electrical systems.

ABB's eight factories now produce over **100 M** poles annually.

01

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The history of the MCB began with the pioneering work of Hugo Stotz, a German inventor and entrepreneur of the early 20th century →01. Stotz recognized a growing problem: the number of domestic and industrial electrical systems was expanding rapidly and these needed a new means of reliable and safe circuit protection. The fuse, commonly used for this purpose then, had significant drawbacks. For example, fuses needed to be replaced after blowing, which was inconvenient, costly and potentially unsafe when attempted by a layperson.

Stotz, recognizing these limitations, sought to develop a more efficient solution. In 1924, some years after his German company became a subsidiary of Brown Boveri & Cie (BBC), a forerunner to ABB, he patented the first MCB →02–03.

HOW AN MCB WORKS

An MCB is designed to interrupt the flow of electric current in a circuit when it detects an abnormal condition, such as an overload or short circuit. It performs this function through a combination of thermal and magnetic mechanisms.

Thermal mechanism
An MCB has a strip made of two different metals with different coefficients of thermal expansion. When current flows through this strip, it heats up due to its electrical resistance. Under normal conditions, the heat generated is minimal and the strip retains its shape. However, when an overload occurs, the increased current causes the strip to heat up more significantly and bend due to the differing expansion rates of the two metals. This bending triggers a mechanical latch, opening the circuit breaker contacts and interrupting the current flow. Once the circuit cools down and the strip returns to its normal shape, the MCB can be reset manually. The bimetallic mechanism has the considerable advantage that it will trip reliably even after decades of operation.

Magnetic mechanism
The thermal mechanism is relatively slow. When a fast current break is needed, for example, when a short circuit occurs, the magnetic mechanism responds quickly, reducing the risk of fire or other hazards. This mechanism consists of a solenoid or electromagnetic coil that generates a magnetic field when current flows through it. In the event of a short circuit, the sudden surge of current produces a strong magnetic field that pulls a plunger or armature. This movement triggers a mechanical latch, opening the contacts and immediately breaking the circuit.

02

— 02 How an MCB works.

Stotz's design was revolutionary because it provided automatic circuit interruption in case of an overload or short circuit and could easily be reset by a layperson and reused after tripping. This invention significantly improved the safety and reliability of electrical systems.

The BBC Stotz subsidiary quickly became a leader in electrical protection devices and the Stotz MCB gained popularity for its robustness and

—

New materials and manufacturing techniques enhanced the durability and efficiency of these devices.

reliability, setting a new standard in the industry. This early design laid the foundation for protection devices for the next century.

In the 1950s and 1960s, BBC Stotz focused on improving the reliability and performance of MCBs. The company's engineers introduced new materials and manufacturing techniques,

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— 03 A Stotz patent from 1928, the year serial MCB production began at the Stotz facility in Germany. The device met with great success as it could be screwed into an existing fuse base.

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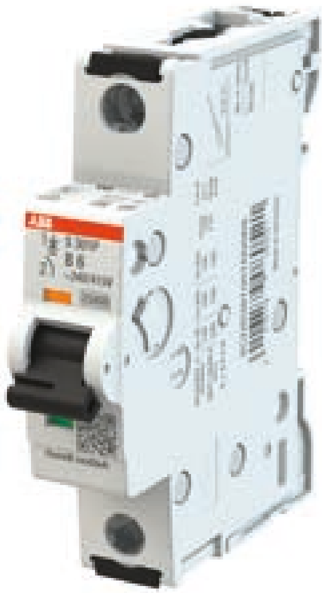

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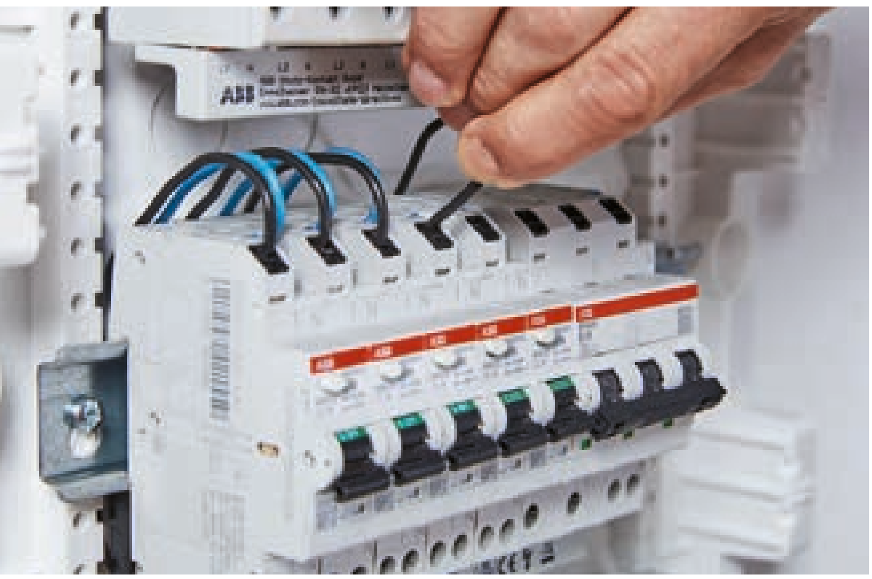

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04 Many million MCBs are produced annually by ABB.

—
05 The ABB S300 P has a high breaking capacity and advanced tripping characteristics.

—
06 The modular Flexline® system is scalable for maximum flexibility.

enhancing the durability and efficiency of these devices. One innovation was the use of thermoplastic materials, which provided better insulation and heat resistance compared to earlier designs. BBC also expanded the application range of MCBs, making them suitable for both residential and industrial use. A commitment to quality and innovation helped establish MCBs as a standard component in electrical distribution systems worldwide.

The electromagnetic release

While the thermal bimetallic strip component of the MCB has not undergone many changes in the past 100 years, the development of the electromagnetic release has continued in significant steps. Initially, the electromagnetic release was only used for unlatching – unlocking the energy stored in the switching mechanism so that the spring can open the movable contact. This action took place relatively slowly and the drawbacks of this lack of speed were highlighted by the rise in short-circuit events that accompanied increased electrification in the 1950s. In alternating-current networks, for instance, due to the inductance of

—

ABB's MCBs became known for their precision, reliability and ease of use.

the transformers, the highest short-circuit current occurs in the first half of the voltage waveform, making it necessary to limit the short-circuit current in the first half-wave and to switch it off as quickly as possible. For this purpose, the second generation of electromagnetic releases was developed, in which the movable magnetic plunger not only unlocks but also hits the movable contact and opens it very quickly. The delay times were thereby shortened from around 3 to 0.5 ms. The electromagnetic release protected by the BBC Stotz patent is called the hammer trip and was first used in 1958 in high-performance circuit breakers. These high-performance circuit breakers had a switching capacity of 10 kA at 220 V AC and 8 kA at 250 V DC.

A modern MCB will interrupt the current in under 10 ms – 10 times faster than the blink of an eye →04. During the short circuit, parts of the MCB are exposed to temperatures of over 5,000 °C – temperatures capable of melting rocks – yet, despite that, homeowners simply flip the switch that has been tripped and power resumes its flow.

Breaker breakthroughs
One significant advance in MCB technology was the introduction of arc extinguishing chambers. When an MCB interrupts a circuit, an electrical arc forms between the contacts. This arc generates heat and can damage the MCB or surrounding components. Arc extinguishing chambers are designed to contain and dissipate the energy of the arc, reducing its impact. These chambers use materials with high thermal and dielectric properties to quench the arc quickly and safely.

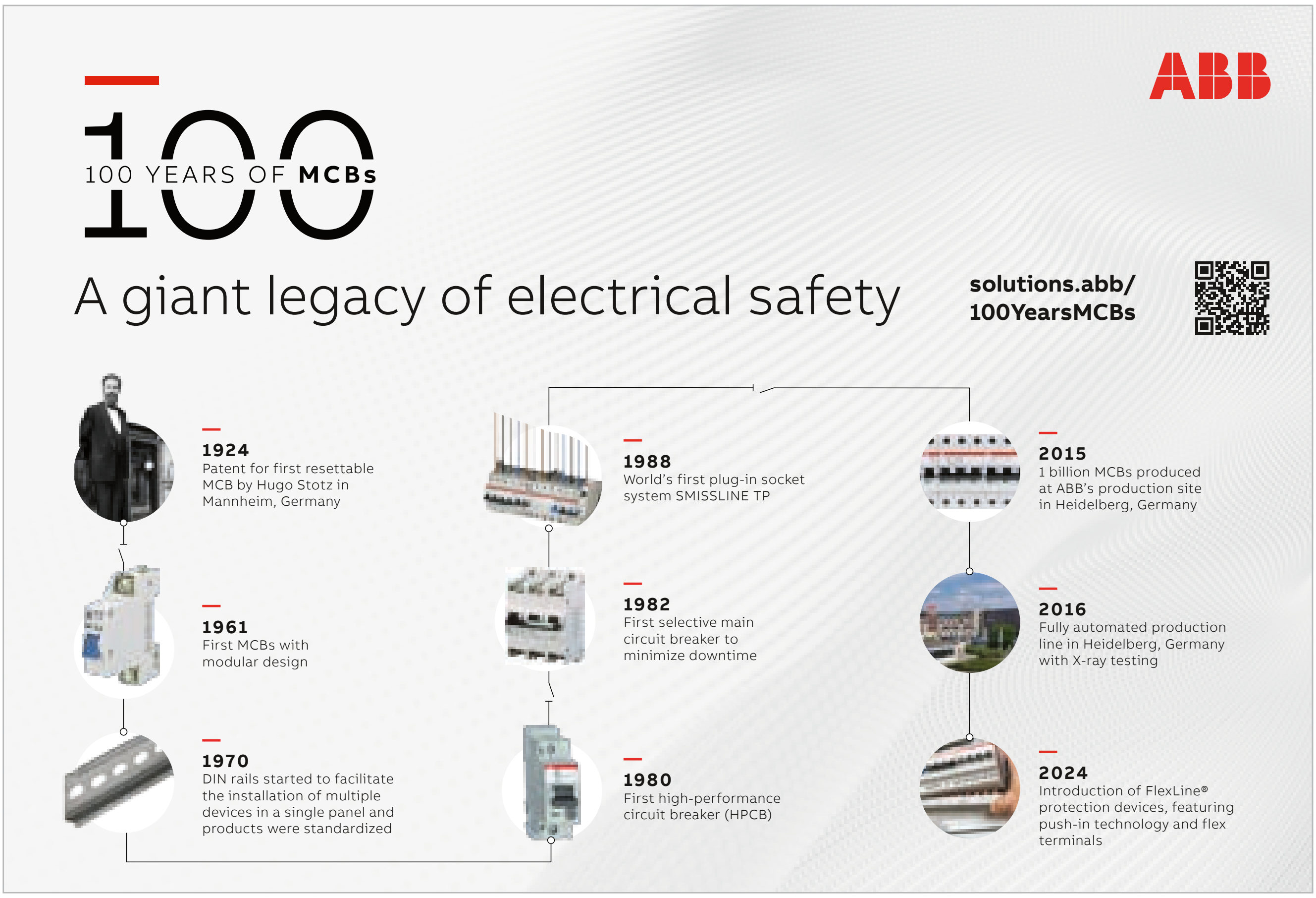
—

MCBs can now be integrated into smart electrical systems via smart accessories, such as current sensors.

Selective coordination is another crucial feature of the modern MCB, particularly in complex electrical systems. This feature ensures that only the MCB closest to the fault trips, while others remain operational. This approach minimizes disruption to the overall system and simplifies fault isolation and repair.

With the advent of digital technology, MCBs can now be integrated into smart electrical systems via smart accessories, such as current sensors, that connect to a control unit. This improvement enables remote monitoring and control capabilities that allow users to track the status of MCBs, perform diagnostics and reset devices remotely. This capability is particularly important in industrial and commercial settings, where a fast response to electrical faults is critical to maintaining operations.

New products and new performance levels
A century of MCB product development has resulted in new levels of performance – for instance, in the ABB S300P range of MCBs. These devices have a high breaking capacity and feature advanced tripping characteristics that provide precise and reliable protection for both standard and sensitive electrical equipment →05. With features such as tool-free mounting and easy-to-access terminals, these MCBs simplify installation and maintenance.



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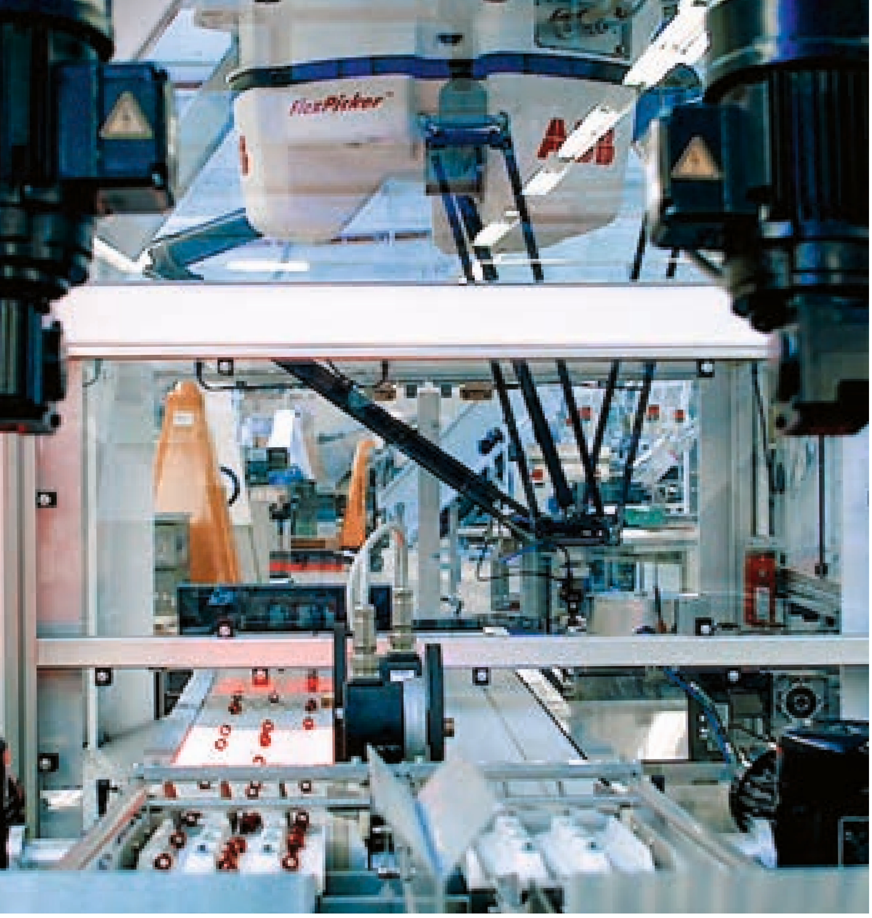
07 MCB historical timeline.



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08 The ABB MCB production line in the Heidelberg factory.

Another example of modern protection technology is ABB's FlexLine® →06. These devices have a modular design that allows users to add or remove protection devices on a busbar in a flexible way. Additionally, they have just one busbar type instead of a large number of variants to choose from and to have at hand. This scalable approach, the device's slim design and the faster installation time thanks to their push-in terminals are some of the key benefits of the FlexLine® system.

All these protection devices fit in with ABB's InSite system, which includes current sensors, a control unit, smart accessories for remote control and automation and software tools that work together to provide real-time data, insights into energy consumption and load management functionality. This information can be used to identify areas of inefficiency, optimize energy usage and reduce costs. The system is customizable and highly scalable, making it suitable for buildings of all sizes.

—
The MCB story is a testament to the power of innovation and the continuous quest for safer and more reliable electrical systems.

Sustainability in miniature
The "M" in MCB holds the key to achieving a goal that was less in the public eye a century ago when MCBs first emerged: sustainability. Through miniaturization, ABB can significantly reduce the quantity of material used overall and thus mitigate environmental impact. For example, the new single-width ABB S200C not only radically reduces the amount of material needed to make a protection device but also frees up space on the distribution board.

The S300P is another example of environmentally virtuous innovation. It is the first MCB in ABB's EcoSolutions™ portfolio. The EcoSolutions concept defines an ABB product's circularity criteria in each stage of the product life cycle. The S300P achieved this status through a 25 percent reduction in power loss, enhanced recyclability at the end of life and significantly improved technical performance while using fewer materials. All this while still providing a performance protection device.

Into the second century
The 100-year history of the MCB is a testament to the power of innovation and the continuous quest for safer and more reliable electrical systems →07. From Hugo Stotz's groundbreaking invention in the early 20th century to the latest ABB innovations in protection devices, the MCB has made a remarkable journey. Today, ABB has eight factories producing over 100 million poles annually. The Heidelberg factory alone produces over 40 million MCBs, with 6,000 variants, each year →08.

As technology continues to evolve, the MCB will undoubtedly see further improvements, driven by the need for greater efficiency, safety and integration with smart systems. The legacy of Hugo Stotz will continue to shape the future of electrical protection, ensuring that electrical systems remain robust and reliable in an increasingly complex world. •

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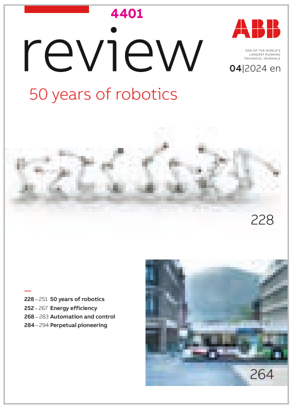

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STEM
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Technology
Engineering
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Highlighting role models to bring balance.

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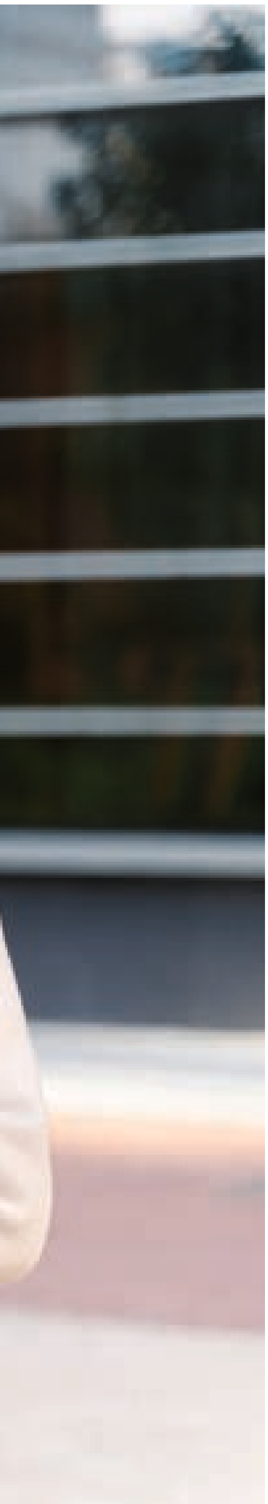
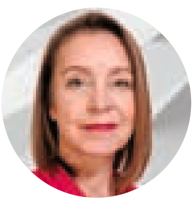


ABB REVIEW SPECIAL REPORT

Women in STEM

In 2004, ABB Review published 56 articles, with three contributions from women engineers. A generation later, women contribute to an average of eight articles annually. This Special Report celebrates the remarkable progress women in STEM have made over the last 20 years, while acknowledging persistent imbalances.



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It gives ABB Review great pleasure to be able to present this Special Report: Women in STEM. This curated collection of 16 previously published ABB Review articles has been guest edited by ABB's Amina Hamidi, Managing Director of the Instrumentation Business Line.

The motivations for this Special Report were diverse. Published in time for the annual International Women in Engineering day, the Review wanted to highlight and applaud some of our women in STEM. There was some healthy hesitation over the appropriateness of a Special Report where the common thread was not topic (which would be the usual case) but the gender of the authors. What swung the decision was the mantra “if you can't see it, you can't be it”.

It is a numerical fact that although the numbers of girls electing STEM careers is growing, women are still the minority. For future generations to have the confidence to select STEM subjects, they must be able to picture themselves in those roles. So much STEM work requires work in laboratories or at customer sites etc, out of sight from students and the public. It requires great courage to walk into the dark, especially alone, so we must install some spotlights (ideally low energy, powered by renewables, with circularity designed in) to make role models visible. As Amina says “May this Special Report encourage that growth and encourage future generations”.

—
This Special Report celebrates the remarkable progress women in STEM have made over the last 20 years.

From digital twins to collaborative robots, from aluminum thickness gauging to vacuum-technology load break switches, ABB Review wishes you an inspiring read from these highlighted authors, and from their colleagues too: teamwork and courage, just two of many energy sources that power innovation. •

Read the Special Report
Scan or click the QR code

Buzzword Demystifier

Cobots

Robots that sit beside you. Is that a thing?

Anthony Byatt
External contributor

For most of their history, industrial robots have been placed behind safety barriers designed to protect humans from potential hazards. These measures impose obvious restrictions on the places robots can be used and the types of tasks for which they can be employed.

What if robots could mix freely with humans, sharing their workspace, lending a helping hand and thereby opening up a whole new world of applications across many industries?

Enter the collaborative robot, or cobot.

Cobots represent a significant advancement in automation technology. Unlike traditional, isolated industrial robots, cobots are engineered to be inherently safe, user-friendly and adaptable. This makes them suitable for working alongside humans in a shared workspace in a wide range of applications across various industries. All ABB cobots, for example, are equipped with state-of-the-art safety features, including force and torque sensing, speed monitoring and emergency stop capabilities.

The concept of cobots emerged in the mid-1990s. Over the years, advances in sensors, artificial intelligence (AI) and machine learning (ML) have significantly enhanced the capabilities and functionalities of cobots, allowing them to perform complex tasks with precision and reliability. ABB has contributed substantially to the development and popularization of cobots and they are now an integral part of ABB's broader strategy to drive the future of automation, leveraging cutting-edge technology to meet the evolving needs of industries worldwide.

Meet the ABB cobot family
ABB's range of cobots includes the YuMi family and the GoFa™ and SWIFTI™ cobot lines. Each model addresses different industrial needs and applications, providing versatility and adaptability across various sectors.

YuMi, derived from "you and me," embodies the robot's collaborative nature. Launched in 2015, YuMi was the world's first truly collaborative

The design of ABB's cobots adheres to rigorous safety standards, allowing them to operate without extensive safety barriers.

dual-arm robot, designed to work harmoniously with human workers. YuMi's dual arms and advanced control algorithms enable it to perform complex assembly tasks precisely. Its compact design and integrated vision system make it ideal for small parts assembly.

Introduced in 2021, GoFa is a single-arm cobot designed for higher payloads and a more extended reach than YuMi. The newest GoFa models, the GoFa 10 and 12, can handle payloads up to 10 and 12 kg, respectively. SWIFTI, also launched in 2021, can operate at high speeds while ensuring safety through advanced sensor technology.

The design of ABB's cobots adheres to rigorous safety standards, allowing them to operate without extensive safety barriers.

Collegial collaboration
Ease of use is an essential aspect of ABB cobots, which often feature graphical user interfaces and drag-and-drop programming. For example, ABB's Wizard Easy Programming software allows users to program the robots without needing extensive coding knowledge and quickly deploy them.

ABB cobots are highly adaptable and can easily be reconfigured for different tasks, essential for applications across multiple industries. Their modular design allows for easy integration with other systems and tools, enhancing their versatility.

Assembly, packaging and quality inspection are tasks typically taken on by cobots. Here, they improve precision and consistency while reducing the risk of errors. For instance, YuMi is widely used in the electronics industry to assemble delicate components with high accuracy. GoFa and SWIFTI assist with sorting, picking and packing tasks.

ABB cobots are also making inroads into the healthcare sector. They are used for tasks such as laboratory automation, sample handling and medication preparation, thus freeing healthcare professionals for more productive tasks.

The future of ABB cobots looks promising as advances in AI, ML and sensor technology continue to enhance cobot capabilities. As industries increasingly adopt intelligent manufacturing practices, ABB cobots will play a crucial role. •

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ABB Switzerland Ltd
Group Technology Management
Bruggerstrasse 66
5400 Baden
Switzerland
abb.review@ch.abb.com

Layout
Publik. Agentur für Kommunikation GmbH
Mannheim/Germany

Printer
Vorarlberger Verlagsanstalt GmbH
6850 Dornbirn/Austria

04/2024 is the 907th edition of ABB Review.

ISSN: 1013-3119

abb.com/abbreview