

# review

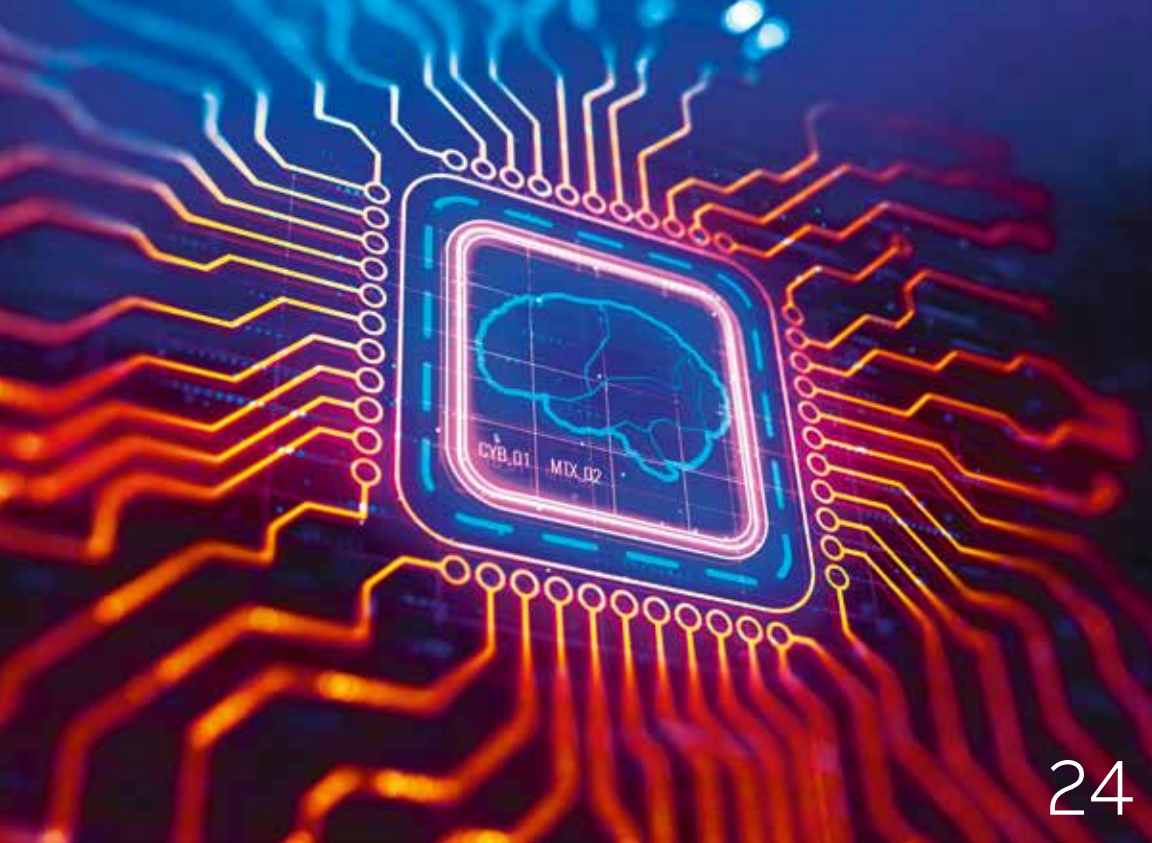
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**Challenging times can serve as the catalyst for immense innovation, much of it driven by the immediacy of necessity. They also challenge companies' accepted norms and plans for the future. This issue of ABB Review explores many of the technologies and ideas that are helping apply the experience of yesterday with the urgency of today to implement the solutions of tomorrow.**

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EDITORIAL

# Powered by knowledge



Dear Reader,

Extraordinary times call for extraordinary solutions. With society in the grip of a pandemic, we are all having to fundamentally re-evaluate many aspects of the way we work and interact. To be effective, we have always had to collaborate and cooperate, and that has never been more true than today. Individual ideas, no matter how brilliant, are of little value unless they are shared and jointly implemented.

At ABB, collaboration is at the core of our company purpose and values – it is how we create success for our stakeholders and contribute to a more sustainable future. This issue of ABB Review includes many examples of ABB jointly working on solutions or helping others to achieve their goals, whether they be startup companies pioneering ground-breaking solutions, or customers seeking to optimize large processes.

Enjoy your reading,

A handwritten signature in black ink, consisting of stylized initials 'BR' followed by a horizontal line.

Björn Rosengren  
Chief Executive Officer, ABB Group

# Innovation highlights 2021







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A brief survey of innovation across industries and technologies can prompt useful conversations about what new solutions could make a difference in a business. ABB's experience uniquely positions it to facilitate those conversations and ground them in a viable when of delivery.

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## YUMI® EXTENDS ITS HELPING HANDS TO HOSPITALS AND LABS

Robots are no longer limited to manufacturing environments and dirty workshops. Increasingly, they are becoming a key part of laboratories, supporting everything from R&D in the pharmaceutical industry and universities to healthcare testing in medical facilities. An example is ABB's YuMi® collaborative robot, which has already established itself a niche performing a range of repetitive, delicate, and time-consuming laboratory activities, such as dosing, mixing, and pipetting, sterile instrument kitting and centrifuge loading and unloading.

YuMi® is unique on the market due to its inherently safe design. With rounded, padded arms, collision-detection, and no pinch points, it is able to operate safely among its human colleagues in relatively unstructured environments with no need for added safety measures, such as fencing. This enables it to take on a range of repetitive, high-volume tasks, even when they require human-like dexterity or might change at short notice. For example, YuMi® can support

process tasks such as device tending, collection and storage, sample transportation and filing alongside human lab workers.

In October 2019, ABB opened a research center at the Texas Medical Center (TMC) in Houston to investigate new robotic and automation concepts for medical facilities and laboratories. Prototype technologies showcased by ABB at the center include YuMi® robots that may be able to aid in centrifuge tending and test tube handling systems and an IRB 1200 robot designed to automate liquid transfers in a pipetting application.

Another prototype concept under development is a mobile dual-arm YuMi® robot. Designed to assist staff with laboratory and logistics tasks in hospitals, it may be able to sense and navigate its way around its human co-workers autonomously, while learning to find different routes from one location to another. •





## NEW SOLUTION SIMPLIFIES MACHINE-ROBOT INTEGRATION



Thanks to a melding of resources between ABB and B&R<sup>1</sup>, machine builders will soon be able to offer their products with an integrated robot. Furthermore, their machines will be easier to operate as there will be only one user interface for machine and robot.

The solution allows machines on the factory floor to communicate with integrated robots in real time. In a nutshell, the solution optimizes communication between B&R servo drives and the motors in ABB's robots.

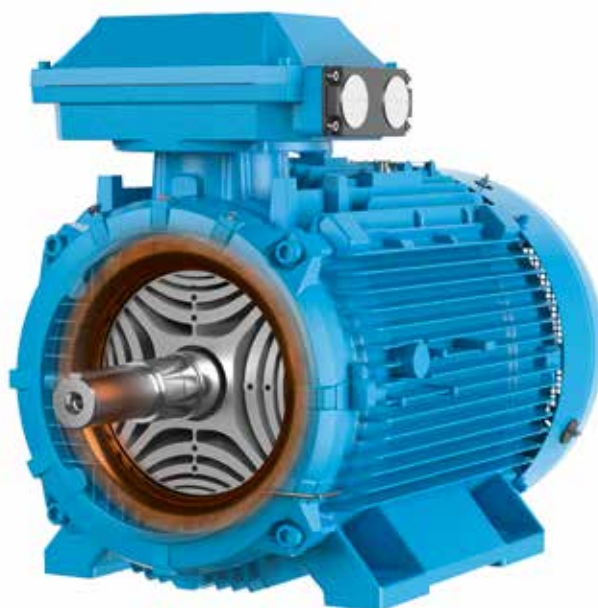
A practical example of what has been achieved to date is the detection of an imperfection by a B&R vision camera. Here, in less than a millisecond, the data is converted into a control command for an associated ABB robot, and the defective workpiece is removed from a production line without any manual intervention and without affecting the speed of the manufacturing process. Since the machine application automatically calculates optimized motion profiles, it significantly reduces overall processing time while improving productivity.

Behind the solution, which integrates ABB robots into the B&R control system, is a single architecture that melds the information needed by these two previously separate systems. This eliminates the need for a dedicated robotics controller, a separate control cabinet and specialized personnel for specific robotics languages.

Integration is supported through the use of pre-configured software modules that make robotics applications easy for machine builders to create. B&R's modular preprogrammed software (mapps) allows users to implement complex and highly dynamic applications without having to write new code, thus dramatically reducing development times. All in all, ABB's new machine-robot integration solution adds up to an unprecedented level of precision when it comes to the coordination of machine processes with robots. •

### Footnote

1) B&R is an automation and process control company that joined the ABB Group in 2017.



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## SAVING ENERGY WITH IE5 SYNRM MOTORS

The traditional induction motor (IM) has inherent drawbacks that arise from its asynchronous speed – such as rotor heating losses, which decrease efficiency and component and bearing lifetime. Since IMs use around one-third of the world's electricity, there is a clear need for a more efficient product. Enter, the IE5 synchronous reluctance motor (SynRM), which is characterized by its high energy efficiency and reliability, and low maintenance needs.

SynRMs work on a very elegant principle that is practicable only since the advent of sophisticated variable-speed drive (VSD) control electronics. In SynRMs, the rotor is designed to produce the smallest possible magnetic reluctance (resistance to magnetic field flow) in one direction and the highest in the direction perpendicular. The rotor turns with the same frequency as the VSD-rotated stator field.

With neither magnets nor cage, rotor construction is more reliable than an IM's, which lessens maintenance needs. The SynRM's lower operating temperature delivers longer insulation and bearing lifetimes and lengthier bearing greasing intervals. Adding an ABB Ability™ Smart Sensor provides remote condition monitoring capability.

SynRMs provide a higher power density than an IM and perform better, even at partial load. With a low-inertia rotor, SynRM response is fast, and torque and speed control accurate. The SynRM hardware is plug-in compatible with ABB's equivalent IMs, making upgrade easy.

The potential of SynRM technology has not been fully explored and higher efficiency levels are quite feasible. •

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## DIELECTRIC TESTING IN A VIRTUAL HIGH-VOLTAGE LAB

Dielectric dimensioning is a crucial aspect of medium- and high-voltage devices like switch-gear and transformers. When introducing a new device, manufacturers must certify the product against dielectric type tests defined by technical standards. The prediction of test results is typically supported by electrostatic field computations that are compared with the critical values specified for the given materials, such as gases, liquids and solids – and interfaces between them. However, this approach is often insufficient because dielectric failures do not have a simple relation to field strengths.

The ABB simulation tool, Virtual High-voltage Lab (VHVLab), provides a software framework focused on the prediction of dielectric test results and is aimed at closing the gap between numerical computations and experiments. VHVLab's predictions are achieved by combining engineering simulations with empirical knowledge obtained from experiments and first-principle simulations of microscopic models. This type

of software is not available commercially because the simulation procedures integrated into VHVLab are derived from ABB test experience gained in a real high-voltage laboratory. Such a tailored platform is a competitive differentiator to commercial simulation software and allows for faster design loops. The development of VHVLab has been driven by industrial research supported by specialized academic partners such as SINTEF – an independent research organization in Trondheim, Norway – who built an experimental setup that enables a flexible choice of experimental configurations.

The tool offers a collection of numerical procedures and empirical rules that allow engineers to evaluate, visualize and understand discharge phenomena. In this context, VHVLab is not only an engineering tool but also a knowledge database into which the experience of researchers and developers has been gathered, providing a foundation for future digital testing. •

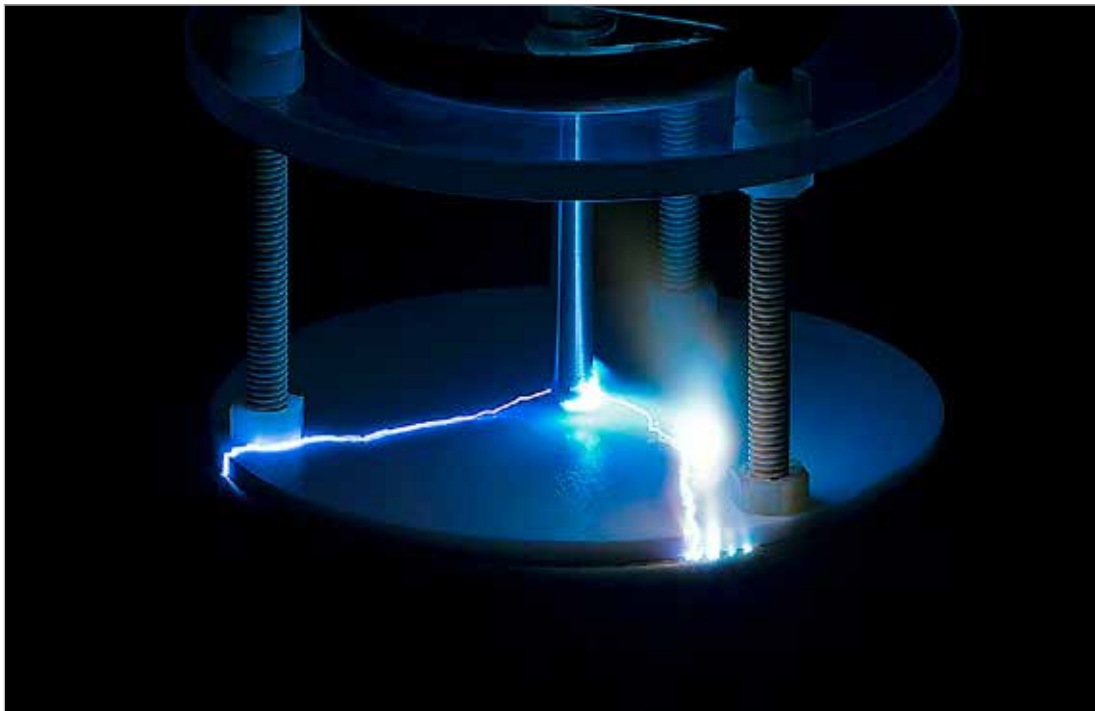


Photo: Sintef, Trondheim





## PLUGGING INTO FAST EV CHARGING

Cities are under pressure to provide cleaner, quieter transportation solutions. With this in mind, ABB has introduced the Terra 184, the most compact high-power charger with the highest power density on the market. The latest member of ABB's best-selling Terra family of chargers, the Terra 184 is fast, compact, robust and provides the ability to charge up to three vehicles simultaneously, thus maximizing convenience for drivers and revenue for charging operators. With a charging power of 180 kW, the new charger is ideal for roadside parking and charging, as well as for fast charging terminal installations for e-taxi and other (electric) fleets.

The Terra 184 can be used by vehicles of all sizes, be it the newest existing vehicles or planned cars, buses and trucks. But unlike other high-power chargers, it comes with a footprint of less than 0.5 m<sup>2</sup>, the same as the current Terra 54 model. Indeed, its innovative design means there is no need for separately installed power cabinets, thus offering an ideal rapid and compact solution for cities with limited space.

The Terra 184 supports all the charging standards on the market, including CCS, CHAdeMO and AC, and caters to the needs of all batteries up to 920 V. It is highly customizable, with features including customized credit card payment terminal, screen and cables.

For added flexibility, operators of other Terra models, such as the Terra 94 and 124, will be able to upgrade their charging solution to the Terra 184 by simply adding power modules.

Since entering the EV-charging market a decade ago, ABB has sold more than 14,000 of its DC fast chargers. ABB recently received the Global E-mobility Leader 2019 award for its role in supporting the international adoption of sustainable transport solutions. •



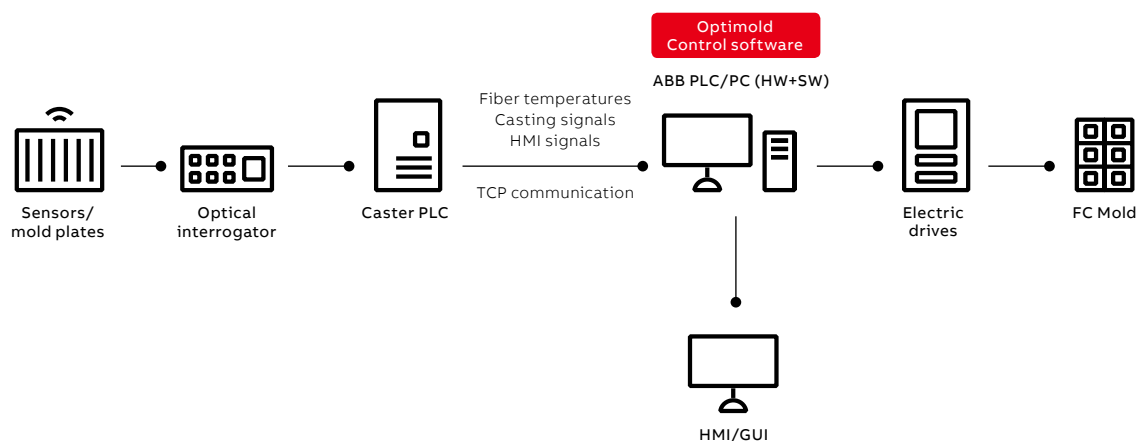
## REALIZING CLOSED LOOP CONTROL OF STEEL FLUID FLOW IN SLAB CASTING MOLDS

Steel production requires both high productivity and quality end-products and this depends on fluid control during slab casting. Flow Control (FC) Mold G3 employs both DC and AC magnetic fields in the slab continuous caster mold to control the flow speed of liquid steel. ABB's Optimold Control solution is the only industrial solution to offer online flow speed measurement and the feedback signals necessary to realize automated control of the FC Mold G3. Recently developed, ABB Ability™ Optimold Monitor is a system in which high resolution optical fibers are installed in the copper plate to measure temperature distribution; this is converted into a flow speed signal using an algorithm developed at ABB. The high resolution and immunity of this technology to electromagnetic disturbances is advantageous.

In September 2019, ABB established a world record at Hyundai Steel in Korea; the installation involved almost 5,000 measuring points – a huge advantage over traditional methods using thermocouples in which only around 100 points can be measured. ABB Ability™ Optimold Control

is a software package that connects ABB Ability™ Optimold Monitor and FC Mold G3 to deliver closed loop control of the FC Mold G3. At this stage, the ABB Ability™ Optimold Control will be added to the deterministic control software already included in every FC Mold installation. Process defects caused by SEN clogging and unstable argon gas are counteracted with the real time control algorithm through adjustments of a predetermined magnetic field.

The first ABB Ability™ Optimold Control installation is planned for Hyundai Steel in 2021 and, in the future, it will be further developed into an autonomous system supported by artificial intelligence. ABB Ability™ Optimold Control system will allow steel manufacturers to quickly identify and correct variations in the casting process that might negatively impact safety, energy efficiency and product quality, thus ensuring optimal casting. •





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## THE DIGITAL LIGHTHOUSE PROGRAM: IGNITING TRANSFORMATION

In 2017, to catalyze digital innovation, ABB launched the digital Lighthouse Program, which selected and partially financed the development of innovative digital solutions in collaboration with customers. ABB believed the Lighthouse Program could marry good internal ideas with the necessary funding, resources and customer co-innovation to shorten time to market.

The primary goals of the program were:

- Accelerate the development and deployment of innovative digital solutions built on the ABB Ability™ Industrial Internet of Things (IIoT) platform.
- Encourage co-development of solutions with customers, engaging them at an early stage.
- Speed up ABB's adoption of leading-edge digital technologies such as artificial intelligence (AI), augmented reality, virtual reality, digital twins and blockchain.

Applicants with good ideas identified customers willing to co-develop new digital products, explained what customer pain points the product would address, outlined the obstacles to success and how the program's support would overcome them, and highlighted the immediate and long-term revenue potential.

Two and half years later, at the program's completion, 66 minimum viable products (MVPs) had been deployed with customers and over 40 customer testimonials published. To date, 30 products developed under the Lighthouse Program have been released commercially. But the most important feature of the program is the culture of digital innovation fostered within ABB, which means that, in future, far fewer digital innovations will now sit untried and untested on the shelves. •



## ABB BRINGS ETHERNET-APL TO HAZARDOUS AREAS

Since 2011, ABB has been working within a consortium of process automation industrial partners, backed by industry standard development organizations, to drive the standardization of Ethernet-Advanced Physical Layer (APL). Ethernet-APL extends Ethernet by combining the simplicity of 4–20 mA wiring with a swifter Ethernet-type of bandwidth and protocol support; and yet is simple and robust enough for use in Hazloc areas. With their domain expertise in the Industrial Internet of Things (IIoT) devices, ABB is able to leverage the benefits of Ethernet, such as the multi-protocol capability, to provide connectivity with broadly distributed two-wire, loop-powered field instruments for use in potentially hazardous environments.

ABB's research has focused on OPC UA technology, a new universally applicable communication protocol that provides heightened levels of cyber security, semantics and information models that obviate the need for descriptions. By making OPC UA technology usable for small resource-constrained field devices, ABB is dissolving the border between Operation Technology (OT) and Information Technology (IT).

Successful tests of ABB's OPC UA solutions for a flowmeter, conducted in 2017, and level and pressure transmitters equipped with APL evaluations boards, conducted in 2019, demonstrated just how well Ethernet-APL and OPC UA integrate with modern process plant architectures as defined by standardization organizations, eg, NAMUR Open Architecture (NOA), Module Type Packages (MTP) or Open Group, O-PAS (Open Process Automation System).

With the expected 2021 release of Ethernet-APL standard with the underlying IEEE802.3cg (10BASE T1L) standard, the IEC standard 2-wire intrinsically safe Ethernet (2WISE) for Ex-protection and the release of definitions for Ethernet-APL implementation, the adoption of field-level communication supported with Ethernet communication protocols, eg, OPC UA, among others, is just around the corner. The targeted launch of Ethernet-APL in June at the ACHEMA 2021 trade show will be accompanied by ABB and other automation suppliers who will introduce the first Ethernet-APL products, thereby initiating a new phase of safe, secure and practical field-level communication for process plants. •





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## SMART SENSOR-BASED INFORMATION ECOSYSTEM

Mechanical components such as bearings and gear reducers are generally located in hard-to-access locations, thus making their inspection difficult and time consuming. The ABB Ability™ Smart Sensor for mechanical products provides a solution. Designed to reduce downtime, improve reliability, and operate safely, this wireless sensor provides an easy-to-use solution for monitoring the health of Dodge mounted bearings and gear reducers. The sensor indicates abnormal vibration- and temperature-related conditions, thus allowing users to avoid down time by planning maintenance before problems occur.

Now, thanks to new firmware, the Smart Sensor can be updated to also display features such as velocity RMS, change measurement interval, change accelerometer range, and start/stop detection. These features, all of which are the result of customer feedback, significantly enhance the Smart Sensor's existing capabilities.

The Smart Sensor provides users with complimentary access to the ABB Ability™ digital platform, and thus to the power of the Industrial Internet of Things (IIoT). Data from multiple sensors can be transmitted by a user's smartphone or ABB's new Plug & Play gateway to a secure, cloud-based server, where it can be analyzed by advanced algorithms to identify bearing faults. The data is stored in the ABB Ability™ digital platform, from which it can be accessed and graphically displayed for further analysis.

This new plug & play solution, which relies on two of the most popular cellular providers in the U.S., provides seamless connectivity and data analytics from sensors and cellular networks all the way to the ABB Ability™ digital portal. •

## GAS LEAK DETECTION COMES OF AGE

Almost 3 million miles of pipeline infrastructure crisscross the United States, delivering 25 trillion cubic feet (or 700 billion m<sup>3</sup>) of natural gas to 75 million customers<sup>1)</sup>. With half of this pipeline infrastructure built before 1970, it can be prone to leaks. Gas lost through leaks leads to increased costs to consumers, supply and maintenance disruptions, as well as serious safety and environmental issues.

A 2018 study published in *Science*<sup>2)</sup> found that the volume of natural gas leaking from across the supply chain would be enough to fuel 10 million homes, and is worth an estimated \$2 billion per year. Further, pipeline leaks are a contributor to climate change and are negating some of the environmental benefits of switching from coal to natural gas. Methane, the main constituent of natural gas, is a greenhouse gas 21 times more potent than carbon dioxide.

The first step to fixing gas leaks is finding them. For years, traditional leak detection has been ground-based with hand-held detectors that are slow and labor-intensive. Such methods do

not meet the demands of the 21<sup>st</sup> century digital economy for fast, accurate, and transparent data.

The ABB mobile solution is a highly-sensitive vehicle-based system that measures and reports minute concentrations of methane in the air, along with wind speed and direction, permitting leakages to be pinpointed remotely. The detection system features ABB's patented methane/ ethane analyzer, a GPS, a wind speed anemometer, and proprietary leak detection software. Electronic compliance records are generated on a map and can be accessed on a mobile device by a service team or in the operations center. This vehicle-based solution can survey a 10 to 25 times greater area per hour compared to traditional methods. •

### Footnotes

1) "Natural gas explained, Natural gas pipelines", EIA, [https://www.eia.gov/energyexplained/index.php?page=natural\\_gas\\_pipelines](https://www.eia.gov/energyexplained/index.php?page=natural_gas_pipelines)

2) R. A. Alvarez *et al.*\*, "Assessment of methane emissions from the U.S. oil and gas supply chain, *Science*, <https://science.sciencemag.org/content/361/6398/186?rss=1>







## ABB'S NEW GENERATION OF SMALL ROBOTS FOR GREATER FLEXIBILITY AND PERFORMANCE

Evolving customer tastes and skill shortages have led manufacturers to develop highly customized and thus small production batches – this low-volume high-mix production philosophy requires greater performance, flexibility and compactness. ABB's new generation of small robots are key in meeting these objectives. Relying on a modularity platform to develop customized robots faster than ever before, ABB's IRB 910INV, IRB 1100 and IRB 1300 robots represent this new generation of small robots. Developed in one-third the time of conventional methods, these robots are available in seven primary variants, and over twenty-two configurations.

Designed with reach, payload, and accuracy to reflect customer and application needs, eg, loading, assembly, and treatment processing, these robots serve the automotive, electronics, semiconductor, healthcare, and food and beverage industries in harsh and complex factory environments, where ingress protection, ISO clean rooms, or food grade lubrication is required.

Highly flexible and space saving, the IRB 910INV SCARA robot has a clean room option. Available

in two variants: with a 350 mm reach and payload up to 3 kg or with a 550 mm reach and up to a 6 kg payload, this robot is ideal for the electronics industry. IRB 1100 standard comes with IP40 protection and a more rugged IRB 1100 option with IP67; both are available in two variants: 475 mm or 580 mm reach, achieving best-in-class payload and repeatability (0.01 mm).

This robot provides 35 percent increased productivity and saves 10 percent space for high quality manufacturing. Recently launched, IRB 1300, with standard IP40 protection comes in three variants: with a reach of 900 mm, 1,150 mm and 1,400 mm and repeatability between 0.02 mm to 0.03 mm.

All variants offer the option of absolute accuracy to enhance accuracy performance for high-precision demanding applications. Thus, ABB's new generation of modularized small robots provide the customization, flexibility and compactness that diverse manufacturing industries require. •

## DRIVE CONNECTIVITY PANEL



All across industry, users of ABB variable-speed drives have been looking for a plug-and-play way to combine internet connectivity, data collection, cloud analytics and visualization. Now, with ABB's pioneering Drive Connectivity Panel, they need look no longer. Just minutes after installing the Connectivity Panel, data can be analyzed in the cloud portal.

The Drive Connectivity Panel collects the drive's operational data and sends it directly to the cloud via a cellular network, using narrow-band Internet of Things (NB-IoT). The Drive Connectivity Panel is the only product on the

market that enables cloud connection without occupying a data collection I/O port. Data transfer is also kept safe as it is encrypted within the panel and uploaded via the secure NB-IoT cellular network – dedicated to industrial devices – to the ABB Ability™ cloud platform.

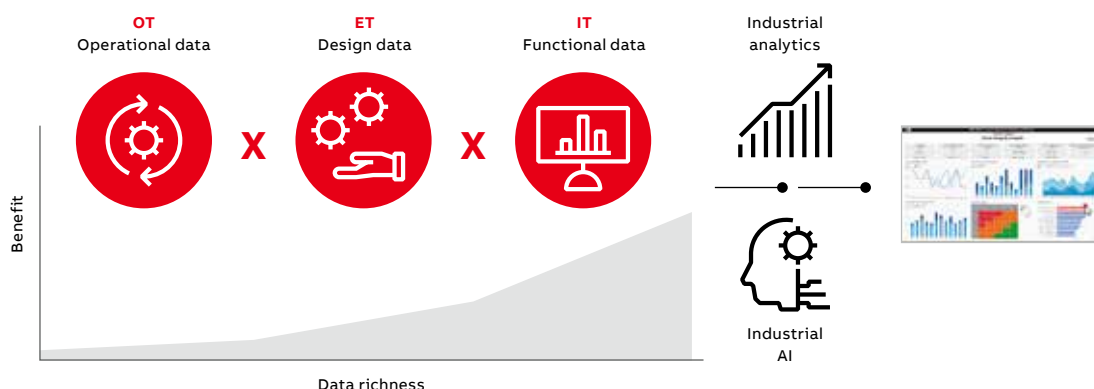
The availability of the latest mobile technology means that when the panel is located in an area with normal signal coverage, it can interact with the cloud services – even if the drive is installed in the basement.

The NB-IoT solution is ideal for condition monitoring in applications requiring a basic level of equipment analytics and alarm notifications but that use low data volumes. Continuous data uploads allow remote health monitoring of ABB drives, event notifications, operational KPI generation and parameter trend creation. Drive health and performance are visualized in an easy-to-interpret way. The panel's Bluetooth interface enables an on-demand remote assistance service – ABB Ability™ Mobile Connect for drives – via the Drivetune mobile app.

The Drive Connectivity Panel-based condition monitoring solution is available for purchase in China and is being piloted in Europe and the United States. •



## THE SYMPHONY OF DATA VALUE CHAINS



The foundational philosophy driving the conceptualization and vision of ABB's digital offerings is the pursuit of combining scattered bytes of digital noise into synchronized enterprise-wide ecosystems of insights – with an impact that extends across every aspect of operational excellence.

In this context, what ABB Ability™ Genix, the industrial analytics and artificial intelligence (AI) suite, and ABB Ability™ Edgenius, the operations data management tool, achieve together is what is best described as exponential impact; or what ABB calls the X factor. At the heart of this X factor, enabling it, is data aggregation and contextualization: Data from diverse sources, ie, real-time operational data (OT), functional data from IT systems and design data from engineering systems (ET) is brought together into a cognitive data model for the application of industrial analytics and AI or machine learning (ML) driven models.

Typically, data rests in silos with more than 70 percent estimated to remain unutilized for analytics purposes. ABB Ability™ Genix and ABB Ability™ Edgenius help convert cross-functional data into powerful insights through this process of using coherent data models and contextualization. For example, a smart maintenance

solution for Azipod® propulsion, was recently developed. This predictive maintenance solution identifies potential anomalies and generates an early warning so that maintenance teams can prevent failure using AI-/ML-based models. The engine for anomalous condition detection and early warning is based on the integration of real-time data, eg, winding temperatures, speed, torque, power and both inlet and outlet cooling air temperatures. Pilot implementations have showcased the benefits: an increased lead time, of over one hour, allows operators to address issues before they turn into catastrophic failure. Thus, ABB Ability™ Genix and ABB Ability™ Edgenius work together to orchestrate a symphony of data value chains. •



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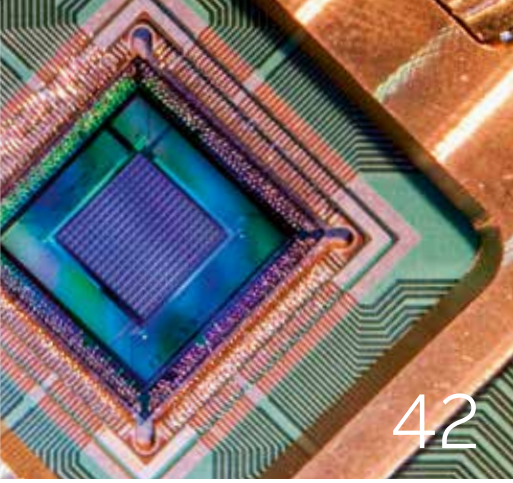
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# Technology insights



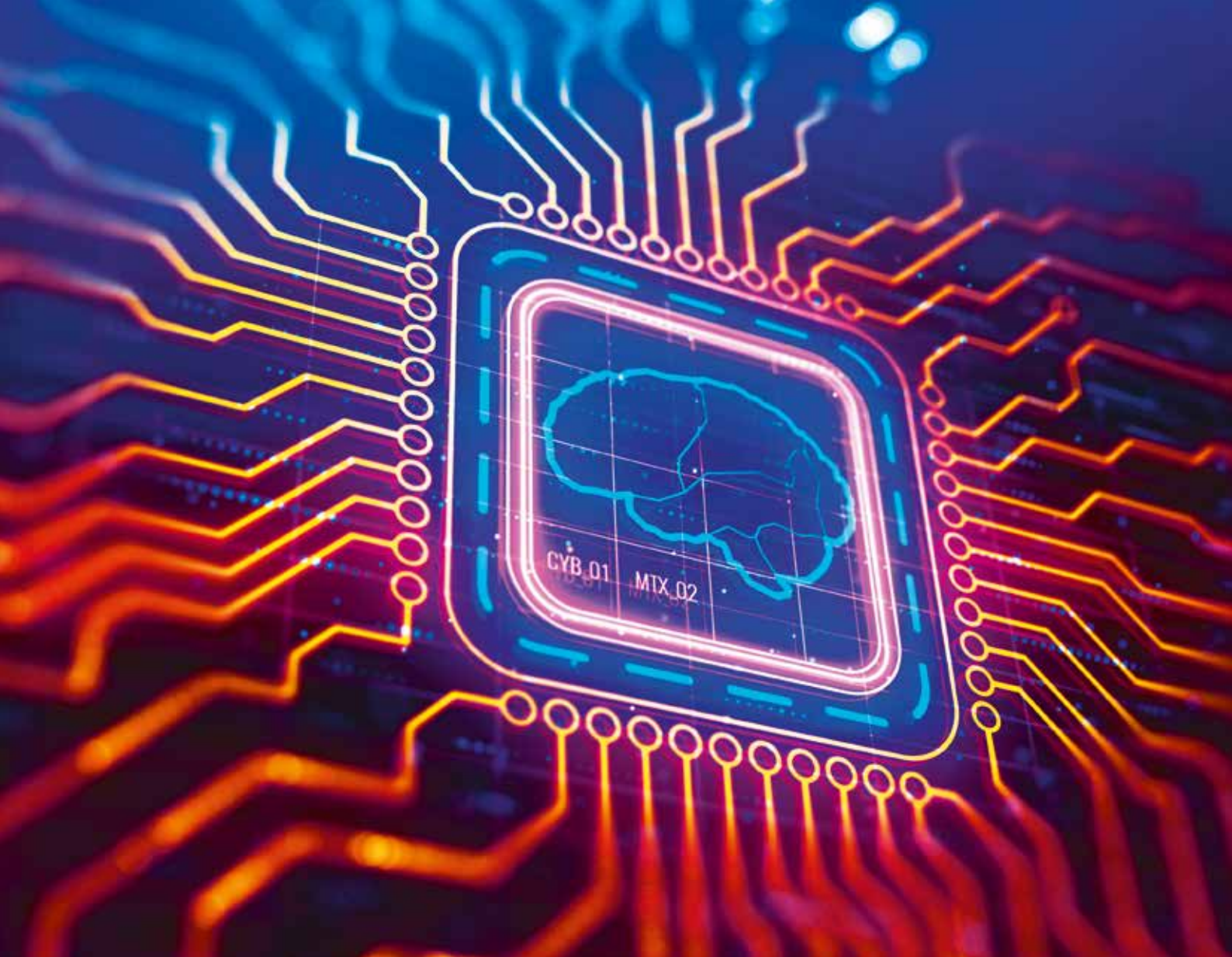


Technology and intelligence are becoming inexorably intertwined, as smart devices and systems can serve as constructive contributors to industrial processes. ABB brings much of what is happening at this cutting edge of innovation to the center of customers' thinking and planning.

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TECHNOLOGY INSIGHTS

# Innovation and speed in industrial AI

Artificial intelligence (AI) is transforming industry. One way ABB develops AI capability is via collaboration with innovation-driven startups. Amongst other activities, ABB conducted the ABB Industrial AI Accelerator program to drive the next level of the industrial revolution via such collaborations.





01

It has long been a part of ABB's philosophy to use an "outside-in" approach, where external ideas are brought into the company to complement ABB's own innovation activities. By engaging with external partners, such as universities, research institutes, or startups, ABB can identify and capitalize on breakthrough technologies or new business models that help the company find new offerings for its customers.

AI – often dubbed "the next technology frontier" or "the Intelligence Revolution" – is one area where collaboration can make all the difference. AI has the potential to enhance human capabilities in a wide range of industries. While AI is still a growing field, in terms of venture capital (VC) investments it is one of the best-funded sectors. Large companies in almost every industry are trying to integrate AI capabilities into their offerings. According to the AI Index Report 2019, globally, investments in AI startups have increased at an average annual growth rate of over 48 percent since 2010 (2018: \$40.4 billion). [1].

In this context, in 2019, ABB ran the ABB Industrial AI Accelerator program, with the aim of fostering the development and utilization of AI to drive the next level of the industrial revolution [2] →01.

The program sought out startups that have new, promising ideas on how to use AI components to provide solutions – or startups that can develop enabling technologies to deploy such solutions in an industrial setting. In joining the ABB Industrial AI Accelerator program, startups received coaching and technical support as well as the opportunity to win customers and grow and commercialize their solution on a global stage. The startups selected for the program also competed for the title of overall winner.

### How the Industrial AI Accelerator winner was selected

In all, seven promising, mostly early-stage, startups were selected to join the Industrial AI Accelerator program to explore industrial applications of their concepts and speed up their development. The seven were chosen from over

The program sought out startups that have promising ideas how to use AI components to power solutions.

100 startups across 20 countries in a two-month review by ABB, supported by delphai (AtomLeap GmbH). Delphai is a self-service market intelligence platform that uses AI to give insights on global innovation trends, market developments, and companies.

The selected startups joined a four-month program in which they were paired with an appropriate ABB Division or function so they could benefit from ABB's deep domain knowledge and thus accelerate their growth.

At the end of the four months, the seven startups presented their solutions to around 70 attendees at a "Demo Day." Each startup had to pitch their solution to a six-member jury – consisting of business and technology experts as well as investors – and face critical questions. The jury selected Greenlytics as the winner.

### Accelerating into the future

While the collaboration projects were spread across different industrial applications, they

01 The Industrial AI Accelerator program sought out startups with capabilities in AI.



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all had in common a clearly defined use case for which the startup and ABB together developed a specific solution and which benefited both parties.

To drive further collaboration with ABB and help the startups to accelerate and expand into a global market, SynerLeap, ABB's innovation growth hub, handed over free memberships to three of the startups – Greenlytics, Vathos Robotics

**We are matching startups to our business organization.**

and OneWatt – for the next six months [2]. The other finalists – Cobrainer, Dutch Analytics, Intelcy and 8power – will continue in their drive to develop promising new solutions.

Accelerating startups through such a program has a strategic motivation, as explains Kurt Kaltenegger, Head of ABB Technology Ventures (ATV): "ABB's Industrial AI Accelerator program was just one way ABB partners with startups. With our global startup innovation hub SynerLeap, for example, we are matching startups to our business organization in order to collaborate and perform proof-of-concept projects together. This approach speeds up the development of differentiating innovations that can win new customers or address pain points of existing customers. We are also providing financial support via strategic venture capital to accelerate and enable the further growth of best-in-class startups." •

#### References

[1] The Stanford Institute for Human-Centered Artificial Intelligence, "The AI Index Report." Available: <https://hai.stanford.edu/sites/default/files/>

ai\_index\_2019\_report.pdf  
Accessed April 7, 2020.

[2] [www.synerleap.com](http://www.synerleap.com).  
Accessed April 7, 2020.

## A WIDE SPREAD OF AI APPLICATIONS

The activities of the seven startups that participated in the accelerator program demonstrate the diversity of possible applications of AI.



#### Greenlytics

Greenlytics, a Swedish startup, develops tools for AI-based forecasting of wind and solar energy generation and consumption, as well as decision support for power trading and plant optimization. As part of the collaboration project between ABB and Greenlytics, their solution has already been deployed for ABB's "Mission to Zero" project ABB Busch-Jaeger's plant in Lüdenscheid, Germany.

As part of the program, the Greenlytics product, SolarMind, was integrated into ABB's OPTIMAX energy management solution to forecast the power generated by photovoltaic plants. The Greenlytics AI system is continuously updated through inputs such as historical data, location-based plant data and weather data.

"We have seen strong synergies between the Greenlytics product offering and ABB OPTIMAX from the start," explains ABB's Julia Marie Leichthammer, who worked closely with Greenlytics. "The significantly more accurate power forecasts by Greenlytics enhance the flexibility of ABB's predictive energy management system OPTIMAX®, resulting in improved operation and trading coordination, and further reduced cost, of our customer's distributed generators, consumers and storage."

The advantages for the startup of ABB collaboration are articulated by Sebastian Haglund El Gaidi, founder of Greenlytics: "We learn from ABB and use the company's global presence to deliver our services."

The exercise also provided Greenlytics with the opportunity to expand their vision: "Collaborating with ABB helps us to develop our vision of tomorrows increasingly renewable, distributed and smarter grid. We already learned a lot about

the market and customer needs and that is important for a startup.”



#### **Cobrainer**

Presenting a very different face of AI was Cobrainer. This Munich-based startup applies machine learning to enable intelligent employee mobility for large and medium-sized organizations by offering employees automatic expertise profiling and intelligent job, project and course matching.

Together with the ABB HR team, Cobrainer built and implemented the ABB Career app, based on Cobrainer's Skill Career technology, which helps students to create a skill profile to receive relevant job recommendations from ABB.



#### **Dutch Analytics**

Dutch Analytics of The Hague, in the Netherlands, offers a hosting and management platform called UbiOps that enables the hosting and management of data science applications. Dutch Analytics worked together with ABB's Marine & Ports business on cooling systems in medium-voltage drives on vessels with diesel-electric propulsion. Ensuring the right level of cooling fluid provision during ship operation is critical. By using data from the ABB Ability™ Marine Remote Diagnostic System installed on ships, the team developed and deployed a model that predicts liquid evaporation rates and advises when the next maintenance should be. Customers in rail, marine and manufacturing industries are already benefiting from this AI technology by predicting breakdowns and increasing asset uptime.

Jorick Naber, COO of Dutch Analytics, says, “collaborating with ABB drives enormous value for Dutch Analytics. We believe the joint project will bring further technology enhancement and help us introduce our UbiOps platform to different industries.”



#### **Intelec**

Intelec, from Oslo in Norway, offers software to analyze production data from the manufacturing and processing industries and utilizes machine learning to prevent breakdowns, predict failures and improve production processes. Intelec used production data from the ABB Ability™ Extended Automation System 800xA to provide automatic processing, structuring, labeling and cleaning of raw data from a specific industrial process. The processed data was then used to select, train and deploy

industrial machine-learning algorithms and provide new insights.



#### **OneWatt**

OneWatt, from Arnhem in The Netherlands, has designed a noninvasive, noncontact predictive motor health maintenance system based on an acoustic method. Data is gathered through their embedded acoustic recognition sensors (EARSs), which literally listen to motors to prevent unnecessary repairs or unplanned downtime. The company worked with ABB to integrate their AI into ABB's Smart Sensors to give insights into asset operation and developing faults. The partnership has also enabled OneWatt to detect even more faults plaguing industries, such as cavitation, electrical imbalance and motor eccentricity.



#### **Vathos Robotics**

Vathos Robotics, from Düsseldorf, Germany, deploys computer vision and machine learning for applications in robotics and factory automation. The modular software architecture of their computer vision technology enabled easy integration into ABB's robotics applications. Local Web APIs (client-side application programming interfaces) allow the computer power needed to train the AI models to reside in the cloud. For more mission-critical applications, customers can be shielded from the effects of disconnections by edge-computing hardware running on the premises.



#### **8power**

8power, from Cambridge, UK, produces self-powered wireless sensor solutions for industrial plant applications and machine condition monitoring. The startup uses its patented Vibration Energy Harvester to power its sensors. This concept helps solve a fundamental problem of the Internet of Things (IoT): how to power the many wireless sensors that the IoT needs without the necessity to replace batteries. 8power has neatly solved the problem by harvesting energy from mechanical vibrations in a very clever way. Together with ABB's oil and gas team, 8power focused on the integration of AI algorithms integrated into self-powered wireless sensor solutions for diagnostics and monitoring of devices. •

## TECHNOLOGY INSIGHTS

# ABB's Industrial AI Accelerator

Artificial intelligence (AI) is a fast-moving field that compels ABB to seek collaborations with promising AI startups. ABB undertook the Industrial AI Accelerator program specifically to foster such relationships. To find out more, ABB Review interviewed Philipp Vorst, project leader of the program.



**Philipp Vorst**

Project leader of the Industrial AI Accelerator program

**AR** Philipp, thank you for talking to us. Perhaps, you could describe the idea behind the ABB's Industrial AI Accelerator program?

**PV** I'd be delighted to! ABB firmly believes that the future of innovation lies in open innovation – which means innovation that includes collaboration with external partners – universities, research organizations, startups and the like. One technology that is moving really fast and where an external alliance is, therefore, essential is AI. So, a year or so ago, we ran this program to foster collaborations in that area, with strong participation of the local business and great management support, particularly in Germany and Poland. The ABB research centers in Germany and Poland were heavily involved,

due to a wide experience in open innovation, as were ABB Technology Ventures – which we call ATV – and ABB around the world, which ensured global reach.

**AR** What is AI? Is it the same as machine learning?

**PV** Simply stated, AI is represented by computer systems or machines that can imitate intelligent human behavior – such as learning, reasoning and self-correction – in different environments. While machine learning is often used synonymously, it is actually a branch of AI. Machine learning simply means algorithms that are designed to learn from data. AI can greatly enhance the power of humans in many industrial settings – in control systems and robotics, for instance. AI is a fertile sector for startups – many are extremely active in this field. Because ABB's interests coincide with those of some of these startups, they make excellent partners with whom we can work to achieve our goals more quickly.

**AR** ABB already has a couple of initiatives aimed at fostering collaboration with startups, doesn't it?

**PV** Yes, we have ATV, our corporate venture capital arm, which we already mentioned but also Syner-Leap, which is our Sweden-based growth hub for startups. We also have various activities running throughout ABB.

**AR** What does ATV do?

The ATV team supports ABB in assessing and investing in startups and promotes collaborations with ABB's businesses. Using strategic venture capital, ABB invests in breakthrough technology companies that are aligned with ABB's purpose and mid- to long-term strategic objectives. By investing in these companies, ABB gets access to new technologies, obtains insights into new sectors, learns about new business models and ensures the company stays on top of innovations happening outside of its own walls.





**AR** And what about SynerLeap?

**PV** SynerLeap – which helps companies from around the world reach a global market and scale up their business – is our other major collaboration initiative. SynerLeap partners with entrepreneurs and startups, and enables them to benefit from the resources, internal networks and competences available to a major multinational like ABB. As I learned recently, SynerLeap has accelerated over 90 companies within three years, which is a great result and effort, I think.

**AR** How did you pick suitable startups for the accelerator program?

**PV** In a two-month review process, we selected seven startups out of more than 100 screened companies. We evaluated criteria such as how the activities of the startups matched ABB target use cases and looked at the technical solutions offered and the teams themselves. By the way, two of the selected companies came through the SynerLeap network.

**AR** What happened then?

**PV** At the end of January, the selected startups joined the four-month program with ABB. During the program, each startup worked with a dedicated partner at ABB on a specific use case. Example use cases were anomaly detection for control systems or machine vision for robotics.

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ABB firmly believes that the future of innovation lies in open innovation.

An initial milestone was the Hannover Fair in early April 2019, where we ran one of the face-to-face workshops with the selected cohort and where the

startups had an opportunity to pitch their solutions at ABB's booth during a special event. With Sweden being the fair's partner country, SynerLeap had an active role in the innovation lab at the Swedish pavilion. SynerLeap joined ABB's pitch event to share successes from their own corporate/startup engagement in front of ABB experts, customers and partners. The event was an excellent teaser for the final "Demo Day" later in May in Berlin. At Demo Day, the accelerator startups presented the final results of their collaboration projects and one of the startups – Greenlytics – was selected as the winner by a jury.

**AR** How did the startups approach AI and how did the accelerator program assist them?

**PV** Startups participating in the accelerator used AI components – such as machine learning or visual perception – to power promising solutions and deploy them in an industrial setting. In joining the ABB Industrial AI Accelerator program, startups received coaching, technical support, the opportunity to tailor their solutions further to industrial needs and the chance to win customers to grow and commercialize their solution on a global stage.

**AR** Was the accelerator program a success?

**PV** Undoubtedly! The program has set in motion collaborations that are valuable for all parties concerned. Without the program, these collaborations might have taken much longer or not happened at all. It was very important that the ABB Divisions were committed to the success of the collaborations, that they supported the startups and that they worked together on predetermined, business-relevant, AI-related use cases. Kudos to all the teams for their involvement, both on the startup side and ABB's side! Let me add that, apart from the seven startups we picked, there were many others with very fertile ideas – a great omen for the future!

**AR** Philipp, thank you very much for the interview. •



## TECHNOLOGY INSIGHTS

# 5G for digital industries

5G – the fifth generation of cellular communication technology – is a key enabler for the digitalization of industry. It is difficult to overstate the impact 5G will have on the industries with which ABB is involved. What are the value propositions of 5G and what is ABB doing to unlock them?



**Dirk Schulz**  
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With the megatrend of digitalization ramping up quickly, vertical industries are looking to improve competitiveness by a deeper integration of value networks, operations processes and production equipment. More than ever, automation systems are expected to enable flexibility, increase productivity and decrease operational risk for their owners. For automation vendors, this means extending focus from the automation of energy and material flows to the automation of information flows and digital processes – even between different vertical industries →01. 5G can address the needs of such a converged digital ecosystem.

## What is 5G?

With the world depending ever more on connectivity and the exchange of data, the communications industry is moving to provide a completely new type of wireless network: 5G [1]. With, for example, the ability to serve many devices nearly simultaneously and even run different logical networks for autonomous driving, voice and industrial applications on one physical infrastructure, 5G is not just a faster 4G, it is a game-changer →02.

There are three key aspects of 5G performance, which will become available, in an incremental fashion, over the next few years →03:

- Enhanced mobile broadband (eMBB) increases bandwidth by an order of magnitude over 4G, targeting applications like high-definition (HD) video-streaming or augmented reality (AR) – not only in the consumer world but also the industrial domain. Public 5G coverage started up in 2019.
- Ultra-reliable low-latency communication (URLLC) reduces the achievable latency and enhances the reliability of communication.

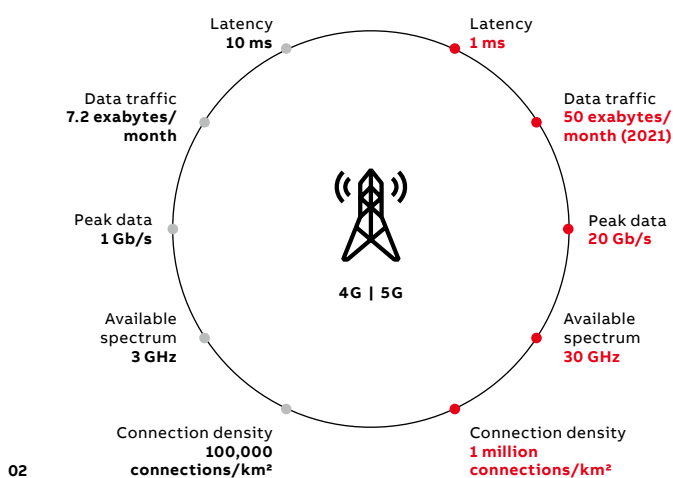
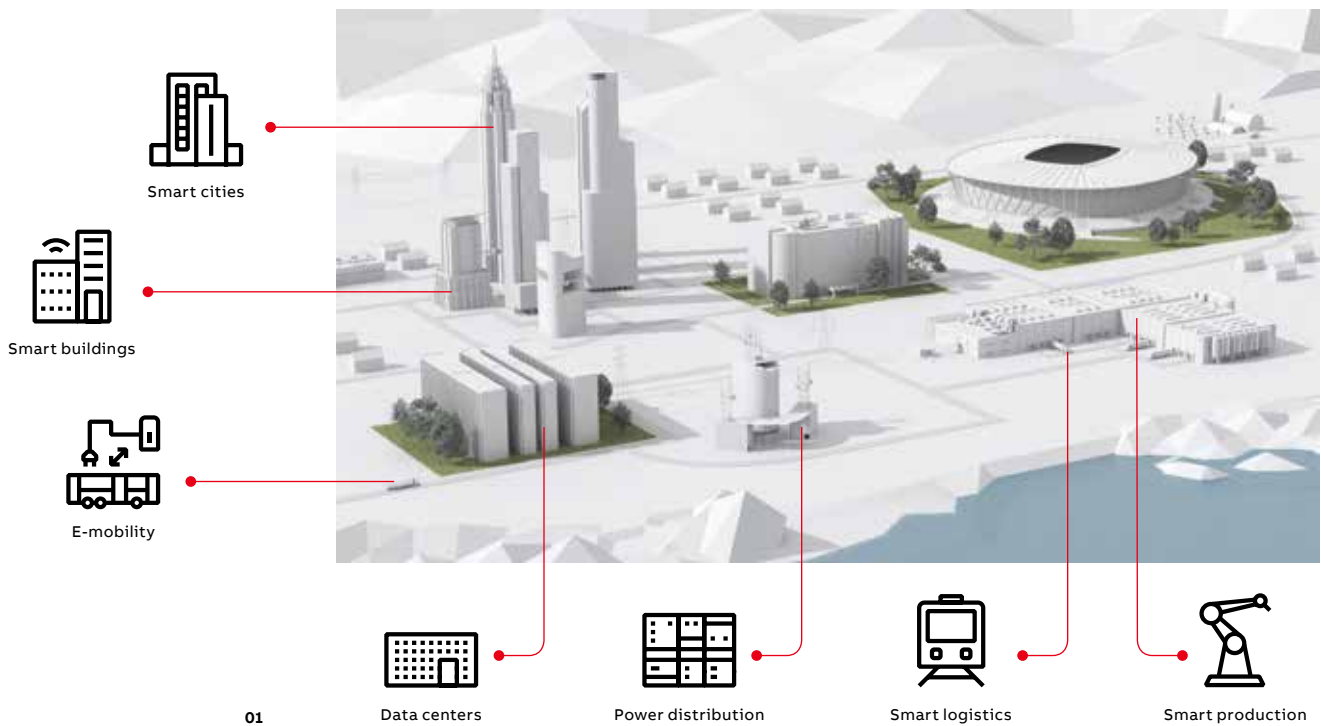
URLLC targets process- and safety-critical applications like closed-loop process and motion control, safe communication and autonomous logistics with automated guided vehicles (AGVs). URLLC may also be referred to as critical machine-time communication. Standardization for this aspect has been completed; commercial availability is expected in 2021/2022.

- Massive machine-type communication (mMTC) aims to increase the number of devices in a given area by orders of magnitude, primarily aimed at sensor applications with low data rates (compared to, for example, video) but high spatial density. This feature will be standardized last and is expected to become available by late 2023.

In practice, applications demand a combination of these performance features. A good example is the streaming of augmented-reality content, which requires both high bandwidth for content itself but also low latency to prevent motion lag – if the delay between head-motion and the

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**5G is not just a faster 4G,  
it is a game-changer.**

AR image is too great, the technology becomes unusable in the field. Similarly, closed-loop control applications require both a high density of sensors and high reliability (but rather low data rates). These two examples also neatly encapsulate the scope of the two basic types of industrial 5G communication:



### Scalable, deterministic communication infrastructure

5G offers mechanisms for guaranteed delivery of data with bounded latency. While network resources are available, applications can easily be scaled because resource protection is built into the technology. Network performance, in turn, can be scaled by plugging in additional radio, fiber and computer resources where needed.

### Network slicing

Network slicing enables multi-tenancy for networks. By subscribing to a network slice, time-critical applications can be run without having to invest in a dedicated infrastructure (eg, autonomous driving and autonomous

- Deterministic communication for the control of physical processes. This type of communication requires high reliability and low latency to close the loops of cyber-physical processes.
- Transactional communication to optimize and maintain the process and the process equipment. Here, a large number of diverse sensors may be connected.

Beyond the mere improvement of protocol performance described above, cellular ecosystems built on 5G technology offer a variety of features and innovations with benefits for automated industrial systems:

Cellular ecosystems built on 5G offer a variety of features and innovations with benefits for industrial automation.

plants could share a 5G network). Alternatively, a single private network can reliably segregate communications from office IT, process control, operations, hazard control, utilities and infrastructure, etc.



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01 Scope of connected verticals. 5G can address the needs of a converged digital ecosystem of verticals, from distributing power to automating smart cities.

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02 5G has a performance about ten times better than that of 4G.

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03 Key performance areas of 5G.  
Communication latencies:  
125 µs to the order of seconds.  
Data rates:  
kbps to gbps.  
Coverage radius:  
1 m to 1,000 km.  
Device density:  
1 to 1,000,000 devices/km².  
Availability:  
99 to 99.999 percent.

### Universality

5G offers universally capable and configurable radio technology. Radio equipment can be configured to support a particular combination of determinism, bandwidth and number of network participants, depending on the available radio resources. No specialized radio technologies are needed anymore to cover the different types of automation applications, from motion control to process video.

### Precision time synchronization

Besides low latency for control applications, wide-area precision time synchronization enables a wireless sequence of events (SoE) for critical processes where alarms and events from distributed equipment must be globally integrated into one chronological sequence.

### Mobile edge computing

Signal processing and data analytics can be flexibly deployed as virtualized software functions in the proximity of the process, without having to burden (energy-constrained) sensors or process-critical equipment. This approach has several advantages: data can be fed back to the process with low latency (eg, to integrate product quality control) and no specialized computing equipment needs to be added on the premises. If a so-called private network is used, sensitive data does not even leave the corporate network, let alone be transferred to third-party data centers.

### Low power and high density

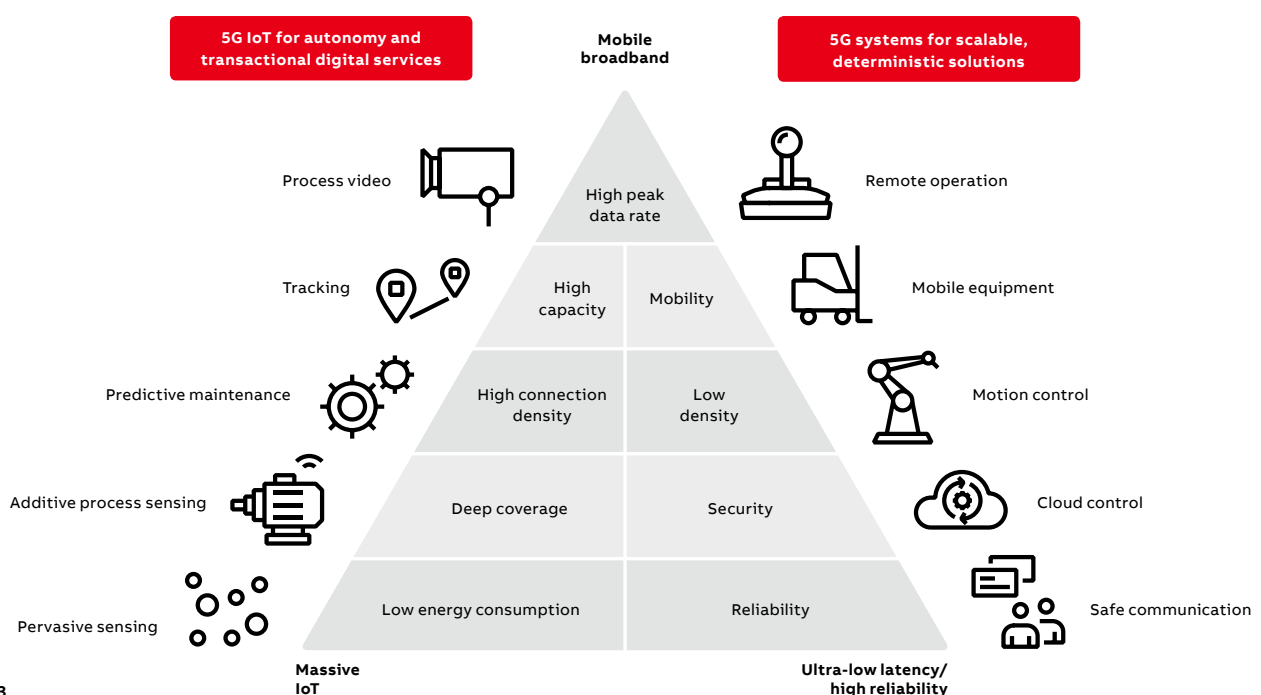
5G offers low-power and low-data-rate protocol variants that exploit Narrow-Band IoT (NB-IoT) to support vastly increased device density (see mMTC). NB-IoT is a low-cost, low-power, wide-area radio network standard running on 200 kHz

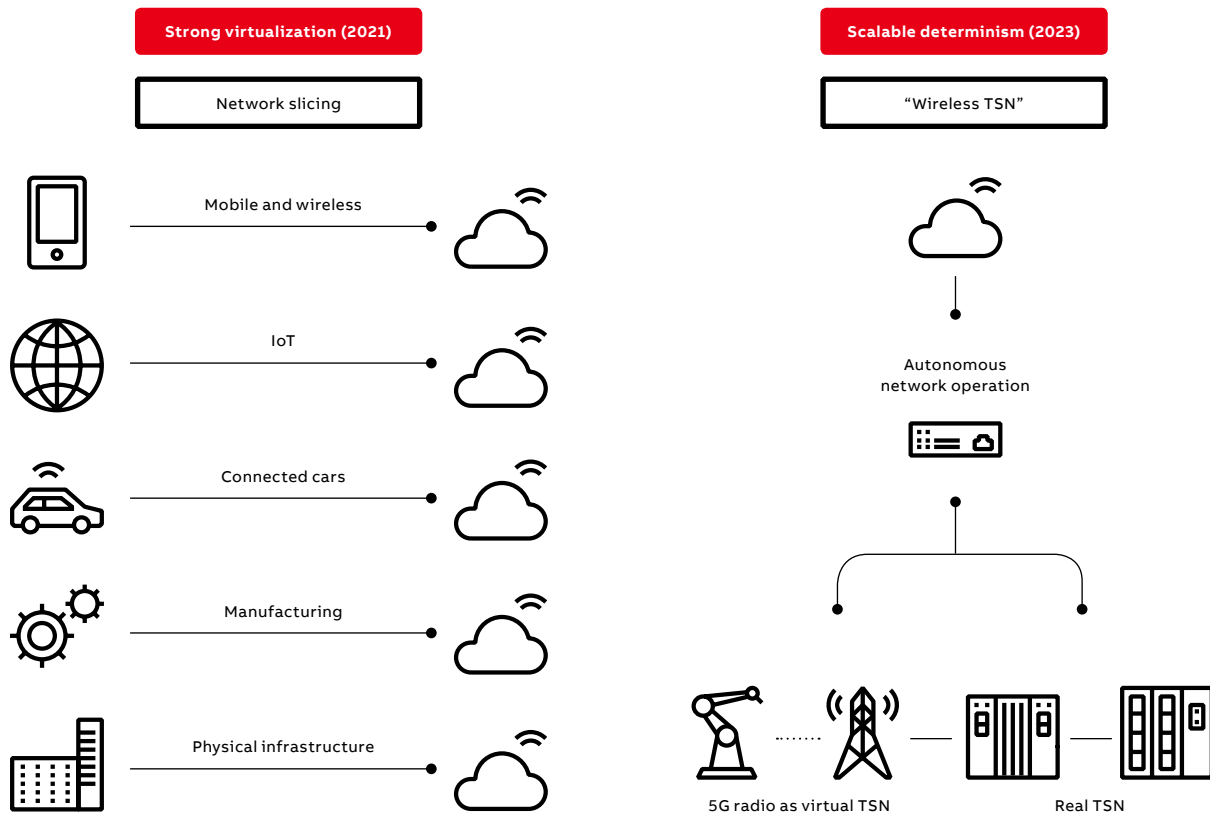
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**Added customer value is the main driver behind ABB's engagement in 5G.**

that enables a wide range of cellular devices and services, focusing on indoor coverage, long battery life and high connection density. With transmission power in the mW range, NB-IoT allows the flexible location of even energy-autonomous sensors – without any regard for communication or power source, thus reducing both cost and installation time.

### The value of 5G

As outlined above, 5G industrial applications can run concurrently over the same network infrastructure, contingent on the availability of adequate radio and network resources. These resources can be reconfigured in software to adapt to the changing mix of application needs in adaptive production systems.





04

Universal connectivity for production systems

## 5G has the potential to provide universal connectivity for industrial systems.

Since network performance can be tailored in a very granular manner, incremental cost (by adding resources) adds incremental value (application-specific performance).

Beyond the technical innovations described above, added customer value is the main driver behind ABB's engagement in 5G. For example, for the first time, it may be feasible to offload the ownership and operation of a mission-critical automation infrastructure to an automation provider. Plant and factory owners can choose to rid themselves of the cost and effort of operating and maintaining DCS hardware but retain control of their fieldbuses, controllers and I/O devices. In this way, it becomes possible to keep or to transfer operational risk.

5G also helps to improve productivity. The ability to add and connect sensors without added infrastructure cost is a catalyst for increasing the digitalization level of physical production processes and infrastructures. Added data means added insight into processes and products that can be used by machine-learning algorithms to predict and prevent system downtime and quality issues.

Further key value propositions are:

- 5G will improve flexibility within production processes. Wireless communication, in general, allows for easier re-arrangement of machines, production modules, or material transport with AGVs. 5G specifically adds the reliability and determinism needed for such flexibility on an industrial scale.
- 5G fosters sustainability and is itself a sustainable technology. 5G infrastructure can be shared between different applications and industrial domains. And the sensors or cellular automation equipment invested in today are expected to last for many years.

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04 Key innovations of 5G and TSN.

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05 5G will have a major impact on many of the industries in which ABB is involved.

Together, 5G and IEEE time-sensitive networking (TSN) – a set of IEEE standards that provides deterministic networking at lower levels – set out to provide universal connectivity and computation for industrial systems and (large-scale) infrastructure. Automation functions in safety applications, closed-loop control, operations, data analytics, or machine learning will be able to negotiate the resources they require without

having to consider communication protocols or deployment questions →04.

#### **Making 5G a reality**

5G is a complex yet versatile communication ecosystem that incorporates a range of different radio technologies, global wire-bound wide-area networks, powerful computers and a significant amount of intelligent software functions. 5G has



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06 When will 5G automation solutions be available? The 5G roadmap from the perspective of vertical industries.

the potential to provide universal connectivity for industrial systems →05. The availability of 5G over the coming years is shown in →06. With configurable communication performance, low-power radio option, collocated computation and availability through subscriptions, 5G surpasses existing communication technologies for industrial applications.

Today, ABB delivers telecommunications solutions in oil and gas environments and cellular technology is already a part of many ABB products. ABB also is among the first companies to leverage the NB-IoT cellular protocol to enable fleet management and telemetry applications for improved asset availability.

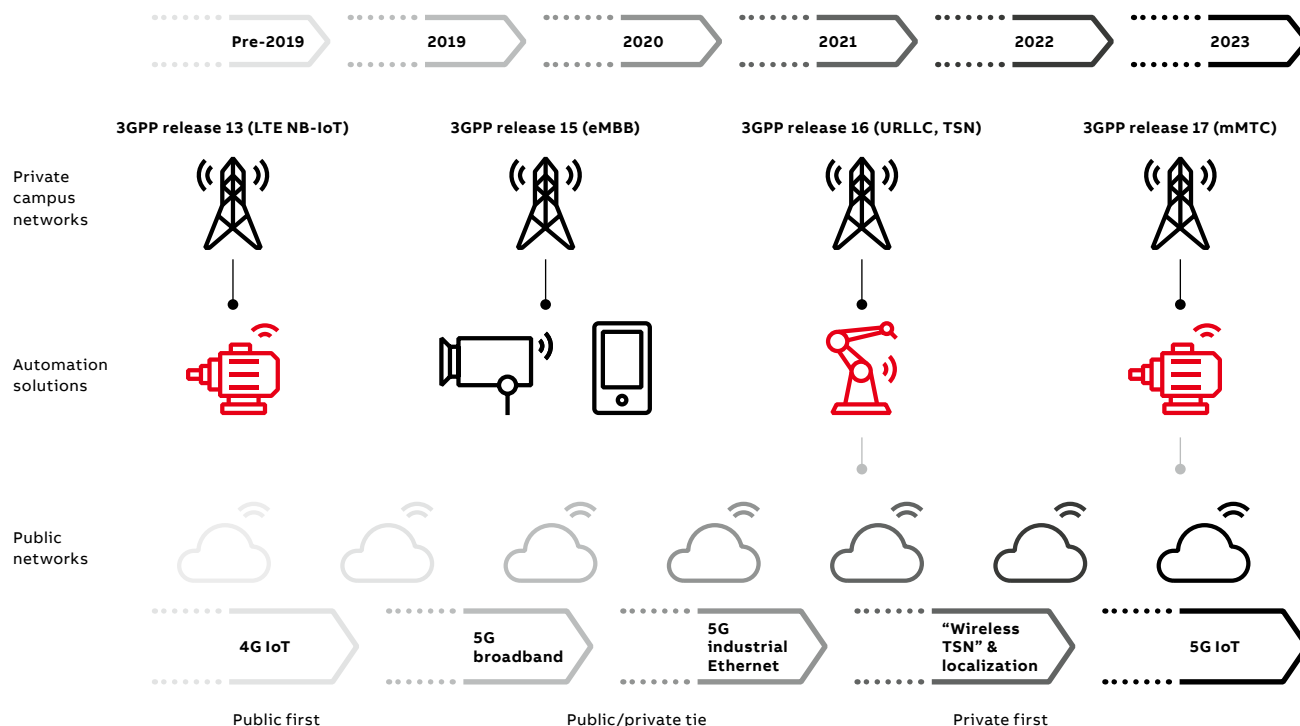
To exploit the digital opportunities ahead, ABB partners with world-leading companies in the

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Together, ABB and Ericsson are driving the standardization, regulation and technology development of 5G.

information and communication technology industries such as IBM (AI), Microsoft (ABB Ability™ cloud), HPE (edge computing) and, recently, Ericsson (for 5G). Together, ABB and Ericsson are driving the standardization, regulation and technology development of 5G. Key objectives here are the availability of local spectrum and hardening of technology for industrial use cases. •

#### Reference

[1] D. Schulz, "Buzzword demystifier: 5G," *ABB Review* 3/2020, pp. 78-79.



3GPP: 3<sup>rd</sup> Generation Partnership Project, an umbrella term for a number of standards organizations that develop protocols for mobile telecommunications.



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TECHNOLOGY  
INSIGHTS

# Asset and power management with Ekip UP

01 Ekip UP monitors, protects and controls power distribution and automation in many different types of application.

01



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Part of the ABB Ability™ smart power offering, ABB's Ekip UP transforms power distribution and automation applications into digital microgrids, increasing energy efficiency, service continuity and safety.

One significant new element in the power landscape is the microgrid – ie, distributed energy resources and loads, mainly in low-voltage (LV) networks, that can work together in a controlled and coordinated way, either connected to a national grid or in “islanded” mode. LV microgrids are especially significant for the rollout of renewable energy. The decentralization LV microgrids represent is the ultimate antithesis of the centralized national utilities of old.

The small scale and tight budget of LV installations mean that the incremental expense of intelligent power control, monitoring, or management can quickly dominate the overall

microgrid cost. This restriction has led to the installation in microgrids and other LV applications of millions of air circuit breakers and molded-case circuit breakers – of all brands – that lack advanced features for monitoring or resource optimization. This unfortunate situation has now been put in the spotlight by the arrival of digitalization in the form of the Internet of Things (IoT) and communications networks that can unlock the power of data to optimize power management – provided the appropriate smart technology is available.

ABB's Ekip UP provides this smart technology →01-02.



02

### Ekip UP

ABB's Ekip UP is a multifunctional digital unit that delivers monitoring, protection, control, programmable logic, full connectivity, easy integration and comprehensive energy management to LV power distribution and automation applications with voltages of up to 1,150 V and operating currents of 100 to 6,300 A →03-05.

By using an optional gateway module, Ekip UP can connect directly to the ABB Ability™ Electrical Distribution Control System (EDCS) to provide a powerful, cloud-based platform designed to monitor, explore, analyze and act upon entire electrical systems. This cloud architecture has been developed together with Microsoft to enhance performance and guarantee the highest reliability and security. The Ekip UP/EDCS combination delivers extensive monitoring and management capability in widespread LV networks.

Five versions of Ekip UP are available:

#### Ekip UP Monitor

Ekip UP Monitor measures a comprehensive set of parameters relevant for good power management for sites up to 4 MW: voltage, current, frequency phase, active/reactive power, etc. Ekip UP Monitor also features a power quality network analyzer – built according to the IEC61000-4-30 edition 2 standard – that measures up to the 50<sup>th</sup> harmonic and a fault analysis datalogger. Eight Fieldbus and Ethernet links plus one proprietary bus allow for easy system integration. Each Ekip UP has four slots for plug-and-play modules to share up to 3,000 data points with supervision systems, guaranteeing modularity for each application.

The digital unit also senses bus bar, transformer and switchboard temperature and humidity values using PT probes and analog sensors in built-in modules.

#### Ekip UP Protect and Ekip UP Protect+

These models add protection functions to those provided by the Ekip UP Monitor based on current, voltage, frequency and power values. Ekip UP Protect+ adds generator protection, as well as adaptive and overcurrent directional protection

Ekip UP can connect to the ABB Ability™ EDCS to provide a powerful cloud-based platform.

for power distribution and generation. The device enables digital zone selectivity via a proprietary bus and native IEC 61850 GOOSE communication

03





— 02 Ekip UP. The device's modular, plug-and-play design makes it simple to configure new systems or upgrade old systems.

— 03 Ekip UP delivers a wide range of functionality to LV power distribution and automation applications.

for substations. It also allows restricted/unrestricted earth faults to be distinguished from each other. Zone selectivity allows the fault area to be isolated rapidly so that disconnection only occurs close to the fault and other equipment remains interrupted.

Both models can be equipped with software kits to cater for load shedding, synchrocheck capability, programmable logic and interface certified protection. These advanced features ensure service continuity and energy efficiency and reduce complexity.

Ekip UP can also simply serve as a backup when a relay goes out of service.

#### **Ekip UP Control**

Ekip UP Control adds to the devices described above a patented power management algorithm that shaves peaks and shifts loads to optimize system performance and productivity. Such measures can reduce electricity bills by up to 20 percent.

Ekip UP Control, installed downstream of the medium-voltage (MV)/LV transformer, can use slope-of-frequency data to disconnect loads in case of emergency imbalance conditions. This interface protection system provides the protection necessary to connect end-users with local generation available to the utility. The generating units will be disconnected from the grid whenever grid voltage and frequency values stray out of range. When the main grid stabilizes, inbuilt Ekip UP synchrocheck logic manages safe reconnection.

#### **Ekip UP Control+**

With control features that effectively make it a microgrid controller, Ekip UP Control+ is the top-end member of the Ekip UP family. Ekip UP Control+ can run a suite of software functions to achieve every target a user in power distribution and automation may have.

#### **Ekip UP application areas**

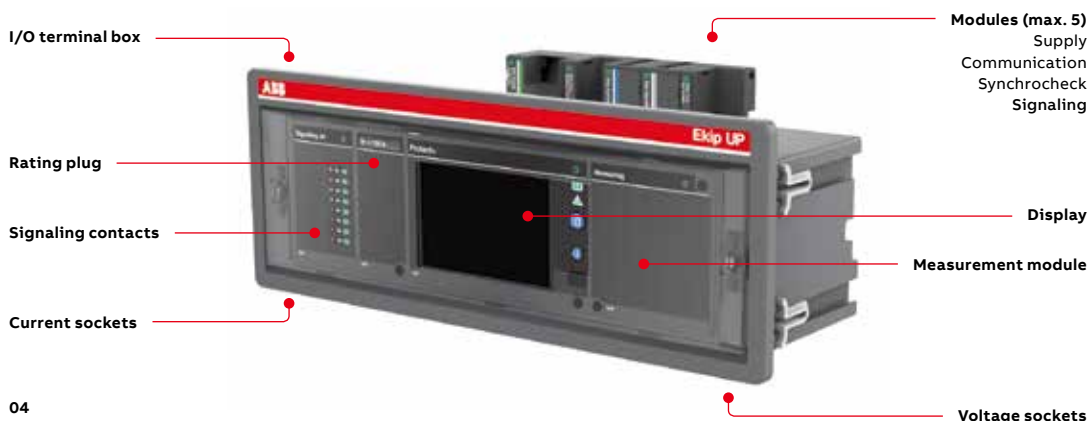
Ekip UP is used in a wide range of LV settings. In commercial buildings, such as hotels, shopping malls, or offices, Ekip UP monitors the energy consumption of existing facilities and connects them to the cloud. Thanks to the remote energy

— **Ekip UP+ adds generator protection, and adaptive and overcurrent directional protection.**

management system and smart power management algorithm embedded in the digital unit, facility managers and end-users can increase the energy efficiency of the location's electrical plant. In new infrastructure with e-mobility chargers, Ekip UP provides the key to understanding current flows, thus enabling peak shaving and load shifting strategies.

In industrial and utility plants, Ekip UP protects plant power systems and automation processes





with a direct interface to every switching device. The unit satisfies a complete list of distribution and generation ANSI protections as embedded programmable logic can send tripping commands to switch disconnectors (a typical example in the oil and gas industries).

Microgrids are LV environments that can especially benefit from Ekip UP, as it can coordinate load/generator loading and flow. Thanks to the software functions available, Ekip UP can maximize microgrid service continuity in data centers, solar plants, etc. Ekip UP's advanced connectivity capability makes integration simple.

#### ABB Ability™ EDCS

The ABB Ability™ EDCS is a cloud-based platform designed to monitor, optimize and control an electrical system:

- **Monitor:** Discover site performance, supervise the electrical system and allocate costs.
- **Explore:** Visualize the system structure, verify asset health conditions and get actionable insights taking into account predictions and prescriptions.
- **Analyze:** Schedule and analyze automatic data exports, improve the use of assets and take the right business decisions.
- **Act:** Set up alerts and notify key personnel; remotely implement an effective efficiency strategy to achieve savings in a simple way; and manage maintenance activities and schedule next maintenance actions.

The data used by the EDCS – from molded-case circuit breakers, miniature circuit breakers, arc

guards, multimeters, etc. – is made available by Ekip UP, which makes the cloud connection without replacing any existing assets in brownfield applications. The EDCS is multi-user and operates through a Web interface, and so can be used anytime and anywhere via a cyber-secure link to a smartphone or personal computer. Through the EDCS platform, Ekip UP predicts maintenance on installed ABB and legacy GE assets, reducing related operational costs by up to 30 percent.

The EDCS gives access to real-time data and historical trends – on a single- and multi-site level – so that performances can be compared and benchmarks set. One maintenance technician can manage several sites and because the EDCS

**In new infrastructure with e-mobility chargers, Ekip UP provides the key to understanding current flows.**

continuously performs diagnosis on the devices in the electrical system, action need only be taken when needed. By measuring device activity directly, the EDCS algorithm can provide the device reliability curve and suggest the next maintenance date.

#### Ekip UP in the field

A typical Ekip UP implementation would be in a switchgear application where the breakers are



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04 Ekip UP main features.

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05 Ekip UP takes up little space in the rack. Having both DIN-rail and door-mounted options, Ekip UP fits the installation requirements of OEMs and panel builders with limited footprint requirements.

still in good working order, but other equipment needs replaced. Such was the case recently in the United Arab Emirates (UAE) with the Sharjah Electricity and Water Authority (SEWA). SEWA distributes water and generates electricity for the residents of the Sharjah Emirate.

The trip units of all the LV breakers – from an ABB competitor – at SEWA's Qasimia substation became defective. The original supplier suggested full breaker replacement – a significant and expensive undertaking. Seeking an alternative path,

SEWA contacted ABB. Because the breakers were otherwise sound, ABB replaced just the malfunctioning electronic trip release with Ekip UP, which is fully compatible with any existing LV breaker, even competitors' devices. Commissioning was aided by ABB's Ekip Connect, a free software tool that optimizes Ekip UP's ability to manage power, acquire and analyze electrical values, and test protection, maintenance and diagnostic functions.

#### A smart choice

A wide range of accessories complements Ekip UP's advanced features. With its modular and standardized design, and strengthened by the capabilities of EDCS, Ekip UP provides an ideal way to deliver cloud-connected technology that saves cost and downtime while making power management easier, more efficient and more profitable. Ekip UP is, literally, a smart choice that can provide any LV plant with a digital unit capable of monitoring, protecting and controlling the facility. •

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Ekip UP delivers cloud-connected technology that saves cost and downtime while making power management better.



## TECHNOLOGY INSIGHTS

# Quantum computing: the hype and hopes

Autonomy in an industrial environment necessitates solving computational problems in the fields of optimization and artificial intelligence (AI). Some of these problems cannot be unlocked with the hardware and software available today. Can quantum computing provide the key?



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Quantum computing is currently one of the most talked-about topics in technology. Yet as it is far from our daily experiences in the classical world, its disruptive power remains somewhat elusive to most. Each new day brings fresh headlines, hype and headway, crowned in late 2019 by the spectacular news of Google beating its rivals in the race for “quantum supremacy.” The breakthrough stirred wild excitement in the technology community, with comparisons being made between this major engineering achievement and the Apollo 11 moon landing →01–02.

Back on Earth, it is of benefit to question and evaluate the significance of quantum computing for future industrial applications: What kind of technologies would quantum computing enable for industrial applications? What are the obstacles preventing quantum computers from being used today? Are there other technologies emerging that could have a similar impact?

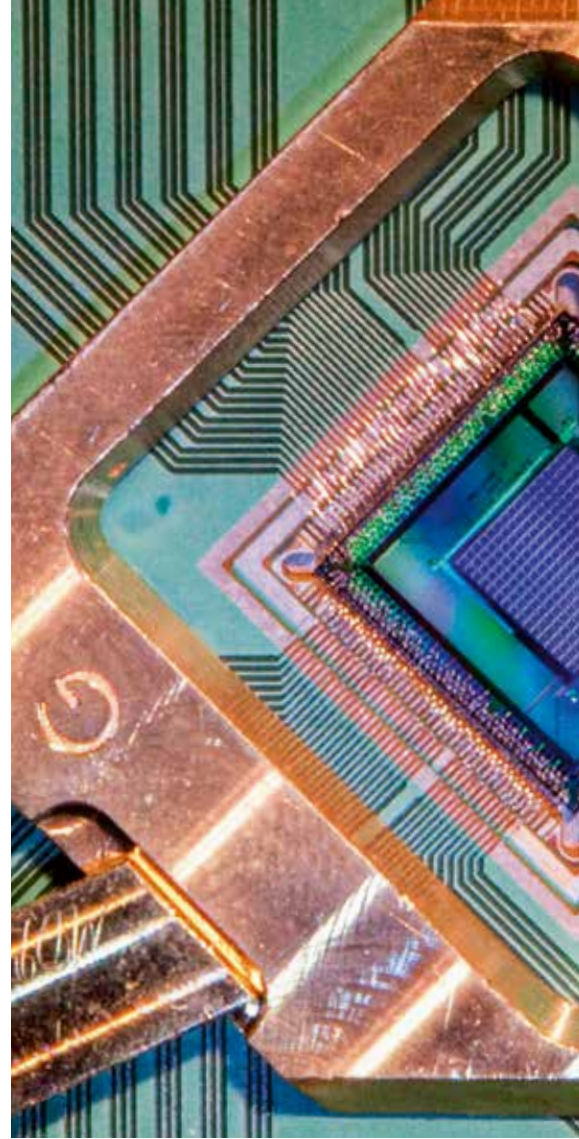
## Can I buy a quantum computer now?

A good starting point is to establish what quantum computers are and who is in the race to build them.

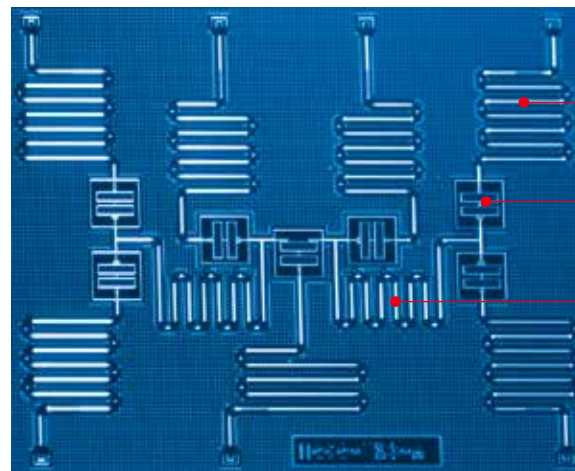
Quantum computers are not anticipated to be a turbo-boosted replacement for laptops – not even in the long term – nor are they universal supercomputers replacing large-cluster computing.

Quantum computers are, in fact, large special-purpose machines.

Quantum computers are, in fact, large special-purpose machines that aim to get an edge over conventional hardware (and its successors) in dedicated computational problems – of which,



01

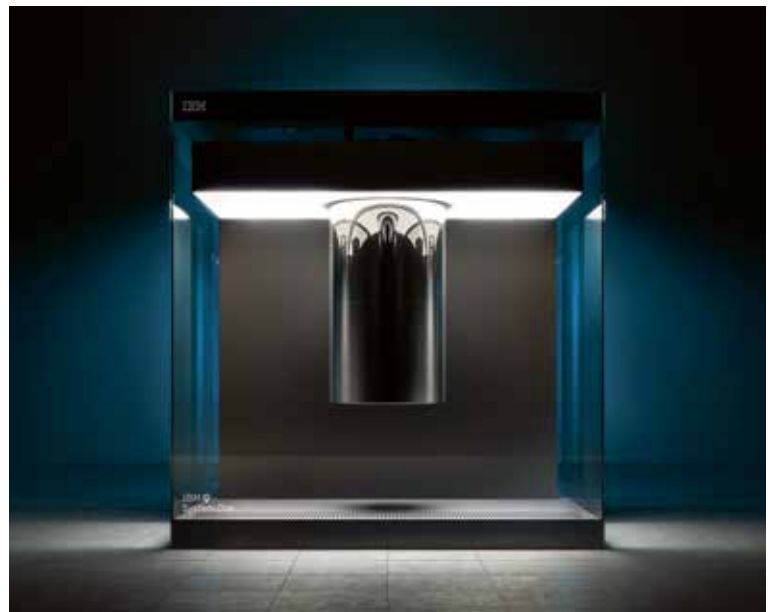


Control and readout resonator (x7)

Qubit (x7)

Bus resonator (x2).  
These enable a two-qubit gate.

02



03

fig. 03: IBM, shared via Kandala et al., Nature and Creative Commons, license details: <https://creativecommons.org/licenses/by-nd/2.0/legalcode>

— 01 Quantum computing may hold the key to the autonomy of machines in industry, but are they practicable outside of the laboratory? Shown is a D-Wave 2000Q Chip.

— 02 An early design of an IBM 7-qubit chip based on superconducting technology.

— 03 IBM Q System One quantum computer.

more below → 03. Quantum computers make use of principles of quantum mechanics to crack problems in minutes for which the fastest supercomputers would need thousands of years or longer. Importantly, the speed-up can only be achieved by using special algorithms (the design of which is a science in itself) that harness the laws of quantum physics; current algorithms are of no use.

The idea of quantum computing was triggered by the Nobel Laureate, Richard Feynman, in a now-famous lecture at IBM in 1982. Experimental efforts followed, resulting, in the late 1990s, in the first quantum computational devices that allowed the manifestation of the so-called qubit, the quantum relative of the bit in classical computing. Recent theoretical progress has advanced the field significantly. Today, 54-qubit chips represent the cutting-edge and corporations such as Google, IBM and Honeywell have

taken over hardware leadership with high-profile research departments while a couple of hardware startups are trying to catch up. (These efforts refer to a universal quantum computer architecture; for hardware optimized for the specific algorithm of quantum annealing, the

— **Speed-up can only be achieved by using special algorithms.**

company D-Wave is best known.) Simultaneously, governmental agencies and the Wallenberg Foundation in Sweden have assisted knowledge development and commercialization. So far, despite all these efforts, the technology remains behind laboratory walls and without commercial application. But for how long?



### What is under the hood?

Since the idea of quantum computing was first introduced and first qubit implementations realized, multiple different candidates for hardware implementation have been investigated. Today, ion traps and superconducting loops are the most mature technologies used for the implementation of quantum computers →04–05.

The most advanced demonstrator chips have 54 qubits, with each connected to four other qubits for superconducting universal quantum computing. In →04, microwave cables for control signals are connected to the quantum chip, which is the dark square in the lower part of the image. For ion traps, the reported qubit number is 11 qubits with full connectivity. Qubits can be implemented on various technology platforms that have pros and cons for the quantum computer design. To run

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Significant technical breakthroughs are needed to scale the technology beyond a few thousand qubits.

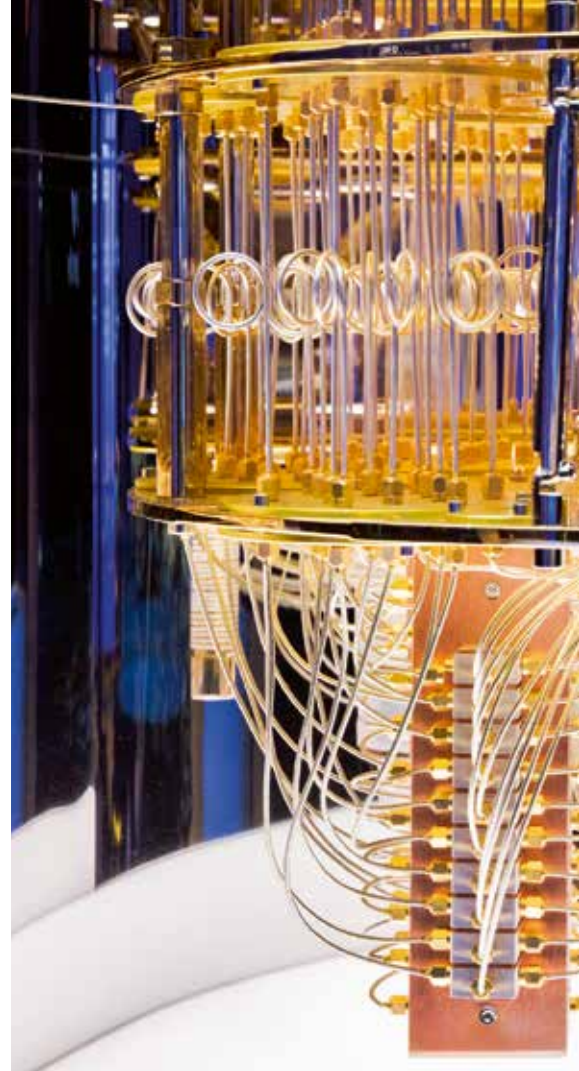
an algorithm on the quantum hardware, the qubits are made to interact via various types of logic gates. Besides the properties of the qubits themselves, their specific arrangement and the gate operation characteristics determine the successful implementation of the quantum algorithms. As the qubits, and thus the information stored in them, are very sensitive to noise introduced by outside sources and the gate operations themselves, it is very challenging to achieve faithful implementation of the algorithms. To reduce noise introduced by interaction with their surroundings, today's quantum computers must be operated at temperatures close to absolute zero or in a high-quality vacuum →06. A future universal quantum computer would, therefore, require efficient error correction algorithms to counteract the detrimental effects of noise. Various error correction strategies have been proposed, but these use up qubits, thus reducing the final number of qubits available on the chip for the computational problem itself.

Today's quantum chips are limited to some tens of qubits, with still a significant number of errors in the gate operations. But how is the hardware expected to scale up in the medium

term and long term? An equivalent of the well-known Moore's law has been proposed that forecasts the doubling of quantum computing power ("quantum volume") every year [1]. However, significant technical breakthroughs are needed to scale the technology beyond a few thousand qubits. While waiting for the technology to scale up to the promised immense computing power, it is practical to ask if there may be some benefit already in the medium term.

### Let the algorithms play

Quantum computers are probably best known for the theoretical threat they pose to existing encryption systems. However, as factoring cryptographically significant numbers requires computation with around 1 million high-quality qubits, even today's best noisy small-scale quantum chips fall far short of the capabilities required. The same outlook applies to all the "Mars mission" quantum algorithms – ie, those that promise an astonishing speed-up for a vast number of applications (as opposed to the "moon shot" algorithms promising a less impressive speed-up, but with limited hardware).



04





—  
04 Interior of IBM quantum computing system. The quantum chip is located in the small dark square at center bottom.

—  
05 Qubit technologies used for quantum computing. The qubits are typically manipulated with microwave or laser technology.

05a Superconducting loops.

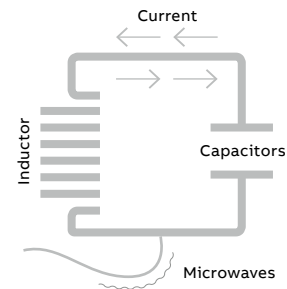
05b Trapped ions.

05c Silicon quantum dots.

Such a noticeable gap between the existing hardware and the requirements for running meaningful algorithms has naturally offered an optimal breeding ground for skepticism: Would the engineering challenge involved in gaining a real advantage with quantum hardware be simply too great? To give the skeptics a better argument than just “wait and

—  
Would the engineering challenge involved in gaining an advantage with quantum computing be simply too great?

see,” in 2012, physicist John Preskill suggested another kind of landmark for quantum computers: quantum supremacy. To achieve this landmark, one would demonstrate a quantum computer doing any non-trivial task (which would not even have to be useful) much faster than the best classical hardware. This landmark is what, in October 2019, Google’s quantum computing team achieved [2].



#### Superconducting loops

A resistance-free electric current oscillates in a microscopic resonance circuit loop on a chip. Microwave signals are injected for manipulation of energy levels.

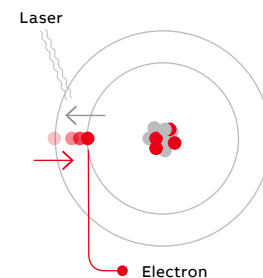


Fast gate operations.  
Manufacturing technology close to semiconductor chips.



Lifetime of information in qubit is short.  
Must be kept in ultra-low temperature cryo-device.

05a



#### Trapped ions

Electron states in ions are manipulated. Laser cooling and RF-fields are used to trap the ions, additional laser beams for manipulation.

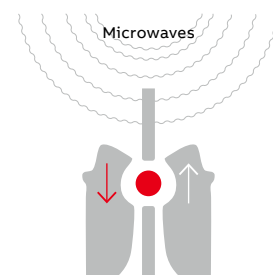


Very stable qubits.  
Highest-achieved gate fidelities.



Slow operation.  
Optical access for laser beams and ultra-high vacuum needed.

05b



#### Silicon quantum dots

“Artificial atoms” containing a single electron are created on a semiconductor structure on silicon. Microwave pulses control the electron’s quantum state.

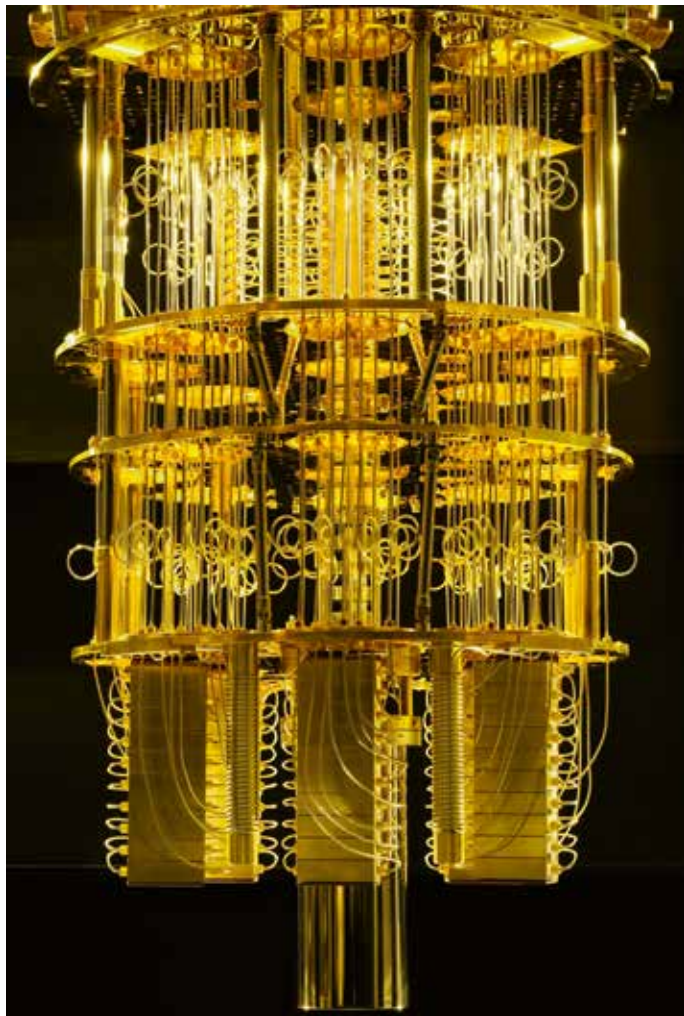


Stable.  
Built on manufacturing technology already used in the semiconductor industry.



Less mature technology.  
Must be kept in ultra-low temperature cryo-device.

05c



06

The Google scientists used an artificial computational problem of sampling random quantum circuits. Sequences of quantum gates were randomly generated, ie, without any intention to form actual algorithms, and the 54-qubit quantum computer was asked to send back the result of the “computation” in the form of a bit string output (eg, 0101...). Due to the quantum nature of the gates, for each sequence, there is a statistical variation with inherent quantum properties in the obtained outputs. The implemented quantum algorithm repeats the computation and creates distributions for sampling the bit strings corresponding to each quantum circuit as fast as possible. Finding the most likely output of such a random quantum circuit on a classical computer becomes exponentially more difficult as the numbers of qubits and implemented gates grow.

The scientists calculated it would take a classical computer 10,000 years to perform this task; the quantum computer took a few minutes.

The task in which the supremacy was achieved is not useful for any applications and there is no suggestion that any useful task could be solved any time soon with the current chips. The demonstration “merely” showed that even a small-scale quantum computer could do one particular non-trivial task better than a classical computer. In this light, a term like quantum “advantage” instead of “supremacy” could be more appropriate to describe the achievement.

There is, however, also evidence that even such noisy intermediate-scale quantum (NISQ) computers with some hundreds or thousands of qubits could help solve complicated combinatorial optimization problems with quantum heuristics such as quantum annealing or a quantum approximate optimization algorithm (QAOA) →07. Such combinatorial optimization

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Even NISQ computers with hundreds or thousands of qubits could help solve complicated optimization problems.

problems have a vast number of applications and quantum chips of relevant scale are already in the short- and intermediate-term roadmaps of all the relevant quantum hardware players. In September 2020, IBM released their quantum computing roadmap, which foresees a 1,000-plus qubit device, called IBM Quantum Condor, by 2023 [3]. For sectors ranging from finance to automotive, there have been recent indications on how such advances in quantum chips could bring benefits [4,5].

#### **In the industrial autonomy driving seat**

ABB has looked into quantum computing technology to map its potential in improving the optimization of large autonomous fleets, energy systems, supply chains, or manufacturing processes. Many of the applications involve extremely complex optimization problems that cannot currently be solved efficiently, or at all. Will quantum computing be the key to solving these problems?

Amid all the recent hype surrounding quantum computing, it is good to keep in mind that it is not only hardware that can revolutionize

— 06 IBM Q Dilution Refrigerator: the low temperature at the bottom ensures low-noise operation of the chip.

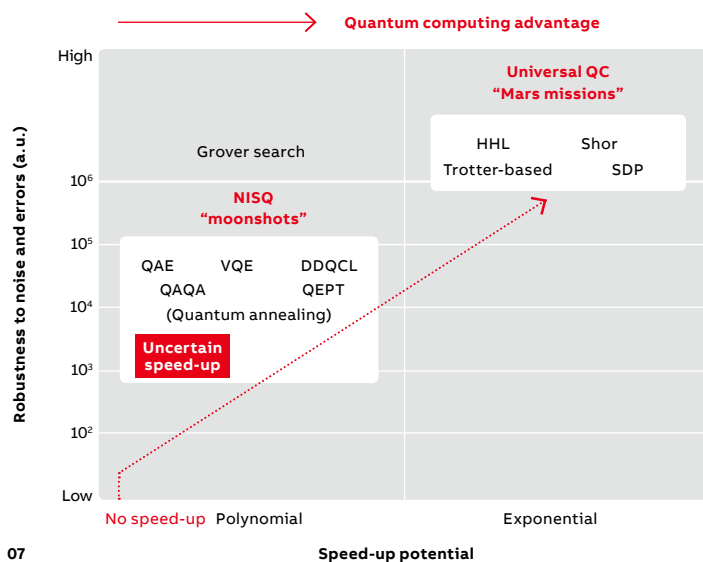
— 07 Selected quantum computing algorithms cluster into the near- and medium-term NISQ regime; long-term Mars mission algorithms are for universal quantum computers [6].

computational approaches to future autonomous systems. Innovations in optimization algorithms themselves may, in the end, present a better return on investment, even with the same old classical hardware. Some of these innovations have been inspired by quantum computing algorithms and have shortened solution times greatly for some problems. These algorithmic developments have not hit the headlines as quantum computing has done, but they could have a bigger impact in the near term.

In the driver's seat of industrial autonomy, ABB is steering the adaption of emerging

It is not only hardware that can revolutionize computational approaches to future autonomous systems.

computational technologies to novel industrial applications. As technological advances unfold in software and quantum hardware, it is crucial to be prepared to unlock any potential to redraw the industrial automation landscape. •



Grover search: a quantum algorithm that finds, with high probability, the unique input to a black box function that produces a particular output value

QAE: quantum amplitude estimation for Monte Carlo sampling

VQE: variational quantum eigensolver

DDQCL: data-driven quantum circuit learning

QAOA: quantum approximate optimization algorithm

QEPT: quantum-enhanced population transfer

HHL: (Harrow, Hassidim, Lloyd) quantum algorithm for solving systems of linear equations

Shor: Shor's algorithm is a polynomial-time quantum computer algorithm for integer factorization

Trotter-based: for the simulation of chemistry

SDP: semidefinite programs for combinatorial optimization problems

## References

- [1] J. Gambetta and S. Sheldon, "Cramming More Power Into a Quantum Device," IBM Research Blog 2019. Available: <https://www.ibm.com/blogs/research/2019/03/power-quantum-device/>. [Accessed September 2, 2020].
- [2] F. Arute, *et al.*, "Quantum supremacy using a programmable superconducting processor," *Nature* 574, pp. 505–510, 2019. Available: <https://doi.org/10.1038/s41586-019-1666-5>. [Accessed September 2, 2020].
- [3] J. Gambetta, "IBM's Roadmap For Scaling Quantum Technology." Available: <https://www.ibm.com/blogs/research/2020/09/ibm-quantum-roadmap/>. [Accessed September 21, 2020].
- [4] F. Neukart *et al.*, "Traffic Flow Optimization Using a Quantum Annealer," *Frontiers in ICT*, December 20, 2017. Available: <https://www.frontiersin.org/articles/10.3389/fict.2017.00029/full>. [Accessed September 2, 2020].
- [5] M. Kühn *et al.*, "Accuracy and Resource Estimations for Quantum Chemistry on a Near-Term Quantum Computer," *Journal of Chemical Theory and Computation* 2019 15(9), 4764–4780. Available: <https://pubs.acs.org/doi/abs/10.1021/acs.jctc.9b00236>. [Accessed September 2, 2020].
- [6] A. Montanaro, "Quantum algorithms: an overview". *npj Quantum Information* 2, article number 15023, 2016. Available: <https://doi.org/10.1038/npjqi.2015.23>. [Accessed September 2, 2020].



# Productivity







Delivering technology that works faster, better, and with greater efficiency and reliability drives productivity and yields sustainability. This is where automation, robotics, and smart controls come together to fulfill a purpose. ABB works at that intersection.

- 50 Condition monitoring for the energy and mobility revolutions
- 54 Stretching the limits of measurement
- 60 The road to automated engineering
- 66 New MP<sup>3</sup>C control method maximizes efficiency and dynamics
- 74 Why robots are focusing on automotive final assembly processes



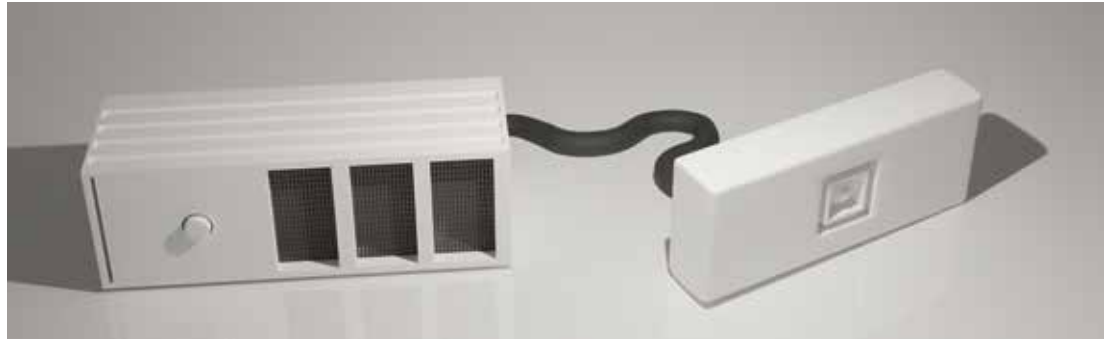
## PRODUCTIVITY

# Condition monitoring for the energy and mobility revolutions

Rising numbers of renewable energy sources and electric vehicles put increasing stress on both the electrical distribution grid and its maintenance strategies. Condition-based maintenance using infrared cameras combined with artificial intelligence (AI) help to detect developing grid equipment faults.



—  
01 FLEMING project technology will improve the reliability of electrical equipment such as switchgear. Shown is ABB's IEC air-insulated UniGear ZS1 MV switchgear.

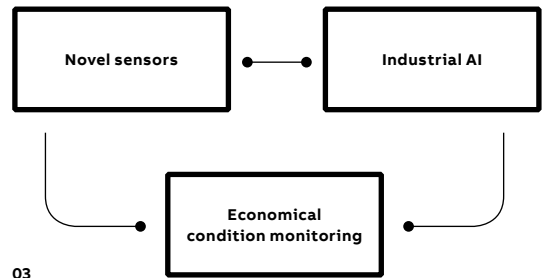


—  
02 Combining AI and sensing equipment.

02

—  
03 Novel sensors and AI enable economical condition monitoring.

Many countries are working on ways to reduce their CO<sub>2</sub> emissions. This effort puts two technical aspects of modern life onto center stage: power generation and personal mobility. These two areas are undergoing great change: Ever more low-CO<sub>2</sub> electrical power is generated from wind and solar sources while, in the mobility sector, electricity is steadily replacing fossil fuels as a vehicle power source, often with the implicit assumption that the electricity will come from green sources.



03

Connecting renewable energy sources and electric vehicles to the distribution grid adds stress to an already stressed system: Renewable sources are intermittent and can fluctuate, and large fleets of electric vehicles will produce new peak loads and a general demand increase. Therefore, grid operators must find ways to increase the flexibility of their network

energy and mobility transition in Germany. Lessons learned can be later applied elsewhere.

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—  
**Infrared cameras combined with AI can help detect developing faults in in MV switchgear.**

operations and deal with a higher occurrence of irregularities and switching events. The increased stress also challenges traditional maintenance strategies and without condition-based maintenance, costs are likely to explode.

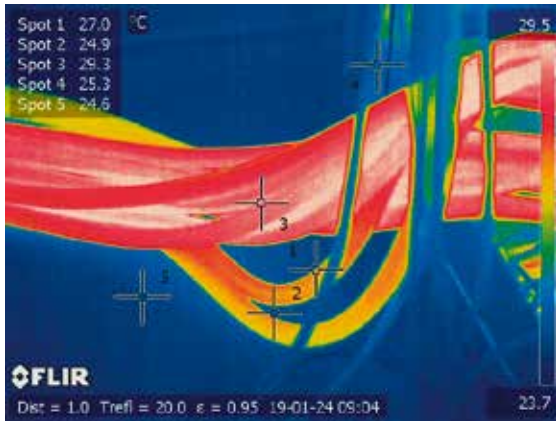
This article describes how infrared cameras combined with AI can help to detect developing faults in medium-voltage (MV) switchgear and enable condition-based maintenance →01-03. The work was conducted jointly by ABB and partners in the context of the FLEMING research project. In the FLEMING project, a consortium drawn from research and industry is investigating how the current use of sensors in distribution networks can be fundamentally improved by using AI methods together with an expansion of sensor technology. The aim is to make a significant contribution to the success of the

ABB leads the FLEMING consortium. Partners are from industry and the world of academia: the University of Paderborn's SICIP Software Innovation Campus; RWTH Aachen, Forschungsinstitut für Rationalisierung e.V. (FIR); Karlsruhe Institute of Technology, Institute of Electrical Energy Generation Systems and High-Voltage Technology; and Heimann Sensor GmbH (a manufacturer of high-quality infrared sensors). Associate partners are the Städtische Werke Überlandwerke Coburg GmbH (a power company) and WestfalenWIND GmbH (a wind park operator in the Paderborn area).

### Thermal monitoring

Thermal monitoring is a useful way of detecting technical problems in an electrical system. Electrical conductors heat up via so-called Joule heating when current passes through them. This principle is exploited by everyday items such as heating rods or electric kettles.

The amount of heat generated depends not just on the level of current but also the resistance of the conductor. Therefore, a resistance increase – due to, eg, corrosion or switchgear elements such as busbars bolts that have been improperly installed or vibrated loose (a problem found particularly in marine vessels) – will create a local hot spot. Such hot spots, and, thus, actual and incipient failure locations, can be made visible by infrared thermographic (IRT) imaging [1-3]. For example, in →04-05, an IRT image reveals the



04

heating due to recent or ongoing flow of current through cables. As extended periods of abnormally high temperature can cause degradation, early detection of hotspots is desirable [1].

#### Thermal monitoring sensors

While it is possible to use contacting measurement techniques to assess the thermal state of equipment, these methods come with certain drawbacks:

- Contact measurement on potential introduces the risk of interfering with the dielectric requirements of the switchgear and reduces equipment safety [1].
- If the monitoring equipment is placed in regions with high magnetic or electric fields, there might be some electromagnetic interference with the measurement process [4,5].

IRT cameras do not suffer from these issues. Additionally, unlike a point measurement, IRT can cover a large area, greatly reducing sensor-related cost [4,6].

Sensors put into switchgear for condition monitoring must deliver a high measurement accuracy over a broad ambient temperature range. They also need to have a long lifetime and the measurements they supply must be reliable and stable (ie, low sensor drift) over this period. While there are several measuring principles for infrared temperature (eg, bolometric and pyroelectric approaches), thermoelectric sensors such as thermopiles meet these requirements best.

Thermoelectric sensors generally consist of several thermocouples on a thin membrane. When the incoming infrared radiation increases the membrane's temperature, the sensor generates an output voltage that is proportional to the infrared radiation detected. By using a pixel array of such sensors, an infrared image is produced. The absence of moving elements, such as shutters, is one contributor to the longevity of these sensors.



05

#### Algorithms

The data provided by the IRT sensors records hot spots resulting from technical defects that alter the resistance of the conductor. However, while a human can easily spot these issues in a visualization of the sensor data, an algorithm is needed if the system is to be monitored without human intervention.

To realize such a system, the data is first cleaned. Often, the notoriously low contrast of the IRT image has to be improved. Also, noise in the pixel signals has to be removed or reduced to avoid skewing values used for statistical analyses.

Once the data is preprocessed, several different types of algorithms can be applied. A classic approach is to implement an expert system. With a collection of human-defined rules, the system essentially uses a checklist to determine whether a state is problematic or not. Expert opinion can

---

Unlike a point measurement, IRT can cover a large area, greatly reducing sensor-related cost.

be refined by referring to simulations based on the laws of physics that show the characteristics of abnormal states. In both cases, one needs to find the right balance between creating a near-perfect model that is too expensive and a simplistic model that is not good enough to capture reality adequately.

Another method is to use machine-learning algorithms from the field of AI that automatically understand common patterns in large data sets. While they take a statistical approach, these algorithms can still benefit from expert knowledge. For example, an expert knows that the maximum temperature within an IRT image,



—  
04 Current flow in cables can be seen in this IRT image.

—  
05 Points of failure can be seen as a hot spot (top right) in this conceptual graphic.

as well as the temperature differences between certain regions, are quite important. Which combinations of temperature levels and differences are still acceptable or not can be determined automatically by the statistical analysis performed by the algorithm, provided it is trained appropriately. The algorithms in the scope of the FLEMING project cover the spectrum from pure expert systems to convolutional neural networks, which mimic the human visual cortex.

### Predictive and condition-based maintenance

The tool chain described above can be used to recognize problems when they occur and allows the maintenance team to take immediate action. But, of course, it is preferable to receive an early warning of a failure. Both expert knowledge and statistical analysis can be used to identify situations that represent the early stages of a failure or events that will lead to damage. This approach leads to a series of possible algorithm types that can be used for predictive or condition-based maintenance.

At its most basic level, an algorithm classifies an input as showing a fault in an otherwise healthy situation. Combined with knowledge of

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**RUL is the most useful indicator of all as it allows the operator to schedule repairs into a planned downtime window.**

deterioration mechanisms, this classification can be refined to characterize the further evolution of the fault. This leads to the creation of a failure prediction or an asset health index. With

more data and/or even better understanding of how failures develop, one can not only predict the upcoming occurrence of a failure but also the estimated time until it occurs, which is a prediction of remaining useful life (RUL). Although it is the most difficult parameter to obtain, RUL is the most useful indicator of all as it allows the operator to schedule repairs into a planned downtime window. RUL is hard to obtain because it relies not only on a profound understanding of failure-stage mechanisms but also on a prediction of usage patterns, which is not always possible.

All of these algorithms are purely informational. However, an intelligent system can and should use the information they provide to recommend actions, maintenance schedules and repair instructions.

### The vision of FLEMING

The significant changes confronting the electrical grid place an unprecedented strain on its components – even high-reliability equipment such as switchgear faces a faster rate of deterioration. The vision of FLEMING is to improve existing condition-monitoring solutions to make them ready for these new challenges. While automated failure detection has been developed prior to FLEMING, the project will explore extended prediction and RUL calculations. The goal is to combine highly reliable sensor technologies, such as IRT, and AI to achieve actionable predictions that minimize the unscheduled downtime of equipment. The IRT-based solution for the critical MV equipment described here can probably be adapted to other types of switchgear.

In future articles, additional failure modes and monitoring solutions such as vibration sensors will be discussed. •

### References

- [1] H. Niancang, "The infrared thermography diagnostic technique of high-voltage electrical equipment with internal faults," *Proceedings of the POWERCON '98, 1998 International Conference on Power System Technology*, Beijing, China, volume 1, pp. 110–115, 1998.
- [2] T. Craig, "Condition monitoring in low-voltage circuit-breaker technology," *Proceedings of the IET International Conference on Resilience of Transmission and Distribution Networks*, RTDN 2017, Birmingham, UK, pp. 1–6, 2017.
- [3] A. S. N. Huda and S. Taib, "Application of infrared thermography for predictive/preventive maintenance of thermal defect in electrical equipment," *Applied Thermal Engineering*, 61, pp. 220–227, 2013.
- [4] M. S. Jadin, and S. Taib, "Recent progress in diagnosing the reliability of electrical equipment by using infrared thermography," *Infrared Physics and Technology*, volume 55, issue 4, pp. 236–245, 2012.
- [5] B. Li et al., "HV Power equipment diagnosis based on infrared imaging analyzing," *Proceedings of the 2006 International Conference on Power System Technology*, pp. 1–4, 2006.
- [6] Y. Chou and L. Yao, "Automatic diagnostic system of electrical equipment using infrared thermography," *Proceedings of the 2009 International Conference of Soft Computing and Pattern Recognition*, pp. 155–160, 2009.

## PRODUCTIVITY

# Stretching the limits of measurement

In a cold rolling mill, measuring and controlling the thickness of aluminum metal strip is as important as it gets. ABB's Millmate thickness gauging (MTG) system does this accurately, dependably and safely. With the novel High-pass Mode option, customers will soon be able to read high frequency thickness variations of thin aluminum strip (0.6 mm – 0.1 mm) for use in feed forward control.



01







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01 The gapless gauge head with nothing above the pass line to obstruct the passage of the strip can be installed below the mill table for protection during threading, tail out and strip breaks.

Lightweight, strong, highly reflective and recyclable, aluminum is ideal for many consumer and industrial product applications. Its use can lower energy costs and reduce CO<sub>2</sub> emissions that are so crucial in today's market [1]. It is no wonder that aluminum sheet metal is in high demand, eg, as packaging material and for can production; for transportation vehicles especially for body-in-white for cars, eg, Ford's F-150 model, etc. [1]. For instance, the North American lightweight material market is estimated to grow dramatically between 2020 and 2025 with aluminum expected to capture the highest market share in terms of value [1]. However, achieving a specific aluminum end-product demands producers to control the chemical composition, work hardening and thermal history of aluminum, or alloy, and its thickness.

To this end, aluminum cold rolling mills require thickness gauging systems that are dependable, safe, robust, compact, and accurate; they must also operate in a harsh and spatially restricted environment. The capability of minimizing thickness deviations during the rolling process is critical. Although this may seem easy to achieve, it is actually dauntingly difficult.

Committed to developing the best possible gauges for measurement and analysis, ABB has engineered the unique gapless MTG Box Gauge system →01 with Pulsed Eddy Current technology (PEC) →02 to determine both resistivity (between 27 nΩm and 65 nΩm) and true strip thicknesses (0.5 mm–8 mm) for aluminum and clad aluminum [2]. Despite this amazing achievement, ABB

—  
In cold rolling mills, tighter thickness tolerances can mean higher efficiency and access to additional markets.

continues to push the limits of thickness measurement. With the new High-pass Mode option that calculates thickness variations for thin aluminum strip (between 0.6 mm and 0.1 mm) customers will be able to measure fast thickness variations for use in feed forward control under specific conditions.

**The rolling process and keeping thickness in-line**  
During rolling, metal is subjected to intense pressure and tension in a harsh environment (in the presence of dust, steam, emulsions or other fluids);

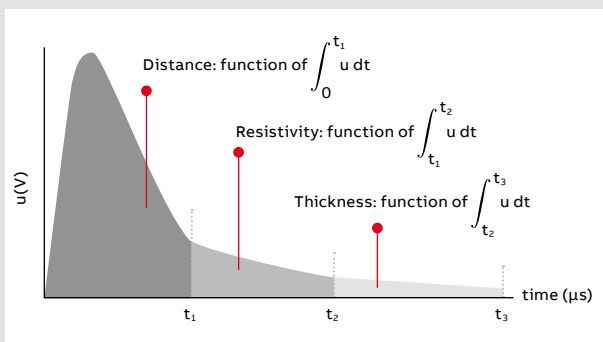
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02

## THE PEC OPERATING PRINCIPLE – THE BASIS FOR MTG'S SUCCESS



ABB's PEC technology is based on a revolutionary principle and is critical to the success of the MTG system. This patented PEC technology allows thickness, resistivity and distance between the sensor and the material being measured to be determined at different times [2]. A pulsed weak magnetic field is generated by electric coils placed in the box gauge head just below a cover plate. After the abrupt interruption of the constant excitation current fed to the coil, the magnetic field produced by the eddy currents in the metal sheet is measured by the voltage it induces in the coil. By tracing the entire penetration sequence via the voltage induced across the coil, this unparalleled process allows three unique signal values at three different times to be derived: the distance, the electrical resistance and the thickness. Thus, the MTG gauge sensor determines true thickness independent of alloy content accurately, with a low signal drift, dependably and safely.

shape and thickness are altered through rolling and stretching to reach the final size and thickness. As the metal is rolled, the speed increases to compensate for the change in thickness. Creating the right balance between the reduction due to the force of the mill and the reduction due to extruding the material through the gap is crucial; if the process is off-balance even slightly, the metal strip could break or cobble with disastrous results. Thus, thickness gauge systems must control thickness within tight tolerances while the material moves through at varying speeds; thereby ensuring maximal productivity and minimizing costs associated with non-conforming strip. In cold rolling mills, where aluminum sheet is produced to exacting thicknesses, and production continuing around the clock, tighter thickness tolerances can mean higher efficiency and access to additional markets. For instance, the high-volume production process used for deep drawing cans in the aluminum can market has extremely tight tolerances; producers require a strip thickness deviation of only a few μm for a strip thickness of 200 μm for the entire strip (lengthwise and widthwise).

ABB has developed the MTG, with PEC technology to measure true thickness with outstanding accuracy and dependability in this harsh and challenging mill environment → 01.

### MTG – gapless gauging for aluminum strip

With many competitive advantages over conventional radiation-based gauges for aluminum thickness measurements, the MTG family of gauges is gaining acceptance worldwide [2]:

- **Robust and compact design**

The aluminum-bronze gauge housing has superior chemical and mechanical properties

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— 02 Because it measures independent of environment, the MTG gauge can be located close to the roll gap, even interstand. Covered by heavy-duty fiberglass reinforced epoxy plate, the electric coil in the MTG gauge head is protected from impacts and shocks originating from the metal strip.

— 03 The PEC response, generated by a small magnetic field, is only influenced by thickness and resistivity; this allows the MTG gauge to measure true thickness independent of environment.

— 04 The schematic illustrates the procedure by which the High-pass Mode measures thickness variations for thin aluminum strip.

that protect the gauge from the harsh mill conditions →01.

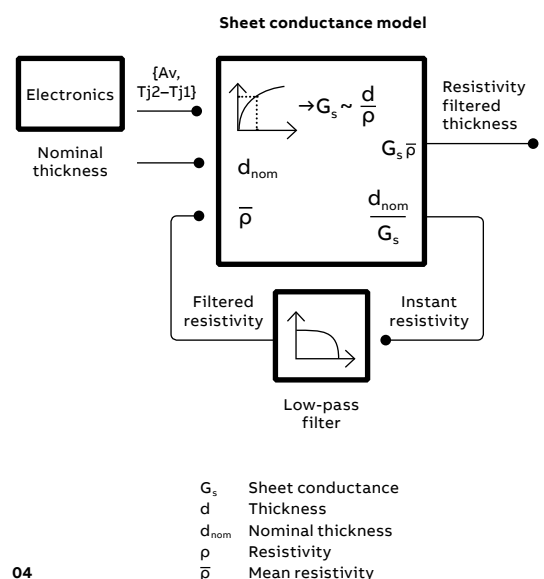
- **Gapless**  
The gauge is gapless, with nothing above the pass line that can obstruct the strip passage →02. Consisting of one sensing element box, the MTG Box Gauge head can be installed below the mill table for protection during threading, tail out and strip breaks.
- **Alloy independence**  
Amazingly, the PEC sensing technology measures true thickness independent of material composition →03 with no need for alloy compensation.
- **Independent of mill environment**  
The gauge is insensitive to anything, eg, coolant, steam or dirt, except for the metal strip in the measuring zone and is therefore ideal for interstand applications.
- **Tight thickness tolerances**  
Alloy chemical variations will not influence the alloy independent MTG gauge. The harsh environment (eg, lubricants) will not impact the measurements either. With an accuracy, in the mill, of  $+1.5 \mu\text{m} \pm 0.05$  percent, metal strip producers can form the desired thickness at the tolerances demanded.
- **Safe for humans and the environment**  
Because the MTG gauge does not rely on radiation-based technology, health and environmental concerns are eliminated. No restricted areas are required, nor is it necessary to dispose of radioactive waste.
- **Infrequent and rapid calibration**  
The gauge arrives calibrated along with 12 calibration plates. Once in use, calibration is performed every six months and can be conducted in only 20 min. The calibration plates ensure that the gauge measures absolute thickness and thickness deviations according to traceable standards.
- **Negligible costs for maintenance**  
Without fragile or aging components, radiation sources or detectors, high voltage transformers or precision mechanics, the MTG gauge is nearly maintenance-free.
- **Increased mill production time**  
Gauge measurements are material-independent so there is less downtime due to reduced need for calibration and maintenance.
- **Short and competitive return on investment (ROI)**  
By reducing mill downtime, non-conforming material, maintenance, need for spare parts, frequent calibration and security requirements for radiation-based technology, the MTG is a cost-effective alternative to radiation-based devices, with a short ROI.

### Stretching the limits

In operation for over 15 years, the MTG with PEC technology allows strip producers to meet tight tolerances and replace their X-ray and contact gauges to improve their competitiveness for standard aluminum strip production. But, what if the measured signals of the MTG gauge could be used to measure thickness of very thin standard metal strip (thicknesses as low as 0.1 mm)? Currently, radiation-based gauges, X-ray and Beta-gauges can measure in this range with high

The MTG Box Gauge system with the revolutionary PEC technology determines resistivity and true strip thicknesses for aluminum.

speed/low noise. The mechanical contact gauges and the MTG C-frame gauge, with a rather small gauge gap, can also measure accurately in this range but only at the strip edge; no center measurements are possible. Most significantly, the safety and environmental costs associated with radiation-based gauges and the impracticality of mechanical gauges make these methods disadvantageous for aluminum strip producers.



### High-pass Mode

Always exploring ways to meet producer's needs, in 2019, ABB's researchers began investigating a MTG gauge function for thin strip aluminum measurement. Although absolute thickness cannot be directly measured for thin strip, ABB created an option that will, under specific conditions, determine thickness variations at high frequency (faster than 0.024 Hz), for thicknesses between 0.1 mm and 0.6 mm, and with a high signal-to-noise ratio: the High-pass Mode option [4]→04. Nonetheless, certain conditions must be met for the high pass filtered value of thickness to be calculated:

- Because persistent thickness changes that last more than 10 seconds will be zeroed, this function is only possible for use in feed forward control (interstand or entry side).
- The relative variation in resistivity of the material must be less than the relative variation of the thickness because in High-pass Mode conductance, which is the reciprocal of resistivity, reflects thickness →04.

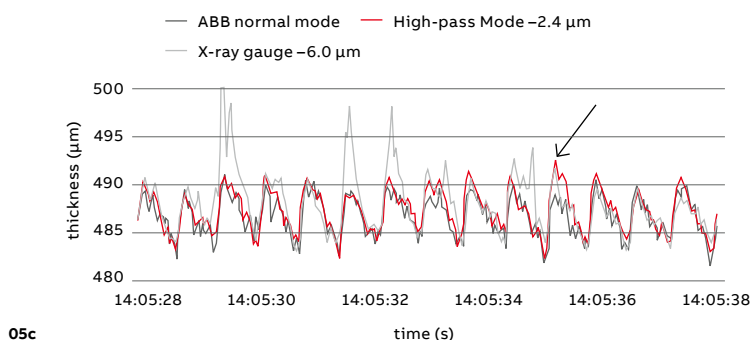
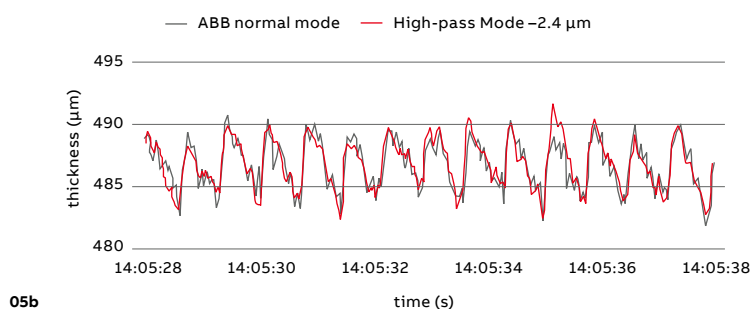
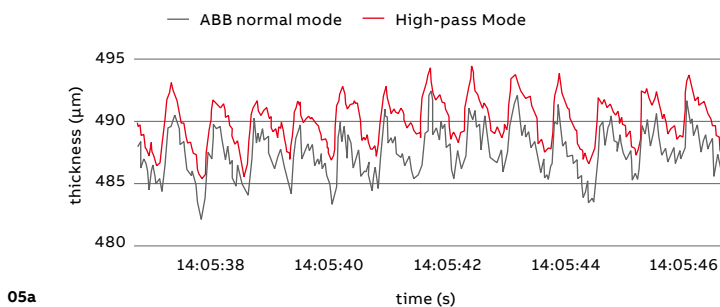
- For the signal to indicate thickness variations accurately the nominal thickness must be close to the actual average thickness.
- Because only rapid thickness variations are measured, any slow variations will not be detected.

### The path to thin strip measurements

ABB's innovative High-pass Mode will provide customers with a practical measurement option for gapless gauge measurement of deviations in thickness of thin aluminum strip. The signals are insensitive to the environment eg, lubricant, dirt or other non-conductive materials. The sound theoretical basis and rigorous testing demonstrate that slight variations in alloy content have, in practice, a negligible effect on the measured thickness.

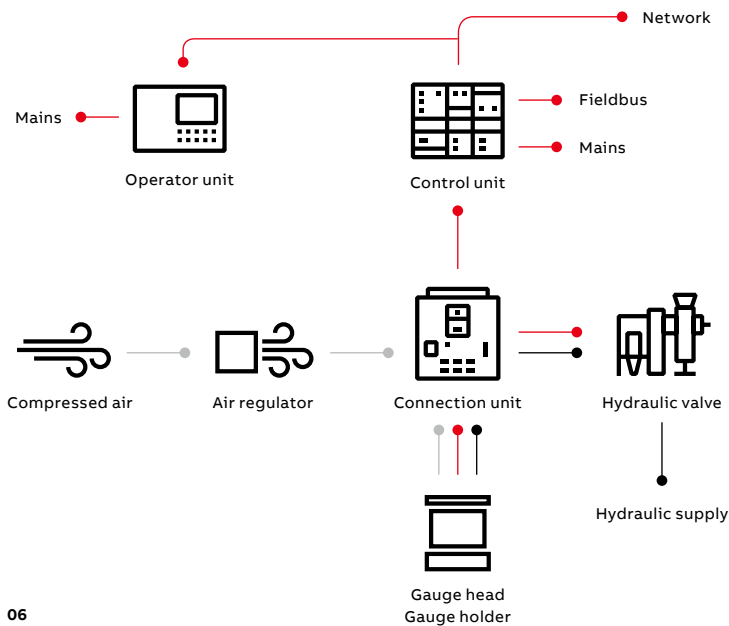
A comparison of ABB's Box gauge thickness variations measured in normal operating mode with those of the High-pass Mode for a thickness of 490  $\mu\text{m}$  was made →05. Although the MTG gauge measures true thickness independent of alloy composition, this becomes increasingly difficult as the strip becomes thinner due to the physics of electromagnetism. In this test case, the MTG gauge measures close to the lower limit of the method, which is slightly less than 0.5 mm, and therefore produces a measurement with greater fluctuations than comparable measurements generated by the High-pass Mode for a strip with a thickness of 490  $\mu\text{m}$  →05a.

However, the High-pass Mode does not measure absolute thickness, its signal variations are centered around the nominal thickness of the strip being measured. Nonetheless, a close correlation exists between the thickness variations of the High-pass Mode and the normal MTG Box gauge output when the mean resistivity is filtered using a 10 s running average. Resistivity variations that are faster than 10 s will, however, contribute



ABB's High-pass option can determine high frequency thickness variations for thicknesses between 0.1 mm and 0.6 mm.

to a thickness deviation error in High-pass Mode. Here, a drop in resistivity lasting only 0.5 s was noted →05b. Such a decrease, 0.4 n $\Omega\text{m}$  (0.7 percent), causes an erroneous increase in the thickness measured, 3.5  $\mu\text{m}$  (0.7 percent), in High-pass Mode as theoretically expected →05b.



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05 Results show the efficacy of the High-pass Mode in comparison with the MTG Box gauge and the X-ray gauge.

05a The input thickness measurement of a cold rolled strip (for 10 s) with a nominal thickness of 490  $\mu\text{m}$  (actual thickness is a few microns less than the nominal thickness) with output signals is shown.

05b The resistivity decrease (0.4 n $\Omega\text{m}$ ) leads to an erroneous increase in the thickness measured in High-pass Mode by 3.5  $\mu\text{m}$  (0.7 percent). The High-pass Mode signal has been compensated for the difference in absolute magnitude in order to make the comparison easier.

05c The small resistivity change measured in High-pass Mode also affects an X-ray gauge used to measure strip thickness. The thickness measured by the ABB gauge in normal mode is alloy independent, but not in the High-pass Mode.

06 The MTG system is a smart measurement system designed for optimal commissioning, operation and service.

Comparison of the MTG gauge strip thickness measurements with measurements obtained from an X-ray gauge indicate that slight local changes in the alloy composition of the strip will also affect the X-ray gauge measurements →05c.

Such encouraging results not only corroborate the theoretical expectations, they demonstrate that ABB's High-pass Mode filtered thickness variations are comparable to those obtained from the MTG gauge and X-ray methods as long as the specific conditions are met.

### The MTG system – working together for dependability and accuracy

The MTG system (gauge head, control and operator unit, air regulator, hydraulics and the connection unit) have been designed for ease-of-use, optimal function, dependability, connectivity and integration ability →06 and can be connected to Automatic Gauge Control (AGC) systems in mills for feed forward, feedback and mass-flow control. With multiple integration interfaces, eg, Profibus-DP fieldbus communication, network communication via VIP, OPC DA, and Modbus TCP, an operation unit (to adjust set-ups, thickness value and status

information), Human Machine Interface (to view thickness deviations as real-time data and trends), diagnostics part for error information, etc. and a service part (for calibration, manual control function, and service-based use case) the systems is flexible and operator friendly and efficient.

Mounted on a vertically moving frame, the gauge adjusts automatically to the right measuring distance via a hydraulic positioning system; rapid positioning allows measurements to be made almost instantaneously, when tension comes on. In this way the thickness-controlled strip length can be maximized. Changes in the distance caused by small changes in speed or tension are corrected for automatically.

The integration of system components and outstanding capabilities of each device and unit allows metal producers to attain specified thickness within tolerances 24/7, safely, with negligible costs for maintenance. The MTG system with

With the High-pass Mode option, producers will be able to control thin strip thickness deviations in feed forward control.

the gapless gauge and PEC technology enables accurate true aluminum thickness measurements. The material independence, environmental and safety benefits, and quick commissioning time results in increased productivity and higher yields for standard metal strip producers in a sustainable process [2,4].

Thanks to ABB's new High-pass Mode option, producers will soon be able to control thickness deviations of thin aluminum strip in feed forward control, thereby enabling aluminum producers to meet the ever-increasing tolerance requirements and access new markets. •

### References

[1] Market Watch, "What are the key market trends impacting the growth of the automotive lightweight material market?" in *Market Watch*, July 16, 2020. Available: <https://www.marketwatch.com/press-release/>

what-are-the-key-market-trends-impacting-the-growth-of-the-automotive-lightweight-material-market-2020-07-16. Accessed July 18, 2020.

[2] L. Thegel and E. Wadman, "Non-ferrous

metal thickness gauges", *ABB Review*, 1/2017, pp. 40–45.

[3] ABB, Measure IT Pulsed Eddy Current technology: Operating Principle, *Automation Technologies*, 2004-05, pp. 1–6.

[4] ABB, Millmate thickness gauging systems; imagine outstanding dependability, *ABB AB Industrial Automation*, 2020, pp. 1-11. Available: [www.abb.com/thicknessgauging](http://www.abb.com/thicknessgauging)



## PRODUCTIVITY

# The road to automated engineering

Automation engineers still must create much control logic and process graphics by hand. The DEXPI (Data Exchange in the Process Industry) initiative aims to automate such tasks by standardizing plant topology models. ABB research demonstrated how these models could save costs and increase quality.

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01 Automation of control logic and process graphic creation can save time and cost and increase quality.

Creating control logic and process graphics for control and monitoring systems such as ABB Extended Automation System 800xA, ABB Ability™ Symphony Plus, or ABB Freelance still requires a significant amount of manual work. While engineering libraries provide low-level reuse and bulk engineering tools automate the handling of I/O lists, automation engineers must still translate many customer specifications by hand. Consequently, the DEXPI industry initiative – supported by BASF, Equinor and Bayer – is currently working on standardized plant topology models to automate additional engineering tasks [1]. An ABB research project demonstrated how these models could save costs and increase quality. The findings are based on the analysis of four plant specifications from recently executed System 800xA projects.

#### Plant engineering today

Today's process engineers specify piping and instrumentation diagrams (P&IDs) as blueprints for the automation of a production process →01. These drawings describe the required equipment – such as tanks, pumps, motors, and valves – and instrumentation, eg, sensors for temperature, flow, level and pressure. Although there are naming conventions and industry standards for the shapes of the components in P&IDs, different computer-aided design (CAD) tools offer process engineers a lot of freedom. They can create custom shapes, add free-text annotations and unintentionally draw unconnected pipes – all of which complicates algorithmic analysis and prevents automated processing of the encoded information.

Consequently, P&IDs are often exchanged as PDF files (or even printouts) from which control logic and process graphics are manually derived by automation engineers. Based on their experience, the engineers can compensate for some semantical ambiguities (eg, shapes that do not fully conform with standards). However, they also often encounter inconsistency or incompleteness in the diagrams in relation to other specification documents, which leads to time-consuming communication feedback loops with the process engineers.

A few CAD tools already feature support for so-called Smart P&IDs, but these are not yet widely used in the industry. Smart P&IDs include a database that contains structured tables of the encoded information (eg, instrumentation lists) and metadata for the drawn items (eg, pipe diameter, alarm limits, etc.). Algorithms can process such structured information much more easily than drawings consisting of generic boxes, lines and circles. Currently, Smart P&IDs are usually stored in formats specific to a particular CAD tool, which complicates the construction of software tool chains.

#### Topology engineering

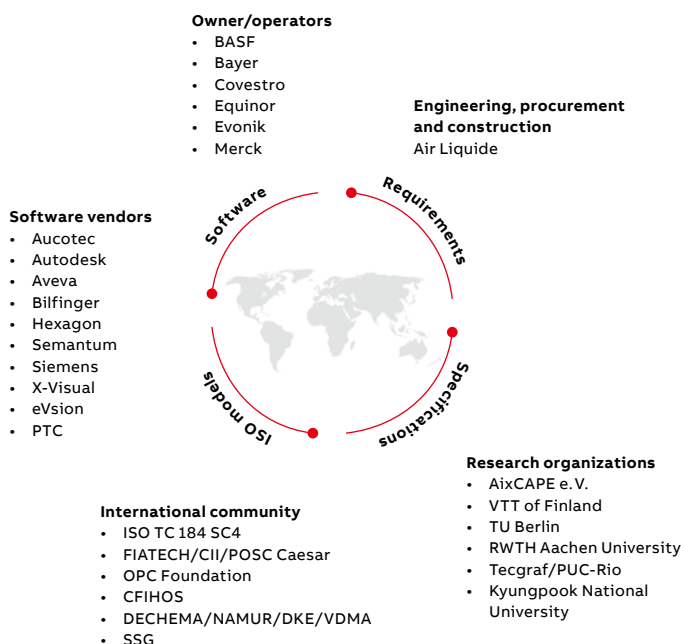
Since 2011, the DEXPI initiative has worked on a common P&ID specification standard, expressed as object-oriented concepts in an XML file format. This standard can be considered to be a standardized version of Smart P&IDs. The specification captures both drawing information (eg, graphical coordinates and drawing instructions) and abstract models of equipment, instruments and their dependencies. The latter are also called “topology models” since they express the plant topology as a kind of network, analogous to the topologies of electronic circuits or computer networks [2]. The initiative is driven by large automation customers, such as BASF, Bayer,

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A few CAD tools already support so-called Smart P&IDs, but these are not yet widely used.

Covestro, Equinor, Evonik and Merck. All major CAD tool vendors are also involved, for example, Autodesk, Aveva, Hexagon and Siemens →02. The specification has matured in recent years (Version 1.2 was released in 2020) and CAD tool vendors frequently participate in DEXPI working group hackathons (intense software development sessions) to test the DEXPI XML importers and exporters that will find their way into the next product release.

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Topology models are at the center of “topology engineering,” developed over the past few years in scientific communities, which aims at utilizing topological information to carry out engineering tasks. Standardized models in DEXPI XML file format allow tasks that are currently performed manually to be automated:

- Control logic generation. To some extent, interlocking logic and state-based control can be derived from plant topology models [3].
- Process graphics generation. The graphical layout derived from a P&ID and encoded in a topology model can serve as a template for the creation of human-machine interfaces for plant operators.
- Simulation generation. Topology models can be mapped to object types in simulation frameworks (eg, Modelica), thereby creating low-fidelity plant simulators to use in factory acceptance tests and to train operators.
- Root-cause analysis. The operator can query plant topology models to investigate the root causes of anomalies [2].
- Alarm management. Cascades of alarm messages in an industrial plant may overload human operators; plant topology models can be used to limit such “alarm floods.”

#### CAYENNE Topology Editor

A recent ABB research project has implemented a prototype software tool called “CAYENNE Topology Editor” to demonstrate the possible

automation of engineering tasks using plant topology models. The tool supports the creation of plant topology models from DEXPI XML files, from Microsoft Visio P&IDs and from proprietary SmartPlant P&ID exports →03. In brownfield projects, topology models can also be derived from existing 800xA process graphics, which contain coarse-grained topological information. Users can inspect and edit imported topology models visually.

The CAYENNE tool provides a control-logic generator that can synthesize interlocking logic from the topology models. A rule engine supports the generator and applies predefined, domain-specific rules to topology models in order to generate the control logic. For example, if a level indicator on a tank issues a “low” alarm, a pump on an outlet of this tank is stopped. The rule engine traverses the topology model and searches for the pattern encoded in the rule. Once a match is found, it retrieves the

The Cayenne tool provides a control-logic generator that can synthesize interlocking logic from the topology models.

relevant tag names and generates the required control logic, conditionally linking the alarm condition signal for the cause to the control signal relating to the effect. The tool supports the generation of System 800xA Control Builder M control diagrams and function block diagrams. In addition, IEC 61131-11 Structured Text can be generated, as well as cause-and-effect matrices.

#### CAYENNE process graphics generator

Also provided by the CAYENNE tool is a process graphics generator, which maps the layout imported from a P&ID to the shapes contained in an ABB System 800xA engineering library. This enables the partial generation of System 800xA process graphics, which can then be completed manually by an automation engineer. The tool supports generating equipment, instruments and pipes. The positions and sizes of the shapes are preserved, which involves translating between the graphical coordinate system of the topology model and the process graphic. This mapping can be customized for different System 800xA engineering libraries so that their specific shapes can be displayed in the process graphics. This procedure has been demonstrated for the System 800xA “standard” library and the

— 02 DEXPI initiative – a common P&ID XML file format for CAD tools.

— 03 Topology engineering: from P&ID via topology model to control logic and process graphics.

“reuse” library that is normally used for oil and gas plants.

#### Integration with AUCOTEC’s Engineering Base

The CAYENNE Topology Editor has been integrated with AUCOTEC’s Engineering Base tool – used by ABB in greenfield projects – as a prototype. AUCOTEC is currently implementing a DEXPI XML importer for Engineering Base, which will enable ABB’s Plant Data Processing (PDP)

ABB conducted four retrospective studies on specifications from automation projects already in operation.

Tool to be combined with a topology model. The CAYENNE Topology Editor can generate process graphics from Engineering Base as well as create interlocking logic that “glues” together the function blocks generated by the tool.

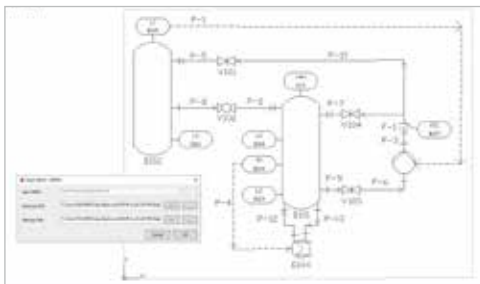
#### Case studies

To evaluate topology engineering and to investigate if the CAYENNE Topology Editor could have sped up engineering, ABB conducted four retrospective studies on specifications from automation projects in plants already erected and automated [4]:

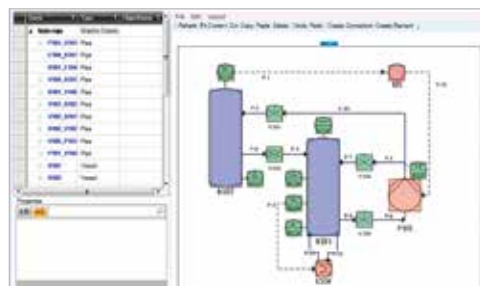
- A mid-sized fertilizer production plant in South America with around 1,000 I/Os →04. The evaluated plant segment contained 18 vessels, eight pumps and a reactor.
- A fuel production plant (4,000 I/Os) in South America.
- An oil separation process (400 I/Os) in the Middle East that featured separation vessels, instrumentation and a sophisticated piping structure.
- An upstream oil production process (7,000 I/Os) in South America →05. This process included a large number of parallel, similar pipelines and instrumentation, so only a selection was analyzed.

For each case, a research team analyzed the EPC plant specifications and selected a representative plant segment, which consisted of 10 to 20

#### AutoCAD Plant3D



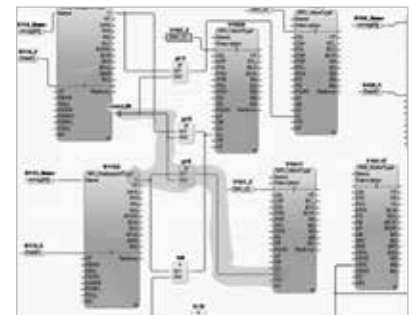
DEXPI



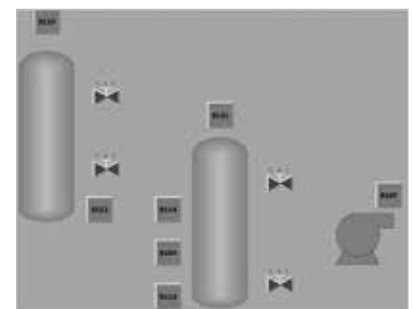
Topology model

Generate

#### 800xA Control Builder



Interlocking code



800xA PG2 graphics



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P&IDs per case. Afterward, topology models for the CAYENNE Topology Editor were created. As the P&IDs were only available as PDF files, this work required the redrawing of the P&IDs in formats supported by the CAYENNE tooling. For example, the research team created Microsoft Visio P&IDs based on the PDF files, which took roughly one day per case. Once EPCs export their P&ID files in the DEXPI XML file format, this step can be omitted. Importing the created files into the CAYENNE Topology editor yielded the required topology model.

Afterward, the research team analyzed around 50 to 100 interlocks per case, specified in cause-and-effect matrices. For each cause/effect pair, the connecting process topology path within

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**Based on the case studies, the estimated cost savings for process graphics generation are even higher – around 50 percent.**

the P&ID was looked up. By comparing this part to the path of other cause/effect pairs, generic interlock concepts were identified and encoded as rules. For example, a commonly observed pattern was that if a pressure sensor raised a

“high” alarm, a preceding valve needed to be closed. For many interlocks the generic rule needed to be defined only once and could later be applied multiple times. If these rules had been available before the project, the cause-and-effect matrices could have been generated to a large extent using the CAYENNE Topology Editor.

In total, 91 percent of the interlocks in the case studies could be generated by rules. The case studies yielded 92 interlocking rules in total, 73 percent of which were classified as “generic,” meaning that they would likely apply in other plants. The remaining 27 percent of the rules contained plant-specific patterns that may hold only for very similar plants; the effort expended on these is only justified if they occur numerous times within the plant.

A few (7 percent) of the rules were applicable across all four case studies. The reason for this low percentage is the plants’ heterogeneity: Where, for example, fertilizer production mainly concerns level measurements, the upstream oil production almost exclusively concerns pressure measurements in pipelines. Selecting cases with greater similarity (eg, five fertilizer plants) would likely increase the cross-case reuse of interlocking rules significantly.

**Estimated cost saved by interlock generation and the elimination of manual coding and testing**





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04 The specifications for this fertilizer production plant were used to test automated engineering using topology models.

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05 Upstream oil and gas production: Many interlocks could be generated based on topology models for an installation such as the one shown here.

is around 15 percent of the overall effort for control logic engineering. Human error sources are also removed. Based on the case studies, the estimated cost savings for process graphics generation are even higher, at around 50 percent.

#### **A significant step toward automating engineering**

Topology models are key elements for automation of engineering tasks for ABB's System 800xA, ABB Symphony Plus Operations and ABB Freelance. All major vendors of CAD tools are

for operator training in the past. To reap the benefits of topology models, more case studies need to be conducted to improve tooling and concepts. The required software tooling will be optimized for usability and integrated into other engineering tools. This step will take the automation industry a long way down the road to fully automated engineering. •

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Topology models are key elements for automation of engineering tasks.

working on support for the recently developed DEXPI XML standard for PIDs. Topology models extracted from these diagrams enable partial control logic and process graphics generation and have been used to generate plant simulators

#### **References**

- [1] <https://dexpi.org/>
- [2] E. Arroyo *et al.*, "From paper to digital," *ABB Review* 1/2016, pp. 65–69.
- [3] Schlegel M. *et al.*, "A combined analysis of plant connectivity and alarm logs to reduce the number of alerts in an automation system," *Journal of Process Control*, 23(6), pp. 839–851, 2013.
- [4] Drath R. *et al.*, "Computer-aided design and implementation of interlock control code," *2006 IEEE Conference on Computer Aided Control System Design, 2006 IEEE International Conference on Control Applications, 2006 IEEE International Symposium on Intelligent Control*, pp. 2,653–2,658, October 2006.





## PRODUCTIVITY

# New MP<sup>3</sup>C control method maximizes efficiency and dynamics

For electric drive applications in marine, mining, metals, process, and hybrid industries, ABB has developed Model Predictive Pulse Pattern Control (MP<sup>3</sup>C) to maximize efficiency and motor friendliness while preserving the superb dynamic performance and robustness of Direct Torque Control (DTC).

01 ABB's marine propulsion Azipod® relies on precisely controlled VSDs to achieve lower fuel consumption, superior maneuverability and fast power adjustments.

02 ACS6080 with MP<sup>3</sup>C control was launched in 2019.

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Today's ships depend on advanced technology and superior performance to efficiently navigate the world's oceans even in harsh marine environments →01. Fuel efficiency is critical to lower the cost of shipping and has the additional benefit of lowering CO<sub>2</sub> emissions [1]. ABB's marine propulsion Azipod® family lowers fuel consumption and achieves superior maneuverability and fast power adjustments, eg, for ice breakers, thereby helping the shipping industry meet sustainability targets while reducing costs [2]. But, how does

the Azipod® electric propulsion accomplish this even in the ice-packed regions of the world's oceans? Azipod®'s gearless steerable propulsion system utilizes an electric motor located in a pod beneath the hull of the ship, which can rotate 360 degrees, permitting thrust in all directions. For this amazing feat, variable speed drives (VSD) are required that need to be precisely controlled. This necessitates motor friendliness (to minimize the motor temperature, noise and vibration) and superior dynamic performance,





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eg, during network events; the high power also mandates low switching frequencies. Enter ABB's breakthrough technology: Model Predictive Pulse Pattern Control (MP<sup>3</sup>C) to maximize operating efficiency and attain superb dynamic performance for such electric drives →02.

#### **Achieving propulsion drive power and efficiency**

For systems such as Azipod®, propulsion drive power is regulated by the power electronics converter, which controls the speed by varying motor frequency and voltage. If a network disturbance occurs, and it easily can, the control system must maintain the dc-link voltage adequately to keep

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To allow thrust in all directions, the Azipod® electric propulsion system relies on VSDs that need to be precisely controlled.

the drive system functioning safely. To increase efficiency, the number of switching events per fundamental cycle must be kept at a minimum. Moreover, the energy stored in the dc-link capacitors is typically reduced to a minimum to increase safety in the event of medium-voltage (MV) faults.

Switching induces current and torque ripples that entail mechanical vibrations; these tend to be pronounced at low switching frequencies. Moreover, ice breakers operating in polar regions must meet strict underwater noise limits to minimize the adverse impact on marine wildlife. Traditional converter control methods require high switching frequencies to meet these noise limits, incurring high converter losses. Achieving these boundary conditions is essential but arduous for traditional control methods. Now, ABB's MP<sup>3</sup>C applied to VSDs opens up the possibility to achieve them all.

#### **Delivering dynamic performance with ACS6080 and MP<sup>3</sup>C**

Saving energy, maintaining safety and incorporating quick, exact and robust control is also crucial for process industries. For the mining and metals sector, both cold and hot rolling mills rely on control of the rotational speed and the torque of the roll to achieve high quality products. Because the material enters and leaves the roll abruptly, rapid load changes between no load and full load make torque control difficult →03.

Despite these requirements, harmonic distortions result in harmonic losses and the need for additional cooling and oversized machines. Finding the right drive with the right control and lowering harmonic losses for critical applications is a key goal of ABB. Reducing losses leads to greater efficiency and hence more



— 03 ACS6080 with MP<sup>3</sup>C control lowers harmonic losses, thereby improving efficiency and sustainability in both hot and cold rolling mills.

— 04 Only MP<sup>3</sup>C achieves both superb dynamic performance, as does DTC, and excellent harmonic performance, as does DTC, and excellent harmonic performance, exemplified by OPPs during steady-state conditions.

sustainability. Enter ABB's ACS6080 drive with the breakthrough technology MP<sup>3</sup>C to control the semiconductors. Developed over the past decade, this control method maximizes dynamic performance and efficiency and minimizes harmonic distortions to deliver optimal motor operation in all situations.

#### Control methodologies: a brief history

For many decades, combining superior harmonic performance (especially the ability to minimize distortions per switching frequency) with excellent dynamics has been elusive and fraught with compromise.

Direct Torque Control (DTC), developed in the 1980s, and Field-oriented Control (FOC) showcase this dilemma →04. Because DTC uses a sampling frequency (about 40 kHz) and relies on hysteresis controllers with a switching table to control the electromagnetic torque and the magnetization of the electric machine, torque response is fast and precise. The result is a superb dynamic performance of the drive and a system robust to dc-link fluctuations and other disturbances.

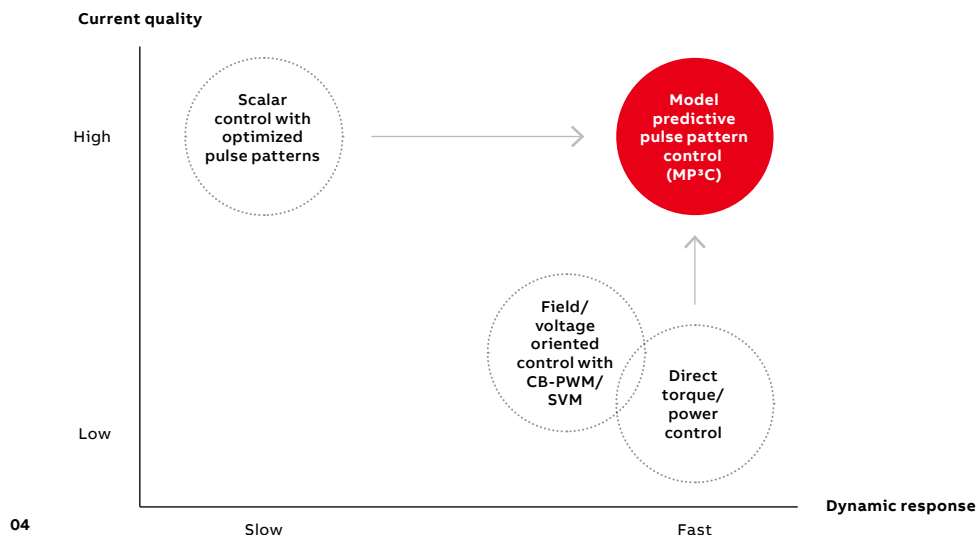
Alternatively, FOC, set in a rotating orthogonal reference frame, uses linear controllers that provide voltage references to a Pulse Width Modulator (PWM) based on Carrier-based PWM (CB-PWM) or Space Vector Modulation (SVM). Since MV converters operate at low switching frequencies (few hundred Hertz), the pulse number (switching

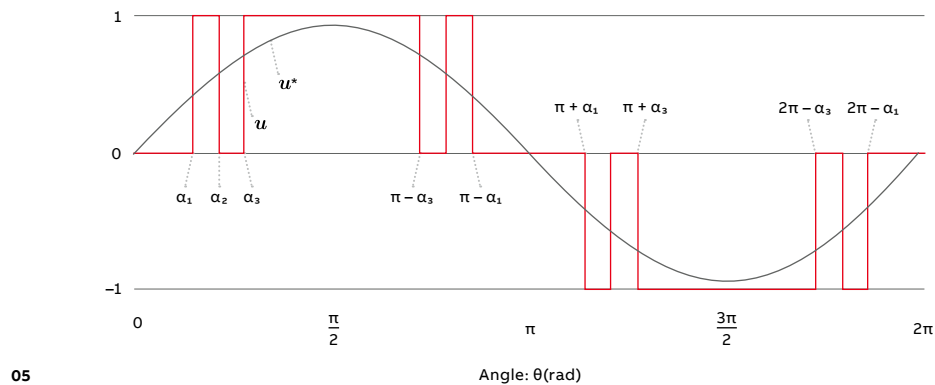
frequency over fundamental frequency) is less than 10, leading to large harmonic distortions. Moreover, the sampling frequency of the linear field-oriented controller is four times the switching frequency (here, around 1 kHz). This limits the

— ABB's desire to provide power savings without compromising dynamic performance led to the development of MP<sup>3</sup>C.

bandwidth of the controller, making it slow and resulting in a poor dynamic performance and poor rejection of disturbances →04.

These disadvantages can be overcome with the help of Optimized Pulse Patterns (OPPs) that minimize the current distortions for a given switching frequency – a superior choice for MV converter systems →05. However, achieving high-bandwidth control with linear controllers and OPPs is intrinsically difficult because strong current ripples adversely affect the controller. Using a slow control loop, eg, volts per frequency control for OPPs, is theoretically possible but is impractical for most MV drives applications. During torque reference changes or when transitions between pulse patterns occur, the controller does not react fast enough,





leading to excessive transient currents and poor dynamic performance.

The small dc-link energy stored in MV systems (energy stored < 5 ms) requires a fast torque reversal during network events to avoid dc-link over- or under-voltages. Thus, traditionally, DTC or FOC methods have been used in lieu of OPP-based schemes.

ABB's 45 years of experience developing VSDs including DTC – an ABB innovation – has enabled unprecedented performance in electric motors and delivered dramatic energy savings by matching motor speed and torque to actual requirements of the driven load. This desire to provide efficiency and power savings without compromising dynamic performance led to the development of MP<sup>3</sup>C – the ultimate control system for the most demanding applications.

#### Finding the balance

With MP<sup>3</sup>C, ABB has found the sweet spot – where enhanced dynamic performance meets excellent harmonic performance, exemplified by OPPs during steady-state conditions → 04.

Here, ABB employs a well-known approach, Model Predictive Control (MPC), in which a mathematical model of the controlled drive system predicts its future evolution over a prediction horizon and chooses the best control input by solving a mathematical optimization problem. Once accomplished, the system obtains new measurements and re-plans over a shifted or receding horizon [3].

#### Superb control principle with MP<sup>3</sup>C

Basically, MP<sup>3</sup>C combines MPC with OPP technology; OPPs provide minimal harmonic distortions per switching frequency and MPC tracks the ideal

stator flux trajectory of the OPP by minimizing a cost function and manipulating the switching instants of the OPP [4]. Using a high sampling frequency (40 kHz) with receding horizon policy, a fast dynamic response and superior disturbance rejection is attained.

In OPPs, the fixed modulation interval of classic PWM, with two switching transitions per phase and modulation interval, is abandoned. Instead, OPPs are computed offline by calculating the optimal switching angles and switching transitions to minimize the current distortions for a given switching frequency. Quarter and half-wave

—  
MP<sup>3</sup>C maximizes operating efficiency and attains superb dynamic performance for electric drives.

symmetry is typically imposed. Assuming an inductive load, the current distortions are proportional to the sum of the squared-differential-mode voltage harmonics divided by the harmonic order. The optimal switching angles,  $\alpha_i$ , and switching transitions,  $\Delta u_i$ , can then be calculated for a given modulation index,  $m$ , and pulse number,  $d$ , minimizing the current distortions:

$$\begin{aligned} &\underset{\alpha_i}{\text{minimize}} \quad \sum_{n=5,7,\dots} \left( \frac{1}{n^2} \sum_{i=1}^d \Delta u_i \cos(n\alpha_i) \right)^2 \\ &\text{subject to} \quad \frac{4}{\pi} \sum_{i=1}^d \Delta u_i \cos(\alpha_i) = m \\ &\quad 0 \leq \alpha_1 \leq \alpha_2 \leq \dots \leq \alpha_d \leq \frac{\pi}{2} \end{aligned}$$

05 The switching waveform of an OPP (with the pulse number,  $d$ , the switching transitions per phase and quarter wave) illustrates minimal current distortions for a given switching frequency for an inductive load.

06 The control principle of MP<sup>3</sup>C is illustrated with the stator flux trajectory, stator flux correction and trajectory tracking. Rotor flux vector  $\psi_r$ ,  $\psi_{s, \text{opp}}$ , stator flux vector  $\psi_{s, \text{opp}}$ , reference stator flux vector  $\psi_{s, \text{ref}}$  and stator flux error  $\psi_{s, \text{err}}$  are shown in stationary orthogonal coordinates.

06a The optimal stator flux trajectory (minimum THD) is derived by integrating the OPP as shown.

06b The Stator flux vector is modified by manipulating the time-instants of the switching transitions (shown here in phase a). Fast closed-loop control is achieved.

06c Trajectory tracking of MP<sup>3</sup>C is achieved by regulating the stator flux along the stator flux reference trajectory (integral of the OPP). This minimizes the current TDD.

The modulation index corresponds to the output voltage and the pulse number relates to the switching frequency.

The reference trajectory of the stator flux vector results from the integrations of the stator voltage of the OPP over time →06. Per definition, this trajectory is optimal; tracking the trajectory tightly, the Total Demand Distortion (TDD) of the stator currents is minimized by modifying the time-instants of the switching transitions accordingly – important in the presence of large disturbances, eg, a strong dc-link voltage ripple. By tightly tracking the stator flux reference trajectory, MP<sup>3</sup>C achieves a close-to-optimal harmonic current spectrum and minimizes the adverse impact of the dc-link voltage ripple on the stator current TDD.

#### Evidence-based performance yields benefits

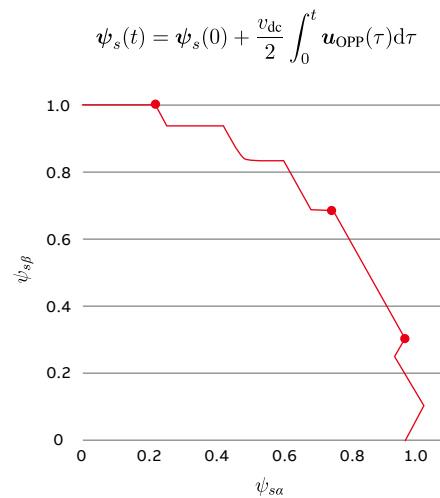
Simulations, lab and field experimental results demonstrate the superiority of MP<sup>3</sup>C compared to conventional methods. For instance, the trade-off between the inverter losses and the harmonic losses of machines when varying the switching frequency show that MP<sup>3</sup>C performs

In 2019, ABB launched the ACS6080 drive with MP<sup>3</sup>C for superb control and best-in-class drive train optimization.

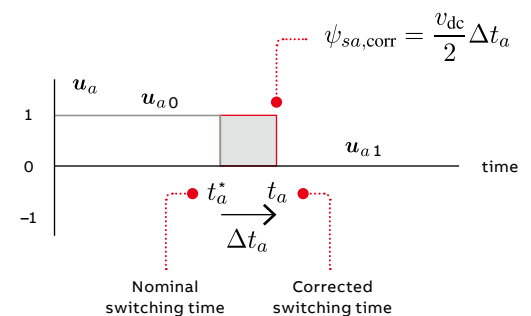
better than FOC in terms of losses →07a. Here, MP<sup>3</sup>C with a pulse number of three achieves a total loss reduction of 25 kW with respect to SVM (carrier ratio nine). This can positively impact both capital and operating costs. Assuming an electricity price of 80 Euro per MWh, the loss reduction of 25 kW would reduce the annual electricity bill by 17,500 Euros.

Similar benefits are observed in terms of reduced TDD →07b. Because lower stator current distortions imply lower torque distortions, the air gap torque TDD can be reduced for similar inverter losses for MP<sup>3</sup>C compared to FOC with SVM. The lower mechanical and thermal stresses extend the lifespan of electric machines and prolong maintenance intervals, ultimately translating to lower operational expenditure (opex).

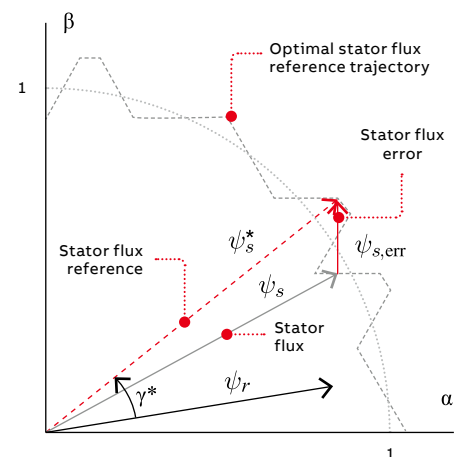
Results obtained for a 3.3 kV induction machine rated at 1,140 kVA affirmed the efficacy of MP<sup>3</sup>C



06a

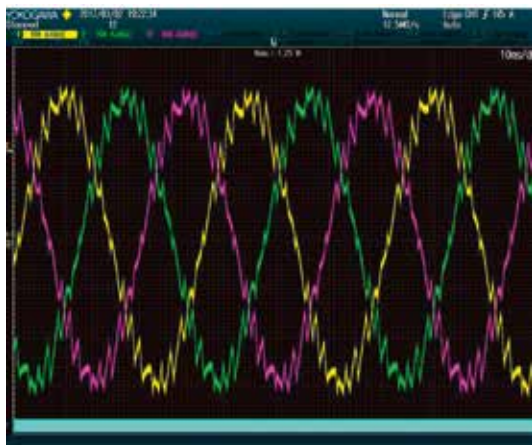
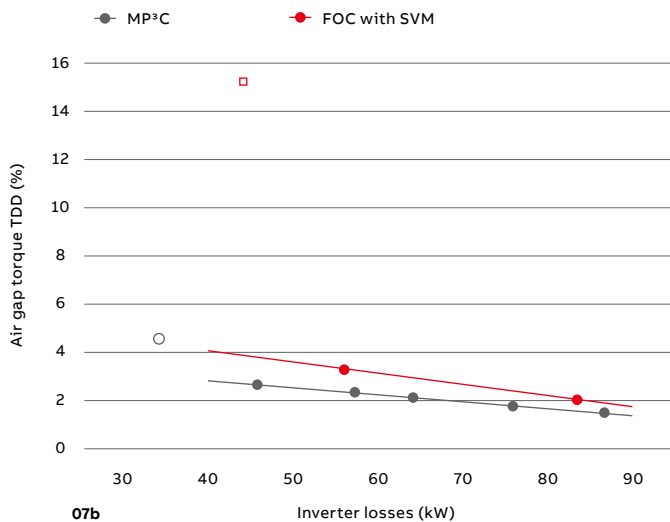
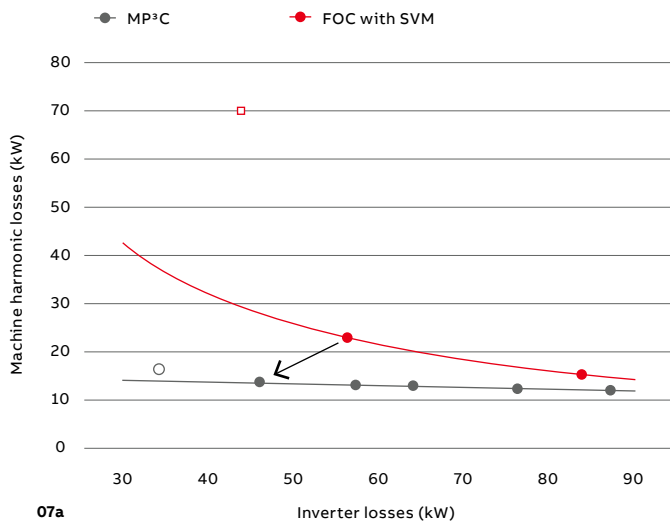


06b



06c





08

→08. Here, MP³C achieves a nearly optimum ratio of harmonic current distortions per switching frequency at steady state. Moreover, during transients, very short current and torque responses are achieved that are similar to those of DTC, if additional pulses can be inserted when required [5].

Thanks to MP³C's low harmonic distortions at low pulse numbers, increasing the fundamental frequency is possible. This increases the system design space for applications such as compressors, which require high-speed motors. By increasing the output speed of the drive, the size and weight of an additional gearbox can be decreased or avoided, leading to significant cost savings in terms of initial investment, the capital expenditure (capex).

#### MP³C use cases

ABB's ACS6000 MV drives have been used to achieve fully controllable testing conditions for test stands. In one case, ABB examined the problem of excessively high temperatures observed for machines connected to the

ABB delivered the first ACS6080 drive used in a pumped storage power plant that utilizes MP³C technology.

ACS6000 drive, which limited the power achieved by the motor test stand. The use of MP³C lowered the motor temperature (eg, 40 K instead of 65 K) and reduced harmonic distortion of the motor currents. The test stand could then be operated at a higher power – a solid result.

Moreover, ABB has delivered the first ACS6080 used in a pumped storage power plant, utilizing MP³C. By combining the benefits of high efficiency and higher output frequency, MP³C opens up new possibilities for customers to modernize their existing frequency converter system.

#### Best in class: ACS6080 drive with MP³C

In 2019, ABB launched the ACS6080 drive with MP³C for superb control and best-in-class drive train optimization. In several important cases, higher system efficiency and motor output power compared with conventional systems is attained: the output power can be increased at high fundamental frequencies. Overall, ABB's

07 Simulation results demonstrate the superiority of MP<sup>3</sup>C over FOC schemes in terms of inverter losses and torque distortions.

07a MP<sup>3</sup>C performs better than FOC in terms of inverter losses when the switching frequency is varied. For both MP<sup>3</sup>C (black circles) and FOC (red circles), a regression line is included as a guide (the non-solid data points were considered outliers).

07b Use of MP<sup>3</sup>C reduces the torque TDD by 33 percent in this case. Comparison of SVM with the carrier ratio 9 and MP<sup>3</sup>C with pulse number 4 shows a reduction of the torque TDD from 3.3 percent to 2.2 percent.

08 MP<sup>3</sup>C achieves a nearly optimum ratio of harmonic current distortions per switching frequency at steady state. Steady state stator current waveforms at a fundamental frequency of 30 Hz and at 60 percent of the rated machine torque are shown. For pulse number 5, the switching frequency is 150 Hz and the TDD of the current is 8.7 percent.

09 The mining industry together with marine, metals, process and hybrid industries can benefit from ABB's innovative technology for electric drive applications.

ACS6080 drive with MP<sup>3</sup>C control results in lower capex (lower initial investment and system cost optimization) and reduced opex, such as lower running- and maintenance costs.

By combining MPC with OPP, ABB's new MP<sup>3</sup>C with ACS6080 meets industry's demand for low current distortions and high dynamic performance. Consequently, the metals and mining

ABB's MP<sup>3</sup>C technology pushes efficiency and motor friendliness to what is physically possible.

industries, the marine sector and industries that rely on test stand applications now have a beneficial additional degree of freedom →09. MP<sup>3</sup>C pushes efficiency and motor friendliness to what is physically possible while preserving the dynamic performance and robustness of DTC. •

## References

[1] ABB, "ABB Azipod® electric propulsion can save \$1.7 million in fuel costs annually, study shows", ABB Group Press Release, June 5, 2019, [Online]. Available: <https://new.abb.com/news/detail/24879/abb-azipodr-electric-propulsion-can-save-17-million-in-fuel-costs-annually-study-shows>. Accessed July 12, 2020.

[2] ABB, "ABB Azipod® takes marine propulsion to the North Pole and

beyond", ABB Group article, Aug. 23, 2019, [Online]. Available: <https://new.abb.com/news/detail/30623/abb-azipodr-takes-marine-propulsion-to-the-north-pole-and-beyond>. Accessed July 12, 2020.

[3] J. B. Rawlings and D. Q. Mayne. "Model predictive control: Theory and design", Nob Hill Publ., Madison, WI, USA, 2009.

[4] T. Geyer, et al., "Model Predictive Pulse Pattern Control", *IEEE Trans. on Industry Applications*, vol. 48, no 2, March/April 2012, pp. 663–676.

[5] T. Geyer and N. Oikonomou, "Model predictive pulse pattern control with very fast transient responses", in *Proc. IEEE Energy Convers. Congr. Expo.*, Pittsburgh, PA, USA, Sep. 2014.







01

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## PRODUCTIVITY

# Why robots are focusing on final assembly processes

In recent decades the automotive industry has automated a wide range of processes, including press automation, body shops, painting and engine and transmission assembly. But when it comes to final assembly, automation is still a big challenge. The reason is that areas such as cable plugging, wheel assembly, and installation of many other components are extremely complex.



—  
01 Example of an automotive assembly line at an ABB demo location.

—  
02 Compliant visual servoing. The technique uses feedback information extracted from a vision sensor to compensate for movements and vibrations.

Now, thanks to advances in ABB robotics and visual tracking technologies, these roadblocks are giving way to pilot applications. What is more, the technologies described in this article are expected to eventually be applicable in other fields that focus on unstable targets, such as logistics operations based on the use of automated guided vehicles.

Historically, automation of many automotive final assembly operations has been considered to be practically impossible. As a result, associated components were never conceived of or designed

## ABB's Visual Servoing technology uses feedback information from a vision sensor to compensate for movements and vibrations.

with current automation capabilities in mind. The result is that today's automotive final assembly lines →01 still overwhelmingly rely on dexterous human manipulation.

Fully automated lines in areas such as body-shop welding operate in "stop & go" mode, which facilitates the automation of different cells. Manually operated lines, on the other hand, move slowly and continuously, with car bodies transported by different conveyor types or, in advanced cases, on automated guided vehicles (AGVs). These systems, which are typically used in factories and warehouses, follow marked lines or wires on floors or use radio waves, vision cameras, magnets, or lasers for navigation. Regardless of whether the transport medium is a conveyor system or an AGV, movement takes place at a moderate speed of around 100 mm/s, which allows human operators to perform assembly tasks with the required level of safety.

For robots, however, such environments present a series of difficult challenges. For one thing, vehicle transport systems tend to be irregular, while floors can sometimes be uneven, resulting in shaking and vibrations. Thus, if a robot is to emulate human behavior in such an environment, it must be equipped with artificial vision. Current conventional vision systems are normally based on captures of static reference positions to locate target positions for assembly tasks. In this case, as car bodies move along a line, an additional capability is required: continuous vision tracking to cope with movements, irregularities and vibrations. This is designed to allow robots to continuously adapt their movement to a sequence of vision-captured reference images, with the frequency of the captures ranging between 20–50 per second.

Vision tracking is based on a technique known as Visual Servoing →02, which uses feedback information extracted from a vision sensor to compensate for movements and vibrations. Here, instead of moving according to a programmed path as a conventional robot would, the robot's movements are guided by the information provided by vision sensor(s). With regard to ABB robots, this functionality, which is called External Guided Motion (EGM), can update guidance inputs every 4 ms, thus resulting in very fast responses.

In addition to EGM, ABB robots also use a force-torque sensor: ABB Integrated Force Control. This technology allows a robot to adapt its movements based on force and torque inputs resulting from contact with a car body (compliant mechanical behavior). The sensor is normally installed between a tool and a robot's wrist →02. The combination of Visual Servoing with compliant mechanical behavior is an example of sensor fusion, a technology in which data coming from different sensor sources is combined in real time.

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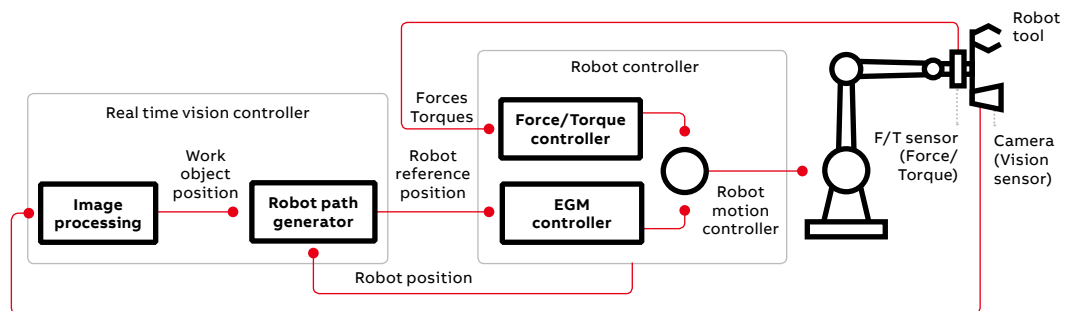
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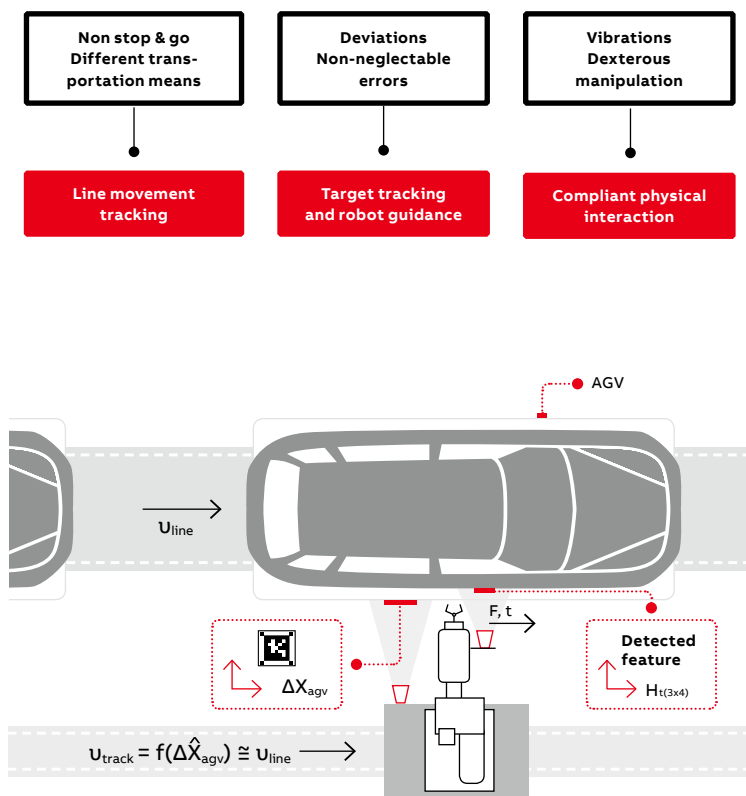
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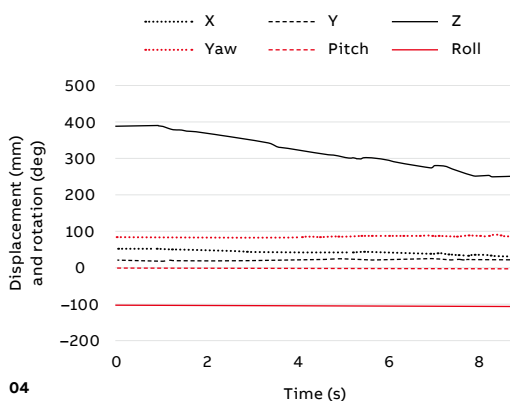


03

As these technologies mature, it is worth considering what a completely automated final assembly process might look like. Basically, as outlined in →03, it would boil down to the following tasks.

### 1. Line movement tracking

This means tracking the main movement of an assembly line to derive a pseudo-static environment. Typically, robots have tracked parts on a conveyor system using what is known as a conveyor tracking function. This is based on using an encoder that is mechanically connected to the conveyor movement. However, in the case of car bodies travelling on AGVs, this form of tracking is not easy to implement due to associated required mechanical adaptations.



04

ABB's solution to this challenge has been to apply its Visual Servoing technology, which calls for tracking an AGV either by means of an AprilTag or by means of a visual characteristic of the AGV. The advantage of using an AprilTag is that it is not only easy to install, but much more robust. Developed by the University of Michigan, AprilTags are two-dimensional bar codes that are conceptually like QR Codes. The difference is that AprilTags are designed to process smaller amounts of data, which makes them comparatively robust and easier to detect, resulting in improved localization accuracy and faster computer processing.

Visual tracking, on the other hand, involves use of floor-mounted cameras or a camera mounted on the robot foot if the robot itself is mounted on a linear axis. Robot linear axis, which is also known as "track motion" in ABB's product portfolio, involves the use of a linear servo-controlled unit that is used to extend the robot's reach. The robot linear axis is required in assembly processes characterized by significant contact time between the part or component to be mounted and a car body.

The technology is not limited to tracking robot movements on AGVs and can also be used in conventional conveyors.

### 2. Target tracking and robot guidance

Once this pseudo static environment has been achieved, a robot still needs to cope with residual tolerances, irregularities and vibrations to reach its assembly target. In this case, a camera is mounted on the robot tool. The robot knows the

Combined inputs from a vision sensor and a force-torque sensor (sensor fusion) are the key to successfully performing an assembly process.

relative position of the camera in relation to the tool's force torque controller (FTC), thus allowing it to focus on the target position. In contrast to AprilTags-based line movement tracking, the camera focuses on an image of a real feature →03 of a tracked car body whose position relative to the assembly target is known. Under these circumstances, AprilTags are not used because of the added complexity required for mounting and subsequently removing them, which would have to be performed at different stations. However,

—  
03 Tracking steps indicate what a completely automated final assembly process might look like.

—  
04 Feature tracking during assembly. Lines illustrate robot movements as they relate to tracking a target using real-time vision.

—  
05 Concept image of cockpit and door assembly.

tracking visual features as car bodies move at high speed is still a challenge, especially with regard to coping with different colors and variations in lighting conditions. →04 illustrates robot movements as they relate to tracking a target using real-time vision.

### 3. Compliant physical interaction

Once the target has been identified, physical contact is initiated, and the robot carries out its assembly task →05 by following a combination of visual and force-torque sensor inputs. This means maintaining visual tracking throughout contact and behaving in a compliant way by

—  
ABB pilot applications include cockpit assembly, carpet placement, seat placement, and door assembly.

using the continuous feedback provided by the Force Control sensor installed between its wrist and tool. This combination of inputs from a vision sensor and a force-torque sensor (sensor fusion) is the key to successfully performing an assembly process.

In some application cases, skills used in steps 2 and 3 may not be required. For example, flawless accuracy may not be necessary when a task is followed by a manual operation in a downstream station. In other cases, step 1 might be

skipped because of the use of traditional conveyor tracking.

### Looking ahead

In the future, new concepts may be implemented that will make it possible to assemble targets in static cells, thus obviating the need for technologies designed for performing assembly tasks in moving lines. For example, one concept considers grouping those cells that can be easily automated into a fully automated sub-line operating in stop & go mode. Other concepts consider static assembly cells that address the logistics of cars as well as components as they move.

However, demand for automating assembly tasks on moving lines will continue to play a key role in the short and medium term. Although this demand currently comes from application needs in the automotive final assembly environment, once the above-outlined technologies have been fully developed, there is no doubt that they will be applicable in other fields that focus on unstable targets, such as logistics operations involving AGVs.

For now, however, ABB is focusing on applying this technology to the automotive sector, where its customer-based pilot applications already include cockpit assembly – currently in production ramp-up – carpet placement, seat placement, door assembly, and much more. Furthermore, experience gained through these and other applications will be applied to other automotive assembly applications characterized by similar technical challenges. •









Tests were run together with the end user (a batch chemical plant) with historical batch data emulating an online approach (meaning data for the current batch was only available until the current step). A multiway principal component

ABB Ability™ BatchInsight helps operators to run complex and nonlinear processes in a smooth and trouble-free way.

analysis (MPCA) model was used to detect a foaming problem that occurred in a fraction of the batches. The model was trained only with batches without foaming. In 83 percent of the cases, the system was able to predict a foaming event at least 5 mins before it occurred. Often it predicted the foaming hours before. Although foaming was wrongly predicted in 20 percent of the cases, the predictions are very helpful as the operator can then focus on suspect batches. •

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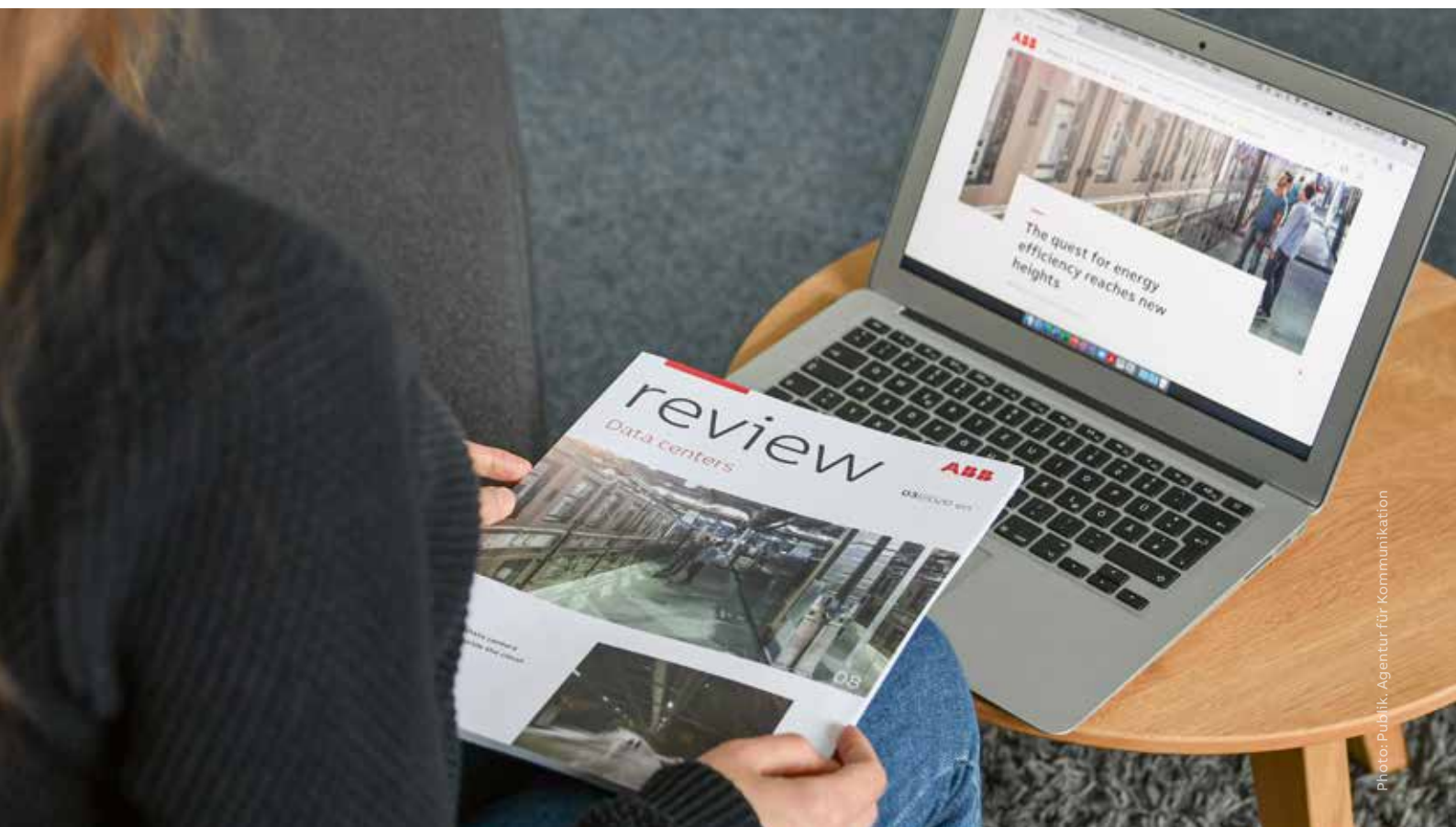


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