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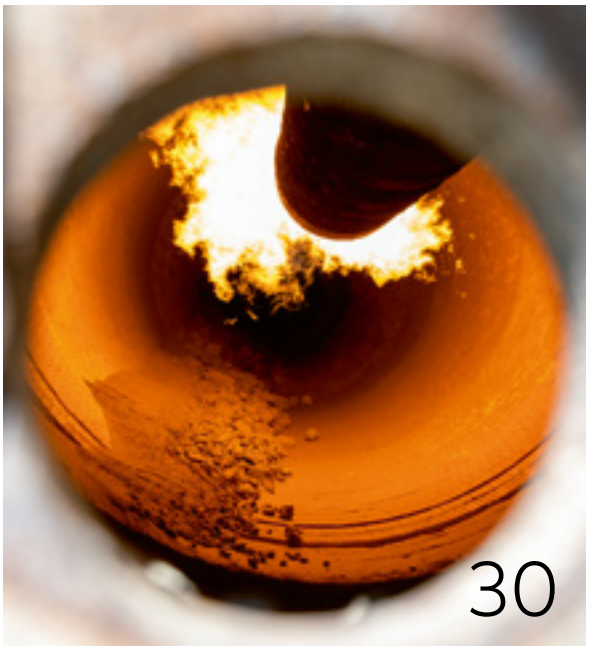
Innovation

Selected innovations in brief



Filter tip

Centralizing protection

Share articles

Have you ever come across an article that might interest a work colleague or a friend? As from ABB Review 03/2023, every article has an individual QR code, typically located on the last page of the article that facilitates the easy sharing of content.

Navigating ABB Review

The present issue of ABB Review features a modified layout with a single table of contents. This reduces the page count without sacrificing articles. It also facilitates navigation in the pdf version. Further changes are planned for upcoming editions.

Share this issue of ABB Review

Innovation

ABB is a leader in helping businesses work better. This means turning innovations in science and technology into products and services. This issue of ABB Review includes the annual selection of the innovations that are ready to make the biggest impact this year and beyond. These are hand-chosen by the company's technology leaders. They are followed by in-depth presentations of selected topics.

Coming up in the next edition: **Production and processes**

EDITORIAL

Innovation

Dear Reader,

There are technologies that are so well established and proven, that one could assume that any room for improvement is marginal at best. The screw propeller has been used in commercial navigation for almost 200 years. The concept is mature, robust and reliable. Unfortunately, it's energy efficiency is also limited, as witnessed by the turbulence and foam that large ships churn up in their wake. Considering the global significance and energy consumption of maritime shipping, this reflects a huge potential for saving fuel as well as reducing greenhouse gas emissions. ABB is rethinking ship propulsion from first principles. Discover more about ABB's exciting new Dynafin™ and other innovations in this edition of ABB Review.

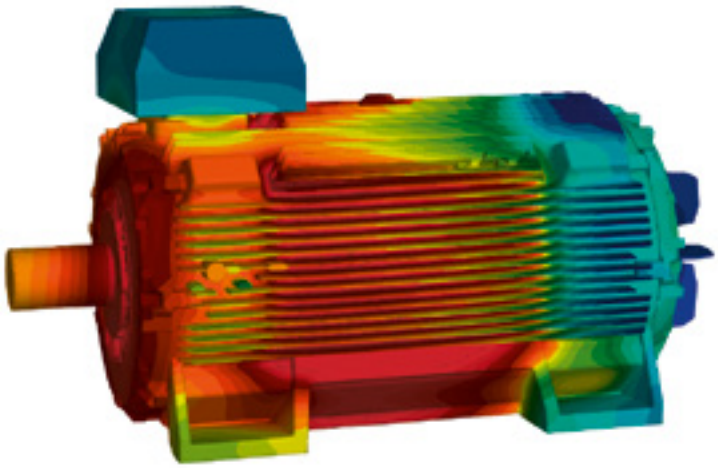
Enjoy your reading,

Björn Rosengren
Chief Executive Officer, ABB Group

Share this article

Innovation

Quick reads. Substantive examples. Intriguing possibilities. This collection of innovations was curated by ABB's technology leaders to recognize world class R&D activities, and present an overview of the breadth and depth of possibilities for your business.



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Share all innovation highlights

ABB DYNAFIN™

ABB Dynafin™ is an industry-first electric propulsion concept that breaks new ground for vessel efficiency. Based on a cycloidal propeller, the technology offers vessel designers unprecedented opportunities for innovation and contributes to shipping industry's goal of cutting greenhouse gas emissions.

The ABB Dynafin™ solution comprises a cycloidal propeller with individually controlled, vertical blades. Its main elements consist of a main electric motor that powers a large wheel rotating at a moderate 30-80 rounds per minute. This is fitted with multiple vertical blades, each regulated by an individual motor and control system. The blades oscillate in a manner imitating the highly efficient movement of a whale's tail.

> The blades oscillate in a manner imitating the high efficiency movement of a whale's tail.

The ABB Dynafin™ configuration has a low height, allowing designers to optimize ship layout. The concept delivers unprecedented propulsion efficiency of up to 85 percent on open water. Compared to a conventional propeller, Dynafin offers an improvement in efficiency of up to 22 percent. Due to its moderate operating speed, mode of action and low pressure pulses, ABB Dynafin™ generates low vibrations and noise, improving comfort and minimizing the impact of underwater radiated noise (URN).

Propulsion and steering forces are generated simultaneously by ABB's Dynafin™, offering immediate and stepless/gearless variation of thrust and its direction. The concept will initially be made available in the power range of 1-4 MW per unit and aimed at medium-sized and smaller vessels, including ferries for passengers and vehicles, offshore support vessels and yachts.

ABB estimates that the first ABB Dynafin™ prototype to be available in 2025. •

For more information, see the article "A propeller revolution" on pages 26–29 of this edition of ABB Review.

WHAT IF OPERATORS COULD PREDICT THE IMPACT OF THEIR ACTIONS IMMEDIATELY?

Equipment operators can sometimes be cautious about implementing changes. Typically, if the operator changes a set point, eg, setting a water valve to 30 percent, in the plant or via a high fidelity simulation, (s)he must monitor the plant system for many minutes to see what will eventually happen.

What if operators could "experiment" by simulating possible actions and observing the results in real-time? Such a diagnostic tool could revolutionize plant system operation.

Thanks to ABB's 800xA Simulator What-if, the operator can now safely experiment and receive an immediate response of what will happen in the plant system in response to a planned operator action.

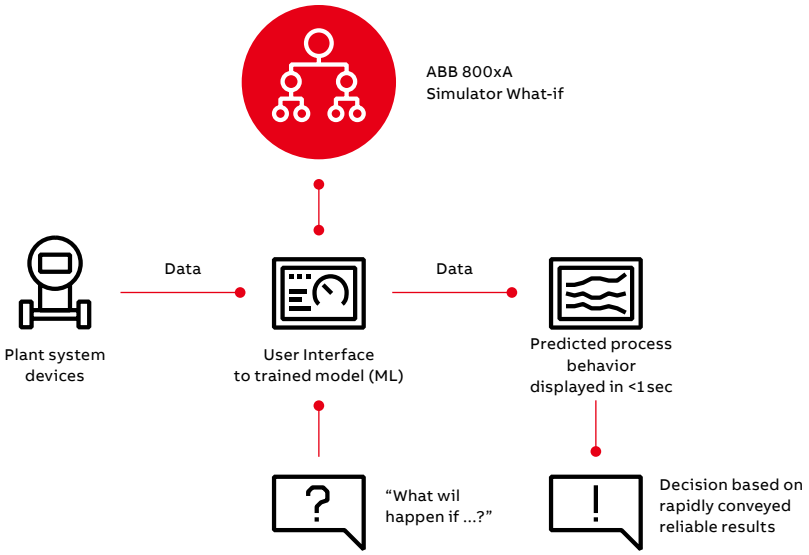
The 800xA Simulator What-if system uses machine learning (ML) to predict process behavior as a result of an operator process change. A Long Short-Term Memory (LSTM) Recurrent Neural Network (RNN) is employed to train using time-series data, resulting in reliable predictions that are presented immediately (<1 s).

The time-series data can be created using historical process data from the plant historian. In addition, the 800xA Simulator system, including a system digital twin, or replica, of the plant control system, employs a high fidelity dynamic process model that can be used to enrich the training of data, thereby resulting in more robust models.

Derived from ABB's research project, Augmented Operator [1], the 800xA Simulator What-if system will:

- help control room operators to avoid critical situations eg, trips due to high pressure.
- significantly improve overall operational efficiency of the plant.
- address the demographic change in future workforce and operations.
- enable operators to confidently perform changes in larger steps than today for efficient operation.

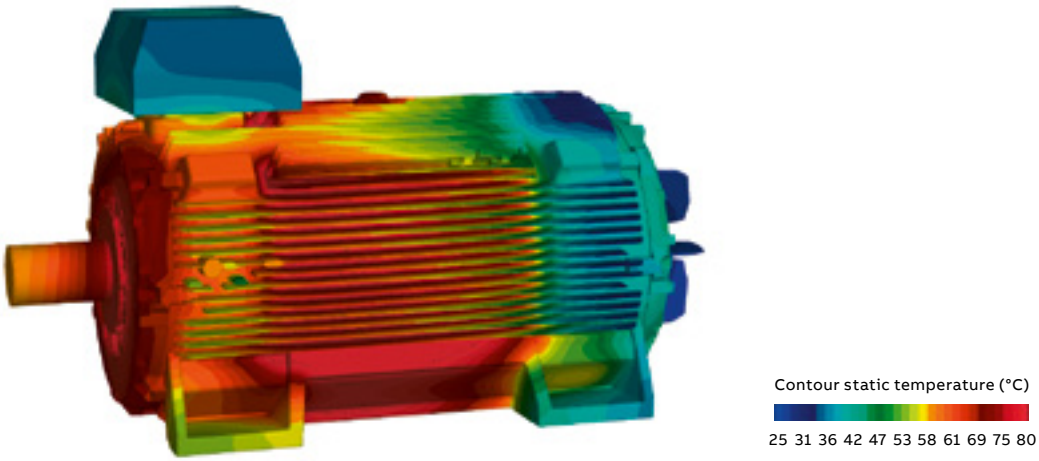
By giving operators enough time to implement appropriate actions, 800xA Simulator What-if will support plant operators in the daily operation of the plant. •



Reference

[1] Ruomu Tan et al., "Smooth Operation", *ABB Review* 3/2022, pp. 18–23.

POWER EXTENSION OF RANDOM WOUND LV MOTOR RANGE



Coils in a low-voltage (LV) motor can either be form-wound – with square or rectangular wires arranged systematically – or random-wound, with round wires arranged in a less definite manner. Though more expensive, the former are usually used in motors rated over 1,500 kW for reasons of performance, durability, etc. However, an ABB study revealed a demand for random-wound motors in higher power ranges – eg, in an IEC 500 frame size.

> The motor has two cooling circuits and these must work together in a perfectly balanced fashion.

In 2018, a project was started to create a water-cooled series of these motors. The productization of this new series needed only a relatively small investment in new tooling and molds.

After the successful productization of this water-cooled IEC 500, it was natural to create an air-cooled version. Such a product would have a much larger customer base. This water-cooled IEC 500 version was harmonized with ABB's existing M3BP cast-iron motor product structure to streamline order and delivery processes.

The main new component required was a cast iron frame featuring internal cooling. This frame has two cooling circuits: one internal circuit cooling the rotor through cooling channels and using the frame as a heat exchanger and one external cooling circuit in which air is driven over the cooling fins. These two circuits must work in a perfectly balanced fashion.

The frame design process used computational fluid dynamics (CFD) extensively to simulate the temperature distribution in the motor. Using the simulations, the number and size of the cooling fins on the motor surface could be optimized while keeping sufficient space for internal cooling channels. Prototype motor temperatures match the simulated ones very well. •

HIGH-SPEED MOTORS

The paper-machine vacuum turboblower manufacturer Runtech Systems – a part of the Ingersoll Rand company – was seeking possibilities to enhance its turboblower's high-speed motor's efficiency.

The Runtech vacuum turboblower is a direct-driven, high-speed unit operating at up to 600 kW at 10,000 rpm. These devices are widely used in the pulp and paper industry to dry excess water from paper. As impellers are directly fitted to the rotor, rotor dynamics play the biggest role in designing a motor for the application.

ABB was known to Runtech for its advanced rotor manufacturing technology. For example, ABB's cast aluminium rotors provide a superior power factor and lower losses due to their laminated rotor structure. Therefore, it was natural to form a partnership to create a new motor for the Runtech vacuum turboblowers.

The task was challenging: not only had 600 kW to be squeezed out of a motor size that would normally deliver 200 kW as a standard product, but vibration, bearing lubrication and centrifugal forces also had to be considered. The team created a prototype that featured a split-core stator for enhanced forced cooling, a special IP23 frame, a new rotor core structure and circulating oil lubrication for the ceramic high-speed bearings. Rapid prototyping casting using 3-D printed molds was used to create the cast iron components.

It was immediately evident that the motor's performance not only achieved the set targets but also delivered an improvement of 1 to 2 percent in total efficiency. Productization of the new motor is complete and ABB has already delivered hundreds of these motors to Runtech. •

SCALING UP ETHERNET-APL TO CONNECT I/OS TO DCS AND POWER THEM OVER THE SAME LINK

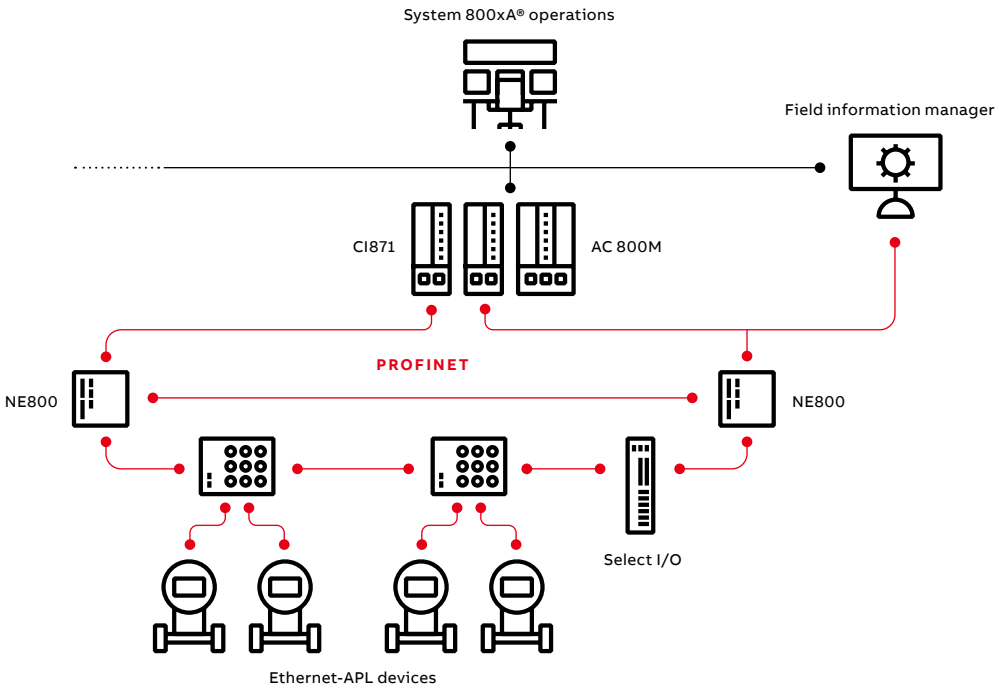
By addressing the need to power field devices and, simultaneously, provide an easy-to-handle “high speed” communication link for process data, device configuration and diagnostic data, Advanced Physical Layer technology (APL) is bringing Ethernet to the field and beyond for process and chemical industries.

Installation is simple and robust as the devices are connected through a point-to-point link with the APL switch that can be part of a network ring of many devices. Such a scenario provides media redundancy whenever increased availability is important. APL eliminates the need for the traditional I/O modules of programmable logic controllers (PLC) or distributed control systems (DCS) as the controller can access the device data directly, instead of indirectly, via an I/O module that converts analog standard signals and sends them to the central processing format (CPU).

Importantly, this technology is ready just as APL network equipment and field instruments are becoming available on the market. ABB has deployed automation solutions, System 800xA® with PROFINET protocol, for three large scale chemical process plants. In one case, up to 252 field instruments are directly connected through one APL network ring to a controller. Each controller typically handles three Ethernet communication rings: two rings for process devices connected via APL and one ring for Ethernet connected electrical format. Additionally, remote IO connected over the same PROFINET ring is used to collect those auxiliary signals that do not originate from APL enabled devices.

Customers benefit from simplified engineering, robust and uncomplicated installation; the solution also takes up less space in cabinets, compared to classical IO device solutions and earlier fieldbus solutions such as PROFIBUS PA or Foundation Fieldbus. The ease and speed of access to device diagnostic and configuration data results in a faster commissioning- and troubleshooting time. And, by leveraging asset management solutions, life cycle cost is reduced. ABB’s scaled-up Ethernet-APL solution is just what the process and chemical industries need. •

For more information, a full length article on this subject will appear in issue 2 of the ABB Review.



VD4 EVO VACUUM CIRCUIT BREAKER FOR MV PROTECTION FOR A SMARTER GREENER FUTURE

As the electrical smart grid becomes reality, the role of MV circuit breakers is progressing from a simple protection device to an active apparatus able to interact directly with the main installation-specific electrical entities and thereby coordinate operations. This evolution is furthered by demands from public utility companies and private industry for greater continuity of service and a better-quality supply of power, required as the grid must manage bi-directional energy flows from intermittent renewable sources of energy. ABB recognizes that advancements in control and protection grid components eg, circuit breakers (CB), combined with sensor systems, data analytics, and the use of machine learning-based algorithms could help make the grid more reliable, robust, and intelligent.

Having evaluated their highly successful conventional circuit breaker, VD4, ABB crafted the VD4 evo. This evolutionary solution, released in 2023, is a more energy- and maintenance efficient, cyber-secure intelligent protection system based on the same sterling level of safety and protection provided by the VD4.

Developed with ABB's established sustainability processes, the VD4 evo CB provides up to a 60 percent improvement in efficiency and up to a 30 percent reduction in unexpected outages. With 15 percent more compactness, VD4 evo provides customers with a complete environmental product declaration (EPD).

The operational effectiveness of VD4 evo is augmented by embedded monitoring and diagnostic features, eg, sensors and the control and monitoring unit (CMU), based on ABB's proprietary Maxwell platform, that promptly and continuously analyze and communicate the operational status, which is easily viewed on the on-premises Web HMI.

Thanks to the seemless integration of these new smart components for control and diagnostic functions, life management services and operation, ABB improves not only flexibility, efficiency and connectivity with a reduced risk of cyber

incursions, but also improves environmental performance, material efficiency, and circularity. Condition-based maintenance enables customers to take targeted recovery actions whenever necessary. Considered overall, VD4 evo helps customers meet the demands of an evolving smart power grid efficiently and reliably, and safely for a digital, greener future. •

For more information, see the article "Breaking with tradition" on pages 54–61 of this edition of ABB Review.

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Further information

ABB website, "IEC indoor vacuum circuit breaker VD4".

ABB website, "VD 4 evo. Evolution that empowers".

ABB website, "ABB sustainability – driving progress for a sustainable tomorrow".

ABB website, "Leading the way to a circular economy".

ETHERNET-APL FOR FIELD DEVICES IN THE PROCESS INDUSTRY

The measurement of parameters such as temperature, pressure and flow is essential for monitoring and controlling industrial processes. Moreover, increased energy and material costs and greater environmental awareness drive operators to monitor processes more closely than ever – not a trivial task when even a midscale plant can have as many as 10,000 field devices that measure and report process parameters.

Traditionally, 4 to 20 mA analog current loops, often using the HART protocol, have been employed to transfer data between devices and control rooms. However, current loop characteristics do not match modern communication expectations. The way forward is a new standard: Ethernet-APL.

Ethernet-APL represents the culmination of a decade-long journey in standardization. The standard allows the reporting of far more device parameters and lends itself to the automation of process plant design and operation.

One area in which Ethernet-APL is of particular interest is in potentially explosive environments as its 2-wire intrinsically safe Ethernet (2-WISE) concept limits voltage and current going to the device. Moreover, the power levels allowed in 2-WISE allow devices to perform more complex computations than in the past.

Ethernet-APL represents the culmination of a decade-long journey in standardization.

ABB has implemented Ethernet-APL into its FSx430 and FSx450 vortex/swirl flowmeters. These devices also feature a Bluetooth interface that simplifies local access with a secure smartphone app.

ABB will employ Ethernet-APL in other products and introduce further enhancements, such as using PROFIsafe to apply Ethernet-APL and PROFINET for functional safety integrity level (SIL) purposes. •

For more information, see the article “Leading the field” on pages 48 – 53 of this edition of ABB Review.

EXPERT KNOWLEDGE AT HAND

Sometimes, troubleshooting complex equipment is not just about the equipment itself. Hidden hurdles in the form of product names and local slang expressions can significantly slow a technician's ability to diagnose and repair a problem. How, for instance, can a novice field operator make sense of a request to repair "the VD4 breaker in outgoing to T11 in TS4 UniGear ZS1 panel"? And things become even more complicated when components from different manufacturers are involved.

In view of these challenges, as well as a declining commitment by many companies to invest in training, ABB has introduced Service Assist, a virtual assistant that provides on-the-spot support and information. Interactions can be via text or voice – in fact, Service Assist can interpret human speech and is particularly versed in electrification network slang. Technicians can request manuals, videos and perhaps most important, augmented reality (AR) guides, which make it possible to troubleshoot problems even if the technician's experience level is not advanced. Furthermore, the system is not limited to ABB documentation or equipment.

Thanks to Service Assist's use of AR technology, operational information is presented in the user's view of his or her real environment, thus making it more practical and easier to understand and act upon, all of which adds up to accelerated resolution of problems and reduced downtime.

Nevertheless, if further assistance is needed, a technician can request a remote support call with an ABB service specialist who can place augmented reality instructions in the operator's field of view, allowing visual information to enhance voice instructions. •

For more information, a full length article on this subject will appear in issue 2 of the ABB Review.

CONVENIENCE COMES HOME

With an eye to improving energy efficiency, convenience and value, ever more homeowners are turning to home automation systems. In view of this, ABB and Busch-Jaeger, a brand of the ABB Group, have introduced the ABB-free@home® flex system, a wireless smart home control platform. Based on a 2.4 GHz wireless Mesh-Network with ABB state-of-the-art encryption and cyber security standards, the platform can address the needs of a single room or be upgraded to control a complete smart home system.

Thanks to its intuitive, user-friendly design, the system enables quick device configuration and digital remote control of various smart functions via Bluetooth® using a smartphone or tablet. The management of blinds, light intensity, and motion detectors can take place individually or be wirelessly networked with up to 32 devices. As a result, scheduling functions and group controls can be easily implemented.

In addition, a System Access Point can accommodate up to 150 wireless sensors or wired devices. Premium and high-end functions include the integration of the ABB-Welcome® door communication system, as well as household and multimedia devices.

In the event that a customer requires support, ABB uses artificial intelligence (AI) and machine learning (ML) to solve queries. The technology leverages data sources from manuals, product documentation, and online communities to train its advanced ML and AI engines to resolve recurring support requests. •

For more information, a full-length article on this subject will appear in issue 2 of the ABB Review.

APPLICATION EXAMPLES

Garden: Thanks to a range of lighting scenes, ABB-free@home® flex guarantees orientation and safety.

Stairs: The platform offers automatic detection of movement and saves energy thanks to its automatic on-off function.

Bathrooms: ABB-free@home® flex creates customized lighting ambiences in harmony with natural biorhythms.

Children's room: ABB-free@home® flex can switch lights on and off and offers pre-set lighting scenes such as its Good Night mode, which automatically dims lights on a predefined level.

KILN GAS SAMPLING WITH PROKILN

In recent years, the cement industry has seen a significant increase in alternative fuels and raw material (AFR) use. Though beneficial in many ways, AFR presents new challenges for gas analysis equipment in the already-harsh environment at the cement kiln inlet. Gas analyzers at the inlet are indispensable as they offer operators valuable information on combustion efficiency and emission levels that help ensure optimal operational efficiency, environmental compliance and effective utilization of AFR.

ProKiln, ABB's fourth-generation gas sampling probe, allows the effective collection of samples even in hostile kiln inlet environments with high AFR levels. The probe – developed in collaboration with FLO2R, a Danish company with long-established and deep knowledge of kiln inlet measurement – focuses on a more powerful probe cleaning regime and increased mechanical strength.

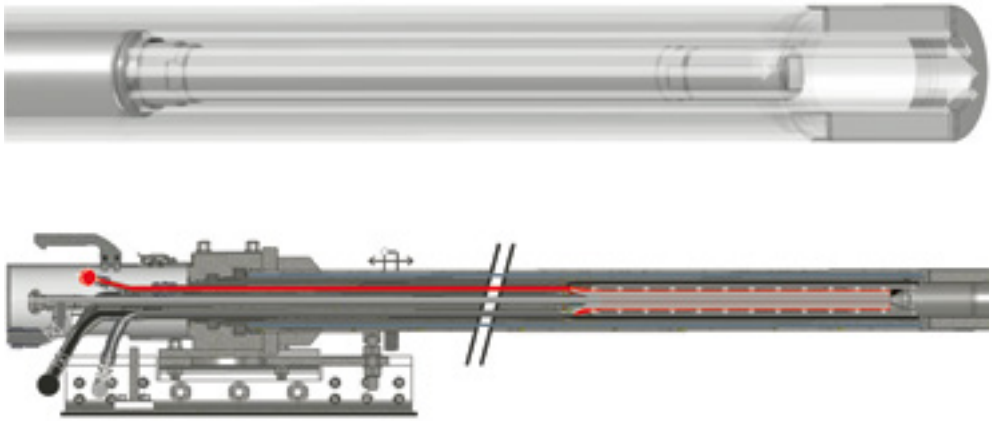
ABB's ProKiln's main component is a 3 m-long, water-cooled probe with an extractive filter at the sample end. Two powerful air blasters provide sample flow and filter cleaning. The probe is installed on a buggy running on a retraction device.

ProKiln was trialed at a Holcim plant in Lägerdorf, Germany. The plant used fuels originating from 17 different AFRs during the trial period, resulting in significant fluctuations of the O_2 and CO process values and giving very light to very heavy scaling. Despite these conditions, the probe functioned reliably in automatic operation and no manual cleaning was required.

ProKiln focuses on a more powerful probe cleaning regime and increased mechanical strength.

The return on investment on this simple and strong probe can easily be justified by preventing kiln stops alone. •

For more information, see the article "Filter tip" on pages 30–35 of this edition of ABB Review.



SACE INFINITUS: ALL-IN-ONE SOLID-STATE PROTECTION FOR DC GRIDS

The characteristic high efficiency of DC power solutions makes them very effective in the mission to reach carbon neutrality. However, until now, the fast nature of DC short-circuit behavior has made adequate protection and isolation technology difficult to achieve. The answer lies with solid-state circuit breakers (SSCBs), which exploit microsecond-fast disconnection. ABB's unique SSCB is called the SACE Infinitus – an all-in-one protection solution that integrates power electronics, mechanics, cooling, control, sensing and communication [1]. The SACE Infinitus is the world's first breaker based on semiconductor interruption technology that complies with IEC 60947-2.

The SACE Infinitus employs reverse-blocking integrated-gate commutated thyristors (RB-IGCTs), having an integral diode in series to protect against reverse voltages. The anti-parallel arrangement of RB-IGCTs enables bidirectional control of currents up to 2.5 kA. Consequently, ABB's solution features up to 99.9 percent efficiency – a 70 percent reduction in power losses compared with equivalent technologies.

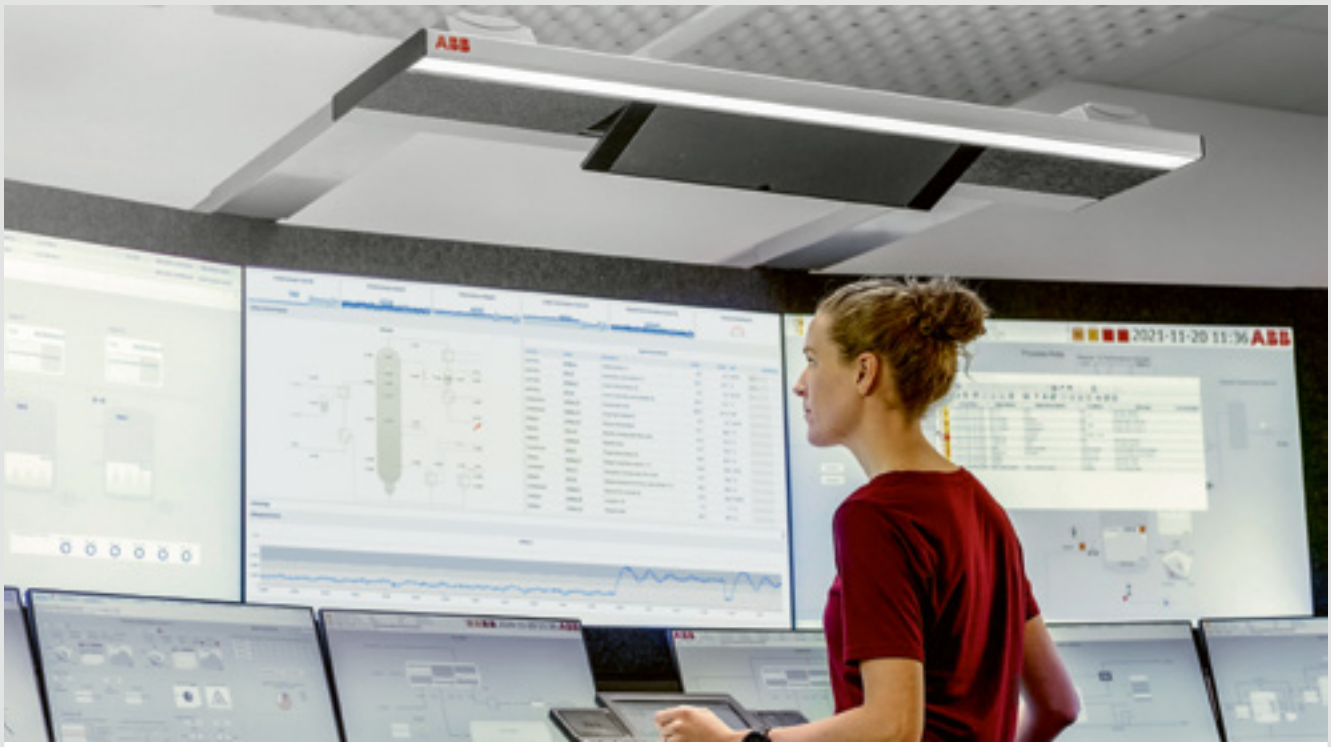
The SACE Infinitus is the world's first breaker based on semiconductor interruption technology that complies with IEC 60947-2.

Nevertheless, power losses are still much higher than in conventional circuit breakers, making integrated cooling necessary. SACE Infinitus, therefore, cools with aluminum-nitride cold plates, combining electrical insulation and high thermal conductivity. Thus, the coolant can be the familiar mixture of water and glycol, and deionization is unnecessary.

Breaking times as short as 15 µs at up to 1 kV DC, compared to the tens of milliseconds needed by conventional electromechanical breakers, makes Infinitus the best option for applications where fault currents may exceed 100 kA in a few milliseconds, such as in novel smart industrial DC grids, battery storage systems, electric vehicle infrastructure or bus-ties in DC marine grids. •

Reference

[1] A. Antoniazzi et al., "One of a kind," *ABB Review* 04/2022, pp. 14–19.



MACHINE LEARNING SOLUTION IDENTIFIES PROCESS STATES IN REAL TIME

Startup, shutdown, half-load, full-load. In many industries determining the state of any given process is not as easy as one might think. There are many reasons for this. For example, events and or manual operations can cause a change in operating states. Furthermore, the signatures of multiple states usually coexist within a large amount of data, making identification of individual states difficult. Added to this is the fact that many substates can exist within one operating state, thus complicating state determination.

In view of these challenges, ABB has developed ABB Ability™ PlantInsight Operator Assist, a solution that accurately identifies and calculates process states and substates to enable operators to more accurately evaluate and correct production processes. The solution is based on an innovative architecture that uses machine learning (ML) techniques to identify the signatures of operating states, which are derived from unlabeled, historical time series data. The solution can successfully identify states with simple signatures and those that are more complex.

Once the operating states have been identified, the solution analyzes the associated operations and configures state-aware ML models that generate the operating lanes for all, or the most important, operating states, individually. When deployed for online operator support, the solution labels the currently active operating state in a process using online data and applies the corresponding ML model to generate operating lanes for operator support in real-time.

Simultaneously, the solution monitors the drift in the online data, eg, when none of the previously identified states can be applied to the newly generated data, and triggers a retraining workflow such that the new operating states can be identified and the ML models can be updated to account for the new states.

To date, the solution has been verified in several customer use cases based on real-life datasets from chemical production, oil refineries and power plants. •

For more information, a full-length article on this subject will appear in issue 2 of the ABB Review.

A DASHBOARD FOR ENERGY AND ASSET MANAGEMENT

As energy prices rise, infrastructures age and government restrictions on carbon emissions tighten, businesses are turning to digital solutions to help them get the most out of their assets while remaining compliant. ABB Ability™ Energy and Asset Manager has been introduced to meet these needs. A modular, state-of-the-art cloud-based solution, Energy and Asset Manager integrates energy and asset management in a single intuitive dashboard. With real-time visibility into energy use, electrical power quality, and the health of low- and medium-voltage electrical distribution system equipment, the solution helps organizations with multiple small or medium size sites – such as factories, commercial buildings, and datacenters – optimize power consumption and minimize downtime.

The solution's modules can be purchased separately or together, as needed. Monitoring can also be segmented down to individual pieces of equipment and/or sub-systems, such as an elevator, a single HVAC system, or a production line, enabling users to make informed decisions regarding when to reduce energy consumption, how to limit unplanned downtime and how to use predictive maintenance to detect and proactively address issues before they escalate.

ABB Ability™ Energy and Asset Manager enables customers to receive alerts and make changes anytime from a smartphone, tablet, or PC; keep workers out of hazardous areas thanks to remote diagnostics; and adhere to government standards on carbon emissions.

Built from the ground up to run on Microsoft Azure, ABB Ability™ Energy and Asset Manager offers the highest levels of scalability and security. It can be used standalone or integrated with existing systems using a flexible application interface. All in all, it maximizes performance and safety while minimizing risk and costs. In fact, the solution has helped customers reduce energy and maintenance costs by up to 40 percent. •

For more information, a full-length article on this subject will appear in a future issue of the ABB Review.

BETTER BY HALF – THE DS301C COMPACT CIRCUIT BREAKER

The DS301C, ABB's new single-phase and neutral residual current circuit breaker with overcurrent protection (RCBO), combines protection against short-circuits, overloads and earth faults in a single-module circuit breaker. The breaker is voltage-independent – ie, it works without an external power source. Compared to traditional two-module breakers, the remarkable space reduction achieved enables smaller electrical panels, more protected circuits and smaller or less-crowded technical rooms in residential, commercial and railway installations. Extensions and retrofits are also made easier.

In contrast to conventional installations, where overcurrent protection is at branch level and earth-fault protection one step upstream, now, with the slim DS301C, a residual fault leads to disconnection of the affected branch only, instead of the whole installation. Such selectivity delivers superior service continuity.

All polymeric parts in this lightweight product are made of recyclable thermoplastic. Furthermore, the "all-in-one" design eliminates the duplicated resistive elements found in setups with miniature circuit breakers or residual current devices. This reduces power losses and cooling requirements. The resulting energy savings are significant over the device's lifetime. The DS301C is part of the ABB EcoSolutions™ portfolio.

The remarkably compact DS301C enables smaller electrical panels and needs no external power source.

Indicators of contact position as well as earth fault as the cause-of-trip simplify system maintenance. The DS301C is compatible with both busbars and cables, with miswiring-prevention features. Installers also appreciate the clipping system that allows easy product mounting and dismounting without removing busbars from neighboring breakers.

An extensive portfolio of ABB System Pro M accessories will supplement the DS301C and satisfy the needs of elaborate installations. Datasheets and technical information are accessible via a QR code on the front. •

For more information, see the article "Compact impact" on pages 70 – 75 of this edition of ABB Review.

MEETING THE PROTECTION AND CONTROL NEEDS OF MV DISTRIBUTION SUBSTATIONS WITH CENTRALIZED AND VIRTUALIZED SOLUTIONS

To handle the increased complexity and unpredictability of the power grid associated with greater penetration of distributed energy resources, medium voltage (MV) distribution substations with the ability to effectively control and protect the network are becoming increasingly important.

ABB launched the ABB Ability™ Smart Substation Control and Protection for electrical systems SSC600 in 2018, a centralized protection and control (CPC) smart software-oriented solution that concentrates multiple relays into one device: only the process interface functionality remains in the bay-level merging units. By permitting information flow between different components, bays, substations, and related operators, one device performs the tasks of 30 protection relays in the substation.

Thanks to network processing capability, newer management and automation approaches are supported, eg, with routable GOOSE (Generic Object Oriented Substation Events).

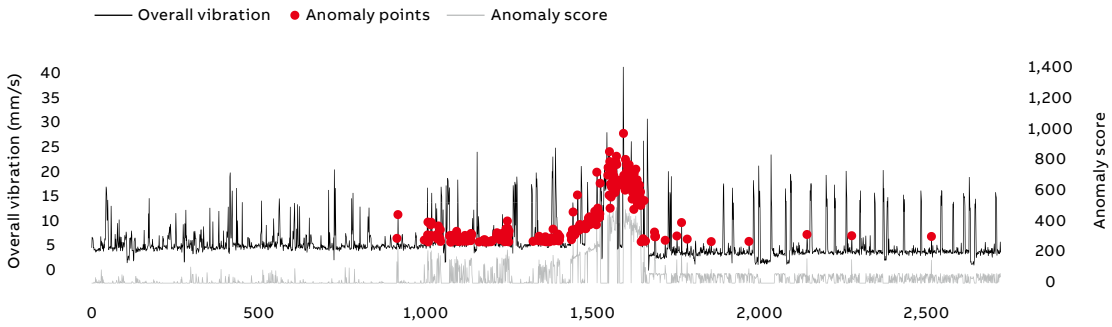
Building upon the success of SSC600, ABB launched the world's first virtualized P&C software, SSC600 SW, in January, 2023. In this virtualized protection and control (VPC) system, software is independent of the hardware.

Successfully tested and verified in a MV substation in western Finland, this virtual image of the CPC equaled the real-time performance of ABB's SSC600, in all ways, eg, during fault clearance. SSC600 SW, combined with merging units, creates an IEC 61850-compliant CPC solution. Customers can now deploy applications and update functions from any vendor on demand, as long as performance requirements are met; hardware is easier to maintain or upgrade and substation life cycle costs are reduced.

With SSC600 or SSC600 SW, MV substations are now able to meet real-time performance for distribution network protection and control as defined by IEC 61850. Modularity of both systems permit flexible modifications and customization. This is an advantage as substation protection needs change in response to an evolving power network. •

For more information, see the article "Centralizing protection" on pages 62–69 of this edition of ABB Review.

ABB'S MOTOR ANOMALY DETECTION FEATURE LEVERAGES ML TO AUTOMATE ABB ABILITY™ MONITORING SERVICES FOR MOTORS



Recognizing that a motor is behaving "unusually" is important as such behavior may reflect misalignment or impending bearing failure. However, such a deterministic diagnosis is incredibly difficult to achieve: For a motor that runs with a constant load, even tiny variations in speed or vibration might indicate atypical behavior that merits quick attention, whereas large swings in speed and vibration might be typical and expected for another motor in the same fleet with a different application.

ABB's Motor Anomaly Detection, an automated cloud-based feature, creates a profile for each asset.

Clearly, it is not enough to define "atypical" behaviors for broad classes of motors: providing world-class service requires an understanding of the unique performance characteristics of each individual motor. Responding to this challenge, ABB inaugurated development of its Motor Anomaly Detection Tool for low voltage (LV) motors, an automated cloud-based tool that leverages machine learning (ML) to create a unique behavioral profile for each asset in a fleet that is equipped with ABB Ability™ Smart Sensors – and to alert ABB's support experts whenever a customer's motor is operating in a manner that warrants closer attention.

For each motor, the platform builds both long-term ML- and rule-based models that recognize the types of anomalies revealed by subtle changes occurring over weeks or months, along with short-term models that detect rapidly-evolving issues requiring immediate attention. The ML models retrain themselves regularly as fresh data becomes available and present their insights through a unified user interface.

This platform will allow ABB's remote experts to recognize emerging problems that might otherwise go unnoticed, and enable them to monitor substantially more assets. Such a tool will help maximize a motors' uptime and efficiency and minimize customers' total cost of ownership. •

For more information, a full length article on this subjct will appear in issue 2 of the ABB Review.

HIGH-POWER INTEGRATED MOTOR DRIVES

With increasing needs for greater power density, better efficiency and guaranteed tolerance of higher temperatures in electric drive systems, more users are turning to integrated motor drives (IMDs). IMDs offer sizable cost and performance benefits over traditional, separated motor and drive systems. However, thermal and electromagnetic considerations are critical in IMDs, especially at higher powers (over 7.5 kW). ABB has now successfully developed 7.5 kW IMD prototypes that exhibit excellent performance – especially in terms of thermal management and low radiated electromagnetic emission.

The new ultra-compact IMD design is based on customer requirements and helps them save space, energy and cost.

The new ultra-compact IMD – ie, an integrated IE5 permanent magnet (PM) motor and drive – is based on customer requirements and helps them save space, energy and cost. By eliminating separate enclosures for the motor and drive and taking away long cable runs, for example, the integrated approach can lower system costs substantially. The removal of cables and their associated electromagnetic noise filters also increases reliability.

The IE5 PM motor's electromagnetic design reduces losses and uses radial cooling fins and a specially designed fan for better cooling performance. The IMD is IP56-rated, thus is suitable for harsh environments.

A pluggable connection cable between the drive and motor means either can be replaced separately and maintenance is simple.

The design satisfied the customer requirement that the maximum temperature at any point on the frame should be below 80 °C at an ambient temperature of 35 °C. Indeed, the frame temperature is lower than that of ordinary permanent magnet motors, while the efficiency is higher. •

For more information, see the article "Beat the heat" on pages 42–47 of this edition of ABB Review.

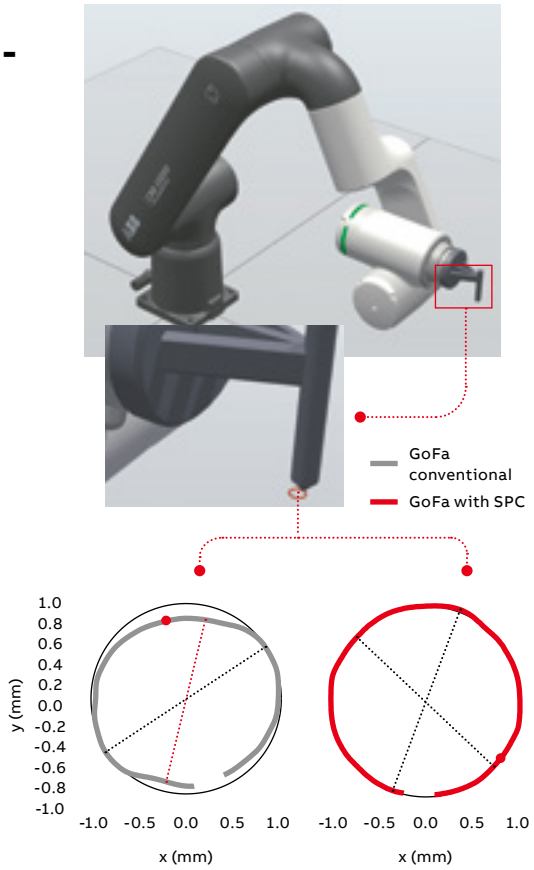
UNPARALLELED PATH ACCURACY WITH SECONDARY POSITION CONTROL (SPC)

The trend toward product miniaturization and the need to meet ever tighter application requirements in robot automation, eg, for cutting, gluing, sealing, and surface inspection, require robots and robot controllers with greater path accuracy. Building on the TrueMove concept, which provides control for high accuracy robots since the 1990s, ABB is integrating SPC to push the limits of robot accuracy even further.

SPC is an innovative technology that uses arm-side information and conventional measurements from the motor-side in the servo loops. This added functionality furthers the controller's ability to reject disturbances and uncertainties introduced by the gearbox and those disturbances that originate externally.

The measurements at the gearbox output seem to be a natural way to improve accuracy compared to conventional motor-side sensing. Despite this, actuation and sensing are physically distributed, and as such pose significant challenges to control systems in general and for control of robots specifically [1]. By developing an improved understanding of the gearboxes and measurement systems, and by integrating such capacity with ABB's advanced model-based controls, ABB could ensure stability and performance of the SPC scheme in the robot's complete work space, covering its full payload- and speed-range.

Using a Leica AT960 high precision laser tracker (evaluating straight lines and more involved shapes, eg, small circles, hexagons, and rectangles – especially challenging due to high accelerations in corner zones), SPC has been shown to improve path accuracy by 65 percent compared with that achieved by GoFa with conventional motor-side controls. Throughout these tests, GoFa SPC consistently achieved a 3D path accuracy of 0.1 mm in speeds up to 80 mm/s, and a 2D path accuracy of 0.05 mm at speeds up to 40 mm/s – an unparalleled path accuracy to the best of ABB's knowledge. These path accuracy levels are comparable to the average diameter of a human hair (~75 µm).



Further tests showed that absolute positioning accuracy improves by 50 percent if SPC is used in combination with absolute accuracy. For example, during testing of GoFa, an average absolute error of 0.1 mm and a maximum absolute error of 0.2 mm was achieved.

Based on these successful results, further research and technology development of SPC is underway. With SPC, ABB targets to provide high accuracy to the market and open-the-door for high precision continuous applications. •

This topic will be covered in greater depth in an upcoming issue of the ABB Review.

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Reference

[1] P. A. Chodavardapu and M.W. Spong, "On noncollocated single control of a flexible link" in Proceedings of the IEEE Conference on Robotics and Automation, Minneapolis, Mn, USA, 22-28 April, 1996.

THE REVOLUTIONARY ABB DYNAFIN™ PROPULSOR MIMICS WHALE TAILS

A propeller revolution

Ship propulsion has changed little since the invention of the propellor. ABB's new cycloidal-type propulsor concept, the ABB Dynafin™, is inspired by the movement of a whale's tail. Dynafin heralds huge gains in efficiency and the prospect of massively reduced emissions across the marine industry.

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The International Maritime Organization (IMO) has issued resolutions to substantially cut greenhouse gases (GHG) emissions in the coming decades [1]. It will be challenging to achieve this target without major technological advances in fuel and propulsion technologies and the more widespread adoption of alternative energy sources such as batteries and fuel cells. ABB's latest innovation that addresses this rapidly evolving environmental compliance landscape is the ABB Dynafin – a cycloidal-type propulsor that meets the urgent demand for higher efficiency and emissions reduction →01.

How the ABB Dynafin works

The ABB Dynafin concept is essentially a cycloidal propeller with individually controlled blades. The operating principle allows the unit to utilize a trochoidal blade path →02. (A trochoid is the curve generated by a point on the radius of a circle as the circle rolls on a fixed straight line.) Trochoidal propellers have been studied before, but until now, technology constraints have prevented them from being commercialized and introduced to the market.

The ABB Dynafin generates thrust by means of profiled blades that project from the bottom of the ship. Each blade can rotate both around the global axis of a main wheel and around its own local axis, which acts as a pivot point for enforcing a prescribed pitch motion →01b. The thrusting blades' trajectories resemble those of the tails of whales and dolphins. This sort of pitch motion leads to a very high propulsive efficiency. The propulsor can also change thrust direction almost instantaneously, increasing vessel maneuverability. In contrast, an azimuth thruster, where a conventional propeller is rotated around the vertical axis to direct its thrust, is slower and thus less effective in maneuvering the vessel.

Several key factors drive the high efficiency of the ABB Dynafin:

Larger propulsive area

The larger propulsive area covered by the ABB Dynafin lowers the loading of the propeller, giving the lowest thrust-loading coefficient. The lower this coefficient, the higher the ideal open-water efficiency of a propulsor. Further, the Dynafin's geometry makes it ideal for shallow-water vessels as it does not protrude as much as an equivalent screw propeller.

The ABB Dynafin meets the urgent demand for higher efficiency and emissions reduction.

High aspect ratio and no rotational component

The high blade aspect ratio (basically, blade length divided by width) significantly increases each blade's lift/drag ratio so it is much higher than a conventional screw propeller. Further,

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01 The ABB Dynafin.

01a Two (shown here) or even four sets can be fitted to a vessel.

01b Each blade is individually controlled and can rotate, as can the main wheel onto which they are mounted.

—
02 Trochoidal propeller behavior [2].

02a Epicycloidal path of a blade with eccentricity and advance ratio λ<1 (cycloidal propeller).

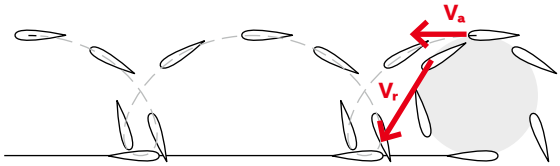
02b Trochoidal path of a blade with eccentricity and advance ratio λ>1 (trochoidal propeller).

screw propellers with rotation axes parallel to the inflow induce rotational losses in their wake; this is avoided in the cycloidal propulsor as there are no major rotational components in the wake flow.

Individual blade control

Each blade is individually controlled by an electric motor, a frequency converter (to control torque and rpm) and control logic. This enables the imitation of the highly efficient movements of a whale's tail and adjustment of the blade movement (eccentricity, advance ratio and angle of attack) depending on different vessel operational situations, maximizing efficiency and thrust in both transit and dynamic positioning (DP) modes.

A major difference to a typical fixed pitch propeller, which is optimized to a single operational point, is that the ABB Dynafin can adjust the movement of the blades continuously to meet optimal performance over a wide speed range and different wake fields. The unit's control and



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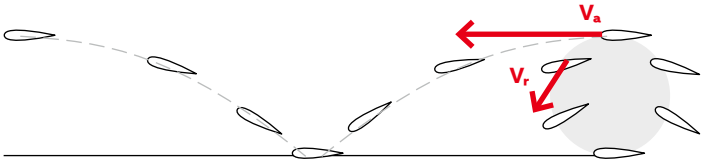

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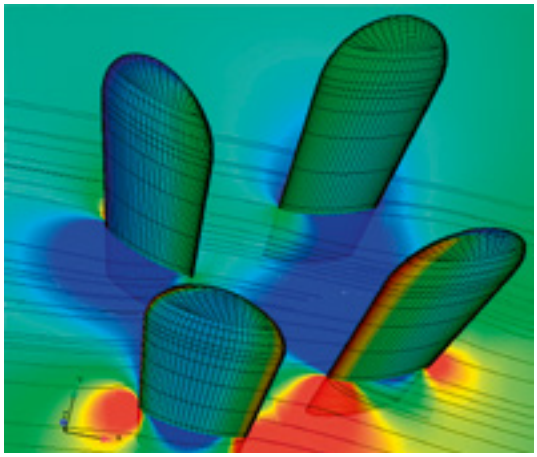

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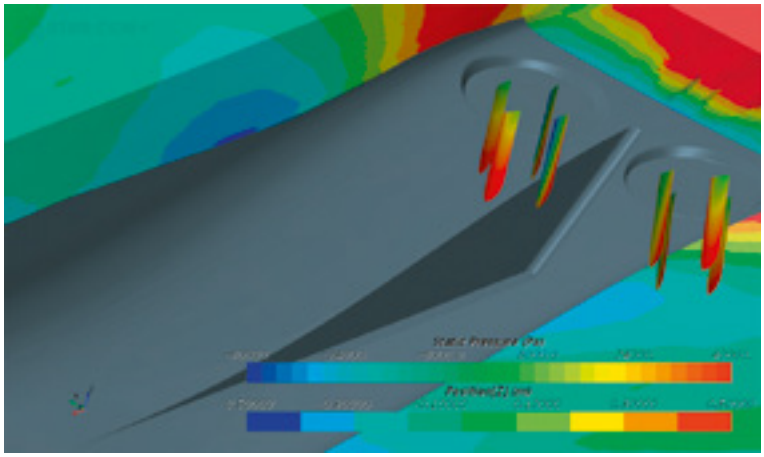

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03 With almost limitless possibilities, CFD simulations provided the fastest and most cost-efficient way to investigate hydrodynamic phenomena and to improve the concept. These two low-resolution screenshots illustrate how simulations can be performed of different aspects of the design.

03a Fluid flow around individual blades.

03b Twin-set simulation.

—
04 Lake trials demonstrating maneuverability capabilities of a vessel equipped with ABB Dynafin propulsors.

software technology opens up the possibility to continuously improve and optimize the vessel's performance throughout its lifetime, creating the concept of a "digital propeller." The ABB Dynafin can also be operated in "rudder mode," meaning that all the blades are controlled as conventional rudders. This feature can not only bring benefits for double-enders and sail-assisted vessels but also increases redundancy in failure situations, providing partial steering capability.

Minimal hull appendages
Propellers with a traditional shaft line require a rudder and struts for the shaft, which induce additional drag. For a cycloidal propulsor, there is no need for a rudder and the only parts protruding from the hull are the blades. Thus, there is minimal added drag, improving the vessel's hydrodynamic performance.

Moreover, the high efficiency of the ABB Dynafin means smaller power plants can be used, leading to a more flexible general arrangement, more room for cargo and passengers and lower maintenance costs. Additionally, maneuverability is enhanced by combining the propulsion with an intelligent control system, which also results in more efficient and safer ship operations.

Precise propulsion control
Rotational movement of the main wheel is produced by an electric direct-drive motor. The main wheel rotates at a relatively low 40 to 80 rpm and has four to six identical blade modules. Rotation direction is kept the same under all operational situations and thrust amount and direction are determined by a combination of main wheel rpm and blade adjustment.

—
Thrust amount and direction are determined by a combination of main wheel rpm and blade adjustment.

Models and modeling
The development of the ABB Dynafin was greatly aided by using computational fluid dynamics (CFD) simulations (to evaluate hydrodynamic performance) and scale-model open-water testing →03-04. Propulsors were retrofitted to a platform support vessel (PSV) hull to obtain a direct comparison against existing Azipod® units in the same power range. Following the successful simulations and model-scale tests, ABB engaged in productive discussions with several ship design offices, shipyards and ship owners and operators to validate the feasibility of the concept. The ABB Dynafin concept was unveiled to the market in mid-2023.

Reducing underwater noise pollution
In addition to GHG emissions, underwater radiated noise (URN) is increasingly recognized as a major issue due to its potential effect on aquatic

04

ecosystems. Limits on URN are expected in the near future. The ABB Dynafin minimizes electromagnetic noise by having the electric motors inside the vessel's hull. Low-pressure pulses and blade-tip speeds create less cavitation and turbulence, resulting in low hydrodynamic noise. In addition, individual blade control enables optimized trajectories to minimize hydrodynamic noise in different operational situations.

Wide-ranging application

Initially, ABB is concentrating on developing the ABB Dynafin units in the power range of 1 to 4 MW per propulsor. With four units installed, up to 16 MW applications can be covered. In addition to having a direct electrical power train for both the main wheel and the blade modules, a mechanical bevel gear may be used, allowing connection to the main engine and extending the benefits to vessel segments where electrical power trains are typically not used.

Propelling shipping into the future

ABB Dynafin's higher total efficiency compared to existing propulsion systems leads to direct savings in fuel costs and makes it possible to reduce the size of the vessel's power plant. This latter aspect is particularly beneficial to hybrid or fully battery-powered vessels, as the size of costly battery banks can be minimized. Lower fuel consumption, enabling smaller fuel tanks,

ABB Dynafin's higher total efficiency leads to direct savings in fuel costs.

and a smaller footprint of the power train, provides more flexibility in general arrangements and more space for passengers and cargo. These indirect savings can have a significant positive financial impact. In addition to high efficiency, the ABB Dynafin enables superior vessel maneuverability, lowering costs and increasing safety →05.

ABB's expertise in hydrodynamics, mechanical systems, ship electrification, automation and control put the company in a unique position to further improve the ingenious ABB Dynafin. The ABB Dynafin will add a new level of adaptability and intelligence at the heart of propulsion performance and change how the shipping industry thinks about propulsion systems. •

05 The ABB Dynafin improves many aspects of a vessel's performance, from efficiency through reliability to crew and passenger comfort.

Video explaining Dynafin
"Introducing the revolutionary ABB Dynafin™ – the latest propulsion innovation by ABB" (hosted on Youtube)

CUSTOMER BENEFITS

High efficiency
- Open-water efficiency up to 85 percent.
- Significant fuel savings, resulting in emissions avoidance.
- Less installed power, supporting the electrification of vessels and utilization of greener fuels.

Excellent maneuverability
- Instant control of thrust and its direction, supporting operational safety, flexibility and DP capability.
- Suitability for demanding operations and sea conditions.

High reliability and easy maintenance
- Combined propulsor and steering and a direct electrical power train for the main wheel and the blade modules result in fewer components.
- The absence of wear-sensitive gears and the main wheel's moderate 40 to 80 rpm minimizes component wear.
- Easy access to the main wheel, enabling inspection and replacement of many components from inside the vessel, improving the ability to monitor components, increasing vessel availability and shortening dry-dock stays.
- The unit's modular structure and higher degree of standardization simplify spare-part management.

High onboard comfort level and sustainable operations
- Low rotational speed minimizes cavitation, pressure pulses, noise and vibration.
- Low underwater noise, enabling operation in sensitive marine areas.

05

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[1] International Maritime Organization, "Revised GHG reduction strategy for global shipping adopted." Available: https://www.imo.org/en/MediaCentre/PressBriefings/pages/Revised-GHG-reduction-strategy-for-global-shipping-adopted-.aspx#:~:text=The%20revised%20IMO%20GHG%20Strategy,points%20for%202030%20and%202040. [Accessed December 10, 2023.]

[2] Fasse, G. et al., "An experimental blade-controlled platform for the design of smart cross-flow propeller." Available: https://www.sciencedirect.com/science/article/abs/pii/S0029801822003547. [Accessed October 12, 2023.]

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EFFECTIVE KILN SAMPLE-GAS FILTERING WITH PROKILN PROBE

Filter tip

The cement industry has seen a significant increase in alternative fuel use in recent years. Though beneficial in many ways, these fuels present new challenges for gas analysis equipment at the cement kiln inlet. ProKiln, ABB's fourth-generation gas sampling probe, helps overcome these challenges.

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With over 30 years of experience and more than 600 kiln systems supplied worldwide, ABB is the market leader in providing gas analyzers for cement plants. These analyzers are indispensable for this application as they play a crucial role in ensuring optimal operational efficiency, compliance with environmental regulations and the effective utilization of fuels and raw materials.

Analysis systems are installed at the inlet of the cement kiln to monitor and analyze the composition of gases entering the cement-making process, offering operators valuable information on combustion efficiency and emission levels. Gases monitored include oxygen (O_2), carbon dioxide (CO_2), nitrogen oxides (NO_x) sulfur dioxide (SO_2) and carbon monoxide (CO). O_2 exit concentrations, for example, are used as a kind of lambda sensor to help set kiln operating parameters. CO measurements, as another example, indicate process O_2 deficiency or surplus and give early warning of potentially explosive conditions developing, especially at start-up or shut-down or under process imbalance conditions.

The harsh environment found at the kiln inlet precludes the use of in-situ equipment, so the dominant commercially available devices rely on sample-extraction designs. However, the introduction of new processes and additives and, increasingly, alternative fuels and raw material (AFR), is testing sample extraction probes to the limits. The most serious detrimental effect seen is scaling on the probe surface and sample intake area. Material fall-through in the kiln riser duct has also become more frequent, increasing the risk of probe damage.

With the increased use of AFR (some plants may use up to 95 percent AFR), complete combustion can be more difficult to achieve than with conventional fuels. Further, due to the greater weight and more complex composition of AFR, it is more liable to fall and burn in direct contact with the bed material of the kiln, causing localized unfavorable conditions or damage. AFR can also increase the quantity of vaporized volatile components in the kiln. These factors make reliable gas sampling all the more necessary.

ABB's patented ProKiln probe is a response to the challenges created by these new process conditions. The probe – developed in collaboration with FLO2R, a Danish company with long-established and deep knowledge of kiln inlet measurement – focuses on a more powerful probe cleaning regime and increased mechanical strength →01-02.

ProKiln has a 3 m-long water-cooled probe with an extractive filter at the sampling end.

Clean and robust sampling

ABB's ProKiln's main component is a 3 m-long, water-cooled probe with an extractive filter at the sampling end →02. Two powerful air blasters that blow through up to six internal pipes (to reduce pressure drop – a key design requirement) provide sample flow and cleaning. The probe is installed on a buggy running on a retraction device →03. A failsafe is provided to extract the probe in the event of a power failure (for installations without an uninterruptible power supply,

01 ABB's new ProKiln gas sampling probe overcomes many of the challenges of placing equipment in the hostile environment at the gas inlet of a cement kiln.

Photo fig. 01: ©Drpixel/stock.adobe.com

an additional pneumatic motor is included). The buggy retractor runs on debris-resistant tracks that prevent obstruction by foreign material.

A control cabinet with a human-machine interface (HMI) operates and powers the system and connects it to any gas analysis system – of either hot/wet or cold/dry types. The cabinet features common serial interfaces for easy connection to the plant control room. A second unit external to the probe contains the recirculating, non-pressurized cooling system.

Two sample-taking air blasters are also employed to clean the probe tip and filter periphery.

Extractive filter in the probe tip
The device's most critical interface is the filter through which sample gas is separated from the process dust. This filter is located inside the probe cooling jacket, which protects it from direct impacts and eliminates the long sampling pipe in incumbent devices in which dust and sample can combine to form a sticky, pipe-blocking residue. The filtered sample gas is transported away via a constant-temperature (180 °C) heated tube.

Double air blaster cleaning of the probe tip
To avoid complications inside a probe exposed to a 1,200 °C process, the two sample-taking air blasters are also employed to clean the probe tip and filter periphery →04. This is accomplished by a novel 3-D-printed stainless steel nozzle arrangement that allows one blaster to direct air through the center of the probe and filter while the other delivers air to the base of the filter, which cleans the periphery and surface of the filter, blowing any dust back into the process.

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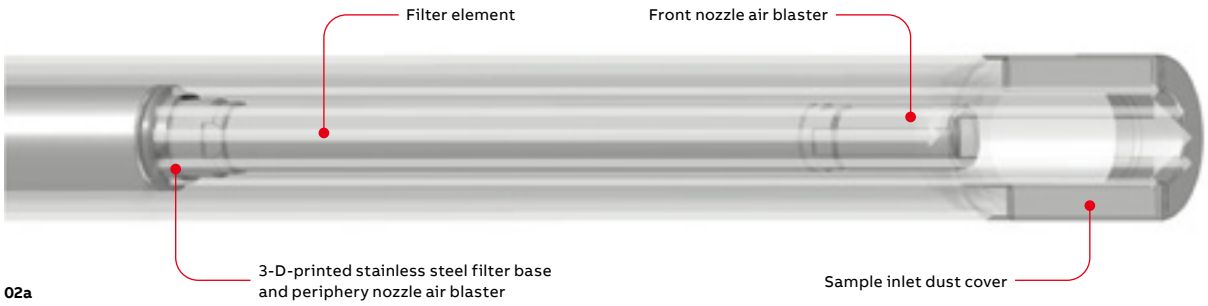
02 ABB's patented ProKiln probe.

02a "X-ray" view.

02b Schematic.



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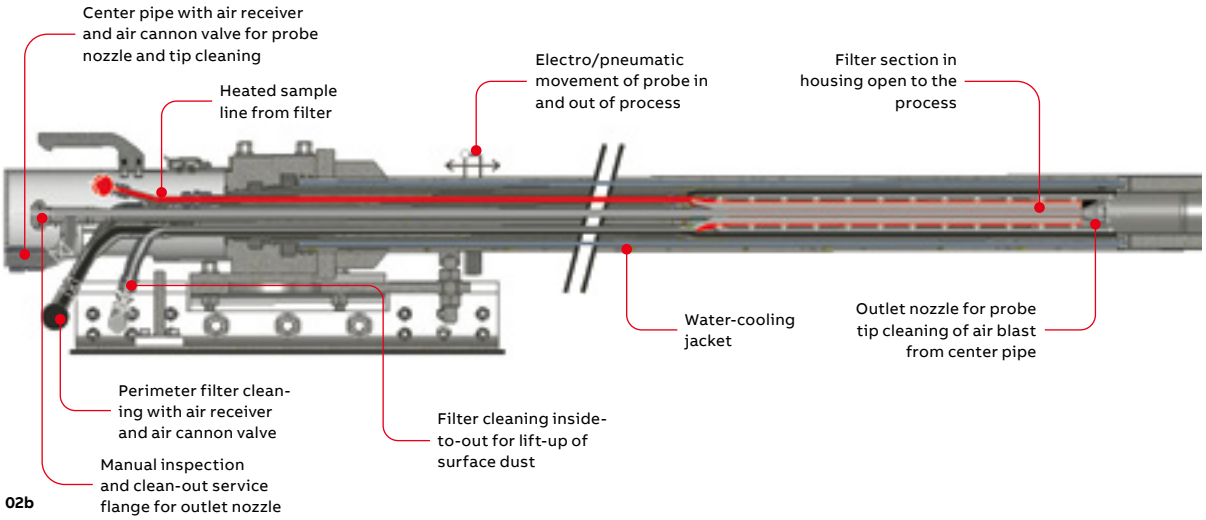

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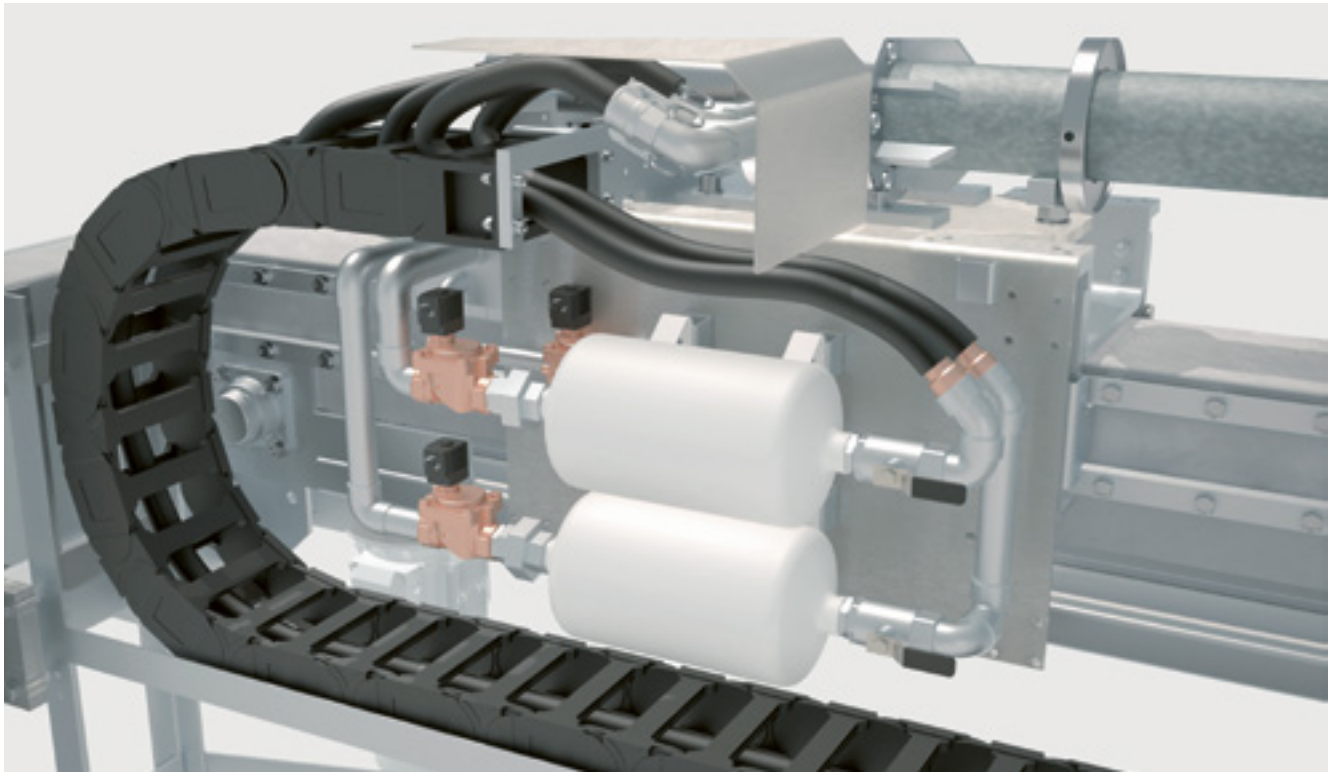

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03 The ProKiln's buggy runs on debris-resistant rails with hoses and wires protected by a flexible track. The two white cylinders are air blasters (protected by a cover, which has been "removed" here for illustration purposes).

Strong mechanical design is needed
The probe design is based on a 4-inch high-temperature austenitic stainless steel pipe. The heavy probe construction is reinforced at the base, much like a kiln burner. The heavy-duty design allows the probe to survive material fall-through from the riser duct. A heat monitoring system continuously evaluates the process conditions and material build-up on and around the probe, triggering the kiln's standard air blasters in the inlet area when needed.

—
As part of the product development, tests were conducted at a Holcim plant in Germany.

Simple layout and standard materials
All probe assemblies are based on standard flanges, O-rings, cutting rings, unions and other standard elements. The center pipe that connects one air blaster to the front cleaning nozzle also provides full and easy access for inspection of the entire probe length without using any tools. This examination is possible even when the probe is fully inserted into the process.

The two air blasters are located on the side of the buggy behind a detachable panel →03. The probe package has clean lines and a sturdy layout with only those parts needed for probe operation exposed.

Probing probe performance – field tests
As a part of the product development, tests were conducted at a Holcim plant in Lägerdorf, Germany. The objectives of the trial were to validate:

- System safety
- Maintenance performance – for at least six months of operation
- Probe strength
- Material choices for process and sample parts
- Probe and retractor ability to remove scaling
- Efficiency of air blaster cleaning in a process using AFR with high concentrations of volatiles
- Gas analysis results from the new probe

A test probe was installed in mid-2021. The test installation was equipped with an automated flange to protect personnel and equipment in the event of an overpressure event. The probe was safety cleared for automatic operation and testing continued for over 10 months.

Two modifications were made during the test: the automated flange was strengthened and the probe tip inlet design was changed to provide a more stable flow under conditions of heavy scaling at the inlet.

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04 Kiln inlet probe test installation, rear view.

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05 A dual-probe implementation will attain a 100 percent run factor. Shown is an on-bottom configuration. On-top, right and left configurations are also available to provide maximum flexibility.

The use of standard maintenance procedures and materials was very successful and easy to grasp for maintenance personnel (no special training is needed). Typical preventive maintenance and inspection required less than 15 minutes each week.

During the test period, material falling from the riser duct struck the probe several times, with no consequent probe harm. A complete inspection of all internal and external parts after seven and 10 months of operation revealed no corrosion or damage. Indeed, a hard oxidized layer had formed on the surface of the probe that provided additional protection.

The plant used fuels originating from 17 different AFRs during the trial period, resulting in significant fluctuations of the O_2 and CO process values and giving very light to very heavy scaling. Despite these conditions, the probe functioned reliably in automatic operation and no manual cleaning was required – regular cleaning cycles were adequate and during times of heavy scaling, a sample vacuum sensor would initiate additional automatic cleaning. A run factor of over 95 percent was achieved, proving the design and confirming that a double-probe implementation (which is available) will provide a 100 percent run factor →05.

— During the test period, material falling from the riser duct struck the probe several times, with no consequent probe harming.

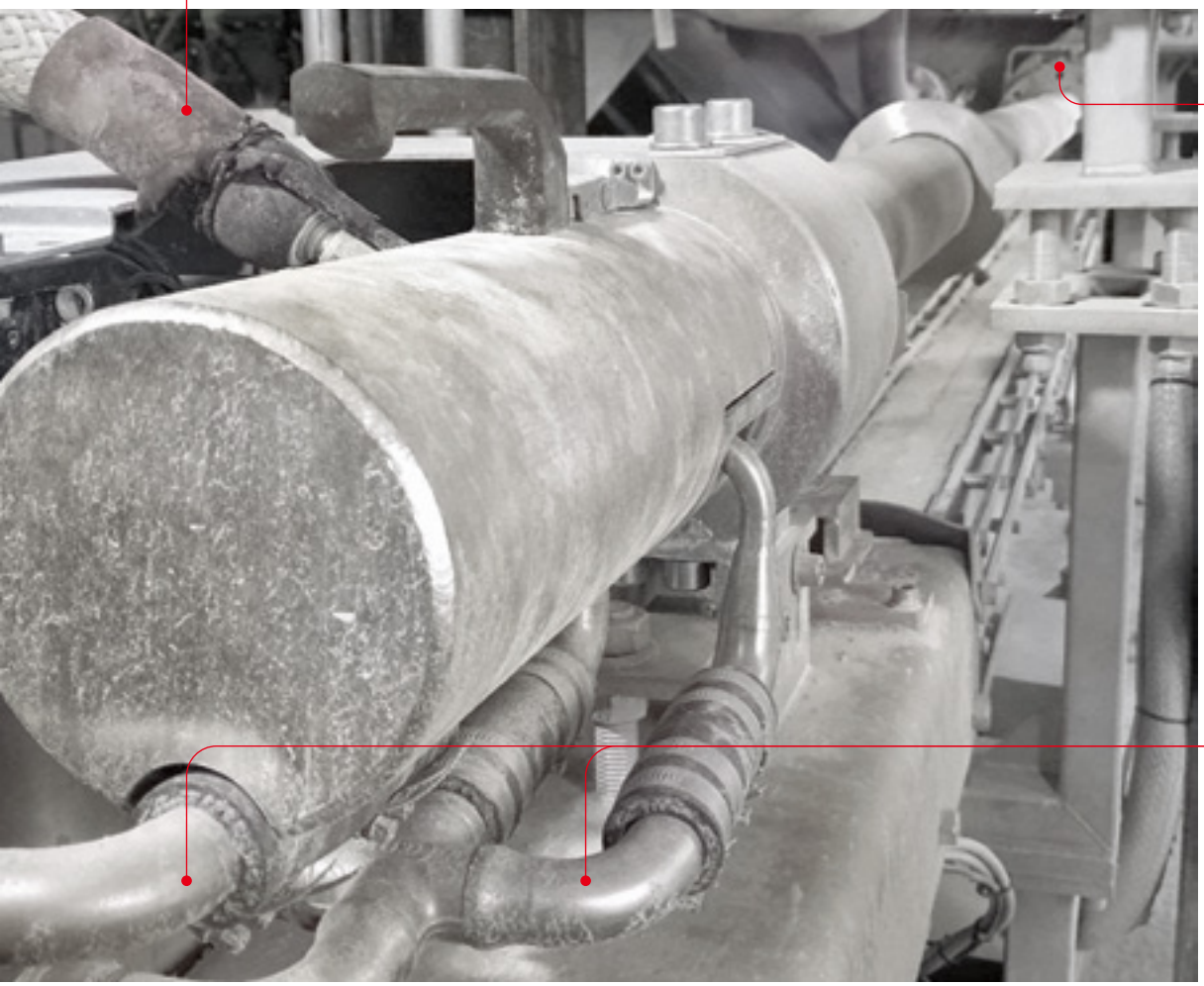
04

The test kiln had an existing extractive gas analysis system installed in the kiln inlet, which allowed a comparison of results. Even though the analyzers were not supplied with sample gases obtained at the same time and the existing system had a considerably longer sample time, a comparison test showed agreement to within 10 percent.

Cementing the future

The use of AFR in the cement industry has created a more challenging environment for gas analysis equipment due to higher concentrations of volatiles. At the same time, the increased complexities of the process make accurate gas analysis more critical if operations are to achieve efficient combustion, improve quality, reduce emissions and environmental footprint, comply with environmental regulations and effectively incorporate AFR. The ProKiln probe has shown itself capable of facilitating efficacious kiln inlet gas analysis under even the harshest conditions. The return on the investment involved in installing this simple and strong probe can easily be justified by preventing kiln stops alone.

As the industry evolves, gas analysis technology such as ProKiln will remain critical in driving the cement sector toward a greener and more efficient future. •



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AUTOMATIC OFFLINE COLLISION-FREE PATH PLANNING FOR INDUSTRIAL ROBOTS

Click & go

Until now, the programming of robot motion has been a cumbersome manual task requiring advanced skills. ABB's new RobotStudio® Automatic Path Planning is radically changing this paradigm. The tool reduces offline robot motion programming to a few clicks and produces motions that outperform those developed by robotics experts in several areas. In short, robots can now be told what to do but are free to translate such orders into the motions that best meet their capabilities and the requirements of their environment.

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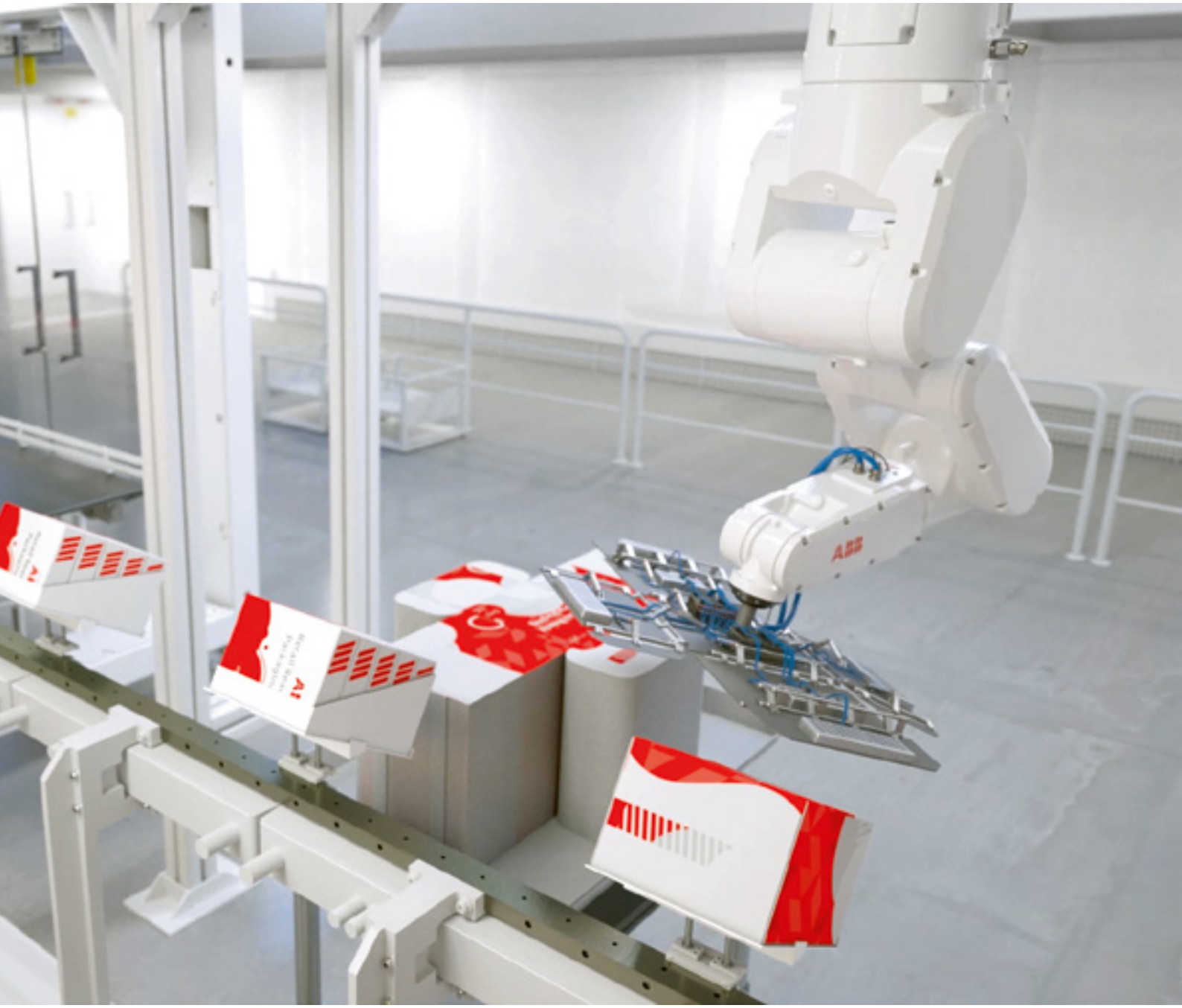
Many decades ago, when people started mimicking robot movements in dances, their jerky and sudden movements were meant as a caricature of the state of the art in robotic motion planning. Today, however, such motions are miles away from being an accurate representation of the state of the art. Nevertheless, since robot programming is difficult and time consuming, inefficient robot programs are still ubiquitous. Even expert robot programmers may produce programs that are not optimal. The reason for this is that articulated robots live in a different mathematical space (a so-called joint space governed by six dimensions) rather than our 3D world.

Articulated robots live in a so-called joint space governed by six dimensions, rather than our 3D world.

In practical terms, this means that what humans consider to be the shortest path between two points is very different when translated into the equivalent path for a robot's joint actuators. Furthermore, the idea of manually optimizing a robot's every move may not be the best use of



resources in a business – a factor that is particularly salient for smaller companies that may lack advanced robotics knowledge. In view of these trends, it is time to start moving toward a world in which robot programming is left to the robots themselves. In short, a user should just tell a robot what needs to be done, and not have to bother with how the robot translates such input into specific individual movements.

Task and transfer motions

A typical industrial robot program can be divided into task-related and transfer motions. The former includes tasks such as welding, gluing, sanding, and tightening screws, where the robot path is for the most part dictated by the task. In most transfer motions and some task-related motions (eg, material handling), the robot path is typically not required to follow a pre-defined geometry, and the user is only interested in the robot traveling from one part of a cell to another

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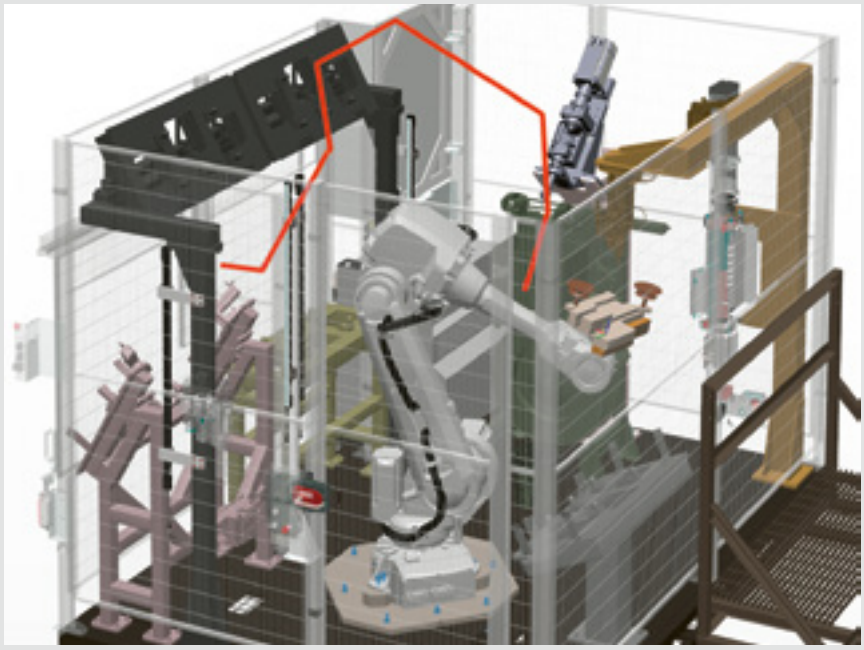
It is time to start moving toward a world in which robot programming is left to the robots themselves.



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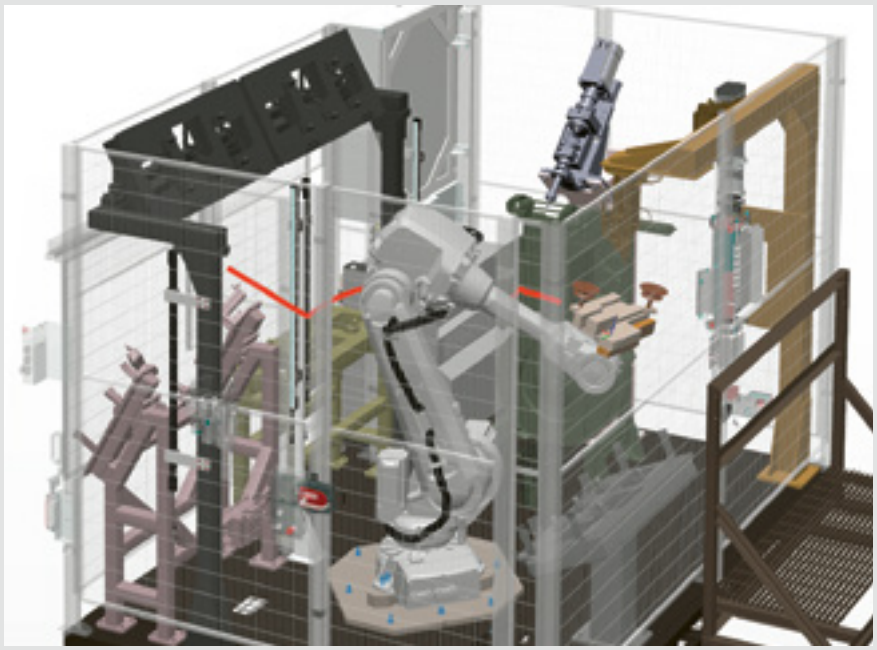

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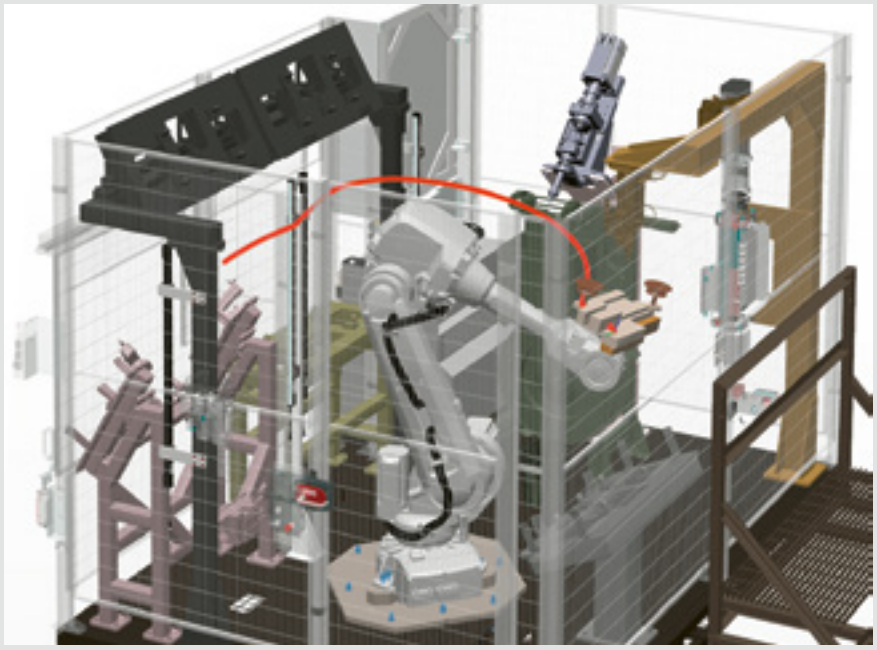

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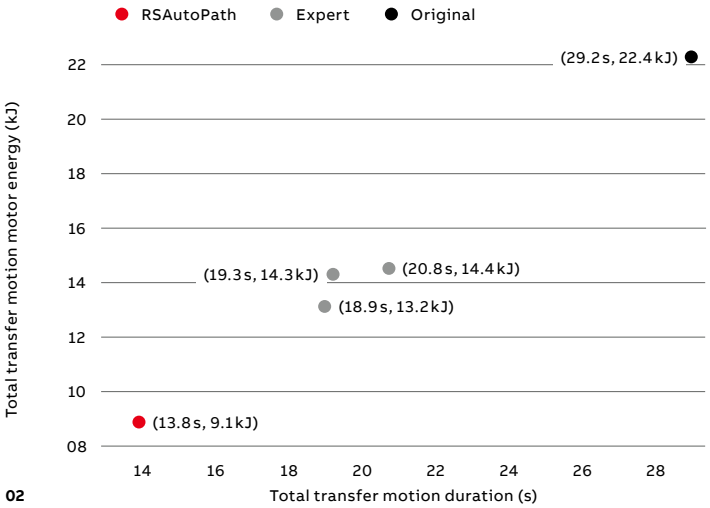

02

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01 Comparison of robot transfer paths. Motion durations are, respectively: 5.95 s, 3.48 s, and 2.99 s.

01a Original program.

01b Expert programmer.

01c RobotStudio Automatic Path Planning

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02 Achieved motion performance in terms of total transfer motion duration and consumed motor energy for original program, experts and RobotStudio Automatic Path Planning. Each dot represents one participant.

in a time-efficient manner. To program such a transfer motion between a start and a goal, a robot programmer iteratively adds via points and checks whether the robot and its attachments remain free of collision with the environment and with themselves along the path. At the same time, programmers often try to shape a path to be reasonably short in order to achieve a shorter motion duration. Finally, the via points must be reachable by the robot. Although this may sound trivial at first, anyone who has spent time on robot programming has likely faced situations where the robot is not able to follow the desired path because of its joints' limitations or associated so-called kinematic singularities.

As cost-saving measures shrink the size of robot cells, programming collision-free, reachable, and efficient transfer motions becomes more challenging and time consuming. In view of this, the recently introduced collision-free path planning feature in ABB RobotStudio allows programmers to generate an efficient path in seconds by simply selecting start and goal targets, as well as robot speed, and then clicking the "create" button. In addition to reducing programming time from several minutes to a few seconds, the resulting path possesses the following advantages:

- It is generated in ABB RAPID Move commands, allowing it to be easily integrated in ABB RAPID programs.
- Regardless of the size or the shape of the obstacles or robot attachments, the nominal path is guaranteed to be collision-free.
- Thanks to the fact that it is optimized for the robot's joint spaces, the path is particularly short.
- Since it is short, the path is energy efficient.
- It is guaranteed to be reachable and free of singularities.
- As the path is extremely smooth in terms of a robot's joint space, it contributes to improved motion duration, reduced energy consumption and reduced stress on robot mechanics.

The last of the above advantages is achieved thanks to the automatic zone parameterization feature of the collision-free path planner. In other words, if a robot is not forced to stop at each via point and instead take a shortcut, its movement path can be traversed more quickly. Shortcuts are defined by the zone parameter for a given target, which specifies, for instance, the maximum distance that a robot's Tool Center Point (TCP) can deviate from a target. With a larger zone parameter, the path can become smoother and shorter.

However, users often need to resort to trial and error to find a zone parameter that is sufficiently large but that does not lead to collisions. Furthermore, this must be done for all via points. This cumbersome process often results in users selecting a small zone for all the via points in a path, thus unnecessarily limiting the performance and smoothness of the intended motion. RobotStudio's Automatic Path Planning completely automates this process such that the resulting path maximizes the number and size of collision-free zones. In addition, programming can be further simplified by selecting several goal targets for any given start target. In this case, a single click in RobotStudio will result in multiple collision-free paths.

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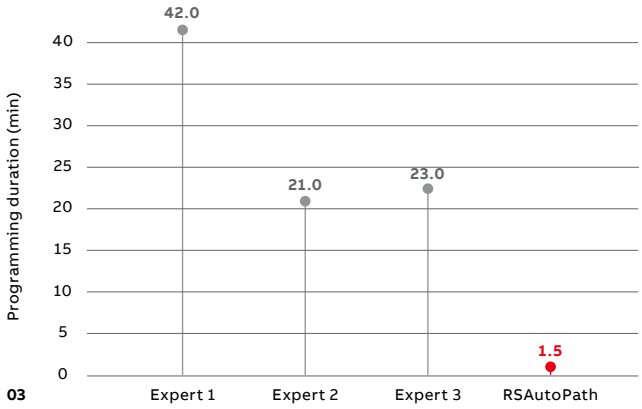
ABB RobotStudio's path planning feature reduces programming time from several minutes to a few seconds.

Experts vs. Robots

Although there is no question that automatic path planning lowers the barrier to entry for many smaller companies and saves programming time, prospective users may wonder whether an automatically generated motion can offer the same level of performance as the



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03 Programming duration of experts and RobotStudio Automatic Path Planning in minutes.

04

motions programmed by experts. With this in mind, ABB recently conducted a user study [1] in which the performance of the transfer motions generated by the RobotStudio path planner were compared to the performance of the motions developed by robot programmers on a real-world robot station.

The user study focused on a robotic gluing cell from the automotive industry. The cell was characterized by a tight layout that makes it

—

In an ABB study, RobotStudio outperformed experts in terms of motion duration and consumed motor energy.

complicated to program the robot motion while avoiding collisions. The robot's assignment was divided into several task-related motions (picking, placing, cleaning and gluing) and six transfer motions. After removal of its original program, the RobotStudio station selected for the study was sent to three RobotStudio programmers who had up to 23 years of experience in robot simulation.

Results

The experts were given written instructions to program the transfer motions of the start-goal target pairs, while trying to achieve good overall motion duration and minimal energy consumption with ordinary effort in optimizing the program. They were also asked to note down the time from opening the station until finishing the programming.

→01 shows one of the transfer motions from the original program, one from the experts, and the RobotStudio path planning motion. The red line depicts the robot's TCP path. As expected, the expert and automatic paths are visibly shorter than that of the original program, with motion durations of 5.95 s, 3.48 s, and 2.99 s respectively for the original, expert, and RobotStudio paths. Interestingly, however, despite the seemingly shorter length of the expert path, the RobotStudio path results in a faster motion. The smoothness of the RobotStudio path is also evident in the figure.

→02 depicts the overall achieved performance from each user, not only in terms of motion duration but also that of estimated energy consumed, combined for all six transfer motions. As can be seen, RobotStudio Automatic Path Planning outperforms all the users including the three experts by a wide margin in both categories. Note that all paths were programmed with the same speed parameter.

Although motion duration is often the principal performance metric of a robotics application, energy efficiency is becoming increasingly important. However, when manual programming is involved, applying a systematic approach to

—
04 RobotStudio's Automatic Path Planning can enable novice users to generate highly efficient robot motion programs.

optimizing motion-related energy consumption, especially when a fixed speed is involved, is not practical. This is where motion planning algorithms such as RobotStudio's offer unique value.

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A new era of unmatched motion performance, greater ease of use, and new levels of robotic autonomy is beginning.

Of course, it is possible that if experts spent more effort on optimizing a program, they would achieve higher performance. However, as shown in →03, the results of such efforts are overshadowed by RobotStudio Automatic Path Planning, which enabled the user to accomplish the task in an almost negligible 1.5 minutes, compared to 21 minutes for the fastest expert.

The 1.5 minutes achieved by RobotStudio auto programming includes converting the path to RAPID and synchronizing it with the controller (the path generation computation takes less than a second per path). Therefore, it can be argued that when it comes to transfer motion programming, experts will be able to rely on RobotStudio Automatic Path Planning in general and spend their effort on optimizing special cases, such as those for which automatic path planning fails to find a solution.

Despite having examined only one robot station and a handful of users for this article, the study's results point to the significant potential of ABB RobotStudio's Automatic Path Planning as a unique offering that can enable novice users to generate highly efficient robot motion programs, save considerable programming effort for experts, and reduce the runtime CO_2 emissions of robotic cells →04. This is just the beginning of an era of unmatched motion performance, greater ease of use, and new levels of robotic autonomy. •

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Reference

[1] ABB internal study. Further information available on request.

Share this article

PERFORMANCE INTEGRATED MOTOR DRIVES THAT RUN BETTER AND COOLER

Beat the heat

Integrated motor drives (IMDs) offer sizable cost and performance benefits. However, thermal and electromagnetic considerations are critical in these devices, especially at high power ratings. ABB's new IMD design approach more than matches the performance demands of high-power applications.

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01 IMDs, such as the ABB Baldor-Reliance EC Titanium axial mount IED shown here powering an axial fan, deliver many benefits.

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02 Exploded view. The drive is fitted between the rear cover of the motor (left) and the motor's fan. Just four mounting bolts are needed, instead of the usual eight.

—
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Due to the increasing need for greater power density, better efficiency and tolerance of higher temperatures in electric drive systems, more users are turning to IMDs. IMDs also reduce costs: By eliminating separate enclosures for the motor and drive and taking away long cable runs, the integrated approach can lower system costs substantially. The removal of cables and the associated electromagnetic noise filters also increases reliability.

Further, integration of drive and motor significantly improves the device's electromagnetic compatibility (EMC) characteristics and allows EMC testing and prevention measures to be applied to the complete package at the point of manufacture. In addition, testing and commissioning is faster when just a single unit is involved. Automation of manufacturing is made easier, too.

Users are grateful for the space freed up by the IMD system's smaller size compared to a traditional, separated solution. For example, inverter control rooms and associated ventilation equipment are no longer needed as the integrated motor and drive can utilize a single cooling system, reducing both system footprint and cost.

IMDs for 7.5 kW

Technological advances over the last decade have produced robust electronic components better able to withstand the rigors of IMD integration. However, to reap the benefits of the IMD approach described here, careful thought must be given to the electrical, structural and thermal implications of combining different elements into a single package.

Existing examples of advanced motor cooling display a targeted approach for removing heat directly from individual heat sources by, for example, indirect stator-winding heat-exchanger cooling or stator-winding heat-guide transport. These techniques of focused thermal management aimed at specific heat sources are enabled by additive manufacturing, highly integrated heat exchangers, multi-functional composite materials, phase-change heat transport and storage and thermal pads. However, such methods are insufficient to solve the challenges faced by high-performance IMDs – for example, the issue that thermal build-up from the motor, electronics and drive presents a practical limit for the operation of drives rated at over 7.5 kW. The physical size of the AC/DC converter also constrains the power rating of commercial IMD units. Above the 7.5 kW threshold, traditional separated motor-drive systems usually offer a better alternative, hence the dearth of high-power commercially available IMDs.

ABB has now successfully developed 7.5 kW IMD prototypes that exhibit excellent performance – especially in terms of thermal management and low radiated electromagnetic emissions →01. These devices have already received positive customer feedback.

ABB has now successfully developed 7.5 kW IMD prototypes with excellent thermal management.

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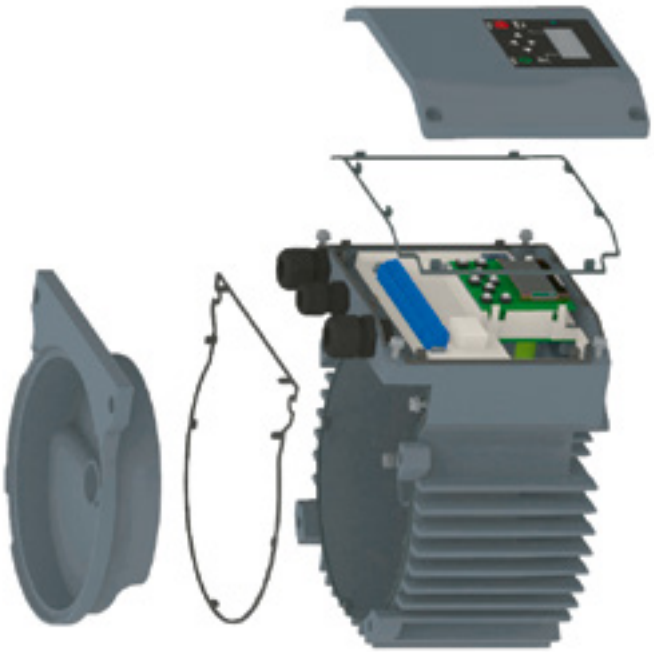

03b

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03 An IP56 rating is attained through effective sealing.

03a Shaft sealing.

03b Gaskets seal cable termination points and circuitry.

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04 Heat dissipation poses more challenges in IMDs than in the conventional motors with a "separated" design shown here.

End-plate-mount integration
Despite significant awareness of IMDs in industry and extensive research and literature on the subject, very little work exists on complete power electronics and machine integration. That which does exist can be divided into three categories: surface-mount integration, stator-iron-mount integration and end-plate-mount integration. For various reasons, such as the stable mechanical platform it provides for the AC/DC convertor, ABB has focused on the latter configuration as a basis for the new IMD design.

Mechanical structure of the new IMD approach
The new IMDs are designed with a shaft height of 90 mm, down from the conventional 132 mm. This compactness reduces the surface area available for heat dissipation and halves the surface area of the non-drive end plate that is available for drive component placement. This situation created a challenge for cooling and packaging the IMD. Here, the concept of an end-plate-mounted drive where the drive is placed between the motor and the fan, together with the new mechanical design of the frame, mitigates thermal issues and saves space →02. An optimized printed-circuit board (PCB) assembly layout saves further space. A pluggable connection cable between the drive and motor means either can be replaced separately and maintenance is simple.

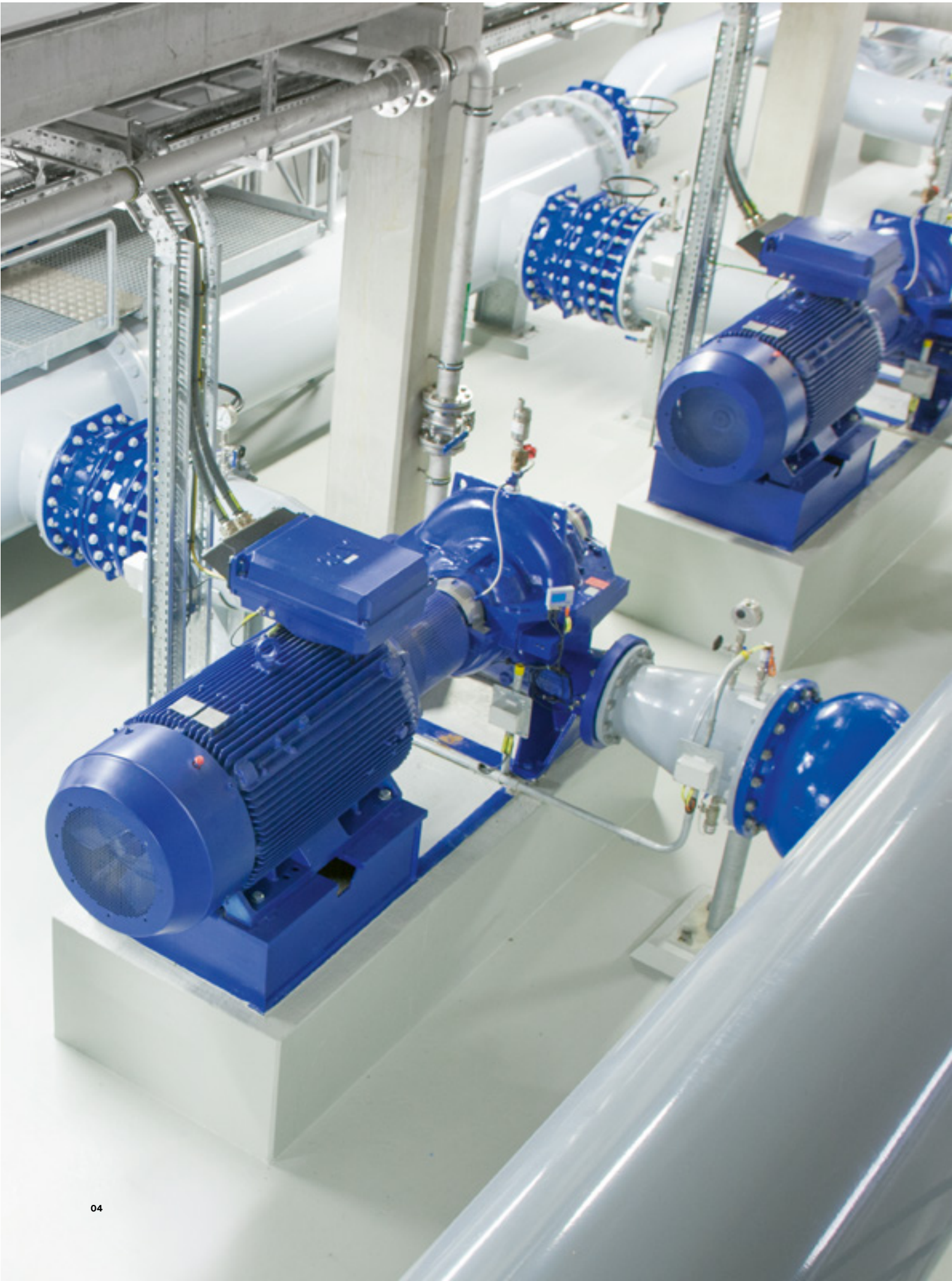
—
An initial thermal design passed all tests and was then enhanced in a second development cycle.

To achieve an IP56 rating, the rotating shaft is sealed at each end →03a. These seals are of a standard design for ease of sourcing. Cables pass through glands and the space in which their termination blocks are located is sealed by a gasket →03b. The junction box cover is designed with integrated buttons and a gasket between the junction box cover and drive frame →03b.

A total thermal management concept
Thermally, the machine suffers because cooling is restricted by the end-plate design; all end-winding losses must now be conducted radially. Therefore, mechanical and cooling aspects must be considered as a whole. Here, heat conduction between the AC/DC convertor and motor and heat dissipation from these two elements are critical factors →04.

An initial thermal design was established and tested with positive results. This design was then enhanced in a second development cycle.

Initial thermal design
Today, devices based on silicon are the dominant power semiconductor choice. However, due to basic physical restrictions, these devices have reached their limits in terms of further development and downscaling. They also have a



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maximum temperature for the device junction in the range of 125 to 150 °C.

Because of these restrictions, ABB's new IMD approach uses devices based on silicon carbide (SiC) semiconductor technology. SiC is a good choice when performance requirements are very demanding. For example, SiC devices typically have low power losses at the high frequencies that permit smaller components and a consequent reduction in equipment volume. SiC also has a higher thermal conductivity than silicon, so quickly conducts heat to its surroundings.

The device's capacitors, relays, chokes, etc., also generate considerable heat. This heat flows via thermal pads and thermal grease to a heatsink for removal by the airflow produced by the specially designed fan. The IMD design discussed here represents the first time thermal pads have been used in an ABB drive.

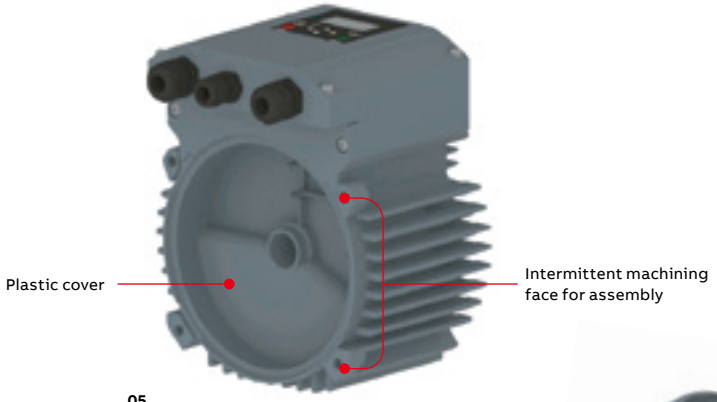
The optimal shape for the heatsink and motor cooling fins was determined by extensive thermal simulations. The surface of the heatsink is coated to meet environmental requirements. Further, the sealed nature of the enclosure isolates

The optimal shape for the heatsink and motor cooling fins was determined by extensive thermal simulations.

— 05 Interface between inverter and motor.

— 06 Cooling air path.

— 07 Stator frame with axial and radial ribs.



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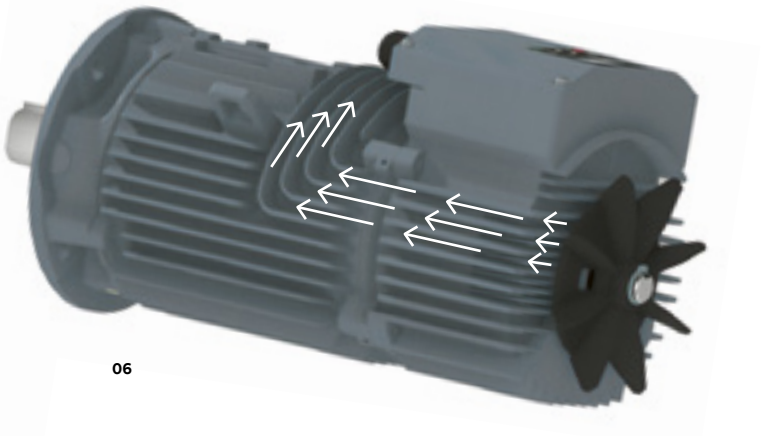

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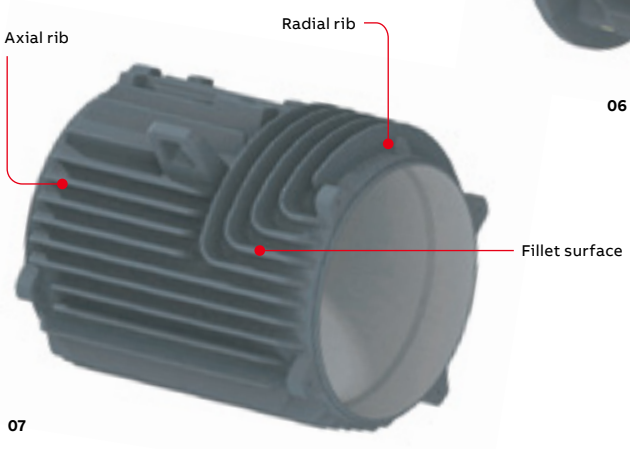

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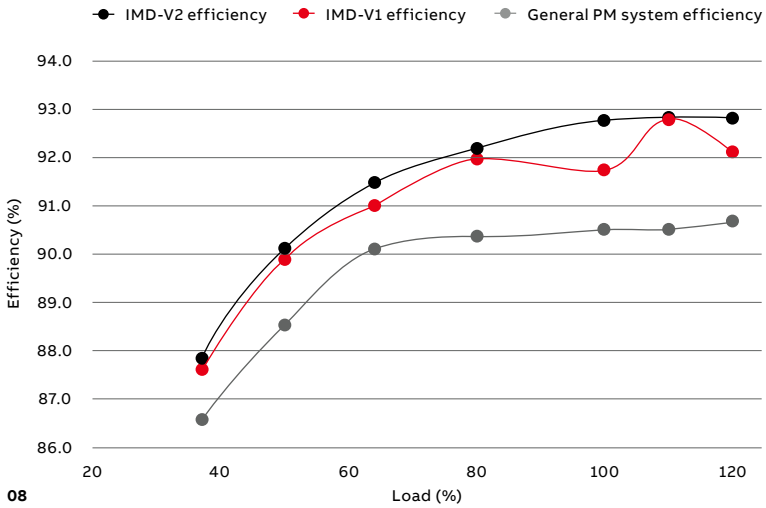

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— 08 Efficiency comparison at different loads (actual test curve).

internal electronic components from any external corrosive gas that may be present. So-called intermittent machining of the inverter/motor touching faces introduces a roughness that ensures reliable fixation – vital for the coaxial elements – and reduces the metal contact area, minimizing heat conduction →05.

Enhanced design

Although the IMD described above is compact and performs well, it presents heat dissipation challenges. The frame can reach 86.9 °C at an ambient temperature of 35 °C, exceeding the customer's maximum spot temperature requirement of 80 °C. The customer also expects the IMD to have a more pronounced energy-saving effect. Therefore, ABB improved the mechanical strategy to boost dissipation and enhanced the electromagnetic design to reduce heat generation and save energy.

—

The frame temperature is lower than that of ordinary permanent magnet motors, while the efficiency is higher.

As a first step in this enhancement exercise, matching ribs were integrated into the metal shells to give a high-efficiency cooling structure →06. Combined axial and radial ribs are used for the motor stator frame, optimizing the cooling air path →07.

The next step was to use computational fluid dynamics (CFD) to optimize the motor frame and thus reduce housing temperature. Subsequently, electromagnetic optimization reduced the frame temperature rise and improved the overall IMD efficiency while remaining within overall volume limitations.

These measures achieved the customer requirement that the maximum temperature at any point on the frame should be below 80 °C at an ambient temperature of 35 °C. Indeed, the frame temperature is lower than that of ordinary permanent magnet motors, while the efficiency is higher →08.

In this design, silicon insulated-gate bipolar transistors (IGBTs) were used to keep costs down, with a view to later utilize SiC devices once they become less expensive.

Driving future development

The thermal, mechanical and electromagnetic designs realized in the IMD described above offer significant cost and performance benefits for high-power applications. Further work should address the relatively high price of SiC devices, which are around three times as expensive as their silicon counterparts, and ways to ameliorate the effects of higher operating temperatures on other system components, such as capacitors. The rapid response times of SiC devices to short-circuit-type events and consequent false triggering is another topic that merits closer investigation. Finally, ABB has initiated collaboration with vendors to align SiC module packaging with ABB's particular needs. •

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ETHERNET-APL FOR FIELD DEVICES IN THE PROCESS INDUSTRY

Leading the field

Ethernet Advanced Physical Layer (Ethernet-APL) widens Ethernet use from commercial environments to the more challenging process industries. With Ethernet-APL's connectivity, field devices can access edge- and cloud-computing features and profit from new opportunities in data-driven applications.

01

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The measurement of parameters such as temperature, pressure, flow, density, concentration and level is essential for monitoring and controlling industrial processes. Moreover, increased energy and raw material costs, greater environmental awareness and higher quality standards drive operators to monitor these processes more closely than ever. Such scrutiny is not trivial when even a midscale plant can have as many as 10,000 field devices that measure and report process parameters.

Traditionally, these constellations of field devices have individually communicated with controllers and engineering tools located in a central control room via 4 to 20 mA analog current loops, commonly using HART protocol to transfer data. The introduction of fieldbuses – such as PROFIBUS, Foundation Fieldbus and Modbus – ushered in an era of digital communication for field devices, but HART retains its hold: the majority of field devices currently installed still use this champion of the industry.

A 4 to 20 mA HART loop typically consumes less than 40 mW, which is sufficient for communication with temperature, pressure, or level sensors and with some types of flow measurement, such as vortex and swirl flow meters. While they also fulfill requirements for cable length, intrinsic safety, robustness and simplicity, current loops have three major limitations:

> While they fulfill many requirements, current loops have three major limitations.

- The transmission speed of 1,200 Baud falls far below modern expectations.
- The communication protocol is tightly linked to the physical layer and does not tolerate any other protocol in the same network, even assuming that modern protocols such as OPC

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01 Ethernet-APL brings the benefits of Ethernet networks to the process industry.

UA would run over 1,200 baud on a 4 to 20 mA loop.

- HART telegrams are not routable through the IP-based networks found on upper layers of the automation pyramid and do not have any semantic, functional safety and security capabilities.

Further, modern flow, level, pressure and temperature devices, for instance, can supply diagnostic and ancillary data along with the primary measurement. Such data is not deliverable when 4 to 20 mA loops are not properly laid out and commissioned to support HART communication.

All in all, HART communication comes from an earlier time. The way forward for communications in the process industries is a new standard: Ethernet-APL. For example, for a vortex flow meter, Ethernet-APL can be used to communicate the device's volume flow, mass flow, process temperature, totalizer values, vortex frequency and diagnostic information. Here, the traditional 4 to 20 mA output would only deliver the basic flow reading, assuming HART communication is not commissioned – which is the case in most installations in the process industry →01. The advantages of Ethernet-APL, however, extend much further – for instance, the protocol facilitates the automation of process plant design and operation and simplifies the tricky task of bringing greater intelligence into potentially explosive environments.

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The way forward for communications in the process industries is a new standard: Ethernet-APL.

Ethernet-APL

Ethernet-APL represents the culmination of a decade-long journey in standardization to bring

—
02 Comparison of communication technologies, focusing on the physical layer.

—
03 Internationally standardized zones define requirements for equipment. For instance, Zone 0 has an explosive atmosphere continuously, for long periods or frequently; Zone 1 has such an atmosphere occasionally in normal operation; in Zone 2, an explosive atmosphere is unlikely in normal operation but, if it does occur, will persist for a short period only.

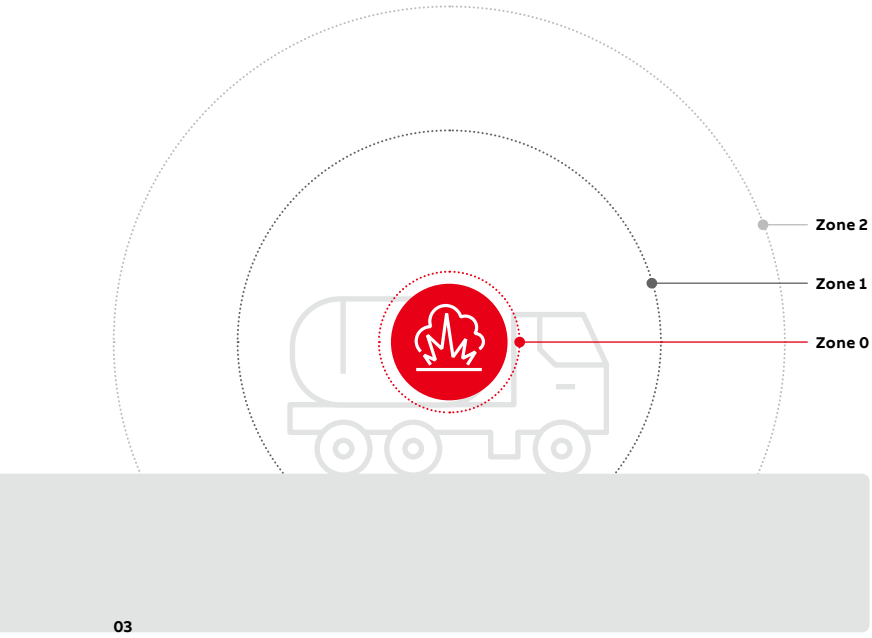
	4-20 mA/HART	Fieldbus	Industrial Ethernet (100BASE-TX)	Ethernet-APL (10BASE-T1L)
Single-pair cable	✓	✓	✗	✓
Communication	1.2 kbit/s half-duplex	31.25 kbit/s half-duplex	100 Mbit/s full-duplex	10 Mbit/s full-duplex
Reference cable	n/a	Type A	CAT 5+	Type A
Maximum cable length	1,200 m	700..1,900 m	100 m	200 m (spur) 1,000 m (trunk)
NE21	✓	✓	✗	✓
Screw/cage clamp connector	✓	✓	(✗)	✓
Polarity independence	✗	✓	✗	✓
Intrinsic safety option	✓	✓	✗	✓
Vertical integration	✗	✗	✓	✓
Measurement (values)	1	n	n	n

02

Ethernet to the field level of the process industries. Ethernet-APL is fully compatible with the IEEE 802.3 standard while satisfying specific criteria for the process industries, including intrinsic safety. Development of the protocol was backed by the leading industry standard development organizations (SDOs): FieldComm Group, ODVA, the OPC Foundation and PROFIBUS and PROFINET International. →02 summarizes how the physical layer specifications of Ethernet-APL fulfill, and in most cases exceed, HART and other technologies.

Ethernet-APL and the automation of process construction, commissioning and operation

The Industrial Internet of Things (IIoT) and Industry 4.0 are already part of everyday operations in manufacturing. Soon, these technologies will also enter the field of process automation and instrumentation. Here, for example, they will play a critical role in domain-specific concepts like the NAMUR Open Architecture (NOA) or the Open Process Automation Standards (O-PAS™) created by the Open Process Automation Forum (OPAF).



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04 Ethernet-APL's low-power attributes are particulary suited to difficult environments.
—
05 ABB Flowmeters FSV450 (vortex) and FSS450 (swirl) combine the robustness, accuracy and stability of classic instrumentation with the simple communication interfaces of the IIoT.

These initiatives are attempting to simplify the construction, commissioning and operation of process plants. Broader use of wireless solutions, simplified field device integration and more prolific Ethernet communications are integral components of these concepts [1]. One way

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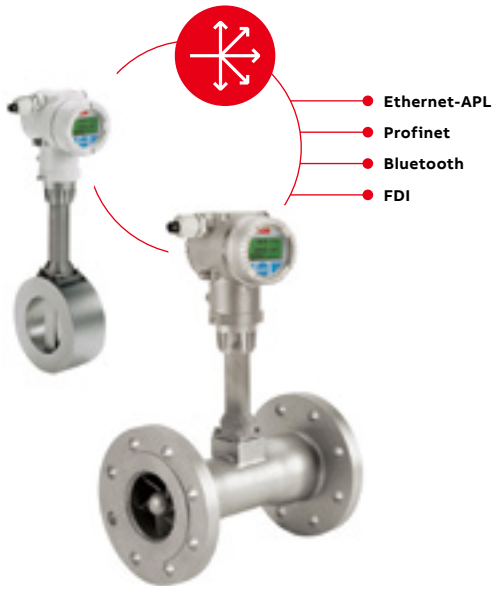
One area in which Ethernet-APL is of particular interest is in potentially explosive environments.



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to advance this transformation is to agree on common communication protocols across the industry. Here, Ethernet-APL is ideal as a common communication backbone as it is – like standard Ethernet – agnostic in terms of the communication protocol and multiple protocols can, to a certain extent, run in parallel in the same network.

Useful in potentially explosive environments

One area in which Ethernet-APL is of particular interest is in potentially explosive environments. Field devices are often installed in spaces in which an explosive atmosphere may arise. Any equipment installed in these locations – and external equipment connected via cable to it – must be designed according to standards such as IEC 60079 and is subject to government regulation →03-04.

Intrinsically safe equipment is usually preferred over placing equipment in an explosion-proof housing due to the advantages of easier installation and working procedures. A device or cable is then simply classed as "safe in itself." The key to avoiding hot surface temperatures that might initiate an explosion in these environments is a strict power limitation for any signal cable entering a relevant zone, in combination with a low-power design for the equipment itself.
As it is standard practice for field instruments to comply with intrinsic safety regulations, it is also

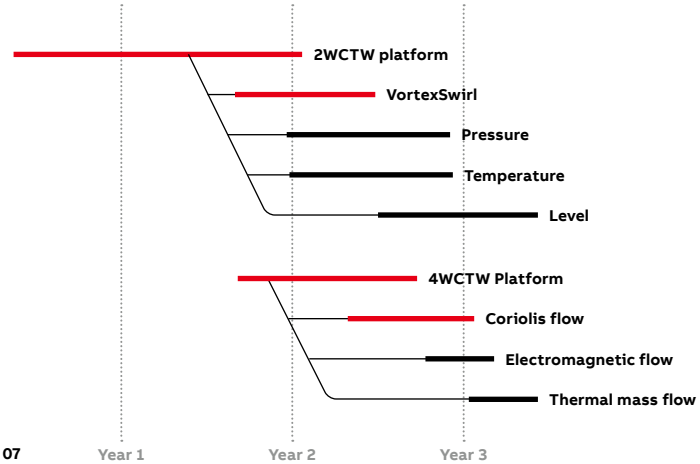
06

— 06 Local and remote device access via a smartphone app or via a browser on a tablet or computer.

standard practice to limit their required current and voltage levels. This restriction makes it impossible to use traditional technologies, such as standard industrial Ethernet.

Ethernet-APL provides the solution because its underlying 2-wire intrinsically safe Ethernet (2-WISE) concept [2] limits voltage and current going to the field device. There is also electronic circuitry at each device input and output that prevents ignition levels of electrical energy from reaching the connector. These attributes allow the installation of Ethernet-APL devices in even the very most hazardous zones and facilitate remote service assistance in the event of process or device issues. Moreover, the power levels allowed in 2-WISE let devices perform more complex computations than in the past, enabling more precise and reliable measurements and more diagnostics. Note, too, that the two-wire implementation makes field upgrades from the two-wire HART and Fieldbus possible without expensive rewiring, as would be the case with four-wire Ethernet.

— ABB has implemented Ethernet-APL into its FSx430 and FSx450 vortex/swirl flowmeters.



07

— 07 Roadmap for ABB's Ethernet-APL portfolio.

Introducing Ethernet-APL into ABB vortex meters

ABB has implemented Ethernet-APL into its FSx430 and FSx450 vortex/swirl flowmeters. This exercise was helped by the company's long experience in industrial communication and collaboration with internal communication and security experts as well as technology suppliers and customers.

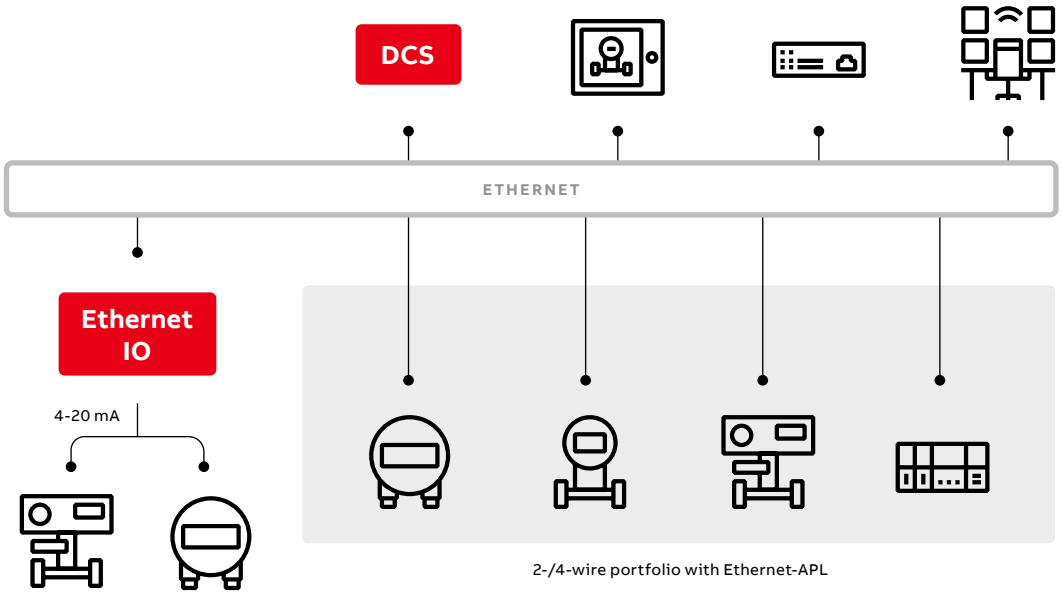
The development is based on ABB's successful Common Top Works platform concepts for instrumentation: 2-wire and 4-wire Common Top Works (2WCTW and 4WCTW). These platforms bundle together measurement-independent features, such as the communication interface, software, power supply, explosion protection, electromagnetic compatibility, human-machine interface (HMI) and housing.

Bluetooth meets process instrumentation

Besides Ethernet-APL, another modern communication technology in the industrial space was integrated into the FSX430 and FSX450: Bluetooth →05.

Although robustness, stability and EMC considerations still impose limitations on it, at one sweep, Bluetooth can eliminate many of the complex tools, cable adapters and specific communication drivers needed by classic field instruments.

08 Future converged Ethernet networks in the process industry, including 4 to 20 mA brownfield devices and IIoT-enabled field devices based on Ethernet-APL and multiprotocol capabilities [3].



08 Existing 2/4-wire portfolio

Bluetooth makes local access easy with a secure smartphone app →06. Using Bluetooth for local device access has many advantages over wired access, for instance:

- Safety: There is no need to physically access the device, which can be installed several meters above ground or between hot pipes.
- Electrostatic protection: No electrostatic discharge is created as there is no contact when using wireless communication.
- Security: Bluetooth and a smartphone offer more efficient user authentication password protection than a locally integrated display on the device.

Casting a wider net

ABB's roadmap includes applying Ethernet-APL to other field measurements – for example, temperature and pressure – as well as further enhancements, such as using PROFIsafe to apply Ethernet-APL and PROFINET to applications requiring a functional safety integrity level (SIL) →07. ABB's TopWorks platform paves the way for upgrading ABB's entire field device portfolio with much less effort compared to running individual projects. Resources can then concentrate on enhancing customer value.

Besides Ethernet-APL, another modern technology was integrated into the FSX430 and FSX450: Bluetooth.

APL will bring Ethernet to process automation – even to its most critical areas. ABB is shaping a future of a connected industrial world and is fully committed to the vision of a network-centric architecture in automation →08. Ethernet-APL will break down the barriers between the layers of the automation pyramid and turn it into a space containing just servers holding data and functions, and clients in possession of comprehensive control, visualization and optimization capabilities. •

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VD4 EVO CIRCUIT BREAKER FOR MV PROTECTION FOR A SMARTER AND GREENER FUTURE

Breaking with tradition

Combining advances in digital and green technologies to deliver a sterling level of safety and protection, ABB's newest circuit breaker (CB) VD4 evo →**01** is built on the proven success of the VD4. The algorithm-based model enables condition-based and predictive maintenance for reliability and a longer service life; safety, connectivity and cyber security are ensured.

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01 The VD4 evo is ABB's newest offering of the IEC indoor vacuum circuit breaker VD4. This smart device can reduce the risk of power outages by 30 percent and increases operation and maintenance efficiencies by up to 60 percent, thereby improving OpEx.

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02 Renewable energy sources, such as the wind turbines shown, require the ability to manage energy flows due to the variability of input among others.

Consistent with the emerging smart grid concept in which the flow of energy and communication are bi-directional, the role of the MV CB is evolving. These devices are no longer simply used for protection, they are proactive apparatuses able to interact with the main installation-specific electrical entities and to coordinate operations. The increasingly pressing demand from public utility companies and private industry for greater continuity of service and a better quality of energy supply lead to further requirements: ie, the ability to manage energy flows generated by renewable energy sources of variable input, eg,

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Profound changes in how electricity is generated and distributed parallels notable advances in grid control and protection.

distributed energy resources (DERs), additional storage and the electrification of transport →02. Such profound changes in how electricity is generated and distributed parallels notable advances in the development of grid control and protection components, growth in the use of electronic sensor systems for collecting data, and the application of advanced analytics. Combining such innovations could help make the power grid smarter, more robust and reliable, as well as efficient in terms of energy and maintenance while improving safety and protection.

Recognizing the opportunities of this convergence, ABB re-examined their conventional, yet highly successful, VD4 CB. With over 2 million installed units, this vacuum indoor CB with mechanical actuator (spring mechanism) is intended for primary distribution up to 46 kV, 4,000 A, 63 kA. ABB wondered if they could provide end-users with the benefits of new digital and green technologies while continuing to deliver the VD4's sterling level of safety and protection. The trailblazing VD4 evo CB is ABB's answer: a smart protection system that builds on the success of the VD4 CB to create a safer, more connective, cyber secure solution that is sustainable.

—
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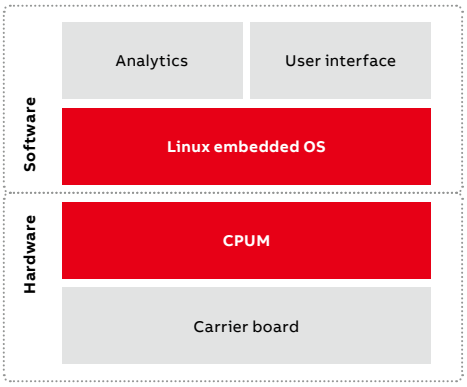

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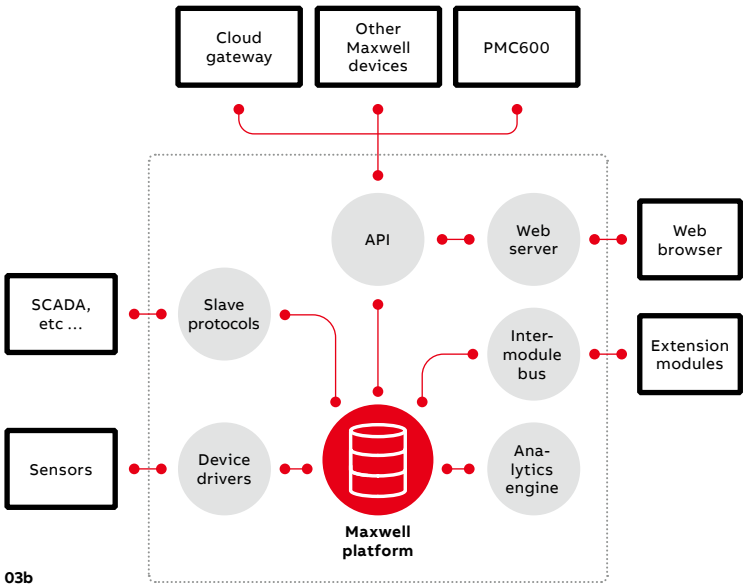

03b

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03 Schematics that indicate the architecture of VD4 evo and CMU and the important interactions and connections are displayed.

03a The schematic illustrates the hardware and software and interfaces for each specific application requirements.

03b The CMU is based on ABB's Maxwell, and has a modular structure; it has been designed to support M&D and ABB Ability™.

Diagnostics and protection for the MV smart grid of the future

The new VD4 family is designed to provide protection and control for cables, overhead lines, distribution substations, motors, transformers, generators and capacitor banks. This new generation of CBs considers the state of the electric power supply (voltage, frequency, harmonic components, etc.) and load conditions (current values, displacement, etc.) in the control and execution of commands, thereby allowing for the optimization of current interruption, mechanical and electrical life by adapting their behavior to the power system conditions [1,2].

With up to a 60 percent improvement in efficiency, a 30 percent reduction in unexpected outage and 15 percent increase in compactness, the VD4 evo improves operation thanks to embedded monitoring and diagnostic features. Sensors not only continuously monitor and analyze the operational status but also communicate this status, displayed on an on-premise human machine interface (HMI).

By integrating new components, control and diagnostic functions and introducing new services in life management for VD4, targeted recovery actions can be taken and condition-based and predictive maintenance is possible [3]. Thus, reliability is improved, leading to a longer service life and limiting the impact on the power grid.

Improving MV CB operations

The high-tech integrated sensors embedded in the CB are the "eyes and ears" of the new VD4 evo family of CBs . Sensors devoted to monitor various parameters are available for the first time onboard the apparatus: mechanical, eg, travel curve, vibration; electrical, eg, current, voltage, temperature and other relevant signals.

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VD4 evo improves operation thanks to embedded monitoring and diagnostic features.

The sensors consistently collect data related to operation consisting of both "continuous" parameters, eg, temperature and, or, primary AC current; and "on event" parameters, eg, vibration during closing or opening of an operation. Moreover, information can be shared with the intelligent device inside the CB control and monitoring unit (CMU) – the core of VD4 evo monitor and diagnostic (M&D) features.

CMU and Maxwell Platform

The CMU in VD4 evo is based upon Maxwell, the ABB proprietary platform specifically designed to support M&D and ABB Ability™. This solution enables the collection, processing and analysis of data from sensors or other smart devices. ABB's all-important Maxwell architecture is based on a modular design →03:

- System on Module (CPUM), in which the Linux embedded OS and customized analytics and user interfaces have been developed according to specific applications.
- Carrier Board that provides a dedicated enclosure for the proper hardware interfaces for each specific application requirements: power management, upstream/downstream communication interfaces, eg, serial and wireless connectivity, I/O →03a.

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Figures 04–06 are taken from a video about the VD4 evo. Watch the full video here:

With more adept communication capabilities, remote monitoring and a prompt response to critical events is ensured. By communicating with automation and control systems, eg, ABB Ability™ zenon supervisory control and data acquisition system (SCADA), to implement necessary corrective protection, negative impacts to other parts of the smart grid are minimized; efficiency and reliability are ensured, outage time is reduced and power continuity is improved →03b.

The monitor diagnostic concentrator
Because collecting data quickly is not enough, the VD4 evo's smart concentrator processes the data, aggregating and forwarding information received from the sensors, eg, meters, continuously in real-time, or periodically →04. Using specific algorithms, the device searches for anomalies or problems in the breaker, eg, overtemperature or other anomalous behavior. Based on the processed information, the intelligent device diagnoses the condition of the CB and provides alarm alerts or warnings of any critical situations that would require immediate action.

The digital "heart" of the VD4 evo also enables direct connectivity to the health management system of the CB [3]: CMU offers both a Wi-Fi access point, on mobile phones and tablets via a QR code →05, and direct integration to the SCADA system. Data transfer and storage are completely safe thanks to the application of the latest cyber security standards.

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By communicating with zenon SCADA for corrective protection, negative impacts to the smart grid are minimized.

Data management – key to cyber security
A CB that enables data collection not only poses technical challenges for advanced monitoring of electrical circuits, the security challenges arising

04 The monitor diagnostic concentrator, shown here, is small enough to fit in the most compact breaker version and ensures that VD4 evo technology is future-proof.

from data availability and sharing can also be significant. Despite offering the benefits of flexibility and efficiency, connectivity increases the attack surface related to M&D features, thereby providing more opportunities for the exploitation of vulnerabilities related to the digital part – the primary function of the breaker is unaffected. Nonetheless, the expanding integration of operational technology (OT) with information technology (IT) drives the creation of more complicated networks and devices that could be prone to encroachment if cyber security is inadequate. Thus, ABB applied best practices to their cyber security approach for VD4 evo.

VD4 evo achieves up to a 60 percent improvement in efficiency, and a 30 percent reduction in unexpected outages.

Establishing cyber security in OT is quite different in scope from cyber security in IT because devices must perform in real-time, outages are prohibited, the technology lifecycle is longer (>20 years compared with five years) and patch updates are more difficult and take longer to be applied. Moreover, security awareness among users is typically lower. And yet, data confidentiality, availability and integrity must be granted, data security risks must be assessed, and a defense-in-depth strategy must be adopted.

For these reasons, ABB's VD4 evo solution integrates cyber security requirements starting at the development process stage, thereby leveraging threat modeling. This approach was initially defined by Microsoft [4] and the ABB vulnerability handling process [5]; as well as assessing the architecture using a STRIDE approach [6].

Consequently, the product has been hardened by removing unused ports and services; integrating a traffic limiter to prevent Denial-Of-Service attacks from upstream interfaces, including encrypting data over a Transport Layer Security (TLS) channel. The device implements a Role Base Access Control (RBAC) policy that allows the configuration of as many user accounts as there are real product users. For the purposes of security, these users are allocated differing levels of privilege according to the principle of least privileges. The system can be easily updated by connecting to its Web interface. All software updates are signed by using ABB Public Key Infrastructure (PKI) and any non-authentic software is automatically discarded.

For additional security in case of cloud interfacing, the product has been based on a microprocessor with a secure-boot module onboard and includes a secure element (Trusted Platform Model-like device). These VD4 evo security improvements ensure that cyber security meets the necessary standards.

VD4 evo dashboard interface

It is only when extensive information, made possible by analytics and expertise, can be interpreted and conveyed to end-users securely, that failures and outages can be avoided. In the case of VD4 evo, the dashboard is the user's control cockpit →06. The CB and parameter interfaces show the current flow value and the general health status of the breaker, informing, and holding to peak current limits through the use of embedded electronic sensors, eg, meters. This information reflects physical quantities: thermal, electrical, and mechanical →06a.

In regard to thermal monitoring, up to 13 thermal sensors can be installed: six sensors are embedded in the contact arms of the CB (close to the interface with the panel), six wireless sensors are added to check the cable and busbar status, and one ambient sensor is added to check environmental temperature and humidity. Here, the analytics detect criticalities on the primary current path, eg, bad, loose, or damaged mechanical and, or, electrical connections →06c.

As for electrical monitoring, the data that arrives from a current sensor, CTs, installed on the panel, are used to estimate the remaining life of the CB vacuum interrupters (VI) by continuously monitoring the primary current, including any breaking currents traveling through the CB →06.

Electrical data is combined with thermal data for an advanced dynamic thermal monitoring that considers electrical load and environmental conditions

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05 The VD4 evo includes a QR code.

05a By simply accessing the QR code via tablet or smart phone, customers can rapidly access important information.

05b With the QR code, the latest catalogs, instruction manuals, and the newest test results are obtainable. In addition customer can contact ABB directly and of course access the breaker.

05a

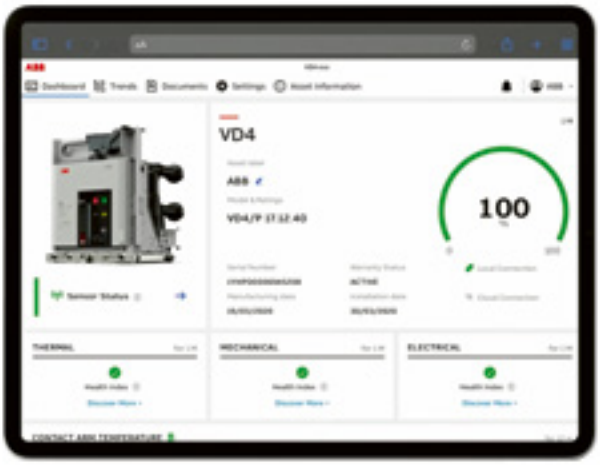
05b

to display the temperature limits of specific applications; the thermal setup is fully configurable.

Mechanical monitoring is a complex interaction of kinematic parts: tolerances, accessories and spring motion. Here, each mechanical operation is monitored by a magnetic angular sensor, placed precisely on the main shaft of the CB to detect the entire motion (position, speed), and by three Hall-effect sensors that monitor the auxiliary currents that power the opening- and closing coils of the device as well as the closing spring's charging motor.

Critical parameters, eg, the opening- and closing times and speeds, are analyzed to check if the CB runs within the design prescriptions →06b.

Each resulting parameter is assigned a unique health index. The VD4 evo system translates this information into user-friendly visualizations displayed on the HMI. And if anomalies arise, the users, eg, maintenance manager or operator, can easily access details within the dashboard to determine a possible root cause, or if actions are required. The user even has the ability to contact an ABB expert through service maintenance sup-



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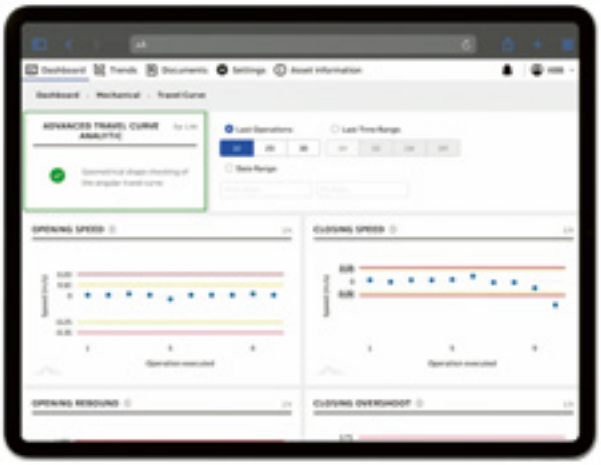

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06c

port. And if errors persist following operations, the user can download the device database and contact service for further support.

Sustainable management and protection of energy distribution

Demonstrating a strong commitment to the environment, ABB aims to reach carbon-neutral operations by 2030 and actively helps customers reduce greenhouse gas (GHG) emissions in their operations. By developing eco-friendly and sustainable technical and digital solutions such as VD4 evo, ABB shows their commitment to helping industry reach their sustainability goals.

Concomitant with these ambitions, ABB considered the environmental impact of VD4 evo throughout all phases of the product's development [7]. The effects of additional electronic components could be evaluated by benchmarking the Life Cycle Cost and the environmental impact of traditional apparatuses and solutions versus the new generations.

The Life Cycle Assessment method was applied to evaluate environmental performance of VD4 evo by defining, compiling and evaluating the inputs, outputs, and potential environmental impacts for manufacturing, including upstream process (eg, acquisition of raw material, etc.), the main manufacturing and processing steps; distribution; installation, including use preparation [7]. Usage includes the required maintenance steps; the end-of-life stage includes all steps until final disposal or product system recovery.

ABB's eco-friendly technical and digital solutions, such as VD4 evo help industry reach their sustainability goals.

Based on the resultant models, ABB found that during the first phase of the product's life, a higher environmental impact results from the additional use of resources and energy but that this can be offset through improved efficiency during the operational phase [7]. Moreover, reliability and life extension through predictive maintenance help VD4 evo reach the lowest possible overall impact.

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06 Examples of some of the VD4 evo dashboards are displayed.

06a This dashboard shows the health status of thermal, electrical and mechanical entities of the CB, thereby reflecting the physical quantities.

06b An example of the opening- and closing times that are used to ascertain if the CB is running properly.

06c An example of the analytics used to detect criticalities on the primary current path.

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07 The VD4 evo not only meets the demands of the evolving intelligent power grid sustainably, this evolutionary product does so reliably and safely according to the cyber security standards.

07

Building on the success of VD4, ABB's new digital MV CB, VD4 evo, provides advanced control and diagnostic capabilities, using an algorithm-based prediction model that allows real-time asset assessment. Thus, VD4 evo helps customers meet the pressing demands of an evolving smart power grid efficiently and reliably, yet safely and sustainably with the utmost cyber security →07. •

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ABB's digital VD4 evo, provides advanced control and diagnostic capabilities to meet the evolving demands of the smart grid.

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Further information

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GREATER FLEXIBILITY WITH CENTRALIZED (CPC) AND VIRTUALIZED PROTECTION AND CONTROL (VPC) FOR SUBSTATIONS

Centralizing protection

Combining the functions of multiple relays into one device, CPC reduces network complexity, thus providing the means to better manage substation protection. And, by offering CPC as a virtualized image, ABB enhances scalability and flexibility – a boon for time-critical control and protection applications.

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By necessity governmental targets for achieving carbon neutrality are ambitious; some countries are even aiming to meet their targets by 2035. Thus, change needs to happen rapidely. Electrical energy plays a significant role, as it can be produced and distributed with a low carbon footprint.

Nonetheless, with the increasing penetration of renewable energy and the advent of wide-scale adoption of battery energy storage systems (BESS), power generation and distribution has become increasingly complex and less predictable. The grid must become more flexible and consumer-friendly to facilitate this bi-directional flow of power and still meet or exceed system reliability requirements. The required rate of change will be exponentially higher than the slow gradual change that occurs today. But, how does one simultaneously increase the rate of change and improve robustness and reliability as the power grid evolves? In this context, medium voltage (MV) substations that step down high voltage (HV) from transmission systems to deliver a supply of electricity to consumers will be vital as will protection and control (P&C) technology [1-5].

To date, microprocessor-based control relays have dominated the protection systems in substations, and yet a new possibility has emerged – CPC, a digital software-oriented solution [1,2]. By concentrating P&C into a single device, a CPC device, communication networks permit information flow between different components, bays, substations, and related operators in the substation environment. Having successfully released the ABB Ability™ Smart Substation Control and Protection for electrical systems

Resilience of the grid, however, is evolving to a broader definition [2,3]; Here, resilience is viewed as a complex process occurring over multiple scales, fluctuating – there is a continuum between function and failure – adaptation to change is critical.

Resilience will also determine and limit the maximum speed of systemic change. New innovative technologies namely, 5G, virtualized real-time computing etc. can be connected to the grid but only if by so doing the resilience of this critical infrastructure is not reduced [3]. And, as the role of cyber security increases in importance, the ability to adapt and update the system is needed. Additionally, platforms are required that

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With increasing penetration of renewable energy, the grid must become more flexible and consumer-friendly.

continue operation even while being updated [3]. First-ever technologies are now available to realize such platforms, eg, machine learning (ML) and artificial intelligence (AI), 5G, and virtualized real-time computing. A complete CPC system, one that incorporates, or accommodates such revolutionary changes is required, and yet the optimal integration of these technologies must be carefully designed.

Protection system evolution – from CPC to virtualized CPC

Over the years, protection in power systems has evolved from electromechanical mechanisms to the microprocessor-controled intelligent electronic device (IED). Relaying is essential to develop a more flexible, interconnected, and smart power system. The IEC 61850 standard released in 2004 not only drives this change, but has instigated the interest in CPC systems. Together with new system engineering tools for support, ABB successfully released the Smart Substation Protection and Control SSC600, a CPC product, in 2018 →01, ABB has taken further steps by releasing SSC600 SW in 2023; a “virtualized” CPC solution in which software is decoupled from the hardware. Here, the “virtualized” environment is abstracted from the underlying platform, isolated from applications that run on the platform [4,5]. Such innovations could help substations achieve P&C with the flexibility needed at a reasonable cost, thereby supporting the grid to meet the supply and resiliency demands.

Resilience and increased demand for flexibility

Traditionally, resilience is related to maintaining the power balance and protecting against network faults – the ability to bounce back from an event. This contrasts with security of supply, which is the ability to deliver electricity in the quality and quantity that consumers require.

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01 The SSC600 , shown here, builds on ABB's solid and proven technological foundation manifested in the renowned Relion® protection and control family.

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02 An overview of a CPC system, with redundant CPC devices.

device, SSC600, in 2018 [1-3]. By moving the P&C functionality from multiple bay-level devices to a single central processing unit within a substation, only the process interface functionality remains in the bay-level merging units (MU). One SSC600 device can handle the tasks of 30 protection relays. The targeted benefits are improved functionality and reduced overall lifecycle costs (up to 15 percent) – a boon for the utilities and electricity consumers alike →01.

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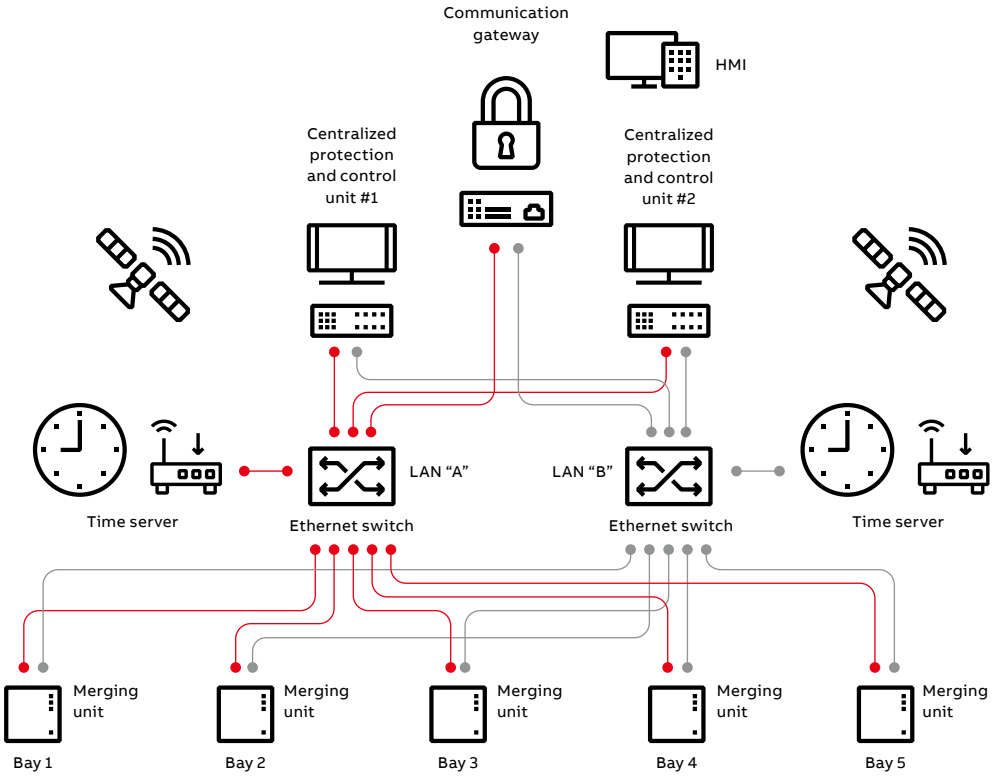
By moving P&C to a single central processing unit in a substation, one SSC600 device handles the tasks of 30 protection relays.

Recently, an evolutionary step in the CPC concept has emerged: Virtualized Protection and Control (VPC). Applied to P&C, virtualization is the use of software for creation of an abstract image of a traditional P&C solution inside a physical host (a ruggedized computing hardware). Hence, the protection application is no longer tied to a particular centralized device; it is a software image that can be independently deployed to versatile industrial server architectures in different environments. ABB released the world's first VPC, a virtualized version of SSC600, the SSC600



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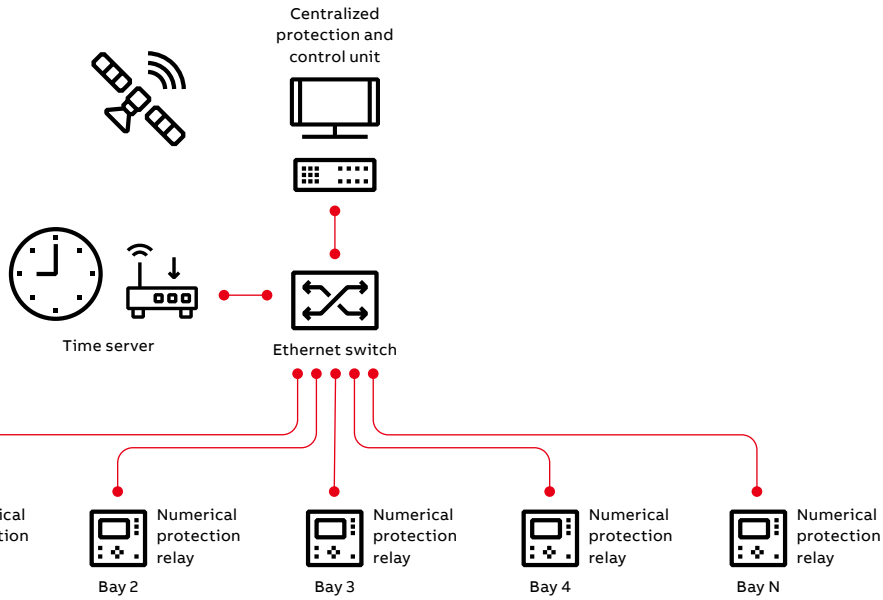

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03 Centralized protection example with numerical protection relays.

SW, in 2023. The goal has been to achieve the same reliability as a CPC system but with greater efficiency and to further reduce life-cycle costs.

Enablers for CPC and VPC – IEC standards
Even though the basic functions of substations have remained unchanged for years, data processing and communication solutions are in flux, resulting in the availability of key technical enablers for CPC systems.

The IEC 61850 standard has made fast and standardized Ethernet-based communication more available; the station bus, as defined in IEC 61850-8-1, allows for the elimination of copper wires between numerical protection relay units on the horizontal level, ie, relay-to-relay communications. The process bus, defined in IEC 61850-9-2, permits digitized information to be shared from instrument transformers or sensors to other relays and, or CPC units, thereby enabling a shift of P&C functions between different relays and, or CPC units at the substation level.

Another vital enabler, defined by IEC 61869-13, is the MU, the interface of the instrument transformers with a relay and CPC unit [2]. The interface accepts current transformer (CT)/voltage transformer (VT), low-energy sensors and binary inputs (BI) and produces multiple time synchronized digital outputs, providing data communication via the logical interfaces. IEC 61850-9-2LE defines a sampling frequency of 4 kHz for 50 Hz networks and IEC 61869-9 defines 4.8 kHz for 60 Hz networks (among other frequencies) for raw measurement values to be sent to subscribers. The MU can also host input/output (I/O) to handle feeder-based digital signals, communicate the digital status of primary equipment, eg, circuit breakers, isolators, earthing switches, to network devices; and receive trip and open or close signals from an external unit through IEC 61850-8-1 station bus.

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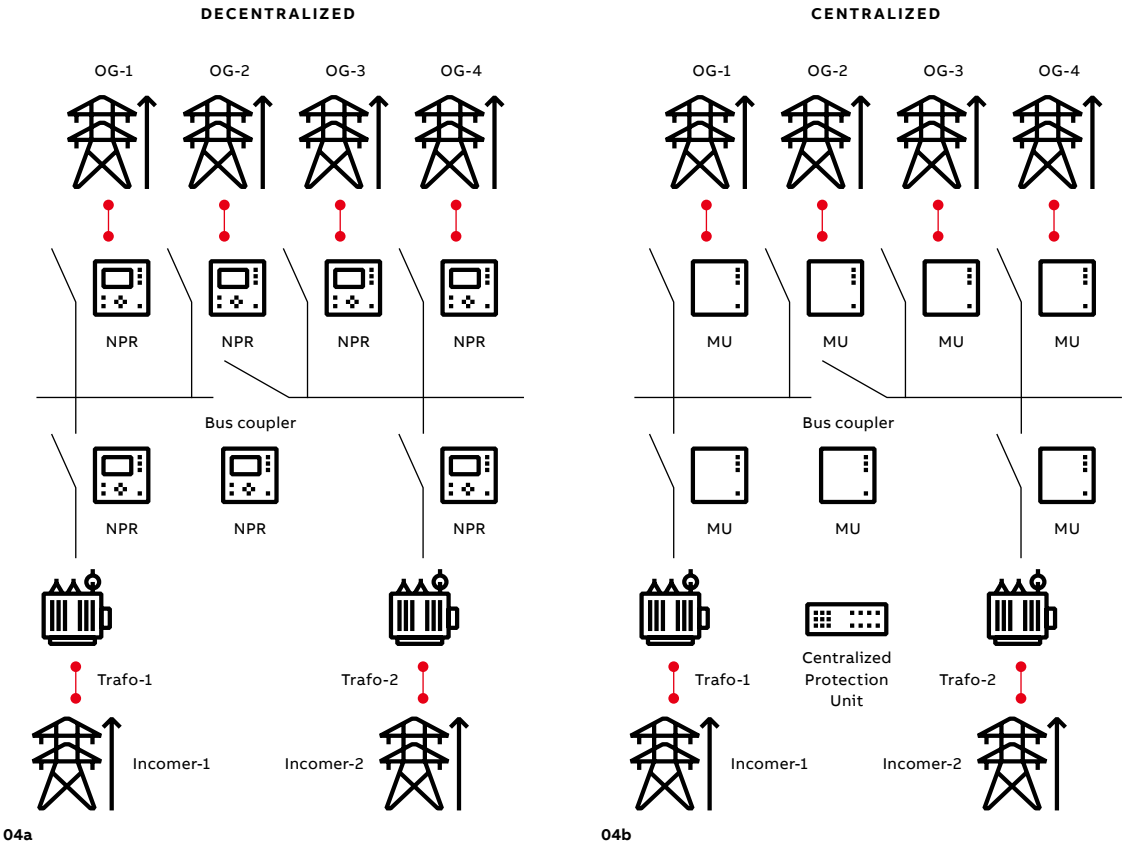
With IEC standards defined, CPC systems evolved and ABB released the world's first VPC, the SSC600 SW in 2023.

Moreover, Ethernet-based technology and IEC 61850 standard, allow time synchronization to be reached with an accuracy of 1 µs. A GPS or equivalent resource is required in every substation in accordance with IEEE 1588v2 and IEC 61850-9-3.

The communication network must also be highly available and reliable in any architecture utilizing a CPC/VPC system. To address this time-critical need, IEC 61850 standard mandates the use of the IEC 62439-3 standard in which Parallel Redundancy Protocol (PRP) and High-Availability Seamless Redundancy (HSR) are defined. Both methods of network recovery provide "zero recovery time" with no packet loss in case of single network failure – vital for CPC in substations.



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04 Substation architecture alternatives.

04a Decentralized.

04b Centralized.

04c Hybrid.

Virtualization technology

With IEC standards defined, CPC system evolution forges ahead. Widely used in information technology (IT), in non-real-time applications, virtualization of substation CPC (VPC) is a logical development. Because Hardware Virtualization (HWV), Kernel-based virtualization and OS-level virtualization, are all able to achieve the required deterministic operation and reliability for P&C purposes, the preferred choice depends on performance and overhead demands. Recent studies show that the necessary real-time performance can be achieved with virtualization technologies, containing both virtual machine (VM) and containers [5]: HWV provides the strongest isolation between different VMs, while OS-level virtualized containers provide the lowest overheads.

But why virtualize P&C in a substation in the first place? Because virtualization enables software to be deployed, executed, exchanged, and migrated in isolation from the platform, applications can be flexibly and rapidly deployed in a substation. It would, thus, be easy to maintain and update hardware; customers could deploy applications from different vendors and update functions on demand. But, this is only possible if virtualization can be accomplished in real-time. And this is just what ABB tested and verified.

Architectural options

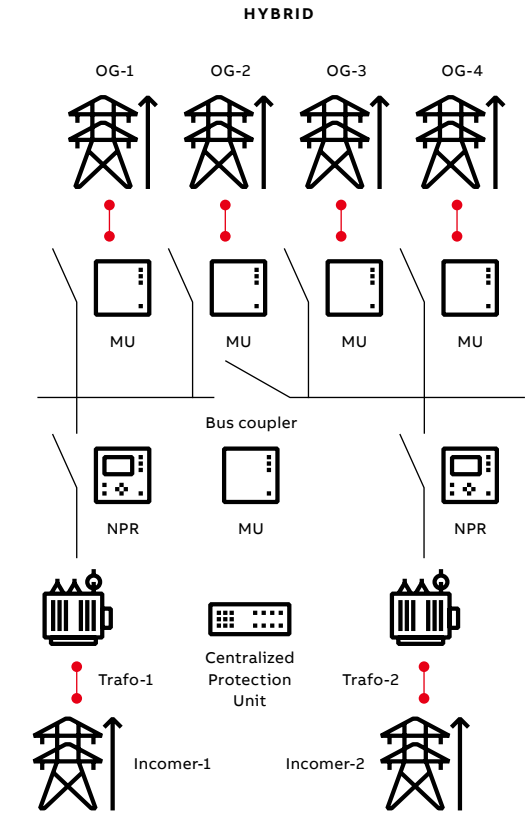
Before testing the efficacy of CPC and VPC concepts in laboratory and field experiments, ABB evaluated various architectures →04. The right choice depends on the substation's specific needs, eg, protection philosophy, defined specifications, time critical applications for P&C,

—

ABB evaluated various architectures before testing the efficacy of CPC and VPC concepts in the laboratory and field.

redundancy requirements at the physical, functional or communication level, flexibility to adapt to the changes that the power distribution grid is facing today, etc. [3,5,7].

Traditionally P&C architectures distribute protection in multiple different Numerical Protection Relays (NPR), 'Decentralized' →04a but in CPC all the safety critical intelligence is in one device. Here, redundancy ensures that full functional protection is available in case of failure [1] →02-03,04b. One way to achieve



04c

—
05 An overview of the virtualization piloted SW environment.

this is to duplicate the central device. Another way to achieve redundancy is to use a hybrid system→04c, a combination of both approaches – a bay-level backup protection (for simplified protection) with the CPC device (for advanced protection) [3,4]. In regard to centralized protection, the hybrid scheme is ideal for retrofitting to existing installations because it allows for the introduction of new functionalities, eg, remote asset management and configurations, upgrades, analytics and advanced applications such as virtualization [6]. Having successfully demonstrated the three architectures, ABB chose the hybrid system approach for the first real-life pilot experiences due to ease of implementation [4,5].

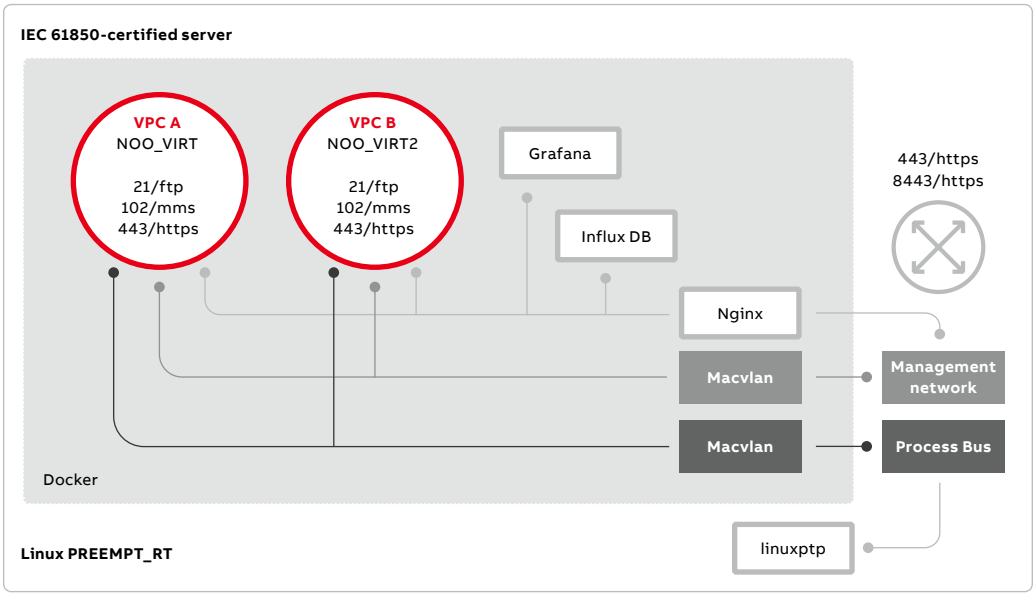
—

Successful pilot study results showed that VPCs were able to match the behavior of a physical CPC, flawlessly.

Pilot experiences

ABB conducted the first pilot for the CPC with a hybrid architecture during 2017-2019 together with Finnish DSO Caruna in a 110 kV/20 kV substation with double busbar and single power transformer→05. The substation, located in Noormarkku, Finland, was equipped with a hybrid architecture between June 26, 2017 and Jan. 2, 2019 [1]. During the pilot study, 99 short circuits and 69 earth faults occurred and were all cleared successfully by the CPC device (ABB's SSC600). The results showed that the CPC technology is satisfactorily reliable and efficient.

In addition to the active CPC protection system previously described, ABB built a prototype solution that virtualized ABB's HW-based CPC solution by wrapping it into a Docker container. Containerization is a lightweight virtualization technology in which containers share the



05

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06 Event Log Comparison for one day, NOO2 as CPC device, NOO_VIRT and NOO_VIRT2 as VPC container images.

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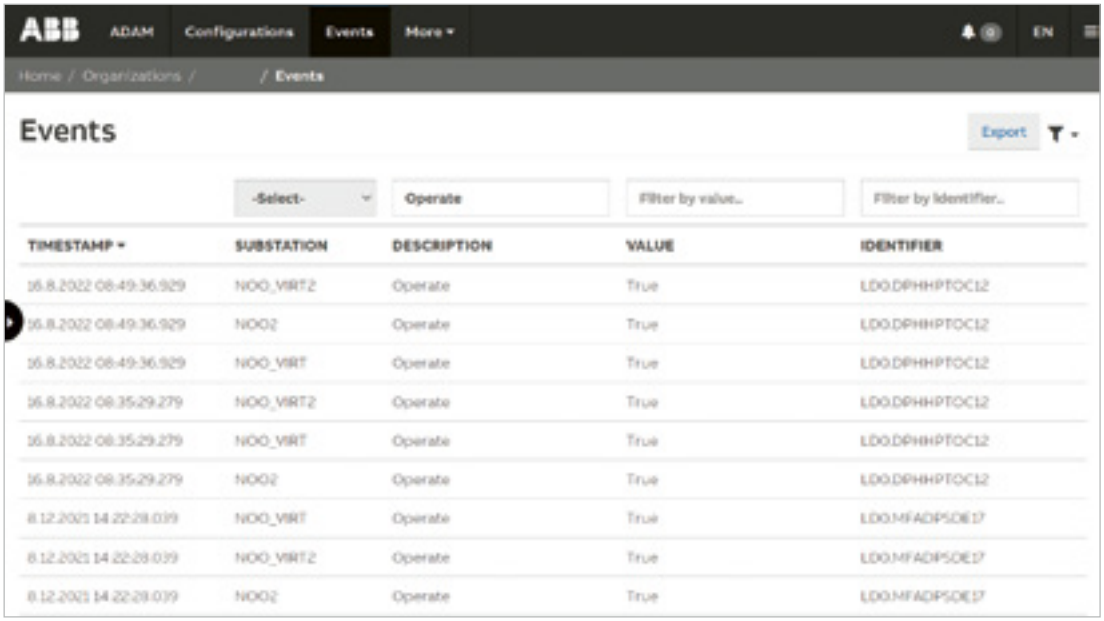
07 As more DERs, such as the wind turbines depicted, connect to the grid, it is critical that utilitiy customers are able to improve resilience and security of supply.



06

operating system kernel. Such a solution meets the latency demands for substation automation applications with improved real-time capabilities.

ABB's VPC solution contained two separate VPC containers, running in one host HW that were deployed to the substation in a standby mode – executing identical protection functions as CPC but without the possibility of sending trip commands to the relays [5]. The two VPC containers ran as a pilot in the substation for over a year, from Sep. 27, 2021 to Jan. 5, 2023. The results reported →06 demonstrate that during the examined period both VPCs were able to match the behavior of the physical CPC flawlessly. The protection function events in both VPC images carried the same timestamps in the event log, measured to the ms, as the CPC. The handling of the many faults did not deteriorate the required real-time performance in any way →06 – a marked success.

System benefits and deployment

The results from the CPC systems in operation are on par with results gleaned from the pilot experiments described above [7]. For example, the SSC600 employed by the Finnish utility Parikkalan Valo in 2020, successfully manages their electrical network and assets to ensure the flexibility needed for the future.

The added flexibility of a fully digital substation solution with CPC or VPC systems yields advantages. When all functionality resides in one SW solution, complete testing can be conducted prior to deployment in a digital simulation environment. With comprehensive simulation tools, it is possible to conduct all required tests without any copper wiring, without any MUs or protection and control relays, thereby facilitating laboratory testing during the early engineering phases. Such tests can help to improve design and simplify later testing phases, thereby potentially improving system reliability [5,7]. Such benefits will ultimately help utility customers achieve the system flexibility they need with lower overhead costs as they seek to improve resilience and security of supply →07 as ever more DERs connect to the power grid. •

—
A fully digital substation solution with CPC systems will help utility companies achieve system flexibility to improve resilience.

—
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07

Photo fig. 07: ©Martin Mecnarowski/stock.adobe.com

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ABB'S NEW DS301C COMPACT CIRCUIT BREAKER IS MAKING WAVES

Compact impact

The DS301C single-phase and neutral, voltage-independent, residual-current circuit breaker with overcurrent protection (RCBO), protects against short-circuits, overloads and earth faults. This single-module device eases congestion and simplifies installation in low-voltage panel boards →01.

01

Driven by the desire for more capillary control and increased safety, the number of branches in low-voltage electrical installations – and the quantity and type of circuit breaker found there – is undergoing profound change. This rapid evolution means more electrical devices must be accommodated into electrical panelboards. This poses a major miniaturization challenge to circuit-breaker manufacturers like ABB. The trend mostly concerns final distribution lines, usually hosting loads supplied by one phase and the neutral conductor.

The DS301C combines protection against short-circuit, overload and earth fault – all in a single-module-wide breaker.

This context explains the remarkable market acclaim for ABB's newly released DS301C. The DS301C is an extremely compact, one-phase and neutral RCBO that combines protection against short-circuit, overload and earth fault – all in a single circuit breaker just one module wide, as opposed to the two-module width of current approaches. Crucially, the breaker is voltage-independent – ie, it works without an external power source.

Space savings through targeted specification
To allow space optimization, the electrical ratings of the DS301C have been precisely matched to the targeted applications – for example, residential, commercial, marine and railway installations. The DS301C is characterized by a rated current of up to 20 A, a more-than-respectable short-circuit

— 01 The DS301C, ABB's new single-module, voltage-independent RCBO.

capacity of 6 kA, and – for earth faults – the classic maximum residual current of 30 mA. The DS301C not only detects current leakages with sinusoidal waveforms but also the truncated or distorted waveforms associated with electronic appliances, such as LED lights, computers, etc. A compact product like the DS301C allows panels to be more compact, too – a benefit greatly appreciated when extending or retrofitting electrical installations in hospitals, boats, trains, etc.

The inside story

One side of the DS301C accommodates the phase and the other, the neutral conductor →02. Overcurrent protection – ie, short-circuit and overload – is arranged on the phase side. Short-circuits are detected by a trip coil, where the strong magnetic field produced by the several kA of the short-circuit current moves a ferromagnet to trigger the trip quickly. A bimetallic strip bends due to the overheating induced by overloads (which are less sudden than short circuits), thus triggering the trip.

On the neutral side of the device, if an earth fault occurs, the current leakage to ground induces an imbalance between phase and neutral currents. A differential transformer detects this disparity and feeds a small circuit board where the signal is filtered to prevent unwanted trips due to surges, for example. A sensitive relay collects the output and triggers the trip.

To meet the demanding size requirements, earth-fault protection and the bulkiest components are accommodated across the two halves of the breaker.

A toggle-operated mechanism controls the position of moving contacts that are tripped under the action of the actuators. The patent-pending structure of the mechanism relies on two connected and interacting subparts:

—

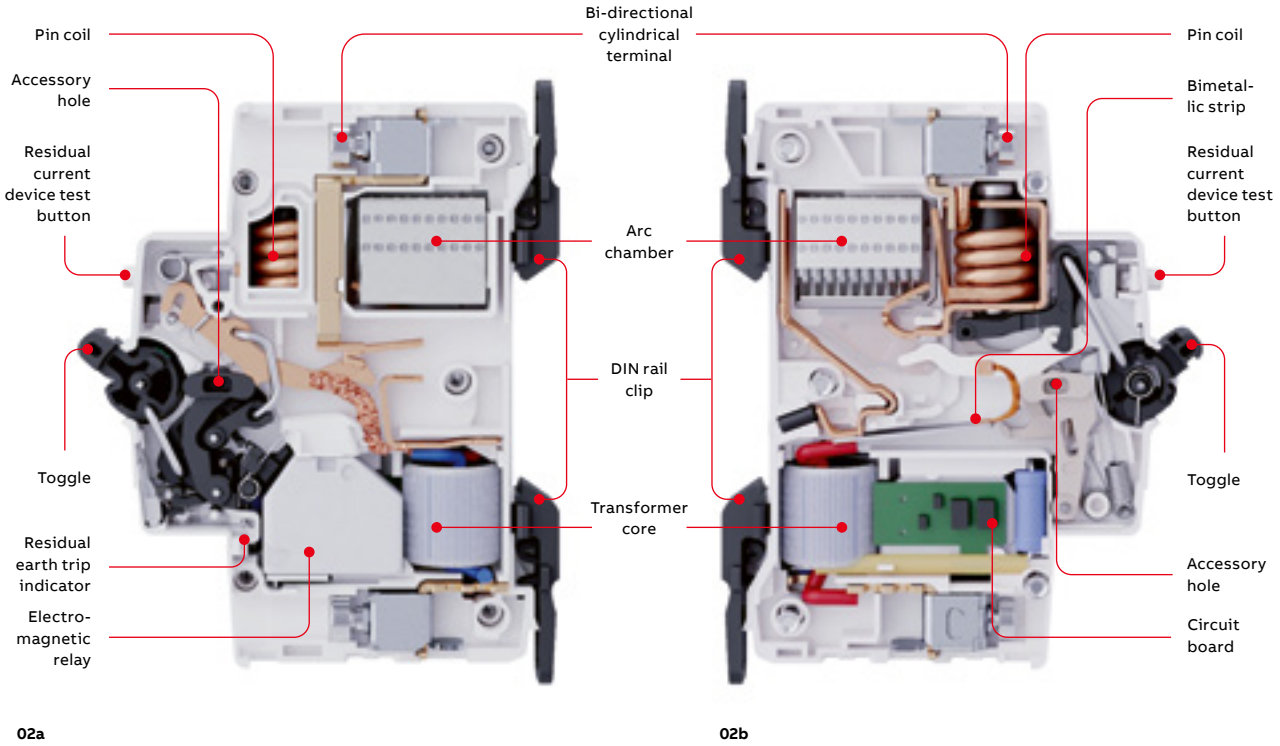
A compact product like the DS301C allows panels to be more compact, too.

Arc extinguishment in an arc chamber finishes the current switch-off process on the phase conductor to complete the disconnection of the faulty branch from the upstream mains, while the neutral conductor is interrupted without the help of an arc chamber.

Earth-fault protection

Earth-fault protection is a particularly important aspect of the device's performance as just a few milliamperes leaking to ground through a person can be lethal.

Remarkably, for the compactness achieved, earth faults are addressed with so-called voltage-independent (VI) technology. In VI devices, the



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02 The DS301C interior. All components have been miniaturized and thoughtfully located in the small available space.

02a Neutral side with earth-fault sensor and actuator.

02b Phase side with short-circuit and overload sensors and actuation, along with current switching means and the circuit devoted to earth-fault processing.

earth-fault sensing and subsequent actuation use only the (very small) energy of the earth fault; no external supply is required. Despite the challenges of miniaturizing VI RCBOs, the DS301C is as compact as an electronic RCBO, which depends on the availability of a voltage difference between phase and neutral for power. This dependency means electronic RCBOs are not operational if the neutral conductor is interrupted upstream and someone is touching the phase downstream. In contrast, this type of potentially lethal earth fault is protected against by the DS301C.

—

Speedy and straightforward installation was a cornerstone of the DS301C design philosophy.

High-resolution selectivity

A reference installation with 18 branches serves to highlight the DS301C's advantages →03.

A traditional solution has the 18 branches grouped into three sets of six. In each set, the six branches are protected against earth faults by a single residual current circuit breaker (RCCB), which is at least two modules wide, and against short-circuits and overloads by six miniature circuit breakers (MCBs), each a module wide →03a. Not infrequently with this approach, earth-fault protection is addressed by a three-phase RCCB that takes up four modules, as in →03a, and only then do the three phases separate into a maximum of six branches (two per phase, as allowed by the relevant standards) that are individually protected by single-phase MCBs. Three DIN rails are required to mount this equipment. In this arrangement, an earth fault in one branch trips the associated RCCB, taking out the five healthy branches in the set, too.

Fault protection selectivity is highly important in any electrical installation, especially when service continuity is essential. An alternative conventional approach would be to use 18 two-module RCBOs, each protecting a single branch →03b. Here, earth-fault, short-circuit and overload protection is selective for each branch, but three DIN rails are still needed.

Due to the half-width size of the DS301C solution, 18 RCBOs now occupy only one-and-a-half DIN rails while still delivering selective earth-fault, short-circuit and overload protection to each branch →03c.

Fast and easy installation

Speedy and straightforward installation was a cornerstone of the DS301C design philosophy in order to shorten installation time and make the process error-proof.

Either flexible cables or rigid busbars may be used to wire the circuit breaker. Additionally, the DS301C comes in versions compatible with ABB's newly released fast wiring system, which allows product mixing on the same DIN rail. This system has the added advantage that the electrical feed-in connections that bring power from one DIN rail to the next in the vertical direction can be accomplished by the first circuit breaker in the line, requiring neither dedicated products nor specially shaped busbars that constrain the type and number of products that can be mounted.

Fail-safe terminals prevent the insertion of the electrical conductor into the wrong aperture and the DS301C clipping system allows easy product mounting onto the DIN rail without removing busbars from neighboring breakers.

With a height of only 85 mm, the DS301C is less tall than competing devices, making wiring easier, particularly in panelboards, where DIN rail separation can be as little as 125 mm →04-05.

Small size but high-end features

Compactness does not prevent the DS301C from providing customers with high-end features. For example, there is a visual indication of the cause of a trip: For earth faults, a mechanical flag (the blue rectangle in →01) informs the user. This feature is not available in competing compact breakers. Should the contact become welded during a trip, the toggle remains midway between the open and closed position. Hence, the "on" and "off" labels are hidden, indicating the contact's situation.

The DS301C clipping system allows easy DIN rail mounting without removing busbars from neighboring breakers.

As per applicable standards, a button allows users to periodically test the earth-fault sensing and actuation drivetrain by injecting an artificial residual current and producing a differential trip.

ABB's comprehensive portfolio of DIN-rail accessories (the System Pro M series), which encompasses, for example, signal and auxiliary

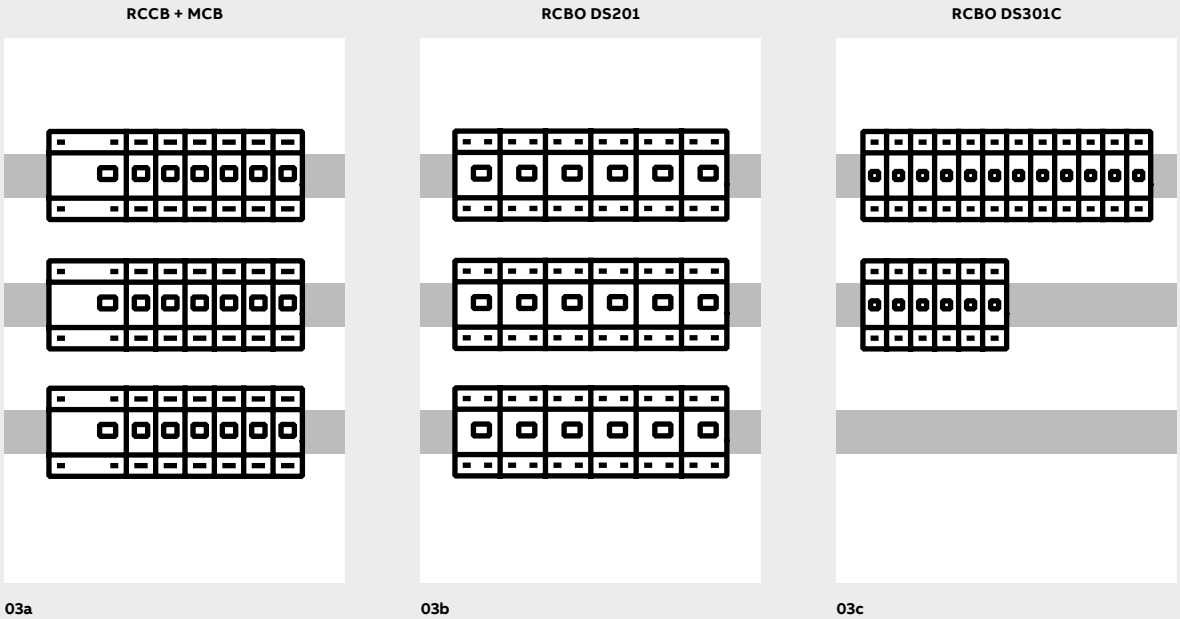
—

03 A reference installation with 18 branches.

03a Traditional solution with three DIN rails, each hosting one RCCB and six MCBs.

03b Three DIN rails hosting six RCBOs each.

03c The compact DS310C solution.



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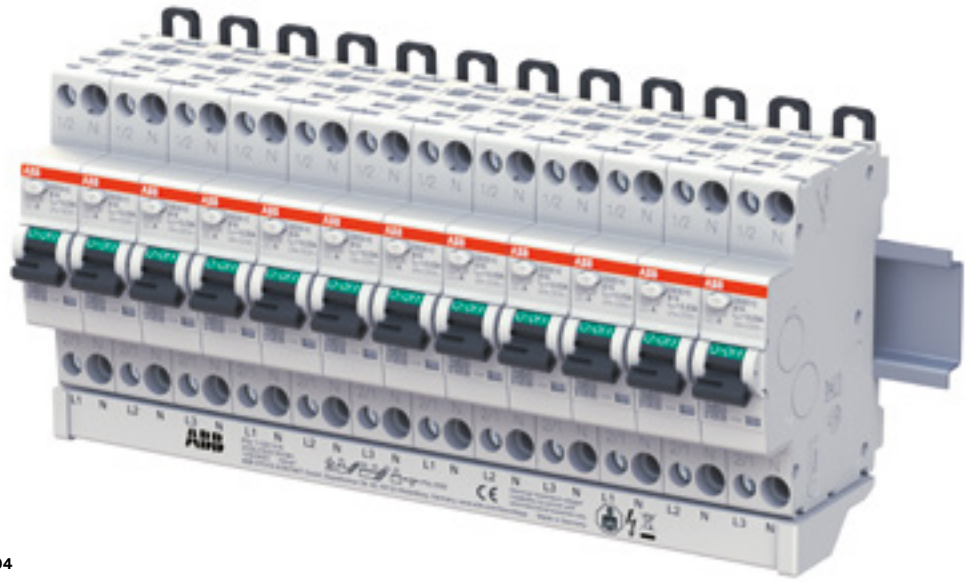

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— 04 With a height of just 85 mm, the DS301C is easier to install.

— 05 Shown is an example of breaker technology today, with single-pole MCB on single branches. With the DS301C, ABB can now offer, in the same space, also earth-fault protection at single branch level.

contacts, trip coils and a motor recloser, supplements the DS301C and caters to all levels of panelboard sophistication.

All inscriptions on the housing, including electrical markings, are laser-printed for precision, readability and durability. With a smartphone, the user can easily access datasheets and technical information from ABB via a QR code on the front of the DS301C.

Green light for sustainability

Sustainability was a major driver during the development of the DS301C (the product is part of the ABB Ecosolutions™ portfolio). For example, all polymeric parts in this lightweight product are made of recyclable thermoplastic. Furthermore, the "all-in-one" circuit breaker design means power losses are lower when compared to the duplicated resistive elements, such as contacts and electrical terminals, in alternative setups with MCBs and RCDs. Cooling requirements are also reduced. These environmental benefits are significant as power flows continuously through the device over its multi-decade service life and power losses form a large part of its ecological footprint.

— The DS301C is a prime example of how innovation can impact even long-familiar products and technologies.

Innovating the familiar

The DS301C development is a prime example of how innovation can impact even long-familiar products and technologies. The key here is to adopt a comprehensive approach that addresses the market needs and matches the user's desired experience while considering sustainability throughout the product life cycle. With the compact DS301C, panel builders can now deliver safety and control to even the furthest or busiest branches of the low-voltage distribution network. •

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05

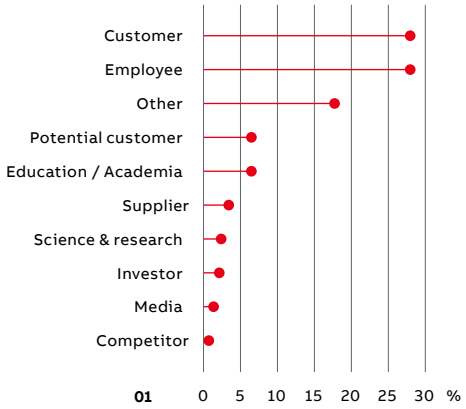
YOU READ, WE LISTEN

Readership Survey 2023

Because reader perception, satisfaction and inputs are important to chart the future course of ABB Review, readers were invited to take part in a survey in ABB Review 3/2023. The results are being shared on the opposite page →01–08.

Some questions are mapped against the results of the 2017 survey in order to observe trends over a longer time horizon (or of the 2011 survey if the question was not included in the 2017 survey). The ABB Review Editorial team would like to thank all of those who gave their time to participate in the survey. We especially appreciate those submissions where readers took the time to write specific comments and constructive feedback. Five winners were drawn from the participants, and each is receiving a Fjällräven Re Kånken backpack. Congratulations to B. Jaumouillé from Belgium, P. Sierpowski from Finland, name withheld from India, B. Mikosch and M. Hofmann from Switzerland. •

01 "What is your relationship to ABB?"



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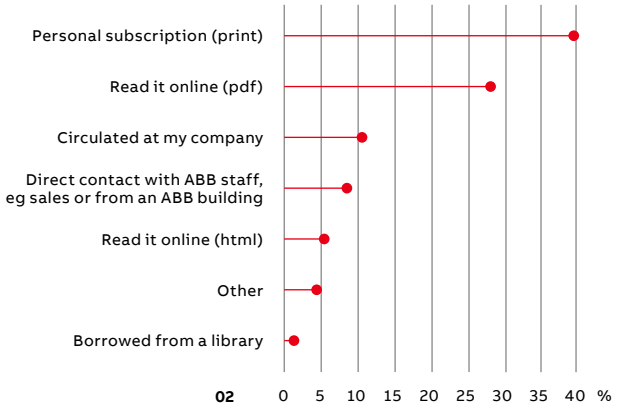

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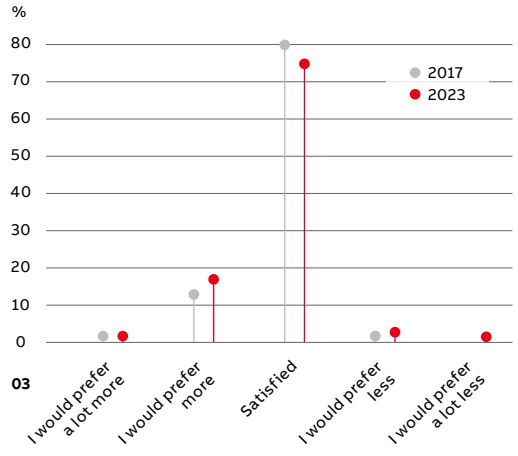
03 "How satisfied are you with the number of articles per edition of ABB Review?"



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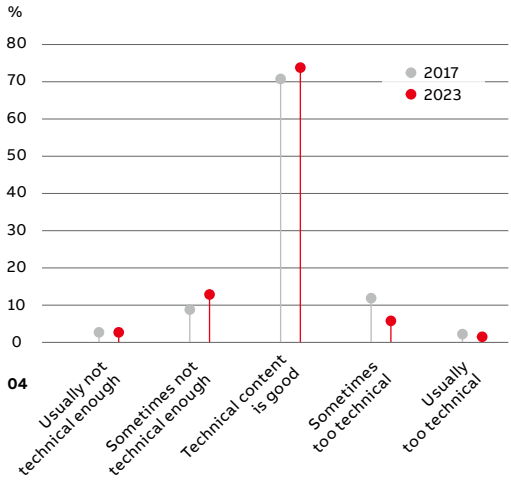

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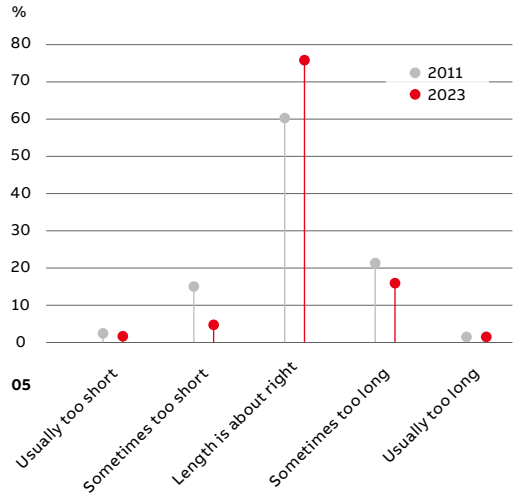

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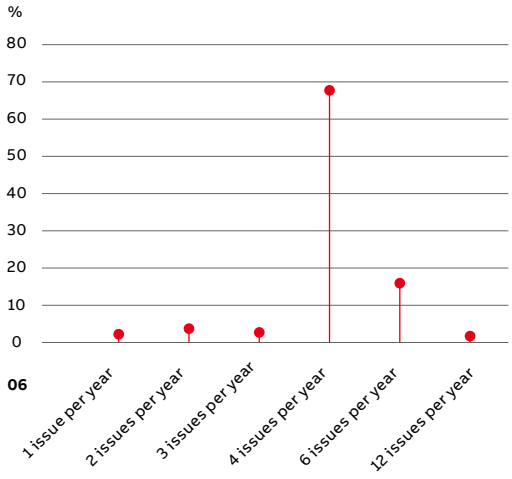

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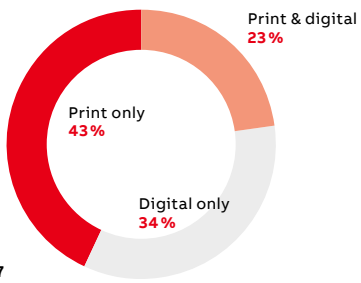
07 "In which format do you read ABB Review?"



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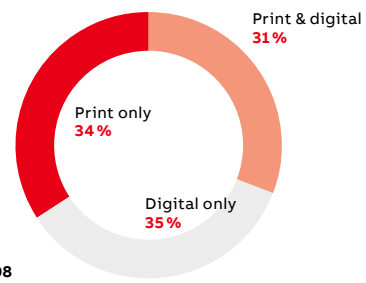

08

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01

BUZZWORD DEMYSTIFIER

Electric motor drives

An electric motor drives things. What, then, is an electric motor drive? An explanation for the non-expert.

Anthony Byatt
External contributor

The pioneers of the electric motor, which emerged just over 200 years ago, could never have imagined how the invention would change the world. Electric motors, in their tens of billions, are now to be found in every imaginable application. Nearly 70 percent of all industrial electrical energy goes to powering electric motors. These industrial motors are the workhorses of business operations, where they run pumps that move fluids or fans that move air or operate compressors, conveyors and every type of machine that depends on rotational force to get its job done.

> The drive regulates the operation of electric motors, enabling precise control over speed, direction and torque.

But motors do not work in isolation; they have to be controlled in some way and this is the purpose of the electric motor drive. The drive plays a pivotal role in regulating the operation of electric motors, enabling precise control over their speed, direction and torque. The drive is the brain of the motor system, receiving inputs and translating them into commands for the motor. In essence, an electric motor drive serves as the intermediary between user inputs, sensor data and the motor itself, ensuring efficient and accurate control in countless applications, from industrial machinery to household appliances and electric vehicles.

And, of course, there are different types of drives for different applications – for AC, DC, low-voltage, or medium-voltage, for example. ABB offers all these plus a wide range of variable-frequency drives (VFDs) and variable-speed drives (VSDs). The ability to tune the electric motor's speed (or torque) is an ideal way to save energy and improve performance →01.

Other drive types (or controllers) include stepper motor controllers, servo motor controllers, three-phase or single-phase controllers and soft starters. The soft starter, for example, gradually increases the voltage supplied to the motor, reducing inrush currents and minimizing mechanical stress during startup.

Putting it all together

Traditionally, the motor and drive have been separate elements. However, more users have turned to integrated motor drives (IMDs), which offer significant cost and performance benefits

01 This water pumping station belonging to Evides Waterbedrijf pioneered the first use of ABB's low-energy SynRM, synchronous reluctance motor and VFD technology in the Netherlands.

over separated systems. Designing IMDs for beefier applications poses thermal management and electromagnetic emission challenges but ABB has now successfully developed a 7.5 kW IMD with excellent performance – especially in terms of thermal management and electromagnetic emission.

The choice of electric motor drive depends on factors such as the type of motor, the required level of precision, energy efficiency and the specific application's demands. These considerations mean that vendors, such as ABB, usually offer a wide range of drives, each with unique advantages, to allow for versatility across industries and use cases.

ABB has now developed a 7.5 kW IMD with excellent performance – especially in thermal and electromagnetic emission terms.

More information on the new ABB IMD can be found on pp. 42–47 of this issue in the article "Beat the heat: Performance integrated motor drives that run better and cooler." •

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