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Cleaner future for ships and ports

Steel melt shop

Product digital twin

Digitalization is creating a new playing field on which businesses can build and grow assets, develop and run processes, and find ways to innovate sales and service opportunities. These innovations are already yielding productivity and profit benefits in the physical world. This issue of ABB Review investigates best case examples that illustrate how these connections are being made between the virtual and real worlds.

EDITORIAL

Assets and connectivity

Dear Reader,

We live in the information age - we have more data and information than we know what do with. What we need is knowledge - how to apply data and information to create value. This is true both for human cognition and for machines. A sensor in a plant produces huge quantities of data but only by interpreting and contextualizing it can we make informed decisions, optimize processes and solve problems.

A digital twin is a virtual representation that predicts or helps understand how an object, a process or system performs in a particular context. It can play a role in every phase of the lifecycle, from planning through configuration to operation, diagnostics and maintenance.

In this issue of ABB Review, we look at how digital twins remove barriers to digitalization and help make production more customizable and flexible, while increasing productivity and improving sustainability by extracting value from data.

Enjoy your reading,

Björn Rosengren
Chief Executive Officer, ABB Group

Digital assets

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Almost anything we can do or imagine in the real world can be rendered and studied digitally, which can then give us insights and abilities – assets – that help us work better, faster, more reliably, and grow in value over time. From digital twins to predictive maintenance, using smart tech that gets smarter is a smart idea being put into practice.

08

DIGITAL ASSETS

ABB Ability™ Genix makes operations and asset optimization easy

ABB's comprehensive and integrated enterprise-grade digital transformation solution helps customers to improve productivity, process performance, product quality, efficiency and safety. Now, customers can more easily navigate digitalization for a better future.

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Is the world truly ready for the digital revolution? From a needs perspective – yes. Today's industrial enterprise, whether in the process, energy or hybrid sector, is an asset-intensive producer – one that is highly complex with fast-moving processes and a myriad of input points; all with a high degree of interdependence.

In today's highly competitive business environment industries search for every possible operational advantage to generate operational excellence →01, to enable them to produce the highest quality products, at the fastest rates, with the best and most reliable asset performance, cost-effectively. With production equipment pressed to maximum capacities, state-of-the-art industrial automation can be utilized to impose efficiency on the production process. By extracting value from a manifold of data generated by, and stored in, existing operational- (OT), engineering- (ET) and information technology (IT) systems, industries can achieve massive gains in productivity and make better business decisions. In this context, industrial enterprise

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In today's competitive business environment industries search for every possible operational advantage to generate excellence.

management teams and operators alike acknowledge the power of digitalization to help achieve challenging outcome targets in today's complex operational and business environment. And, yet, many companies struggle – not knowing where to begin their digitalization journey [1].

At the vanguard of digital innovation, ABB combines its vast industrial and automation experience with its capability to develop or utilize innovative digital technologies to help industries on their digitalization journey. In July 2020, ABB launched the ABB Ability™ Genix Analytics and AI Suite; this comprehensive and integrated enterprise grade digital transformation solution

consists of a range of software, applications and services to help customers to improve productivity, process performance, product quality, efficiency and safety. In this way, ABB is poised to help customers successfully navigate digitalization.

Understanding the challenges
Given the high efficacy of employing digital technology – eg, 40 percent increase in productivity – it is surprising that enterprises are slow to digitalize. Currently, enterprises typically only exploit 30 percent of their generated data. This hesitation limits their ability to apply data analytics in a meaningful way and restricts their ability to harness potential business value [2,3]. Clearly, there is a gap between the acknowledgement of the efficacy of using digital technologies and being able, or willing, to harness the unimaginable value associated with digitalization [4]. By analyzing available trends, ABB investigated this conundrum and found that the root cause is not the lack of desire to digitalize but in knowing just where to begin. This is compounded by

the scarcity of available and easy to implement market solutions, eg, requiring minimal change management; immediate in terms of results; customizable according to needs and preferences, and completely relevant in how impact is created.

As with any journey through uncertain and unchartered territory, insight leads to clarity and understanding. Clearly, the industrial world needs a quick, configurable, relevant solution, one that

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ABB's industrial and automation experience and innovative digital technologies help industries to navigate digitalization.

is high on impact and aligned with strategic business objectives. ABB's digitalization concept crystallized out of this insight. This concept
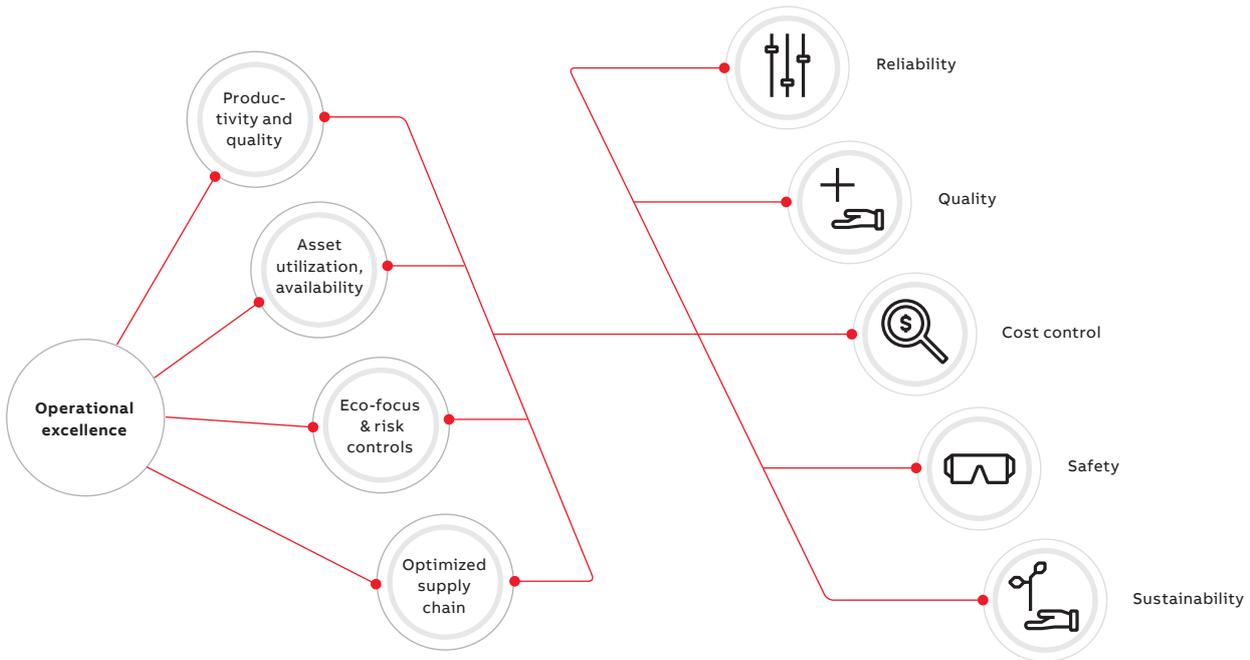
01

builds upon ABB's common business ethos, namely, to address and alleviate customer's concerns over adopting digital technologies to ensure productivity gains. This conceptualized proposition takes into account the five "Ss":

- Speed – rapid implementation; generating value in the shortest possible time
- Smartness – inherently intelligent with several pre-built features, driven by industrial domain knowledge
- Security – characterized by the highest standards of cyber security, thereby ensuring that customers are protected from exposure to cyberattacks and data privacy breaches
- Scalability – the ability to be implemented from edge to enterprise; and configurable based on context, requirements or preferences
- Simplicity – with complete ease-of-data integration, a high degree of interoperability, out-of-box integration, and easy-to-understand visualizations and applications

Digitalization – the path from idea to realization
Launched in June 2020, ABB Ability™ Genix is an enterprise-grade open architecture-based platform and suite that harnesses the power of industrial analytics and industrial AI to convert cross-functional data into actionable insights. The key lies in collecting, combining and contextualizing data from a multitude of sources across a diverse set of systems – OT (real-time data from operational technology), IT (functional data from information technology) and ET (design information from engineering) systems.

For example, OT data from a critical asset, eg, a turbine, indicates how this asset is performing; the ET data indicates just how well or how poorly this turbine performs according to compliance specifications in regard to integrity and opera-

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The ABB Process Automation asset and digital portfolio has a solution for every step customers choose to take.

tional safety; and IT data indicates how to keep the asset performing at a desired condition with the right maintenance strategy, spare parts inventories, risk and investment planning, and more.

The ABB Ability™ Genix has evolved into a powerful platform, extending from the asset level through to asset ecosystems at plants and ultimately to the entire enterprise, covering all stakeholders, and yet critically, the basic unit remains the asset. Of course this includes the collation of the massive data that each asset generates.

Since customers rely on assets designed and delivered by ABB eg, analyzers, instruments, drives, motors, generators, switchgear,

propulsion systems and turbochargers, ABB is perfectly positioned to know how best to extract, converge, contextualize and utilize this data for prediction possibilities, flag improvement potential, and foster business opportunities.

However, this requires a new unified analytics model that relies on domain knowledge and AI. Historically, Original Equipment Manufacturers (OEMs) provided models for equipment based on physics, and, or, first principles, often referred to as digital twins. Nonetheless, industrial manufacturing relies on a system of equipment or assets that all work in unison to complete a process.

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The ABB Ability™ Genix Analytics and AI Suite is a comprehensive and integrated enterprise-grade digital solution.

The effort of creating a first-principals-based model for such a complex system of assets would be prohibitive →02. The application of machine learning (ML) models, which are purely data driven, although quite promising, has drawbacks for industry. These models only provide insight about the conditions and anomalies for which the dataset has been trained. ML models have an inherently limited scope in an industry context because such situations have yet to occur. For this reason, ABB combines industrial domain knowledge with data driven AI/ML models to maximize algorithms for optimization.

Unleashing the power of data
Idolized in science fiction until as recently as three decades ago, the idea of autonomous manufacturing plants has been a dream for many. Recently, the rapid emergence of self-reporting and self-performing equipment have once again fired the imagination and this excitement permeates manufacturing enterprises worldwide as Industry 4.0 begins to unfold.

At first glance, Industry 4.0, is driven solely by automation. This perception is not entirely erroneous. Smart sensors and the Internet of Things (IoT) are among the most visible harbingers of this industrial transformation. And, automation, with ABB at the forefront, has a long history of bringing quality, accuracy and precision to industrial processes. But, automation does not propel digitalization, the scale and sheer ubiquity of automation does. Moreover, data plays the most decisive role – data from IT, OT, ET, and geospatial sources and others. The focus is on how to capture data, integrate it, contextualize it, store it and analyze it; and how to create insights from data that span functions and systems →03.

Managing the data value chain is key to achieving the five "Ss" of speed, smartness, security, scalability and simplicity – every element is dependent on the effective capture and treatment of data. The power of managing the smart data value chain is evident: Solution providers typically spend over 80 percent of their implementation effort on understanding industrial processes and data sources; and designing methods to capture data. But, this involves complex change management and implies a delayed return on investment (ROI) – invariably leading to company decisions to deploy only limited digital point solutions that

First principle models
Physics-based modeling of isolated physical phenomena in a system/equipment
Time-consuming, inability to predict behavior in different operation conditions

Machine learning models
Simple ML models for complex, non-linear systems
Works only for datasets for which the model has been trained and with attributes of anomalous condition

Ensembled approach-Industrial AI
Combining Artificial Intelligence with industrial domain knowledge
Safer, smarter, more sustainable industrial operations

will never match the impact of an enterprise-wide digital transformation.

To achieve an enterprise-wide outcome, a seamless and secure edge computing integration is advantageous. Thus, ABB created the connection between the powerful industrial analytics and AI platform, ABB Ability™ Genix, and ABB Ability™ Edgenius, ABB's operations data management tool. By offering this comprehensive integrated solution, ABB offers industrial enterprises a compelling argument to extend their digital transformation capability across the entire value chain; thus enabling strong outcomes on key indicators like operational excellence, asset integrity and

performance, safety, supply chain optimization, energy efficiency and sustainability.

With data as the starting point of every element of the value chain, ABB Ability™ Genix and ABB Ability™ Edgenius uniquely combine ABB's inherent strengths: domain knowledge, technology expertise and digital capabilities across the industries served. For ABB what really makes the difference in industrial analytics and the Industrial Internet of Things (IIoT) is the word "industrial".

Unless digital technology is deeply integrated with operational processes, the path to Industry 4.0 adoption will languish and the value gained will be limited. At ABB, all expertise and industry-specific practical knowledge is therefore harnessed to create relevance in addition to transformation →**04**.
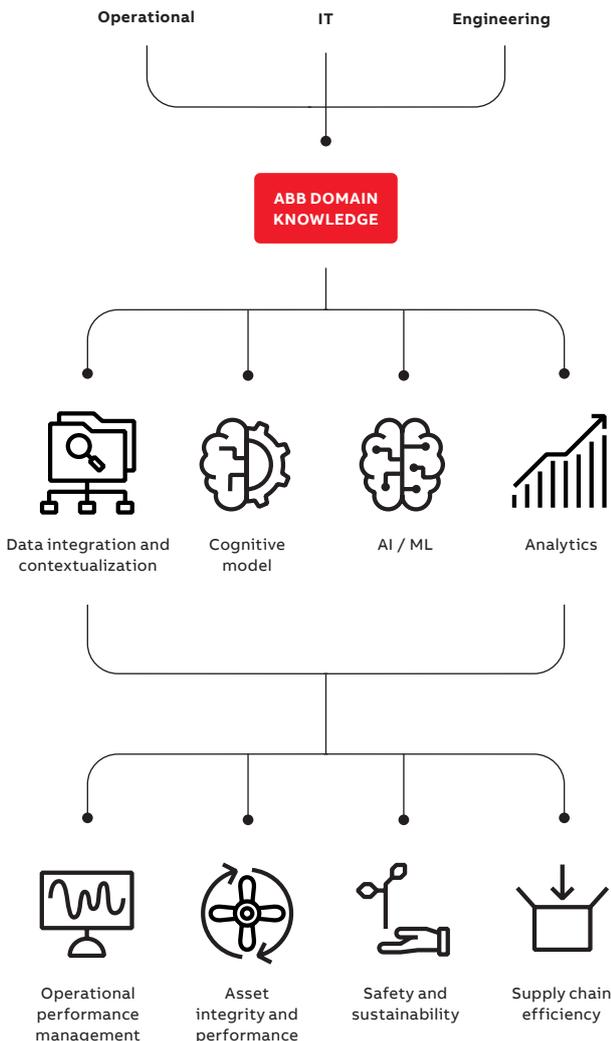
**Achieving exceptional value – the ultimate result**
At the end of their digitalization process, customers gain from a comprehensive solution; extensible from edge to enterprise; easily deployable on cloud, on premise or in a hybrid model. ABB has a solution in the ABB Process Automation asset and digital portfolio for every step customers choose to take on their digital transformation journey.

The first step is the introduction of smart equipment – assets that create digital footprints and data points. This step helps industries

CUSTOMER DATA SOURCES

03

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The focus is on how to capture data, integrate it, contextualize it, store it and analyze it; how to create insights.

monitor asset health and performance, process, safety with real-time- or near-real time data. Only then can digital value-driver solutions be implemented.

Despite an understanding of the benefits of digital transformation, programs often run for multiple years and can be daunting. To alleviate apprehension, ABB created small pre-built analytics applications with clear value drivers for incremental benefits in mind. ABB's digital portfolio combines data and domain expertise as the force behind applications to address five families

Data **Domain** **Technology** **Capabilities**

OT + IT + ET with spatial convergence
Brings together data from silos into one cognitive data lake and modular end-user options

Analytics pre-built with domain expertise
Highly visible, easy-to-understand and intuitive to action

Platform + service + apps
Industrial AI at each step to drive actionable insights with consultative approach to implementation

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03 ABB Ability™ Genix, ABB Ability™ Edgenius combines customer's data sources with data integration and contextualization, cognitive models, ML/AI based models, analytics and ABB's exceptional domain knowledge to generate value across the entire enterprise.

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04 ABB's Genix is designed as a modular architecture to offer options to end users. Analytics that are pre-built with domain expertise lead to insights which are highly visual, easy to understand and intuitive to act upon.

of value drivers – operational performance management, asset integrity and performance management, safety, sustainability and supply chain optimization →04. Nonetheless, for full long-term benefits, such analytics applications must be

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ABB is heralding the way in which digital technologies, Industry 4.0, industrial analytics and AI shape the future.

built on a robust, scalable and modular platforms such as ABB Ability™ Genix. Some examples of pre-built analytics applications include: system anomaly detection, opportunity loss manager and heat exchanger fouling.

Additionally, the power of the ABB Ability™ Genix platform can be leveraged for rapid development of a specific analytics solution. For example, a smart predictive maintenance solution collaboratively developed for ABB's

Azipod® gearless steerable propulsion system identifies potential anomalies and generates an early warning signal for maintenance teams – AI/ML-based models prevent failure. The engine for anomalous condition detection and early warning is based on the integration of real-time data of winding temperatures, speed, torque, power and inlet, outlet cooling air temperatures drawn from internal collaboration. Here, pilot implementation studies demonstrated an increase in lead time, of over one hour; this allows issues to be addressed before they potentially result into catastrophic failure.

Together, ABB Ability™ Genix, ABB Ability™ Edgenius with packaged analytical applications based on industry value drivers are heralding the way in which digital technologies, Industry 4.0 principles, industrial analytics and AI are shaping the future of industry. •

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DIGITAL ASSETS

Partnerships with startups speed delivery of digital tools

Collaboration with external technology leaders lets ABB deliver customer solutions faster. ABB's partnership with RE'FLEKT, a Munich-based augmented reality (AR) company, brings ABB expertise directly to customers, when and where they need it most, via Big Data, analytics and visualization.

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Collaboration partnerships also allow ABB to learn more about emerging technologies.

Dirk Schart
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For ABB, the future lies in open innovation that focuses on collaboration with external partners – universities, research organizations, startups and the like. Consequently, the company drives external collaboration in a structured way, via ABB channels such as ABB Technology Ventures

(ATV) and SynerLeap. SynerLeap provides technology resources and expertise to ignite innovation and growth across industries while ATV provides financial and business-model support. These two bodies complement and leverage each other: ATV has already

invested in some SynerLeap partners, with more to follow. The SynerLeap/ATV setup has increased ABB's attractiveness to the startup community worldwide.

Collaboration partnerships also allow ABB to learn more about emerging technologies, where they can be best applied (eg, high-value use cases) and how they can be leveraged to solve customers' problems →01.

RE'FLEKT, an AR technology company based in San Francisco and Munich, is one prominent Synerleap partner with whom significant successful technological progress has been made. RE'FLEKT's world-leading technology enables any business or industry to create their own in-house AR or mixed reality (MR) applications. ABB is collaborating with RE'FLEKT to introduce AR to a wide range of applications, beginning with visual remote support, service, maintenance and training.

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01 Collaboration with
external companies
that are experts in their
field shortens time to
market.

Bringing data together
Historically, industrial automation data resided in
separate, isolated systems and networks, forcing
operators to look at a multiplicity of screens or
dashboards if they wanted to evaluate the status
of a particular piece of equipment or process.
As industry started to move through the digita-
lization life cycle, these separate systems were

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AR is already delivering value
in maintenance, training and
service.

connected so that data could be aggregated and
associated. The challenge then was to place all
this data in a context where it becomes mean-
ingful and useful. Such a context is supplied by

AR. Using AR, the user can now look at a device,
identify it precisely, visualize all the available
data associated with the device, apply advanced
analytics, attach Internet of Things (IoT) data
and, ultimately, apply artificial intelligence (AI)
algorithms to it to derive even more information.
This means AR can be used in every phase of the
equipment or plant life cycle.

Taking a wider view
AR is already delivering value in maintenance,
training and service, especially via ABB Ability™
Collaborative Operations Centers →02. The next
steps are to implement the technology in areas
where the potential value of combining data is
high, such as in design, assembly and operations.

In these areas, the more data that is brought
together, the more meaningful the aggregate
becomes. This data allows smarter, more-
informed decisions to be made. For example,

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ABB ABILITY™ COLLABORATIVE OPERATIONS CENTERS

In this new era of digitalization, close collaboration between producers and suppliers is important in order to reap the full benefits that Big Data, analytics and visualization offer. ABB provides this collaboration through ABB Ability™ Collaborative Operations Centers – remote operations and maintenance structures that help industrial producers harness the potential of digitalization.

ABB Ability™ Collaborative Operations Centers allow ABB experts to provide insights through data analytics, thus making customer information actionable and meaningful while driving decision making to optimize enterprise performance. The facilities provide 24/7 remote access to ABB digital technologies, data analytics and domain expertise. ABB Collaborative Operations Centers around the world are equipped with advanced applications that allow the customer and ABB experts to collaborate remotely and adapt operations to fluctuating demand quickly.

The centers utilize the ABB Ability™ cloud infrastructure, enabling the customer to securely integrate and aggregate data, apply predictive analytics and generate insights that can help drive profitability.

In a typical application, ABB designs a remote monitoring center for the customer and integrates it into a Collaborative Operations Center. Field devices are installed at site to gather data and data analytics are applied to quickly identify, categorize and prioritize issues. Common communications protocols are established between the customer site and ABB technical centers, as well as with customer headquarters for further financial analysis and decision-making.

The accelerated support delivered by the ABB and RE'FLEKT AR solutions will greatly increase the power of Collaborative Operations Centers to reduce maintenance, onboarding and training costs through step-by-step instructions displayed in the real-time environment. AR guided maintenance procedures (GMPs) will keep production running by providing faster time-to-repair.

Kim Fenrich, ABB Simulation Product Manager, summarizes the AR approach thus: "We are using transformative digital technologies like augmented reality to build new business models that improve customer performance. These technologies are changing the way we work with customers, providing people with expertise faster." •

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The ABB Ability™ platform and cloud infrastructure let the customer securely integrate and aggregate data, apply predictive analytics and generate insights.

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connecting design data to operations data makes it possible to compare current operating conditions with expected performance. It could be that operations are running as per design, but

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Often, digital twin performance can be greatly enhanced by exploiting RE'FLEKT AR technology.

the design data was wrong. If so, the operational data can be rolled back into the original as-built drawings to amend the design and ensure future iterations are founded on correct, real-world data.

Underpinning the entire life cycle with a single source of accurate data – and overlaying 3-D or live data with AR support – enables more accessible training and better and faster plant support. In addition, remote support can be simplified, limiting the need to send service engineers to site.

Digital twins
A digital twin is a virtual representation of an object or a system that has operational awareness. A plant will be represented by many,

interconnected digital twins, allowing operators to zoom in to a specific location and obtain comprehensive real-time status information, enabling problems to be solved faster.

The more data that is available to the digital twin, from the design phase onwards, the more customers can improve performance, extend equipment lifetime, cope with changes and reduce downtime. For example, if a motor becomes defective and no exact equivalent is available because of changed specifications or obsolescence, AR, the digital twin and some simulation software can allow the user to evaluate what will happen if a motor with a different specification is used.

For many applications, the performance of the digital twin can be greatly enhanced by exploiting RE'FLEKT AR technology →**03**.

Start small
A flow meter application – called ABB Ability™ AR Guided Support for measurement devices – crystallizes out some of the concepts discussed above. In doing so, the application provides a concrete example of how the collaboration with RE'FLEKT has led to the development of concepts that can directly benefit customers.

Scattered across industry, there are hundreds of thousands of ABB flow meters. These meters arrived at their destination via different

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04c

channels – directly from ABB, installed by system integrators, sold by third-party resellers, etc. – which makes it difficult for ABB to control overall quality or have an overview of the installed base. When a meter fails, the user sometimes does not know who to call.

ABB has the 3-D content and the expertise to build AR-guided support procedures for these meters. RE'FLEKT has the AR know-how to catapult these procedures to new levels of utility and simplicity. RE'FLEKT does more than just bring data together: the company leverages its considerable intellectual property foundation to enrich the entire AR environment →04 – 07.

Flow meters provided an excellent use case for a deepening of the ABB/RE'FLEKT collaboration in particular because they offered the

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Flow meters provided an excellent use case for a deepening of the ABB/RE'FLEKT collaboration.

opportunity to prove ABB's assumptions using an uncomplicated device with a high-value use case. Conversely, beginning with a large, complex target – such as a gearless mill drive or paper machine – would have resulted in a long, high-risk development effort.

After clearly defining deliverables, running a proof-of-concept project and completing development and pilot phases, a preview application containing a small number of guided support procedures has been introduced to channel


05a

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04 ABB viewer.

04a Main screen.

04b Menu.

04c Device selection.

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05 Example screen
displays for meters.

05a Safety instructions
are presented.

05b Disassembly
instructions.

05c Detailed
instructions.

05d Presentation of the
real-world surroundings
assists orientation.

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06 Photos can also be
included in the display.

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07 Detailed handling
instructions improve
safety.

partners and customers to gather market
feedback. In addition, ABB has introduced a
new visual remote support tool – ABB Ability™
Remote Insights for service – that utilizes AR to
speed problem resolution. Based on RE'FLEKT's
platform, this tool is a global standard solution
that allows experts in ABB support centers to see
what the customer sees at site.

Market introduction
By providing plant operators with innovative
tools that further support self-maintenance,
show proof of value and drive increased perfor-
mance, ABB will increase customer confidence.

Through a phased market introduction, begin-
ning with the proof of concept, ABB aims to
demonstrate the value that guided support
procedures provide when solving real-world
problems. Once this value is proven, customer
and management buy-in will follow. This will
drive development and introduction of additional
guided support procedures. As the range of
procedures widens, they will rapidly become an
expected part of many deliverables.

RE'FLEKT's AR ecosystem will greatly simplify
the development, introduction and use of these
enhanced features.

Delivering digital tools faster with partnerships
ABB Ability™ Collaborative Operations Centers
and RE'FLEKT's AR ecosystem will combine contin-
uous monitoring and data insights with real-time
visualization and instant access to knowledge.
This advance turns data and analytics into

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In time, AR-based approaches
will be exploited to deliver va-
lue in many ABB systems and
devices.

easy-to-use, step-by-step instructions with live
remote support, enabling any service technician
to perform the task required to resolve a condi-
tion in an efficient manner.

RE'FLEKT's AR ecosystem will allow ABB to
provide not just instant customer support but
also in-house creation of AR-powered manuals
and support. Replacement procedures that can
be deployed directly at the customer site can also
be generated. This facility will improve work-
flows, enhance the technicians' capabilities and
increase customer satisfaction.

In time, AR-based approaches will be exploited to
deliver value in many ABB systems and devices.
Full potential will be reached when total integra-
tion with the customer's data is achieved, though
this is some way off.

By making AR and MR affordable and scalable
for business, RE'FLEKT's groundbreaking
human-centered platforms empower ABB to
infuse their industry knowledge into customized
AR and MR solutions. •

01

DIGITAL ASSETS

The digital twin: from hype to reality

Increasing demand for digitalization and the industrial internet of things (IIoT) makes the digital twin a key enabler for digital industries. How do digital twins improve digital technologies, drive the development and standardization of architectures and create new use cases and business models?

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01 Digital twins are key enablers of digitalization in many industrial sectors. They are often defined by the setting in which they were used.

Digital representations have been used for many years to model information relating to assets over their lifecycle. These models were not known as "digital twins" until the term was first coined in 2003 in a university course. Over time, many different definitions of digital twin have emerged. These definitions typically focus on the digital twin's particular use case. →**01**. Latterly, different consortia – such as the Industrial Internet Consortium (IIC), to which ABB contributed – set out to define digital twins world beyond the boundaries of specific use cases. For example, the IIC defines the digital twin itself as the digital representation of an entity (eg, device, production cell, or plant) that meets the requirements of a particular set of use cases [1,2]. This definition has two implications:

• Although many associate the digital twin with the IIoT, the definition places no emphasis on IIoT aspects as the notion of the digital twin (though not the name) predated the IIoT.
• Digital twins should be discussed in relation to enabling use cases, which determine the data, models, computations, and services to be offered.

**The digital twin in industrial systems**
The lifecycle data of industrial devices can be classified as engineering technology (ET) data, information technology (IT) data and operational

technology (OT) data. This lifecycle data is often stored in different places and in different formats due to requirements of functionality, needs of diverse users, company mergers, etc.

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The digital twin can offer a common information model for defining otherwise incompatible ET, IO and OT data.

→**02**. These data silos lead to a lack of interoperability at multiple data access levels and require error-prone and time-consuming manual data exchanges. Combining data for harnessing by analytics applications is also made difficult.

These problems can be solved by digital twins, which may be deployed locally or in the cloud. Here, the digital twin can offer a common information model for defining otherwise incompatible ET, IO and OT data. This model serves as the basis for application programming interfaces (APIs) to access data and to define semantic correlations between data sets that would ordinarily be dispersed. The digital twin can offer unified APIs for querying various types of lifecycle data,

BOUNDARIES OF ONE COMPANY

Applications

Asset Administration
Shell

Digital twins

Other companies

Simulation
models

Information
models

Machine-
learning
models

Devices

Installed
base

Master
data

Internal
systems

Selection
tools

Engineering
tools

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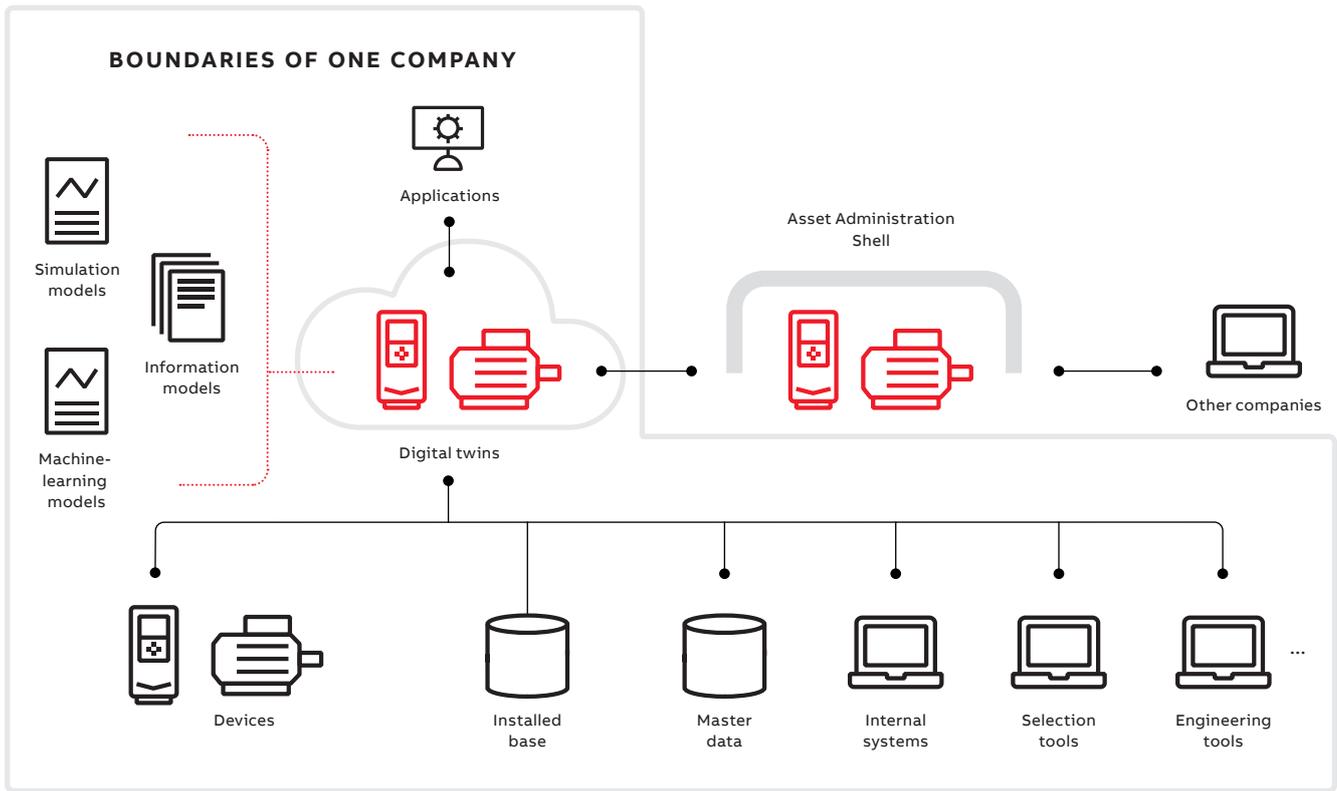
02

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regardless of whether the data is stored in the cloud or in external data sources [4].

The maturity level of digital twins can be increased further by expressing correlations between different models embodied within the digital twin and deriving more reasoning from this information →03. Digital twin content can be extended even further by using machine learning and simulation models. Such enhancement increases the intelligence of the digital twin and allows better reasoning with regard to the status of the physical twin. It also provides support to real-time simulation models. More advanced use cases can be achieved if multiple models are combined – for example, to have intelligent simulation models to predict the status of a device.

In the IIoT era, technologies such as the cloud, edge computing, 5G connectivity and augmented reality move the digital twin concept to the next level by enabling improvements in digital technologies, development and standardization of architectures, creation of innovative interactions between systems or users, and establishment of business models →04.

With these technologies and interactions in place, digital twins can enable new use cases – for example, integrated information management across the value stream, integrated

cloud-based engineering, plug-and-produce for field devices and virtual on-site support. Integrating digital twins into automation processes helps to decrease commissioning time and effort and shorten time to production commencement.

Two use cases – integrated cloud-based engineering and plug-and-produce for field devices – illustrate the benefits delivered by digital twins:

Integrated cloud-based engineering
Rather than consider the broad scope shown in →02, one may focus only on using the digital twin to enable integrated data exchange among tools. For example, device parameters used earlier can be stored as a dedicated model within the digital

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Digital twins decrease commissioning time and effort and shorten time to production commencement.

twin in the cloud so the engineering tool can later pick these out to initialize its engineering parameters correctly. The digital twin also enables cloud-based backup and restoring of engineering data.

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02 The digital twin addresses the data silo problem.

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03 Digital twin maturity level.

Plug-and-produce for field devices
Today, configuration or replacement of field devices can often be laborious as potentially non-standardized information from different sources in different formats must be collated. The digital twin of a field device, however, enables a plug-and-produce scenario that speeds field device commissioning. Automatic device discovery and cloud computing combined with standardized information formats, such as AutomationML and OPC UA, can be used to automatically discover devices connected to the network, map engineering and operational parameters to each other, and download the appropriate parameters from the cloud to the devices. While the physical replacement still requires trained personnel, the digital twin allows instant reconfiguration without the need for a device or process expert.

Digital twin standardization and initiatives
There are various standardization activities in progress related to digital twins. For example, Aspect Object technology, standardized in IEC-81346, defines the so-called aspects needed to structure information related to various views (eg, product, function or location) of an industrial system. IEC 62832 defines a digital factory framework with the representation of the factory's assets at its center, although this representation is not called a digital twin.

Over the past few years, more initiatives have appeared: IEEE P2806 aims to define the system

architecture of digital representations of physical objects in factory environments, focusing on connectivity requirements and industrial artificial intelligence data attributes. Likewise, ISO/AWI

—
## The Asset Administration Shell fosters digital twin interoperability.

23247 drives the use of digital twins for manufacturing by defining a reference architecture.

While companies often offer digital twins as isolated solutions, many use cases could benefit from interactions between digital twins from different vendors. The German platform "Plattform Industrie 4.0" launched Asset Administration Shell [3] as the industrial digital twin for smart manufacturing to foster interoperability across the value stream.

As well as the IIC and Plattform Industrie 4.0, other groups exist – for example, the Industrial Digital Twin Association (a user organization for Plattform Industrie 4.0 with open source intentions); the Digital Twin Consortium [5], which drives consistency in vocabulary, architecture, security and interoperability; the Open Manufacturing Platform [6], which aims to offer platform-agnostic solutions; and the GAIA-X


Level 4:
Integrated models –
eg, integrated
machine learning
and simulation

Level 3:
Beyond information
models – eg, machine
learning, simulation

Level 2:
Semantic correlations
across different
information models

Level 1:
Unified APIs and
information model

Level 0:
Data silos

03
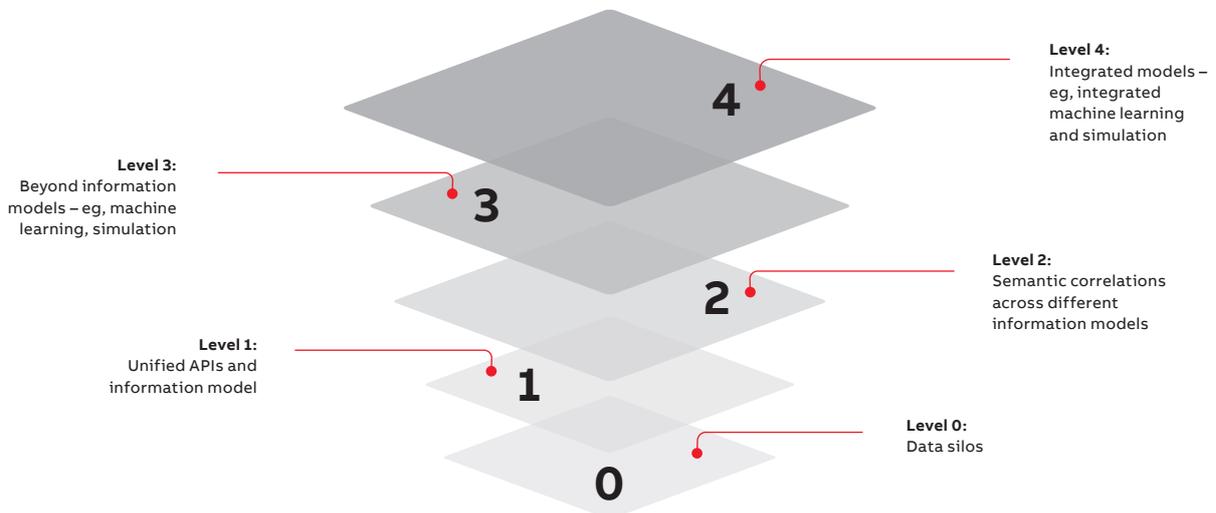
BASED ON VARIOUS DIGITAL TECHNOLOGIES SUCH AS ...

Sensors

Cloud computing

Big Data

Cyber security

Virtual/ augmented reality

5G Connectivity

DIGITAL TWIN ASPECTS SUCH AS ...

Information modelling

Data ingestion

Security

Interoperability

Data synchronization

Deployment

APIs

Connectivity

ENABLE NEW USE CASES SUCH AS ...

Integrated information management across the value stream

Plug-and-produce of field devices

Integrated cloud-based engineering

Virtual on-site support

project [7], with interoperability at the level of information models and the digital twins as a cornerstone of its vision.

The digital twin and digital business models and the future
The digital twin lays the foundation for new digital services and collaborations and helps existing services become more accessible and more efficient. Further, since many production errors are caused by wrong or outdated data, having a broadly agreed means to access and exchange device-related data eases collaborative engineering throughout the lifecycle [8] →**05**.

In contrast to the physical device, a digital twin and all its aspects can be made widely available, with appropriate cyber security measures, allowing cloud-based "X-as-a-Service" applications. Moreover, integrated access to ET, IT and OT data via the digital twin APIs allows data access and usage rules to be made at the level of the digital twins. This managed data access eliminates the need to define such rules individually for each data source and facilitates the definition of usage policies for external consumers of the digital twin data.

—
A broadly agreed means to access and exchange device-related data eases collaborative engineering.

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There is no doubt about the critical role that the digital twin will play in the ongoing rapid digital evolution of industry. Through various projects and collaborations, and contributions to consortia such as IIC and Plattform Industrie 4.0, ABB is helping to drive the establishment of common definitions and standards for digital twins. •

— 04 An overview of topics related to the digital twin.

— 05 Digital twins can deliver broad access to device-related data and help eliminate production errors caused by wrong or outdated data.

05

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DIGITAL ASSETS

Products have a digital twin and you can find it too!

Industrial plants can contain thousands of devices, each with associated documentation. Using Industry 4.0 technologies, an ABB demonstrator shows how to manage the administrative overhead of making sure documentation is comprehensive and up-to-date – throughout a product's entire life cycle.

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01 Industry 4.0 provides tools to help manage administration of the documentation for the thousands of devices found in a typical industrial plant.

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02 Example of an AutoID weblink encoded as a QR code for a temperature transmitter.

https://id.abb/9AAC129110?SN=3K650000554982

02

Information – such as documentation, manuals, technical data, drawings, notes and certificates – follows a product throughout its entire life cycle, all the way from the design process, installation, operation and maintenance, to eventual decommissioning and recycling. Locating relevant and up-to-date documentation for a product is often a struggle for users as much of it is created, filed

—

Digital twins can help the exchange of information between customer tools, ABB's data repositories and other systems.

and updated manually. And even a mid-size plant can have many thousand pieces of documentation →01. Automating the administration of these masses of data faces barriers – for example, uniquely identifying the device, providing machine-readable documents, clear semantics (meaning) of information, standardized metadata and appropriate update mechanisms.

Fortunately, advances in Industry 4.0 specifications for interoperable industrial digital twins help to overcome these barriers. Digital twins create a digital, interoperable, end-to-end solution for information on devices, starting with product design and certification, through production, logistics, transport and distribution, to the customer's facilities, operation and maintenance organizations.

This article will show how digital twins can help solve the challenge of exchanging information between customer tools, ABB's data repositories and other systems.

AutoID – identifying devices and device types
In 2018, ABB was invited to support a European process industry initiative to create a global-scale, smart identification system for devices – from high-volume sensors to large custom-made machines. Robust and secure identification of devices is essential to provide asset-related information.

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ABB worked with more than 50 partners, suppliers and customers to standardize an identification system ("AutoID"), which resulted in DIN SPEC 91406. ABB is supporting the working group to enshrine the DIN SPEC in an IEC standard, accelerating implementation around the globe.

The approach is as simple as it is efficient in that a unique identification key in the form of a machine-readable label is enough to:
- Distinguish and reference any devices marked with such a coded label.
- Create, process, store and exchange any kind of information related to a physical object.

A basic principle was defined to eliminate the need for a central coordination body to guarantee code uniqueness: The code should contain one element identifying the vendor and a second element under the vendor's control and unique in its domain. Internet addresses (weblinks) were used to solve this coding challenge.

As a physical container, a 2-D code (QR code or data matrix) was chosen, allowing the AutoID to be read by optical scanners and smartphones. AutoID also works with radio frequency identification (RFID) or near-field communication (NFC) to cover applications where optical scanning is not feasible.

ABB uses the weblink feature of AutoID QR codes to take the user directly to the product Web page →02.

03

Sources of ABB digital, machine-readable product information
Product type-specific information for ABB's large and diverse portfolio is found in several machine-readable ABB sources:
- The ABB Library, developed and maintained by ABB, which contains marketing and technical documents, software, movies and other documents related to ABB products and services.
- The Product Information Management (PIM) system – an ABB master data repository for language translations, ABB's customer-facing ABB Offering Tree, product and parts data.
- The PIM application – this application provides, eg, Web services, XML exports for product data and classification tree exports to downstream applications.

- Product Information Services (PIS) – a master data application that provides consistent navigation, search, selection and presentation of ABB offerings. PIS is deployed as a service to multiple internal and external-facing downstream applications.

These sources are exploited by the ABB product information exchange demonstrator, as will be described further on in this article.

Standardized information formats
Alone, the availability of digital information is not sufficient for a cross-organizational exchange. Luckily, there are standardized concepts available to close this gap.

Technical properties of devices need to be provided to the customer in a form that leaves no ambiguities about their meaning. This challenge is solved by predefined semantic dictionaries like ECLASS [1] or the IEC Common Data Dictionary

—
Technical properties of devices need to be provided to the customer in an unambiguous form.

[2]. These dictionaries define equipment classifications, such as "temperature sensor," and properties, such as weight or height, and their values →**03**. The definition itself is based on the IEC 61360 standard and contains a human-readable
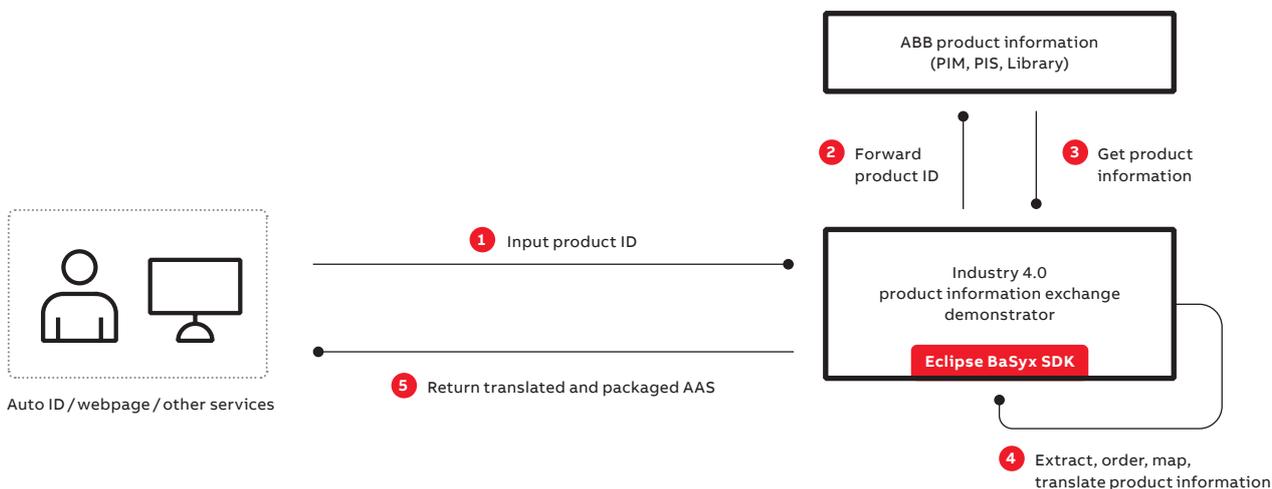
04

description, a data format and a unique concept identifier, a so-called semantic identifier.

Regarding documentation, the German standard VDI 2770 defines an information model to package electronic documents and extend them with meta-information. This information provides not only structured multilanguage documentation for any device, but also a way to search, categorize and review this information efficiently.

The industrial digital twin
One of the core ideas of Industry 4.0 is to enable an interoperable, vendor-independent and open information exchange along the life cycle and across organizational boundaries.

This idea is technically addressed by the so-called Asset Administration Shell (AAS) concept, the interoperable implementation of a digital twin in the industrial domain. The development of the industrial digital twin, including AAS, is governed by "Plattform Industrie 4.0", a German consortium of industrial and IT companies, trade associations, academia and political institutions and the Industrial Digital Twin Association. Ongoing work includes standardization of submodels to enable reuse and cybersecurity aspects to provide access control. Furthermore, an IEC working group (TC65 WG24) is well on the way to turn the AAS ideas into an international standard.

In the context of Industry 4.0, an asset may be any physical or virtual entity that is of value for an organization. In the context of this article, assets are devices and their types. The digital

twin is always linked to an asset, adding a digital representation of asset information for specific use cases – eg, for product information exchange. The collection of information for one specific use case of the related asset is called a submodel.

The industrial digital twin consists of a technology-independent information model and mappings to technical implementations suitable for the life-cycle phase under consideration. For

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Ongoing work includes standardization of submodels to enable reuse.

example, the digital twin may be exchanged as a file package during application specification. Later, the information can be exchanged using a Web interface in later life-cycle phases, such as monitoring during operation and maintenance.

Digital twin infrastructure – finding the digital twin of the product
Manufacturers will manage the AASs for their products. To locate an AAS, registries allow the identification of, or search for an AAS based on a given asset ID, just as in a telephone directory. If no ID is available, the content of an AAS can be searched or queried by specifying some of its properties.

05

Putting the building blocks together in a product information exchange demonstrator
The ABB product information exchange demonstrator makes use of all the tools that have been described in the previous sections →**04–05**.

As a first step, the demonstrator takes a product ID from AutoID as an input. The demonstrator uses this ID to query the ABB information systems described above for product information, documentation and images. The extracted

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The demonstrator shows how the Industry 4.0 tools work together and address the barriers mentioned.

information is assigned to different digital twin submodels and, if necessary, mapped onto the internal digital twin format. Semantic references in the form of ECLASS identifiers are also taken into account. Finally, the digital twin is translated and packaged as an AAS and returned as a file to the user.

→**06** shows a screenshot of the AASX Package Explorer Tool [3], which is based on specifications published by Plattform Industrie 4.0. The explorer can display the content of an AAS file: In the screenshot, the left part shows the product image. The middle part shows

the submodels and their content in the form of a tree. The right part shows details for the selected element – in this case, the documents contained in the documentation submodel.

The demonstrator shows how the Industry 4.0 tools work together and address the barriers mentioned at the beginning of this article:
- The product type of a device is uniquely identified via AutoID.
- Product information is accessible in a digital and machine-readable format from the ABB information systems.
- Information is converted into a standardized format (ECLASS, the IEC Common Data Dictionary and VDI 2770).
- Information is packaged in the form of an industrial digital twin and implemented as an AAS.
- The industrial digital twin can be identified and its content downloaded using the AutoID.

ABB's contribution to industrial digital twin standardization and applications
Starting with early papers on cyber-physical systems and the AAS [4], ABB has contributed significantly to the evolution of the digital twin concept [5]. Since 2017, ABB has led the Plattform Industrie 4.0 working group "Reference Architecture and Standardization," which finalized the first AAS specifications in 2019.

Since 2016, ABB has been participating in the BaSys 4.0 and BaSys 4.2 [6] projects, which defined and implemented the first AASs within an industrial and research consortium.

06 View of a product's digital twin, including identification, technical data and documentation.

07 Emerging hybrid systems pose the next challenge for information exchange between customer tools, ABB's data repositories and other systems. Complete information integration is, however, the ultimate aim.

07

—
ABB is continuously working toward a vision of industrial digital twins from both standardization and implementation aspects.

At the Hannover Fair in 2019, ABB presented the first end-to-end demonstrator that provides information on a power train (motor plus frequency-converter drive), aggregating information from technical product databases, engineering and configuration tools and online monitoring into a cloud-based AAS. At SPS IPC Drives 2019, ABB presented an interoperable implementation of the "digital nameplate" in a joint consortium of multiple industrial vendors and research organizations.

ABB is continuously working toward a vision of industrial digital twins from both standardization and implementation aspects. Current work includes steps to bridge Industry 4.0 concepts to the process automation domain – for example, by defining a submodel for a process module interface, the so-called module type package [7]. This work is particularly important for emerging hybrid systems – ie, production systems mixing discrete and process equipment, processes and domain standards →07. •

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DIGITAL ASSETS

Hybrid approach bolsters predictive maintenance

How can we use artificial intelligence to fortify the predictive maintenance of industrial critical assets? By combining domain knowledge and machine learning algorithms, ABB delivers a unique yet practical approach to do just that.

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Process industries such as refineries, cement- and power plants, etc., rely on a multitude of crucial equipment such as motors, pumps, fans, compressors, turbines etc., running around-the-clock, to ensure smooth production. Keeping these machines at peak health is critical as wear-and-tear is inevitable and machine failure undesirable. This is typically accomplished through planned maintenance in which certain spare parts are replaced and lubricants are applied to the rotating parts etc., on schedule or through reactive-, or unplanned maintenance,

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Digital techology is advancing and a new paradigm for asset health maintenance is emerging; ABB is at the vanguard.

in which machines are serviced only once they fail – a costly endeavor [1,2]. For instance, a recent ARC survey found that companies loose between 3 and 5 percent of their production to unplanned downtime [2]. Just a 1 percent gain in asset utilization could easily yield several millions of dollars in additional revenue [2]. Additionally, energy businesses spend about 40 percent of their operational expenses on both planned and unplanned maintenance – only to cover 20 percent of their

assets [2]. Clearly, planned maintenance has advantages over reactive maintenance, because running machines to failure can not only result in an unplanned plant shutdown it can seriously compromise the safety of personnel, equipment and the environment [3,4].

With the onset of Industry 4.0, advances in digital technology, machine learning (ML) and cloud and edge computing, a new paradigm for asset health maintenance is emerging and ABB is at the vanguard of this genesis. Nowadays, assets are highly digitalized so that critical sensor measurements generate vast streams of data. Advanced analytics can be used to discover just when the asset needs maintenance. This sensible

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Practical experiences show that ML approaches often lead to several types of false positives and, or false negatives.

data-driven-approach to asset maintenance, the predictive maintenance approach, opens up a world of cost efficiency as it is based on actual real-time asset health. Industry must no longer choose between running a machine to failure or replacing parts that are perfectly fine; mainte-nance can be forecast and optimized.

Predictive maintenance: the ends and outs
Predictive maintenance can add value to pro-duction processes by improving efficiency and lowering the need for unplanned maintenance and redundancy; thereby reducing costs [1]. In process industries, utilizing this approach can reduce downtime between 30 and 50 percent and extend equipment lifetime between 20 and 40 percent [1].

For the successful adoption of a predictive maintenance strategy, the early detection and identification of incipient faults is a prerequisite. This necessitates equipment inspection and early warnings for investigation of potential causes of faults that might develop.

FAULTS	Casing temperature	Room pressure	Location distributor	Vibration turbine casing
Rotor unbalance	5	7	5	3
LP compressor fouled	5	7	5	3
HP turbine hot and damaged	5	7	5	3
Overheating	5	7	5	3
No output voltage	5	7	5	3
Rotor unbalance	5	7	5	3
Risk	5	7	5	3

01

Truly forecasting maintenance is not straight-forward. To effectively schedule maintenance, it is necessary to predict how a detected abnormal condition is likely to develop in the future. Only then can valuable insight into the probable future consequences be gained [1]. Thus, successful predictive maintenance requires a three-pronged process:
- Condition monitoring that can provide early detection of faults
- Identification of specific failure mode(s) related to the fault detection
- Quantification of the extent of fault development to support maintenance planning

Despite the availability of various popular ML approaches to develop models for asset condition, eg, Principal Component Analysis (PCA), K-Nearest Neighbor (KNN), Local Outlier Factor (LOF), One Class Support Vector Machine (OCSVM) etc. [5], ML approaches are black box approaches and fully dependant on asset data; they make no assumptions about the asset or its failure modes. Practical industrial experiences indicate that such approaches are not always successful; often lead to several types and, or, several instances of the same type of false positives; and false negatives. Raising an alarm when the asset is completely healthy or vice versa; this can increase unplanned and redundant costs, decreasing viability [6].

To circumvent such unwanted consequences, ABB proposes the use of a robust hybrid approach; one that utilizes ML models and Failure Modes and Effect Analysis (FMEA) of the asset to provide accurate information about actual asset health.

ABB's innovative hybrid approach

ABB's hybrid approach relies on historical data and engineering models of an asset to enable the implementation of predictive maintenance. Here, online condition monitoring combined with data science uses one of two techniques:
- Detection of anomalies where online measurements deviate from normal operating behavior
- Identification of known failure characteristics where online measurements closely match a "fault signature"

Both techniques use a data model: the former represents "good health" and the latter captures the "data signature" present under fault conditions. Given that these two techniques are essentially the corollary of one another, it is natural to conclude that they may be equally useful. Practically, however, the former is often the best approach because there is almost always sufficient historical data available that represents good health. This health data enables the model to be trained. Conversely, there is usually no- or insufficient data available to represent

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ABB proposes a robust hybrid approach; one that utilizes ML models and FEMA of the asset to ascertain health status.

all possible failure conditions; thereby obviating the ability to train the model. Additionally, the latter model relies on equipment characteristics, as observed in the data; and these depend on the installation and operating conditions. Thus, data that relates to a specific machine is usually insufficient to train an accurate fault model.

With the hybrid approach, an engineering model is used to quantify the extent of the deviation of the online measurements from the health model. A Failure Mode Analysis model is used. Commonly referred to as a Failure Mode and Effect Analysis, or FMEA, this technique is a core component of Reliability Centered Maintenance (RCM) programs. Because models already exist for the most commonly encountered equipment and systems, this technique is advantageous. FMEA, incorporates the means (through observation) to define the potential detection and identification of a fault. Where such

02

detection is enabled through online sensor measurement, prediction of failure is possible.

Three steps to success: the hybrid approach process
ABB's scientists have proposed a new three-step process for an asset health configuration:
1) Define the engineering model by defining failure modes and associated measurements.
2) Train the data model on historical data.
3) Deploy the model.

In step 1, the association between failure modes and associated measurements is captured as a set of weights. A non-zero weight indicates that the fault is observable in anomalous values of the measurement, and the magnitude of the weight reflects the relative strength of the observation relative to the other measurements →01.

Historical data is used to train the health data model in step 2. Selected data reflects the equipment operating in a health condition, and across all operating conditions. The training uses several statistical and ML methods to derive a compressed model suitable for real-time calculation.

In step 3, the trained models are then deployed. Such models take data from the asset at regular intervals, eg, one minute, and provide information about asset health; eg, how likely would the condition lead to failure mode.

How does the hybrid model work?
Relying on both data and fault analysis models, the hybrid approach generates indicators for predictive maintenance: Key Diagnostic Indicator (KDI) →02 and fault indicators. First, for each measurement in each model a KDI is calculated

—
ABB's scientists have proposed a new three-step process for an asset health configuration: defining, training and deploying.

by comparing the deviation of the measured value from the "expected" reference value. The reference value is derived by searching the entire data for the closest fit to the current conditions.

TOP HEALTH INDICATORS

Property	Graph	KDI	PV	Reference	Time to critical
PI_Motor	～～～	● 45.85 %	52.48 A	50.46	--
PV_Shaft	～～	● 71.75 %	162.94 rpm	157.42	--
PF_Water	～～～	● 74.39 %	45.91 t/hr	47.01	--

TOP FAULTS

Fault	Severity	Probability	Time to critical
Pump fault	● 39.11 %	● 98.82 %	--
Gas valve malfunction	● 22.15 %	● 95.61 %	--
Boiler steam loss	● 22.1 %	● 95.43 %	--

03
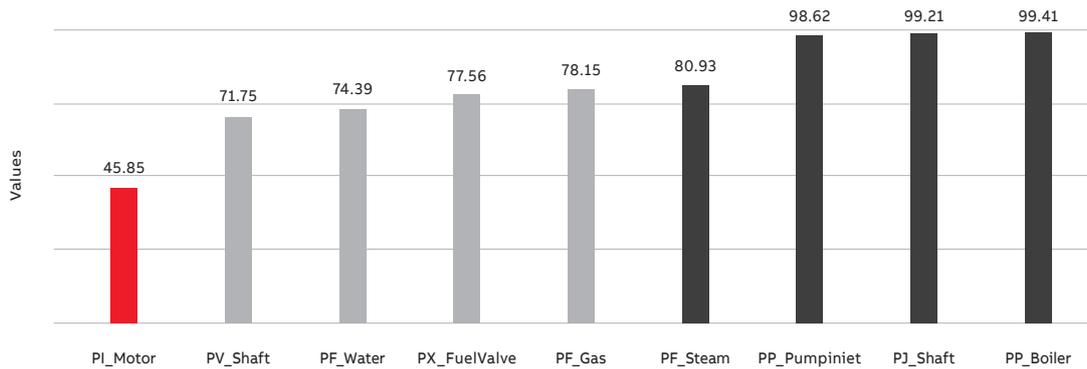
	PI_Motor	PV_Shaft	PF_Water	PX_FuelValve	PF_Gas	PF_Steam	PP_Pumpiniet	PJ_Shaft	PP_Boiler
HI Value	45.85	71.75	74.39	77.56	78.15	80.93	98.62	99.21	99.41
PV Value	52.48	162.94	45.91	32.73	11.59	46.06	0.5	2129.22	32
Reference	50.46	157.42	47.01	44.13	11.85	47.05	0.5	2128.52	32
Std Dev Values	0.66	2.75	0.59	6.62	0.16	0.64	0	6.5	0.03

04

Motor fault

Property Name	KDI		PV	Reference	SD
PI_Motor	🔴	46 %	52.48 A	50.46	0.66
PV_Shaft	⚪	72 %	162.94 rpm	157.42	2.75
PJ_Shaft	⚫	99 %	2129.22 Nm	2128.52	6.5

05

An ML algorithm such as KNN is used to efficiently compute the nearest neighbor.

All KDI's are expressed as a percentage; thereby allowing the user to easily interpret the value, irrespective of model, measured quantity or range. It is noteworthy that although a singular value, the KDI calculation uses a multivariate technique such that the closest fit considers all measurements defined for the model →02–03.

Second, fault indicators →02: Fault Probability Indicator (FPI) and Fault Severity Indicator (FSI) are calculated for every fault →03. The calculation represents an aggregation of the deviations of all the weighted measurements. The aggregation calculation differs to provide a distinction between severity and probability based on the relative distribution of deviation across all the measurements →03.

Additional to viewing the summary information for the KDIs and faults, users can view all

indicators →04 ordered by score. For each fault, users can access the underlying KDI information →05. The standard deviation value is calculated for the values extracted from the data model

—

KDIs are expressed as a percentage, allowing the user to interpret the value, irrespective of model, quantity or range.

using a KNN algorithm. This value is used to calculate the KDI score and provides an experienced user with insight into the underlying calculation.

While the aforementioned indicators relate to the current equipment condition, to provide the basis for predictive maintenance →06 a forecast of future condition is required. First, the user is

—
04 An example of health indicators with corresponding reference values. Parameter (P) abbreviations are per the ISA S5.1 standard notation.

—
05 Sample results for a motor showing the underlying KDI values Parameter (P) abbreviations are per the ISA S5.1 standard notation.
—
06 Because users not only need to view indicators of current equipment condition, ABB's innovative hybrid approach provides them with the basis to predict future conditions.

provided with historical trends to enable manual analysis →07; This is accomplished by providing historical trends for each of the key indicators.

Second, a forecast profile for the indicators that reach some future horizon is provided. This is calculated (and visualized) using the regression technique Auto Regressive Integrated Moving Average model (ARIMA).

The fault model provides additional information related to cause analysis and corrective actions, which are easily viewed →08. A fully automated workflow is provided by integrating the fault indicator values and the fault information with a Computerized Maintenance Management System (CMMS). Such systems typically orchestrate maintenance activities based on priority and resource availability.

Architecture of the proposed hybrid approach
ABB has defined a typical architecture for use with the hybrid model approach →09. Here, the historical data of an asset that is stored in the historian trains the model. The historical data

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Relying on both data and fault analysis models, the hybrid approach generates KDIs and fault indicators.

and calculation engine for the proposed application is ABB's proprietary CPM platform. The MS SQL database is used to store the application

06

From 10/12/2020 17:04 to 10/12/2020 22:10

—— PI_Motor (Process value)   —— PI_Motor (Reference value)
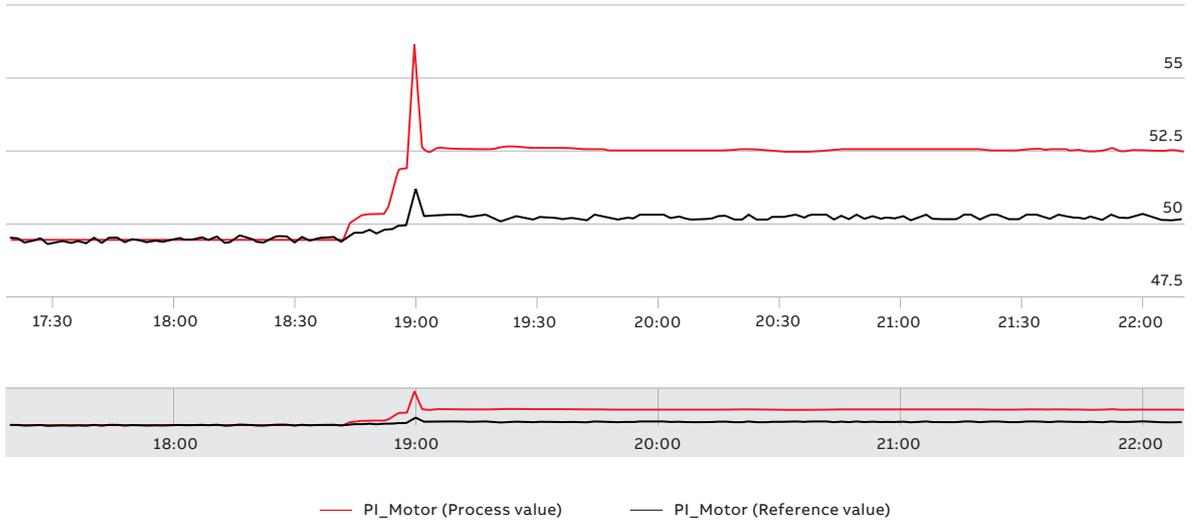
07

Fault	Severity %	Probability %	Time to critical	Description	Recommendations
Pump fault	39.11	98.82	--	Pump fault	Check impeller, volute, instrumentation
Gas valve malfunction	22.15	95.61	--	Valve opening does not match expected	--
Boiler steam loss	22.1	95.43	--	Loss of steam	Check drum
Motor fault	10.66	83.97	--	Loss of efficiency	Check copper, iron and mechanical losses

08

data and models are trained and developed using an open source R platform. A web server is used to present the results and an intranet web client is employed to access and view results.

Hydropower plant testing
The resultant software has been successfully deployed in 33 hydropower plants by Enel Green in mid-2020. Currently, real-time condition monitoring of diverse assets, eg, hydro-turbines, pumps, motors, generators, etc. is ongoing with an anticipated project completion in 2022. Overall, the results are presented in a hierarchical view, combined, and can be easily viewed by users – a significant benefit. Initially, the assets are logically combined as per plant sub-section; these are then logically combined to represent the whole plant. The number of assets can be

viewed that are in good- (green), borderline- (yellow) or poor (red) health at the plant level. A user can then drill down to different levels; a plant

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ABB's resultant hybrid approach software has been successfully deployed since mid-2020 and is easy-to-use.

section or even a specific asset can be accessed; thereby accessing just the right information required.

Intranet
web client

Data
Source
(PI historian)

Time series
historian equip-
ment model
& calculation
engine (CPM)

OPC

Health models
(metadata) and
indices historian

SQL-Server

Machine
learning
engine

R platform

"System
manager" and
web server

Microsoft IIS

Windows server
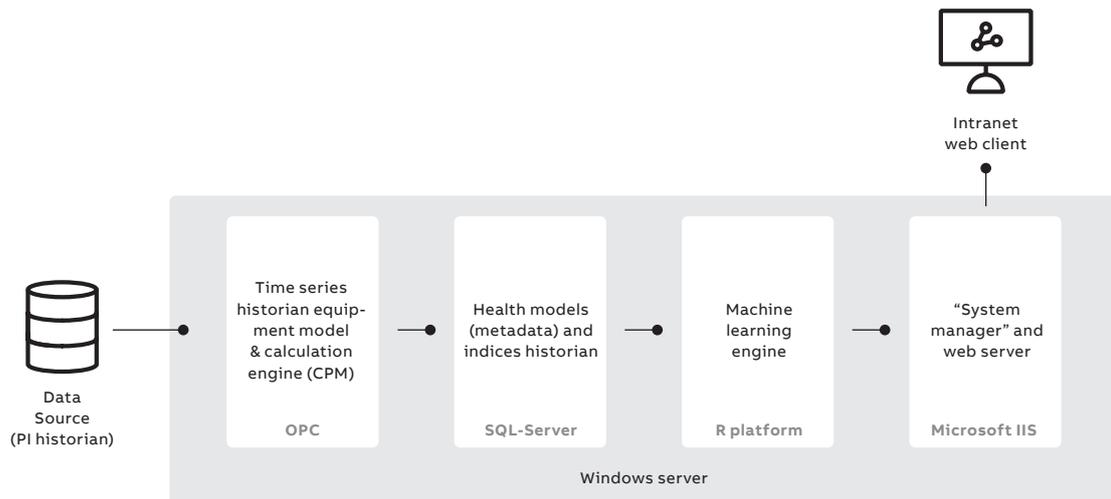
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07 Future trend
prediction examples of
health indicators.

08 Various faults and
their probabilities of
occurrence are shown.

09 Architecture of
the proposed hybrid
approach is illustrated.

Based on the initial pilot project success, ABB plans to expand the use of this hybrid approach to predictive maintenance to different industrial verticals such as conventional power plants, refineries, cement mills, the oil and gas industry, etc. This is possible because unlike first principle modelling that requires exact knowledge of sector specific equipment and processes, ML- and FMA modelling are completely generic by nature and therefore not industry specific – a transformational approach.

By putting industry's needs first, ABB is developing the means to use the massive streams of generated data and advanced analytics to make predictive maintenance truly predictive; thereby ensuring process industries gain value from improving production to maximizing their return on the investment of equipment. •

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Real-time condition monitoring of diverse assets is ongoing with an anticipated project completion in 2022.

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Produc-
tivity

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Simply put, productivity is the measure of output per unit of input. Increasing that number often means running into complications of cost, time, even basic physics. ABB is working with customers on using digital technologies that offer ways around and past many of those barriers.

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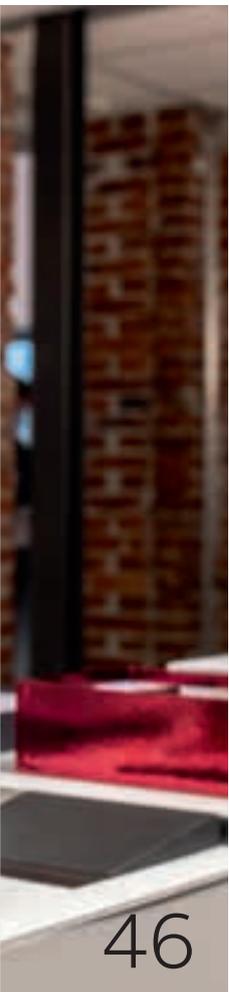
PRODUCTIVITY

IE5 synchronous reluctance motors

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ABB IE5 synchronous reluctance motors (SynRMs) deliver ultra-premium energy efficiency – a new level of efficiency defined by the International Electrotechnical Commission (IEC) – and are the first choice to meet the growing global demand for improved energy efficiency.

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One-third of all electricity is converted into motion by electric motors and the number of such motors is expected to double by 2040, which is the equivalent of adding an electricity market the size of China to global power demand. This impending massive increase in the use of electrical energy is driving a need for more efficient motors.

The traditional induction motor (IM), though the most common electric motor in industry, has inherent drawbacks that arise from its asynchronous speed – such as rotor heating losses, which decrease efficiency and component and bearing

lifetime. ABB's new IE5 synchronous reluctance (SynRM) motors, however, deliver ultra-premium energy efficiency, which is a new level of efficiency defined by the IEC. The SynRM is characterized not only by its high energy efficiency but also by its reliability and low maintenance needs →01–02.

What is a SynRM?
SynRMs work on a very elegant principle that has been known for a long time, but only since the recent rise of sophisticated variable-speed drive (VSD) control has it been possible to exploit fully these super-efficient electrical machines.

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01 ABB's new IE5 SynRMs are ideal for applications such as water pumping.

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02 The IE5 SynRM represents a major step forward in sustainable electric motor technology in terms of efficiency, reliability and power density.

—
03 The IE5 SynRM improves performance in applications such as silo operation.

In a SynRM, the rotor is designed to produce the smallest possible magnetic reluctance (the resistance to the flow of a magnetic field) in one direction and the highest reluctance in the direction perpendicular. The VSD steers the

—
The rotor has neither magnets nor windings and suffers virtually no power losses.

stator field so it "rotates" around the motor. The directionally unequal magnetic reluctance properties of the rotor cause the rotor to rotate with the field and at the same frequency.

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

ABB's SynRM was launched in 2011 with an IE4 efficiency class, available at first for pumps

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and fans, and now available for all applications. ABB introduced the IE5 SynRM ultra-premium efficiency motor in 2019. ABB offers two ranges of SynRM:
- High-output SynRMs with an output of 1.1 to 350 kW in frame sizes IEC 90 to 315.
- IE5 SynRMs with an output of 5.5 to 315 kW in frame sizes IEC 132 to 315.

On the drive side, the number of VSD applications is increasing, helping the drive technology for SynRMs become more commercialized.

Customers can increase their energy efficiency, improve sustainability and enhance reliability by upgrading to ABB IE5 ultra-premium SynRMs, which offer up to 50 percent lower energy losses compared to IE2 motors, as well as significantly lower energy consumption and CO_2 emissions than the commonly used IE2 IMs →03.

Lower temperatures and mechanical compatibility
SynRM technology offers up to 30 °C lower winding temperatures and up to 15 °C lower bearing temperatures. These lower operating temperatures have multiple benefits – including longer insulation life and longer bearing greasing intervals and lifetime. Lower bearing temperatures are an important factor because bearing failures cause about 70 percent of unplanned motor outages.

The IE5 SynRM is the same size as an IE2 induction motor, eliminating the need for mechanical modifications if upgrading, thus making replacement of the traditional induction motors easy. This compatibility also simplifies spare part provision and maintenance.
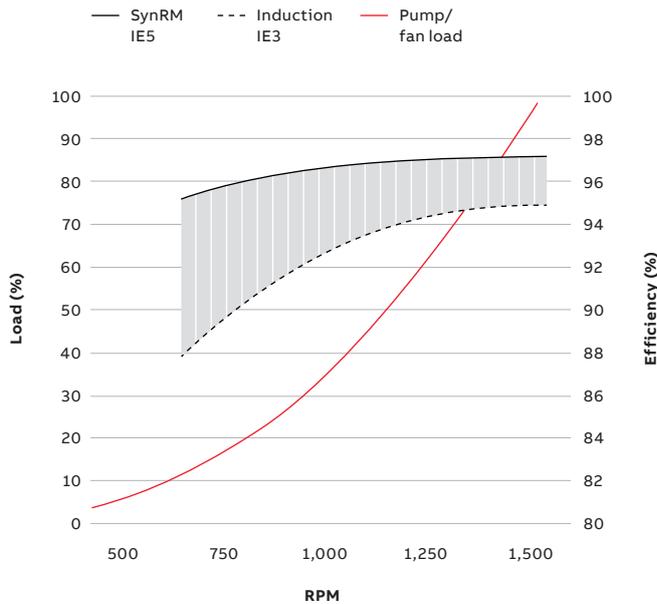
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IE5 according to IEC TS 60034-30-2
The IEC 60034-30-1 technical standard for IE efficiency classification has now been superseded by IEC 60034-30-2:2016, which defines new efficiency classes of variable-speed AC motors that cover, for the first time, ABB IE5 SynRMs. It is from this standard that the "Ultra Premium Efficiency – UPE" classification that describes ABB's SynRMs originates.

The new standard allows direct comparison at the IE class level of traditional induction motors in variable-speed usage with advanced technology motors designed only for VSD (like SynRMs). It does not matter if the IE classification is done

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IE5 motors have 20 percent lower losses compared to an IE4 motor, regardless of the technology or IEC standard used.

with a direct on line (DOL) supply according to IEC 60034-30-1 or with a VSD supply according to IEC TS 60034-30-2 as the given IE class still characterizes the efficiency performance of either solution in VSD operation – ie, motors of the same IE class have the same efficiency performance.

To make a valid comparison, the IE class limit values in IEC 60034-30-2 are reduced by adding the additional harmonic losses in the DOL motor

caused by the drive: 15 percent further losses for DOL motors up to 90 kW and 25 percent for DOL motors above 90 kW. For example, a 15 kW IE3 DOL motor of 92.1 percent nominal efficiency working with a VSD would have an actual efficiency of 91.0 percent (ie, 15 percent less). This is the value that must be compared against the 94.8 percent efficiency of an equivalent SynRM. Limit values are to be achieved at 90 percent speed and 100 percent torque. The ABB IE5 SynRM catalog includes a precalculation of the typical IE3 motor efficiency with a VSD to help make an easy comparison.

In practice, IE5 motors have 20 percent lower losses compared to an IE4 motor, regardless of the technology or IEC standard used.

Partial load efficiency
According to the new Regulation EU 2019/1781 (which lays down eco-design requirements for electric motors and VSDs) manufacturers need to state the losses at specified load points for a motor. This data enables motor-to-motor comparison under partial-load conditions on VSD duty. Traditionally, a comparison has not been possible due to the lack of loss information for IMs on VSD duty. IE5 SynRMs perform very well at partial load.

IE5 SynRM versus IE3 induction motors in VSD duty
ABB laboratory measurements have demonstrated the advantages of SynRM IE5 motors over IE3 motors, including under partial-load conditions, where the benefits are even more marked than at the nominal point. →**04** shows the typical efficiency performance of an IE5 SynRM versus an IE3 induction motor in pump/fan duty according to ABB laboratory measurements.

Lower energy use results in lower total cost of ownership
Reducing energy consumption with SynRM and VSD packages means that the cost of running the process and the total cost of ownership will be reduced too. And, although companies can be reluctant to change motors or add drives to their processes due to the upfront investment costs, the cost of a motor is only a fraction of the cost of the energy used to run it

Lifetime energy savings payback
For a 110 kW motor running at 1,500 rpm, the difference in initial cost price between an IE5 SynRM motor and an IE3 motor is negligible compared to the annual savings in energy costs. An IE5 motor package will save energy and costs compared to the IE3 package as soon as it is operational, paying back the cost difference after about 13 months. In addition, the IE5 SynRM

package will continue to generate annual savings
for the rest of its working life, which may be
from 10 to 15 years. Within about 10 years, the
savings generated through reduced energy use
will have paid back the initial cost of the whole
IE5 package.

Motoring into the future
Because IE5 SynRMs use less electricity than
other motors, CO_2 emissions are reduced.
Constant, quadratic torque with high efficiency
delivers fast, precise control. ABB IE5 SynRMs
deliver full torque from zero speed and give
excellent partial-load efficiency →**05**. Speed
control is very accurate due to the synchronous

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Constant, quadratic torque with
high efficiency delivers fast,
precise control.

nature of the motor and there is almost servo-like
performance due to low rotor inertia. The motor
is very quiet and is ideal for driving pumps, fans,
compressors, etc., in any industrial application.
Numerous customer installations are already
operating with ABB IE5 SynRMs to cut costs
and boost productivity. One food processing

company, for example, nearly halved the energy
use of a fan system by switching to ABB SynRMs.

In motors, ABB prides itself on having the
right solution for any industrial need and as a
response to market demands for higher output,
higher efficiency, longer service intervals and
footprint reduction. ABB believes that IE5 SynRM
technology – which exceeds by far the minimum
efficiency performance standards (MEPSs) put
in place by all major industrialized regions –
provides the basis for sustainable efficiency of
low-voltage motors into the future.

Efficiency is becoming a critical issue for
manufacturers of motors and motor systems:
the trend in the EU, United States and Asia is
in the direction of further legislation – not only
for motors but for the system in which they are
embedded. This is why ABB is thinking ahead –
with IE5 SynRM technology. •

05

PRODUCTIVITY

A new class of coworkers

Increasingly, robots are working hand in hand with humans. As this trend takes shape, these one- and two-armed helpers are becoming smaller, smarter, faster, easier to train, and, above all, safer. In short, they are evolving into a new class of coworkers known as "cobots."

Robots are on the move. Once fenced off from workers, they are increasingly migrating into the comparatively open spaces →01–02 that characterize small- to mid-scale manufacturing environments, collaborating with humans in material handling, machine tending, and component assembly, and offering welcome support in laboratories →03, logistics centers, warehouses, and workshops.

Essentially robots designed to operate in the presence of human workers without the need for safety measures such as fences, this new class of helpers known as cobots supports businesses as they struggle to recruit and retain staff for a wide range of dull, dirty, repetitive, dangerous, or ergonomically challenging tasks. Indeed, according to a 2020 McKinsey report on the Future of work [1], Europe may face a shortage of workers

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as the economy recovers following the Covid-19 crisis: "Europe's working-age population will likely shrink by 13.5 million (or 4 percent) due to aging by 2030," says the report.

Bot benefits
For businesses, automating processes without requiring physical fencing not only reduces the overall cost of an installation, it saves space and creates a more open work environment. This allows people to carry out their tasks freely, and minimizes interruptions caused by having to physically stop and restart production to access a robot.

Installing robots can also help a business to reduce its operating costs, improve product quality and consistency, enhance production output and manufacturing flexibility, and improve the use of facilities. As well as helping managers to offset labor shortages, automation can improve workplace health and safety because robots support workers with heavy lifting and repetitive tasks.

Adding automation to a process or production line has also been shown to improve job satisfaction, with employees able to upskill and focus on value-added and more rewarding tasks.

In view of these trends, ABB recently expanded its collaborative robot portfolio with the introduction of GoFa™ and SWIFTI™, which complement its YuMi® and Single Arm YuMi® industry-leading cobot line-up.

GoFa™ – the go-anywhere cobot
Capable of handling a payload of up to 5 kg and operating at 2.2 meters per second, which is significantly faster than other cobots in its class, GoFa →04 can perform more operations in a set period than competing cobots. These capabilities make it ideal for assembly or picking-and-packaging tasks where items need to be

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Europe's working age population will likely shrink by 13.5 million (or 4 percent) due to aging by 2030.

quickly and accurately transferred from place to place. GoFa's performance is further enhanced by its micron-level positioning repeatability, allowing objects to be precisely picked, moved and placed time after time.

Furthermore, at 950 mm, GoFa's reach outperforms other 5 kg cobots by around 12 percent. And with a 70 percent longer reach than ABB's YuMi single arm robot, GoFa can help to reduce the number of cobots that may be needed in a single space.

GoFa incorporates a passive safety system, enabling it to work alongside humans without any safety barriers. Integrated torque and positioning sensors in each of its six joints allow GoFa to come to a complete stop in milliseconds if it comes into contact with a human.

And GoFa can go wherever it is needed. Weighing a manageable 27 kg, with a footprint of just 165 mm² and able to be mounted in any direction, GoFa, like ABB's YuMi and Single Arm YuMi, offers the flexibility to be used when and where it is needed, to support short-term process changes, or to fill gaps in production lines wherever and whenever needed. These capabilities give users the flexibility to quickly adapt to changing circumstances or customer demands.

GoFa is designed to work with ABB's OmniCore robot controller family. Offering high levels of flexibility, connectivity and performance, Omni-Core features a 50 percent reduction in footprint compared with previous robot controllers,

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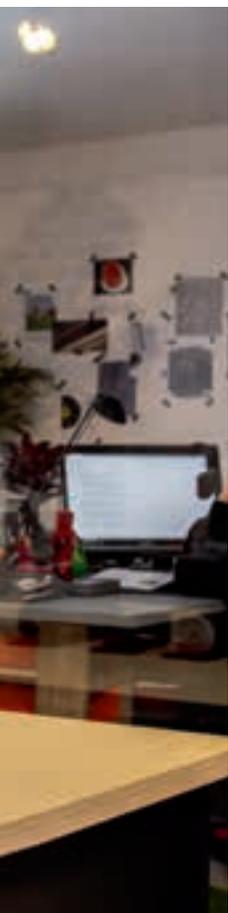
A COBOT FOR LAB TECHNICIANS

At Sweden's Karolinska University Hospital, adding an ABB collaborative robot to the laboratory team to take over laborious manual tasks has created a better working environment and increased efficiency [1].

Robot solutions are nothing new in healthcare. As pressure grows across the healthcare sector, from vaccine development and testing to patient care, the search has intensified for new ways to utilize robots to fill gaps in production capacity and staff availability.

With its own dedicated innovation center, Karolinska University Hospital in Sweden has been searching for ways to provide improved levels of performance through automation.

Working in collaboration with various organizations, including ABB, the hospital has been exploring ways to use robotic technology in areas ranging from surgery and pediatric care to transporting instruments, laundry, and food. One area where automation has been deployed is the Karolinska University Laboratory. The lab processes millions of medical samples every year, and although fixed sorting automation helps

to handle the large volumes, it was clear that many manual steps involving laborious repetitive tasks might benefit from robot assistants. One such area is scanning test tubes and opening transport sleeves. Today, thanks to an ABB

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As pressure grows to fill gaps in staff availability, ABB robots are scanning test tubes and opening transport sleeves.

collaborative robot that has taken over this function, lab technicians have been freed from this monotonous and exhausting task, resulting in reduced strain on wrists, improved workflows, and greater efficiency. •

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In hospital labs, many manual steps involving laborious, repetitive tasks can benefit from robot assistants.

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Range
950 mm

Interactive light

Lead through function anywhere on the robot enabled by joint sensors and advanced motion control

GOFA

EASY TO OPERATE. HANDLES UP TO 5 KG.

Axis 6 with standard flange and enhanced user interaction (Arm-Side Interface)

Lightweight and small footprint
27 kg

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03 ABB is exploring ways to use robotic technology to support hospitals and their staffs.

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04 Weighing only 27 kg, GoFa can go wherever it is needed.

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SWIFTI is capable of speeds exceeding five meters per second – five times faster than most other machines in its class.

together with best-in-class motion control and path accuracy. OmniCore can be easily integrated with the latest digital production technologies, including a wide variety of fieldbuses, advanced vision systems and force control.

SWIFTI: high-speed partner
Substantially faster than GoFa, SWIFTI →05 is a collaborative industrial robot aimed at tasks such as assembly and polishing. Capable of speeds exceeding five meters per second, which is five times faster than most other machines in its

class, SWIFTI is designed for intermittent collaboration with humans while handling a payload of up to 4 kg.

SWIFTI is equipped with an active safety system, which is based on a laser scanner. If a human worker approaches, for example to load, unload or reposition parts, SWIFTI slows and stops, then automatically restarts as the person exits the robot's sensory safety zone, allowing production to resume as quickly as possible.

Designed specifically to close the gap between collaborative and industrial robots, SWIFTI addresses many of the barriers that have prevented companies from fully realizing the potential benefits of robotic automation. By coupling the safety features and ease of use and installation of a collaborative robot with the high speed, precision, performance, and compact design of ABB's IRB 1100 industrial

Interactive light

As fast as a standard industrial robot
5 m/s

Load capacity
4 kg
max. range
580 mm

Easy safety configurator on Flexpendant

SWIFTI

COLLABORATIVE AND SAFE WORK – EVEN AT HIGH SPEEDS

Attachable device for handheld programming

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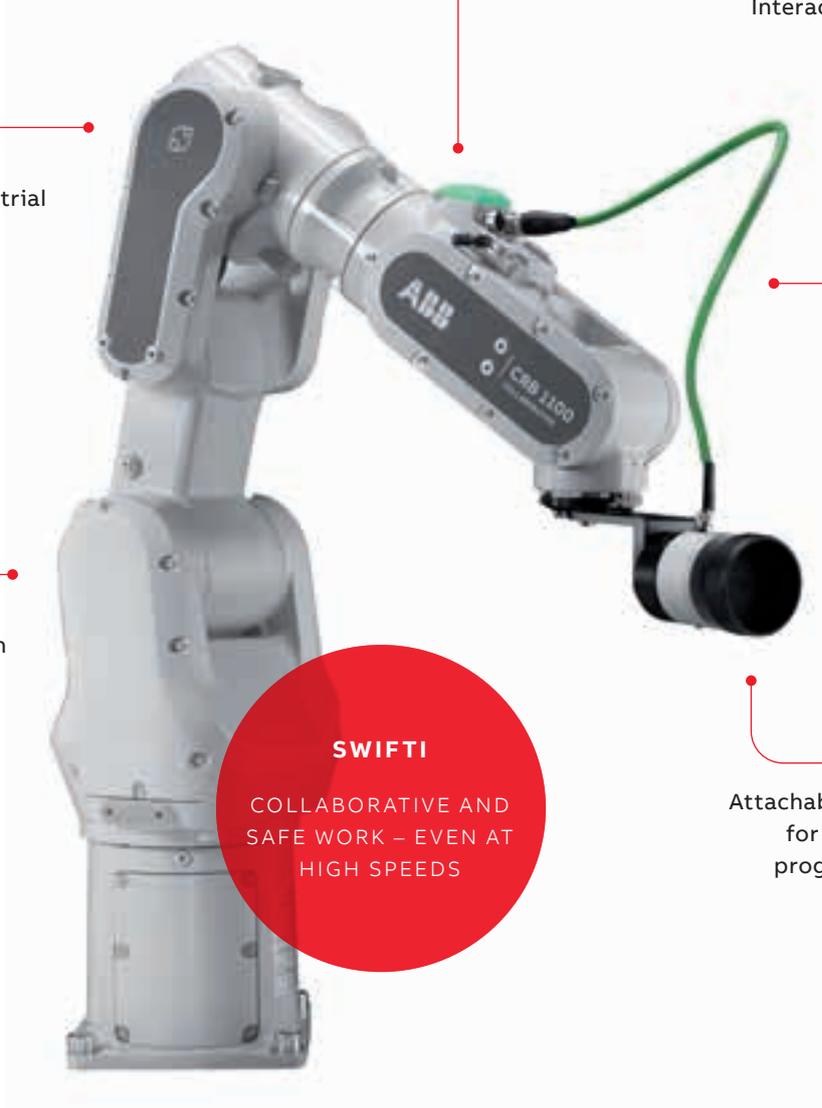
robot, SWIFTI provides the best of both worlds. With collaborative safety, speed and accuracy on a par with an industrial robot, it will help companies transform their productivity by

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SWIFTI provides collaborative safety, speed and accuracy on a par with an industrial robot.

enabling greater cooperation between their robotic and human workers across a wide range of applications.

Another SWIFTI advantage is that it can be used with the same tooling as a standard IRB 1100 industrial robot, thus opening the door to cost savings. An example is the inclusion of a vacuum

pack, which features four integrated air supplies that can be used to enable simultaneous picking of multiple items using suction. Normally used on ABB's IRB 1100 industrial robots, the same vacuum pack can be fitted to SWIFTI to offer identical functionality with no need for modifications.

In addition, since SWIFTI uses the same platform as the IRB 1100, it provides the ideal solution for applications such as loading and unloading, assembly where workers intermittently need to operate in the same workspace as a robot, as well as kitting, materials handling, screwdriving, insertion and polishing tasks.

Painless programming
Although GoFa and SWIFTI are highly sophisticated machines, operators do not need to learn complex programming languages to train them. Lead-through programming anywhere on the cobots' arms allows users to move

the machines into various positions to create tailored programs using ABB's Wizard drag and drop easy-programming software. With Wizard, the programming process is reduced to simply dragging and dropping graphical blocks on an

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Custom programming blocks can be produced to control grippers or create actions for specific applications.

ABB FlexPendant screen →06. This allows the user to see the results immediately and adjust a cobot's actions as needed. By linking these blocks, complete programs can be assembled for a wide range of applications.

For companies with more specialized programming needs, new blocks can be created to perform specific tasks. This is achieved through ABB's Skill Creator software, which can turn standard RAPID programming routines into Wizard blocks and make them ready for use by non-programmers. The custom blocks, known as skills, can be produced to control grippers or create actions for specific applications such as laboratory automation.

Users can also use RobotStudio®, ABB's simulation and offline programming software. This is the industry's leading PC-based solution for programming, configuration, and virtual commissioning before installation. In addition, when preparing SWIFTI for service, users can establish safe working zones with SafeMove Visualizer, which puts safety configurations directly onto the ABB FlexPendant. •

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PRODUCTIVITY

Digital transformation of a steel melt shop

Few industrial scenarios have as many critical aspects as a steel melt shop does: Equipment use, scheduling, safety, and energy use must all be perfect to avoid major negative impact. ABB's smart melt shop solution promotes energy-efficient, safe and productive melt shop operation.
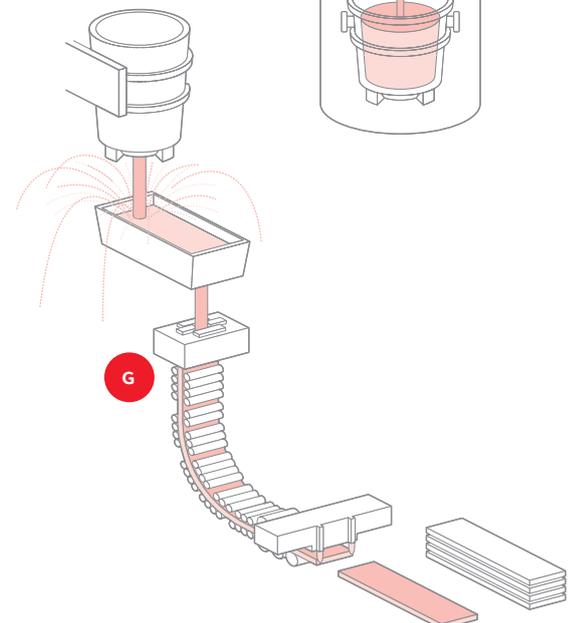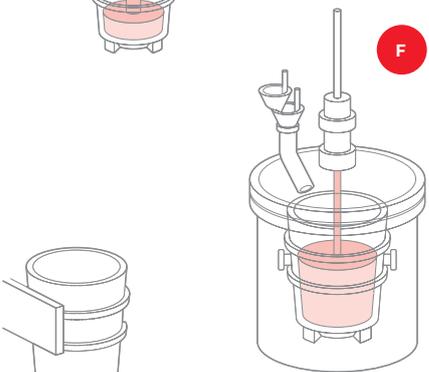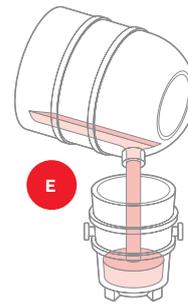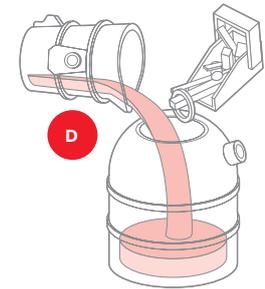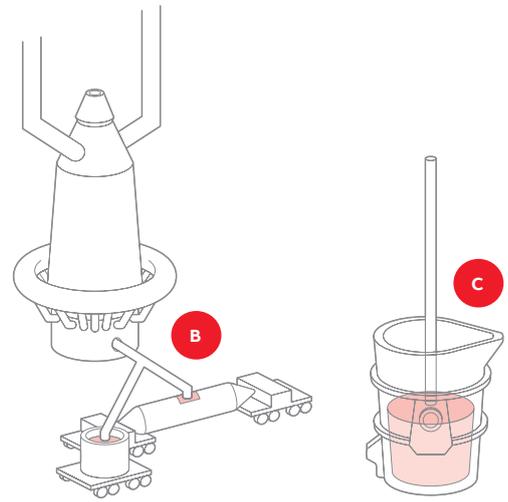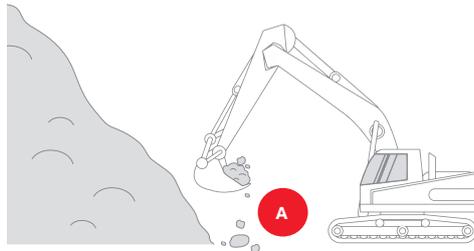
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02 Units and process flow in an integrated steel plant.
A   Raw material handling
B   Blast furnace
C   Ladle-based transport
D   Basic oxygen furnace
E   Ladle-based transport
F   Secondary processing
G   Continuous casting

—
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With origins stretching back many centuries, steelmaking is one of the oldest industries still practiced. Technology has greatly changed – and is still changing – the steelmaking process, but the basic principles remain the same. In a modern steelmaking setup, the steel melt shop is the heart of the process. Here, feed materials

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Production and handling of such quantities of molten metal is a potentially very dangerous undertaking if performed incorrectly.

are treated in a furnace and the resulting molten metal batch – typically weighing around 200 t and at about 1,600 °C – is poured into an empty refractory vessel (a "ladle") so it can be moved to the next step in the steelmaking process →01. The production and handling of such quantities of molten metal is not only a very energy-intensive undertaking but also a potentially very dangerous one if performed incorrectly.

Once filled, the ladle containing the batch of molten metal is moved to the so-called ladle furnace (LF) on a rail-based transfer car or overhead crane. In the LF, the desired composition and temperature homogenization of the molten metal is achieved. Once LF processing is complete, the ladle is transported using overhead cranes to a continuous caster where the melt is formed into solid slabs, billets, etc. This transformation is achieved by draining the ladle's liquid melt into a buffer vessel (a "tundish") fixed at the top of the caster mold. The tundish then drains the liquid melt into the mold for continuous casting →02. After emptying all the liquid melt into the tundish of the given caster and subsequent deslagging in the dump yard, the empty ladle is moved, using overhead cranes, to a maintenance stand. After maintenance, the ladle is ready to take the next batch of molten metal.

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casters, as stoppage of the casting process is highly undesirable. However, the continuous casting step is preceded by the LF batch step. This combination of batch and continuous processes further complicates the supervisor's real-time, manual decision-making task.

Here, ABB sees an opportunity for a digitized solution to help the supervisor run a safe and productive melt shop.

While productivity improvement has a bearing on revenue generation, equally important from an incurred-cost perspective is an energy-efficient operation of the melt shop. Of particular interest is the energy-intensive LF operation, in which the

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ABB Ability™ Smart Melt Shop addresses safety, productivity and energy efficiency.

ladle's liquid melt is raised to a high temperature. During the subsequent transfer to the caster, the melt will cool and perhaps fall below the appropriate temperature range, necessitating rework and reheating, leading to energy wastage, lowered production efficiency and possible equipment damage. Preemptive overheating to above the requisite temperature range leads to longer processing time and higher energy consumption.

ABB Ability™ Smart Melt Shop, a comprehensive digital solution for melt shops, addresses the issues of safety, productivity and energy efficiency discussed above by incorporating:
• A ladle tracking system for full melt shop visibility.
• A scheduling module for effective job management of cranes and processing equipment for high production efficiency.
• A thermal module for improved energy efficiency and productivity.

Visibility – ladle tracking system
In a melt shop, it is important to know the location and status of ladles and cranes at all times. While cranes may be located visually with ease, the precise location of ladles can be difficult to ascertain. Various ladle-location techniques have been tried – for example, by using radio-frequency identification (RFID) tags. All the techniques tried have limitations – for instance, an RFID tag can only be detected when near a base station and, despite a cooled housing, tags are still prone to failure.

Opportunities for digitalization in the melt shop
A typical melt shop has a limited number of electric arc furnaces/convertors, LFs, continous casters, cranes, transfer cars and, in some plants, degassing equipment and other units for producing cleaner and special steels. It is, therefore, critical that these are utilized effectively. In most melt shops, equipment operation is directed by an operations team that tracks crane locations, unit availability and ongoing and upcoming jobs. Tracking of cranes, ladles, etc. in real time is done by the supervisor – or by dedicated personnel on the ground. These activities pose a major safety risk, considering that melt shop accidents can be fatal.

The supervisor must ensure the continuous availability of molten metal for casting at all the

—
03 Ladle tracking system. Over a dozen pieces of equipment can be operational at any one time.

—
04 Consolidated schedule display.

—
05 Crane operator's screen.

—
06 The casting process.

ABB Ability™ Smart Melt Shop gets around these limitations by accurately tracking each ladle carrier in the melt shop. The principle of the method relies on the fact that a ladle can only be moved by a crane or transfer car. A ladle entering the active zone of the melt shop is identified by its ladle number using a camera. As the ladle moves, its location is continuously updated in the run-time database and the same details are displayed in the central monitoring displays →03 until another transfer carrier, such as a crane, comes to the same position and picks it up. Between actual monitoring points, the ladle position is inferred from the expected motion of the ladle carrier.

Scheduling module
The scheduling module ABB Ability™ Smart Melt Shop uses the real-time information in the ladle tracking system to help plan future activities in the most productive and efficient way, up to a particular time horizon. As one schedule of activities draws to a close, the scheduler calculates the next. In generating a schedule for each horizon, the scheduling module:

—
The scheduling module uses real-time ladle tracking data to plan activities in the most productive and efficient way.

- Collects information from each piece of processing equipment.
- Establishes where the ladles identified for pick-up need to be dropped off.
- Determines the cranes responsible for the ladle transfers.
- Calculates the precise times at which the ladles are to be picked up and dropped off at the respective equipment by the cranes.

In making these calculations, it must be ensured that certain constraints inherent to melt shop operations are observed. For example, each ladle must follow a particular sequence of operations in a cycle and each ladle must remain at a piece of equipment for a designated period of time

06
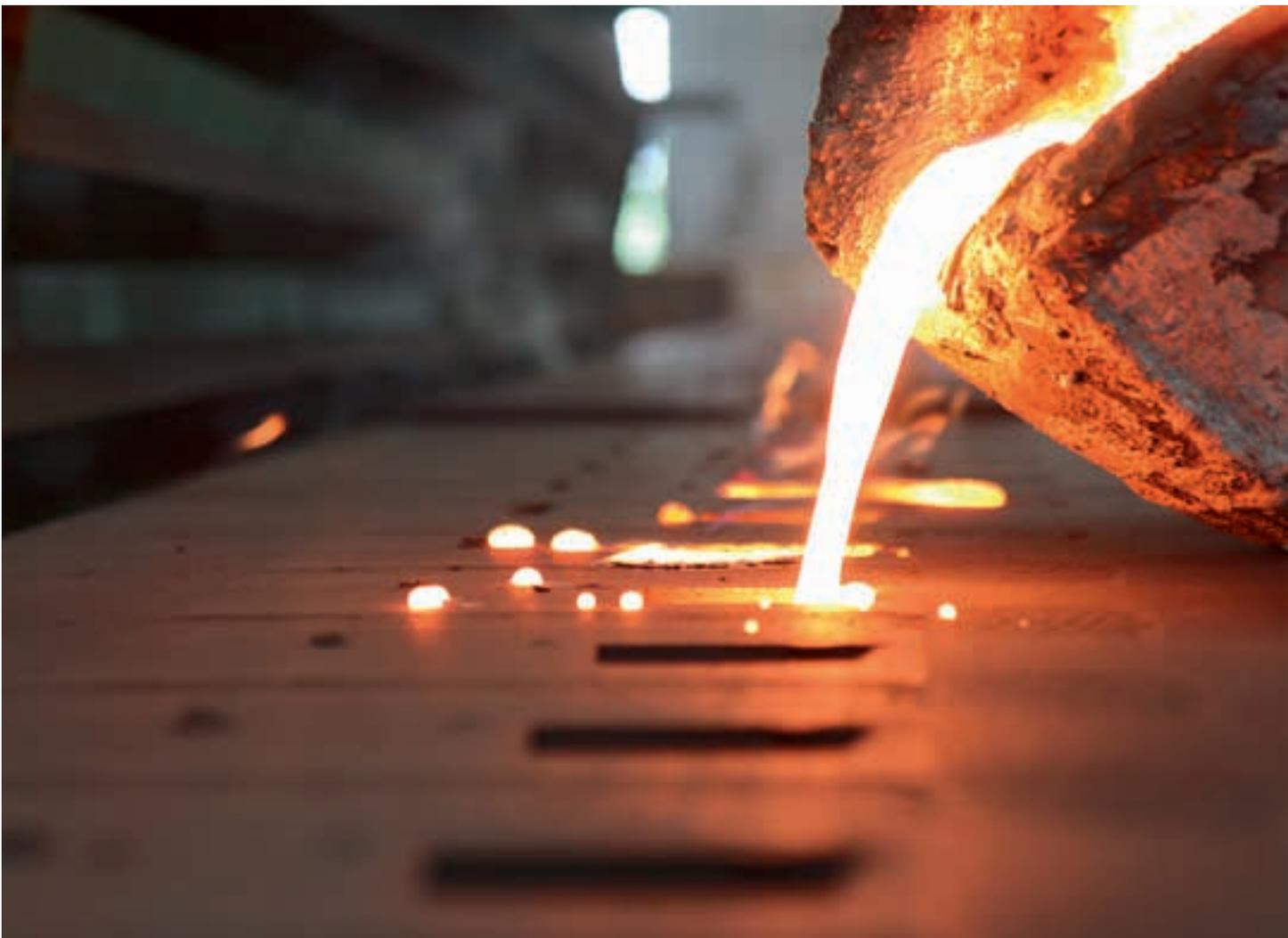
before it can be picked up. With these, and more, constraints incorporated, the module produces a schedule for centralized display and supervision →**04**.

—

The crane-specific extract from the general schedule serves as instructions for the crane's timely maneuvering.

Further to the centralized display, a separate screen is made available to each crane operator in their cockpit that shows future scheduled activities specific to that particular crane. This crane-specific extract from the general schedule serves as instructions for the crane's timely maneuvering →**05**. Finally, in addition to its utility as a guiding tool for productive operation, the output from the scheduling module also provides useful information to the thermal module.

The thermal module
As mentioned earlier, the melt should be within a narrow window of temperature values when it arrives at the caster. However, heat is lost during holding, transfer and teeming (pouring of the melt for casting) →**06–08**.

The melt heat loss depends on process variables such as melt properties, holding time, melt temperature, slag layer characteristics and casting type, as well as ladle properties like wall

09

Batch number

Legend:
- Thermal model
- Actual lift temperature
- Average superheat at tundish
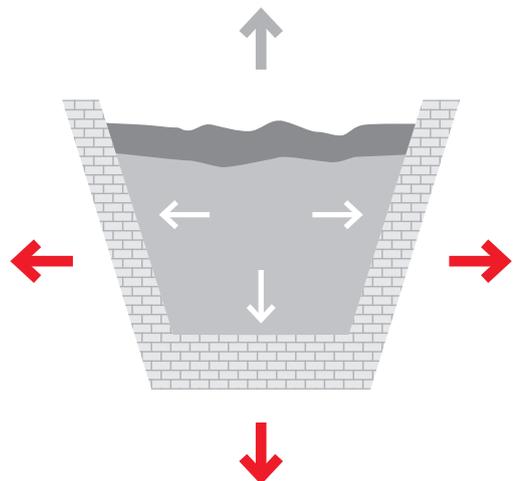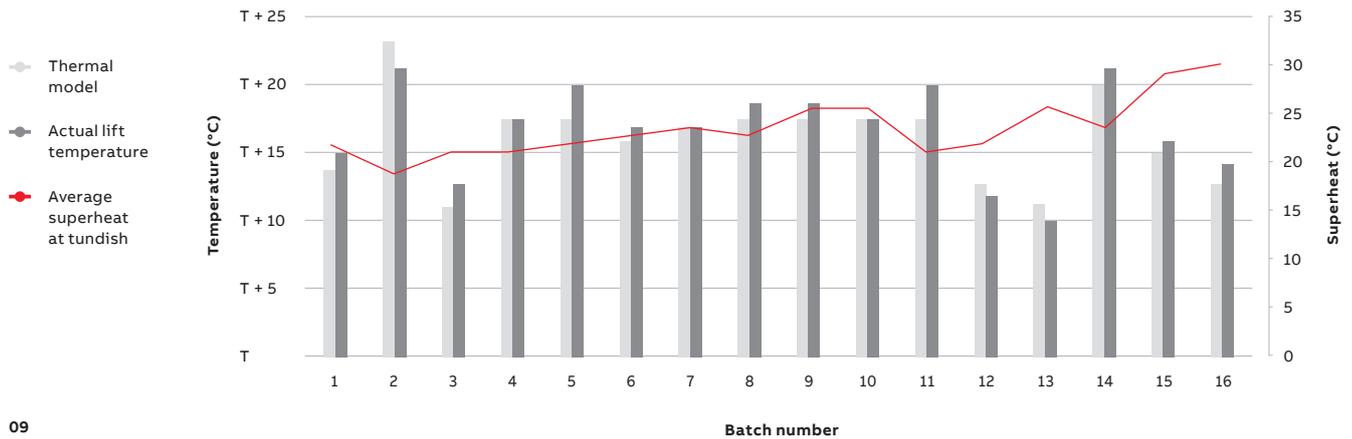
—
07 Heat is lost during the process.

—
08 Heat loss from a ladle carrying steel melt.

—
09 Thermal model prediction and temperature at the caster. Superheat requirements are between 20 and 30 °C.

composition, erosion status of the ladle inner lining, ladle thermal history, etc. Since these features are bound to change with every melt load a ladle transfers, the heat loss and, hence, the temperature required at the end of LF operation are also different. The optimum temperature at the LF may vary between batches. In the plant where the model was first implemented (see next section), this variation was more than 40 °C.

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ABB Ability™ Smart Melt Shop improves productivity, energy efficiency and operational safety.

ABB Ability™ Smart Melt Shop employs a thermal model to estimate this dynamic heat loss behavior and predict the end temperature required at the LF for successful casting. The model employs a discretization scheme and solves for heat transfer through the ladle wall as well as various other interfaces. Based on the heat loss thus calculated, a temperature setpoint is provided to the LF operator.

ABB Ability™ Smart Melt Shop in a steelworks
The Performance Optimization for steel melt shops solution was implemented at a major steelmaker in India and has led to a smooth and efficient operation of the processing units in the melt shop. →09 illustrates the performance of the thermal model. All the batches were heated to a temperature of ±2 °C of the values dictated by the thermal model. All but one (batch 2) of the 16 batches were within the desired temperature range at the caster. By incorporating the model, an estimated yearly saving of 4,500 MWh can be achieved in the melt shop, which has an annual production capacity of four million tons. Side benefits are found in lower electrode consumption and lower ladle relining cost per batch of steel. At the same time, presenting a melt at an optimal temperature to the caster results in higher casting speed and better productivity.

A milestone in steel melt shop autonomy
ABB Ability™ Smart Melt Shop exemplifies how digitalization can bring about a radical change in manufacturing units with some of the most inhospitable, hazardous and dangerous conditions. The digitalized operation of Performance Optimization for steel melt shops improves productivity and energy efficiency and leads to higher operational safety. Given that many melt shops currently operate on a manual basis, there is broad scope for improvement and automation. ABB Ability™ Smart Melt Shop sets a milestone on this path toward autonomous and efficient operation. •

Connec-
tivity

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Data and electricity are arguably the two resources on which tomorrow's connected world will run. Putting together such networks is incredibly hard. Managing and protecting them is even harder. ABB has deep experience doing it.

74

CONNECTIVITY

ABB brings Ethernet-APL with OPC UA to the field

Together with other market leaders and standards organizations, ABB has developed field-level Ethernet connectivity for use in hazardous areas of process industries. Expanding its use toward converged networks based on OPC UA, ABB is helping industry transcend the boundary between IT and OT.

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Over the past decade, Ethernet-based networking technologies have been increasingly adopted in industrial automation settings. Despite this, their adoption in process automation is still constrained [1], mainly due to their limitations in hazardous-location applications. Relying on 4–20 mA analog, 4–20 mA + HART or fieldbus technology, this important sector has had to sacrifice high bandwidth and communication speed for safety.

Significantly, the vast data collected at the field sensor level is, as a result, restricted – or unavailable, generally, for use across the entire enterprise from internal systems to the cloud. Since data and its transmission is the enabler of Industry 4.0 and the Industrial Internet of Things (IIoT), any data network communication dam prevents enterprises in the process industries from achieving the full value potential inherent in data availability and transfer.

For this reason, ABB joined a consortium of 11 other market leaders and three communications standards development organizations to develop the Advanced Physical Layer (APL) standard to make field-level Ethernet a reality for process automation industries even in hazardous areas [1]. The Ethernet-APL technology developed is simple, practical, compatible, easy-to-use and brings bandwidth and communication speed to a level that allows process industries to reap the

rewards associated with digitalization such as asset management and condition monitoring applications. Concurrently, ABB has worked to expand the benefits possible through use of Ethernet-APL through their research on IIoT devices. Available prototypes demonstrate that it is possible to bring modern protocols, like OPC UA, with cyber security and information model-

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Despite Ethernet's acceptance in industries and business applications, its adoption is comparatively limited in process industry.

ing capabilities that are suitable for bridging IT/OT boundaries into small resource-constrained field devices [2]. With the technology introduction in June 2021, such products, combined with Ethernet-APL, will allow process industries to leverage data across the value chain from the field-level device to the control system, the cloud and everywhere in between [2].

Extending Ethernet to process industry
Communication and networking technologies developed rapidly over the past decades →01. Today, Ethernet is the widely accepted standard

	Past				Present
	Pneumatic		Electronic + Fieldbus		Ethernet
Technology	Pneumatic	4-20 mA	4-20 mA + HART	Fieldbus	Ethernet
Media	Air	Analog	Analog + serial	Serial digital	Network
Measurement	1 value	1 value	1+n value	n value	n values
Local access to data			Gateway required	Integrated	Integrated
Remote access to data			Gateway required	Gateway required	Integrated

01

Parameter	Attribute
Power supply output (Ethernet-APL power switch)	Up to 92 W
Switched network	Yes
Reference cable type	IEC 61158-2, type A
Maximum trunk length	Up to 1,000 m, into zone 1/div. 2
Maximum spur length	Up to 200 m, into zone 0/div. 1
Speed	10 Mbit/s, full-duplex
Hazardous area protection inspired by fieldbus	2-WISE for all zones and divisions, with optional intrinsic safety at the device
Standards	IEEE 802.3cg-2019 (10BASE-T1L), IEC TS 60079-47 ED1 (2-WISE)

02

for wired digital technologies in the great majority of industries and business applications, with its huge set of standardized tools for installation, troubleshooting, and diagnostics, as well as high bandwidth and communication speed. Still, its adoption is comparatively limited in process industry [1,3]. Why is this so? Two reasons stand out: the simplicity and cost-effectiveness, thus dominance, of legacy communication technologies installed and the hazardous nature of many process industry environments [3]. Cost, suitability and practicality make the extension of Ethernet-level technology to the field challenging.

Data transfer technology over time
Early on, the predominant way to connect field instruments to distributed control systems (DCSs) to measure process values relied on simple wiring to convert analog measurements to 4-20 mA analog signals [3]. HART technology later introduced digital communication on the top of the analog signal, thus maintaining the beneficial simplicity of conventional wiring. Nonetheless, bandwidth and communication speed, albeit digital, were extremely low (1200 Bps) →01−02. Not surprisingly, this technology still makes up the largest segment of the market in terms of installed base and greenfield plant design and construction [3].

Another technology, the fully digital serial fieldbus technology, introduced in the 1990s, became the technology-of-choice in the early years of the second millennium. With improved bandwidth (31.25 Kbps) →02, this technology requires gateways and has proven too complex in engineering, operations and maintenance

to truly satisfy process industry vendors. What process industry needs for a fully digital future is a technology with an Ethernet-level bandwidth and communication speed that is as simple to engineer, operate and maintain as the 2-wire, 4-20 mA solution, yet extends to the field device and operates in hazardous areas.

Collaboration: key to an Ethernet-level solution
Establishing an Ethernet-type communication technology that fulfills the aforementioned demands is a tall order. Challenges abound: short cable reach (100 m), complex wiring (Ethernet twisted-pair cables) and lack of safety for use in hazardous areas. Rigorous research and development efforts as well as strong cooperation between the process automation leaders and

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The hazardous nature of many process industry environments impedes the extension of Ethernet-level technology to the field.

standards organizations are fundamental to resolve these difficulties. Recognizing the need to establish fully digitalized plants and enable Industry 4.0 applications for the future of process industries in 2010, key industry leaders established the critical importance of extending Ethernet connectivity to the field-level [3]. In 2015, a group consisting of leading suppliers of process automation; ABB, Emerson, Endress+Hauser,

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02 Technical attributes applicable to Ethernet-APL are listed.

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03 Ethernet-APL increases bandwidth to the field device in both hazardous and non-hazardous environments.

Krohne, Pepperl + Fuchs, Phoenix Contact, R. Stahl, Rockwell Automation, Samson, Siemens, Vega, and Yokogawa with backing from leading standards development organizations (SDOs): FieldComm Group, ODVA and PROFIBUS & PROFINET International initialized the Advanced Physical Layer (APL) project [3]. They established in 2018 that any solution to be sustainable should be fully compatible and embrace the IEEE 802.3 Ethernet standard and satisfy specific criteria [3]:

- Two-wire cable
- Long cable runs
- Power and communication on the same cable
- Support of all explosion protection techniques including intrinsic safety
- Simple installation technology
- Reuse of existing fieldbus cable type 'A', which reduces cost and provides easy migration strategies from fieldbus to Ethernet-APL
- Resilience to electro-magnetic interference
- Support of surge protection

Ethernet-APL
Ethernet-APL, the culmination of a nearly decade long journey to extend Ethernet to the field, is an offshoot of the original 802.3 Ethernet standard

with the recently published IEEE 802.3cg-2019 standard [4]. The 10 BASE-T1L variant of this standard simplifies the network architecture and vastly increases the available bandwidth for digital instrument communications (300 times faster than FOUNDATION Fieldbus H1 or PROFI-

—
Ethernet-APL is an enhanced physical layer that enables SPE communication over a distance of 1,000 m.

BUS PA, and more than 8,000 times faster than the early HART protocol) →02, thus achieving the aforementioned criteria issued by the APL project [1]. Ethernet-APL is an enhanced physical layer that enables single pair Ethernet (SPE) communication over a distance of 1,000 m with the provision of power to devices as an option [3] →02. By defining Port Profiles matching different explosion protection classes, APL enables the
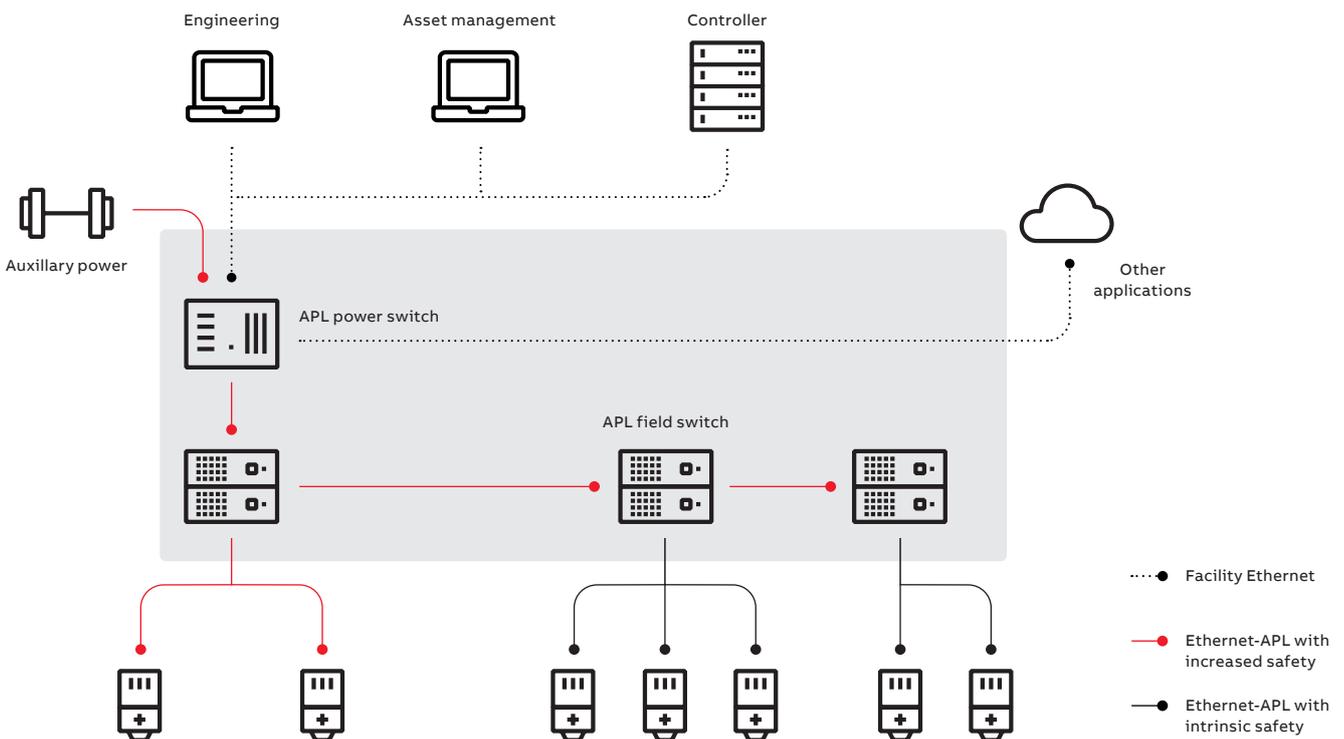
Engineering   Asset management   Controller

Auxillary power

APL power switch

APL field switch

Other applications

Facility Ethernet

Ethernet-APL with increased safety

Ethernet-APL with intrinsic safety

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extension of 10BASE-T1L for use in hazardous areas – an essential technical achievement for the process industries. Additionally, the soon-to-be released IEC technical specification, Two-wire Intrinsically Safe Ethernet (2-WISE), sets the guidelines for intrinsic safety (without the need for calculations) for loop-powered and separately powered instruments in hazardous areas up to Zone 0, 1, and 2 / Division 1 and 2 →03, [4]. With an expected release in 2021, 2-WISE, based on Fieldbus Intrinsically Safe Concept (FISCO), will simplify the engineering and verification of this technology [4].

Supporting topologies
Ethernet-APL is designed to support various installation topologies, with optional redundancy or resiliency concepts and trunk-and-spur. The trunk provides high power and signal levels for long cable lengths, up to 1,000 m. Whereas, the spur carries lower power with optional intrinsic safety for lengths up to 200 m. Ethernet-APL explicitly specifies point-to-point connections only with each connection between communications partners constituting a segment. Ethernet-APL switches thus isolate communications between segments.

Ethernet-APL success: rooted in protocol compatibility
Despite the promise of success, adoption of Ethernet-APL technology will take time [3]. With analog 4-20 mA + HART technology still dominant, process industries will need convincing reasons to revamp their engineering and systems to employ APL. Reluctance to shift away from legacy technology can only be overcome if the value proposition to incorporate APL technology is clear.

Since Ethernet-APL supports EtherNet/IP, HART-IP, OPC UA, PROFINET, and other higher-level protocols, this business shift is realistic. Nowadays, many process industries utilize DCS systems that already support PROFINET and/or Ethernet/IP protocols, and so will be able to easily adopt Ethernet-APL [1]. And, because APL eliminates the need for gateways or other protocol conversions, industries should swiftly recognize the added value achieved through reduced complexity, lower cost of ownership, improved usability and robustness as compared to conventional fieldbus systems or the analog 4-20 mA + HART systems.

Significantly, modern protocols can run over APL too [1]. ABB has been investigating one protocol

in particular – Open Platform Communication Unified Architecture (OPC UA). Ethernet-APL allows OPC UA to be deployed directly in field devices for easier integration with IT and OT applications of Industry 4.0.

Extending Ethernet-APL to the field level with OPC UA integrated devices
Around 2016, the customer organization Standardization Association for Measurement and Control in Chemical Industries (NAMUR) released a position paper (finally resulting in NAMUR Recommendation NE 168 in 2018 [5,6]), pointing out that any Ethernet solution for devices must overcome the limitations of fieldbus systems – in other words, vendors should avoid making mistakes inherent in previous generations of fieldbuses [5,6]. Seizing on this, ABB focused on removing existing barriers that interfere with information communication, such as the massive conversions and data description

—
APL enables the extension of 10BASE-T1L for use in hazardous areas; is an essential technical achievement.

that traditional fieldbuses require to make data useful in a process plant, eg for control, monitoring, optimization and maintenance. In particular, OPC UA technology provides data with semantic information and according to ABB could eliminate, if properly deployed, the inconvenience of fieldbus-type barriers. Beginning from 2017, ABB developed a series of prototypes to demonstrate that OPC UA is suitable for transferring device data securely with sufficient performance and low memory footprint, which is suitable for resource constrained devices. Prior to this, OPC UA was only used for interchanging information between more powerful devices like PC servers or controllers.

Initially, ABB evaluated the applicability of OPC UA to 4-wire flow meters (power and communication on separate wires). Relying on an Ethernet adapter that converted the HART protocol from the device into an OPC UA server, ABB achieved sufficient performance; hence, it was possible to access hundreds of device parameters via OPC UA easily, without the need of additional device descriptions →04. Furthermore, ABB investigated

2-/4-wire portfolio with Ethernet

4 -20 mA

Existing 2/4-wire portfolio
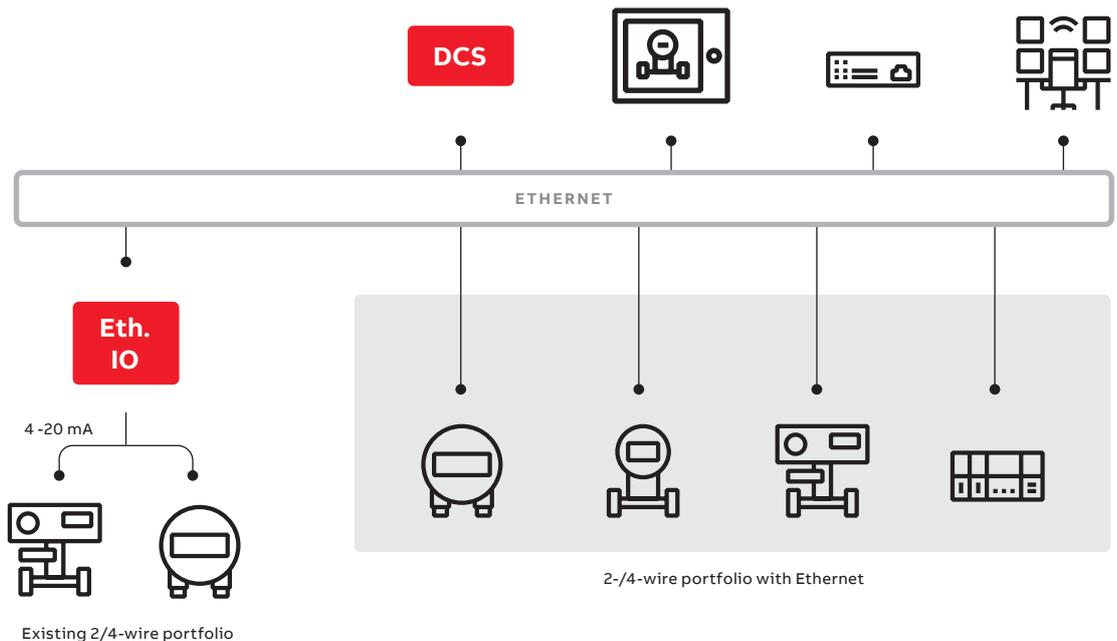
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the applicability of OPC UA to lower-footprint devices such as level transmitters, with low-power consumption requirements →05. Choosing a newly available OPC UA communication stack that targets embedded devices (high performance and low memory footprint), ABB could use

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By integrating OPC UA technology, with Ethernet-APL, ABB makes this communication protocol available for field devices.

an Ethernet platform that natively integrates OPC UA together with the full device functionality into this prototype. Hence, power consumption and memory footprint could be further reduced while maintaining update rates.

Understanding that the result matched the performance and power budget, which can be provided with Ethernet-APL, ABB then implemented a native OPC UA device with power and communication over Ethernet-APL. Here, the level transmitter application was successfully ported to evaluation boards, developed by the Ethernet-APL consortium →06. Next, the ABB team successfully evaluated the ability of OPC UA to be ported and integrated to a pressure transmitter prototype that requires one of the

fastest update rates (2 ms) encountered for process instruments.

Currently, these ABB device prototypes are used by selected customers in their first Ethernet-APL testbeds and they demonstrate full interoperability at a multi-vendor Ethernet-APL network. Thus, ABB is not only implementing Ethernet-APL devices, it is driving the standardization of OPC UA-based devices together with the OPC Foundation and FieldComm Group standard organizations.

Based on these test cases, customers can be confident that once OPC UA field devices are commercially available, Ethernet bandwidth and speed will be possible with two-wire power consumption and communication, and unproblematic fast update rates →07. With information models embedded in the device that incorporate semantics in the information being transmitted, these devices do not need additional descriptions and can be easily integrated with different applications.

Creating value from the field to the enterprise
With a simple network architecture and no need for protocol conversion, Ethernet-APL is highly compatible and easy to use. With a speed of 10 Mbps Ethernet-APL exhibits the simplicity of the 4-20 mA communication protocol, but with a Ethernet-level bandwidth suitable for instrument communication and multi-protocol support. By enabling connectivity with broadly distributed

two-wire loop powered field instruments in hazardous location areas, Ethernet-APL enables improved communication performance without sacrificing safety →08. By integrating OPC UA technology, with Ethernet-APL, ABB makes this

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ABB, and others, introduced the first Ethernet-APL products at the ACHEMA Pulse virtual trade show in June 2021.

universally applicable and modern communication protocol available for field devices. The resultant semantics and information models remove the need for descriptions and will help bridge the gap between Operation Technology (OT) and Information Technology (IT).

Prior to the launch of Ethernet-APL in the third quarter of 2021, ABB together with other automation suppliers successfully introduced the first Ethernet-APL products at the ACHEMA Pulse virtual trade show in June. Thus, the decade long journey to expand Ethernet to field-level communication for process automation plants is completed; thereby initiating a safe, secure, and practical communication from the field to the entire enterprise and the cloud. •

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08

01

CONNECTIVITY

Distributed generation sparks demand for new circuit breaker

Decentralized energy generation systems such as combined heat and power (CHP) offer the potential of significantly reducing the CO_2 produced in large urban areas.

it easier and cheaper to connect Net-Zero-ready energy technologies such as CHP units to the network [1].

Faster, smaller, cheaper
The new super-fast circuit breakers are a quarter of the size and half the price of limiters representing competing technologies and are expected to open the door to connecting an additional 460 MW of distributed generation to the city's network. Their advantages are particularly evident when compared to conventional circuit breakers where the current is interrupted by opening a contact gap, using mechanical contacts, and extinguishing the arc. In such circuit breakers the full fault current flows

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ABB's fault current limiting circuit breaker is 20 times faster than any existing circuit breakers.

through the breaker and the rest of the network for 50-100 ms. If all of the downstream substations and network components are designed for the current, the fault is cleared safely. However, if new distributed generation is to be added to a network there is a risk that this design limit will be exceeded, in which case other measures need to be implemented. One possibility is to introduce a device that will limit the fault current below the critical design value of the power grid, ie, a fault current limiter (FCL).

An FCL needs to be so fast that it limits the current within milliseconds, rather than tens of milliseconds. Here, two basic concepts have already been in use for years: dynamic impedance, and fast interruption.

Dynamic impedance devices have a low impact on the grid under normal operating conditions but will rapidly increase their impedance during a fault event, thus limiting the maximum peak current. Examples of this type of device are electromagnetic and superconducting fault current limiters [2]. Their main characteristic is that they limit the maximum peak current but do

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01 Fault current limiting circuit breakers have been installed in the Tower Hamlets pilot project in east London.

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Enabling decentralized energy generation systems to safely connect to the grid without incurring huge additional costs has been a long-standing challenge. Now, thanks to a new emphasis on the energy-saving potential of CHP, authorities in London, UK are testing a fault current limiting circuit breaker (FLCB) device designed by ABB that promises to be exactly what is needed to safely and affordably exploit this low-carbon technology.

The FLCB designed by ABB combines state-of-the-art power semiconductors with extremely fast mechanical switches to detect and limit fault currents in just a few thousandths of a second – 20 times faster than any existing circuit breakers.

In view of this, UK Power Networks, an electrical distribution network operator covering London, the South East and East of England, recently claimed a world first by installing FLCBs in a substation in Tower Hamlets, east London →01. The new circuit breakers are designed to make

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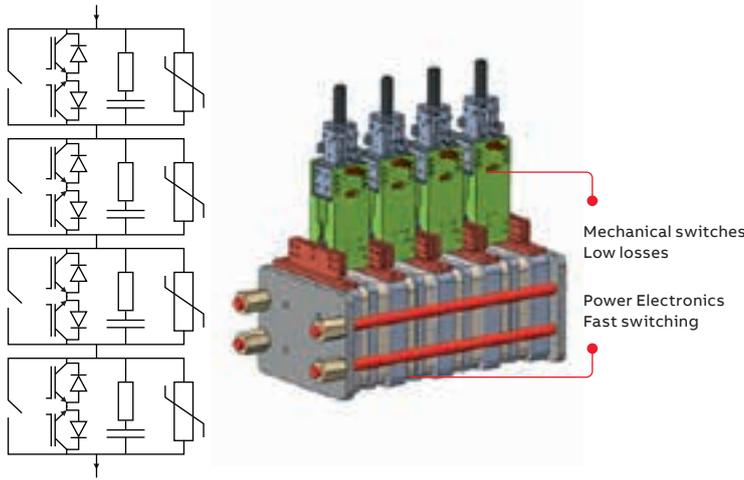
is detected, a pyro device opens the switch, which commutates the current into the fuse. This melts the fuse and thus interrupts the current.

Another possibility for fast interruption is the introduction of power semiconductors. These devices have the capability to interrupt currents within microseconds and may easily be switched back on remotely after a fault is cleared – an advantage over fuse technology, which needs manual replacement after operation. However, power semiconductors are expensive and require additional cooling, especially at higher nominal currents.

Hybrid solution
The FLCB developed by ABB offers significant advantages over the above-mentioned technologies. Unlike an I_s-limiter where the pyrotechnical device and the fuse have to be replaced after each operation (single shot device), the hybrid FLCB is designed for many operations both with and without current. To achieve this, a hybrid solution has been implemented that combines the fast switching of power semiconductors and

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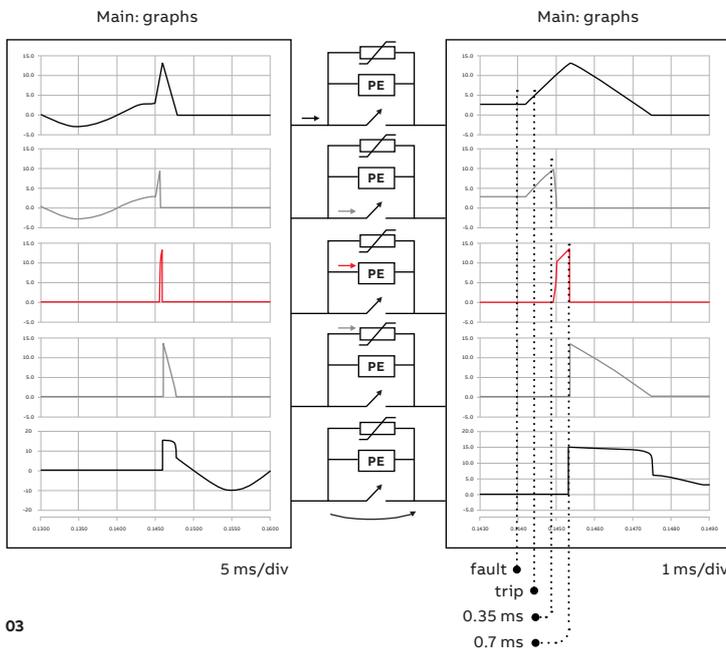
The FLCB developed by ABB offers significant advantages over dynamic impedance devices and fast interrupters.

the low losses of mechanical switches. The result is a more compact solution than passive dynamic impedance devices, which has made it possible to implement it in the London area and other densely populated urban areas where other technologies are difficult to adopt.

The hybrid FLCB has three major structures – a fast mechanical switch, power electronics, and a surge arrester →02. In nominal operation, current flows through the mechanical switch with very low losses. When a fault is detected, the switch is opened, and the arc voltage transfers/commutates the current to the power electronics (PE). In a second step the PE is turned off and the current is commutated to the surge arrester. The arrester is designed to create a counter voltage that is greater than the system voltage, thus forcing the current to zero. A second important design parameter for the surge arrester is the ability to dissipate stored inductive energy during a fault interruption →03. To illustrate the interruption in comparison to the full prospective fault current a conceptual graph is shown in →04.

not interrupt the current completely. After the fault is cleared, the impedance is restored, and nominal operation resumes. A common disadvantage is that these devices are, in most cases, large, heavy and, when based on a superconducting system, require advanced low temperature cooling. The advantage of this technology is that these solutions are intrinsically fail-safe because most credible failure modes result in failing into a high impedance state where overcurrents are limited.

The second concept, fast interrupters, limits the fault current by interrupting the current before it reaches the critical design limit. This should occur in a few ms. One example of this type is the already commercially available Is-limiter, [3]. The I_s-limiter consists of a fast detection device and a fast commutation switch in parallel with a fuse. When a fault

Fast commutation switch
To be able to implement a hybrid concept characterized by interruption times below 1 ms, which would be necessary for a 25 kA prospective fault current, an ultra-fast mechanical switch is essential. Looking at the interruption sequence in →04, it is understood that the contact separation needs to take place in approx. 0.35 ms after a fault is detected or a current is identified as a fault. This is accomplished by combining a tailor-made, light weight contact system with an electro-magnetic drive system. This provides the proper reaction time and acceleration.

Performance
For the pilot installation at UK Power Networks' Tower Hamlets location, a development that has been run as a joint project and pilot by ABB and UK Power Networks under the project name Powerful CB, the basic requirements for the FLCB were:

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- Nominal voltage: 12 kV
- Nominal current: 2000 A
- Prospective fault current: 25 kA (RMS)
- Limited current: 13 kA (peak)
- Current limited in less than 1 ms after fault detection

In an earlier project, [4], it was shown that these requirements are achievable with the suggested hybrid concept described above. During the project's execution several tests were conducted to verify performance. An example of an interruption test with full prospective fault current is displayed in →05.

To ensure that the maximum allowed fault current in the grid is never exceeded, while taking into account the maximum current derivative di/dt for a 25 kA prospective fault current of approximately 11 kA/ms, the FLCB needs to limit the current within less than 1 ms after detecting the fault. This puts extremely high demands on both the detection system and the operation of the device. To meet these demands an Is-limiter control unit was used. In the context of this application, this device continuously measures the instantaneous value of the current and, when a pre-set value is exceeded, sends a trip signal to the control system of the FLCB within
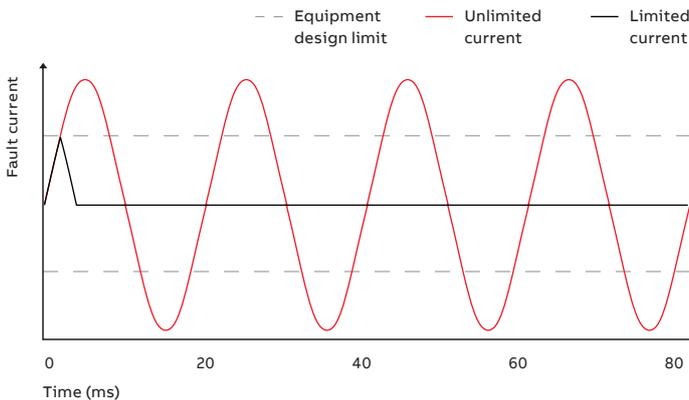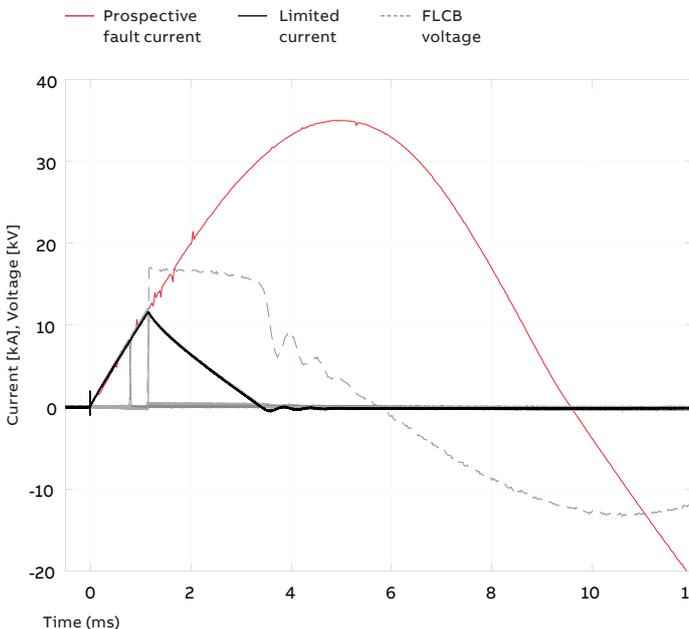
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The main purpose of the FLCB is to limit the maximum fault current in the grid or in a substation.

a few micro-seconds. Since the FLCB consists of several active devices, a fast and accurate control system was implemented for the operation sequence. The time resolution of the control system is in the micro-second range.

Implementation in the grid
The main purpose of the FLCB is to limit the maximum fault current in the grid or in a substation. To accomplish this functionality there are different ways of introducing it onto the grid. Some examples are shown in →06 and →07. In the configuration shown in →06, when one transformer is taken offline due to a fault or planned maintenance, the busbar sections are connected to run solid to support the load without overloading the remaining transformers. This, however, can increase fault levels up to or above

06

07
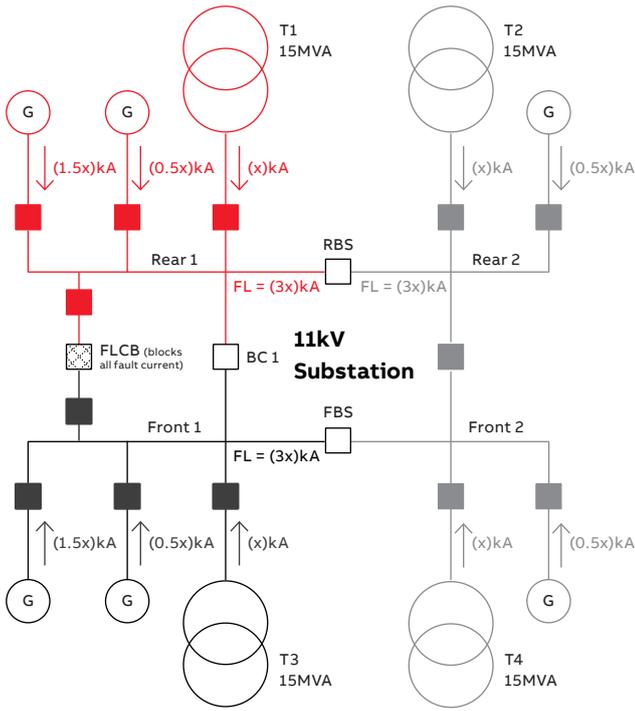
the design limit and usually requires generation to be disconnected. However, if an FLCB were connected as a bus coupler instead of a standard circuit breaker, this would reduce the fault level contribution from one bus section to another and allow generation to remain connected during these abnormal running arrangements. The reason for this is that the FLCB will separate the busses in less than 1 ms during a fault, resulting in a very limited fault current being transferred
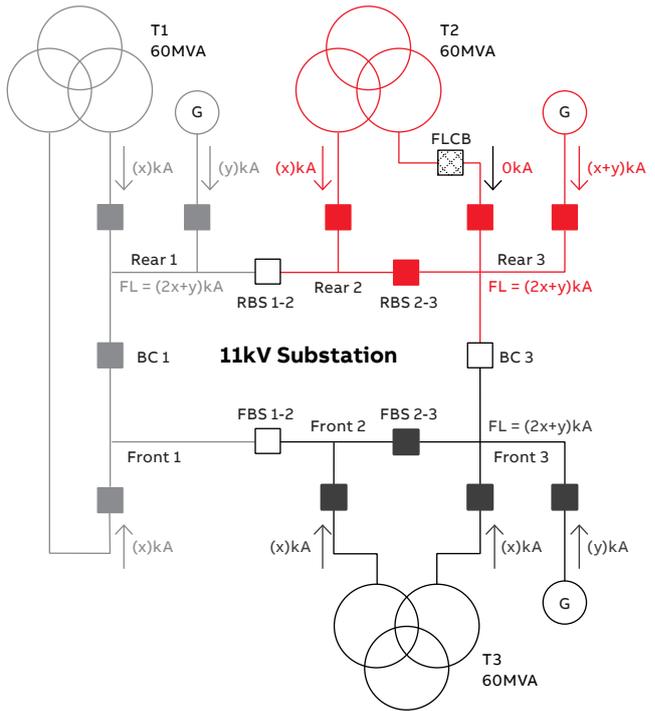
from one bus section to another. This creates maximum operational flexibility while minimizing the risk of over-stressing the substation and allowing generators to remain connected.

In an alternative configuration the FLCB is placed on one or more of the incoming feeders →**07**. In this arrangement, it disconnects the incoming feeders connected via FLCB during a fault so that the fault contribution is effectively limited based on the high performance of the device. This configuration provides additional fault level headroom, making it possible to connect more
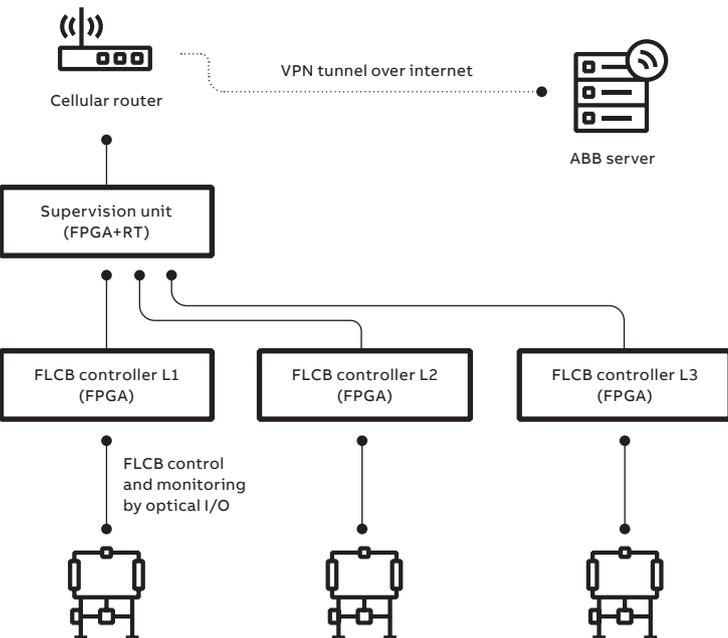
08

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The health status of various components will be automatically gathered and transmitted to ABB for analysis.

distributed generation without exceeding the fault level design limit.

Another option is that the FLCB could be directly connected to a generator feeder, eg, from a newly installed CHP system. Here, in the event of a fault, the current from the generator would be limited within 1 ms, thereby enabling connection of new distributed generation without infringing on available fault-current headroom.

09

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06 FLCB introduced as a bus coupler.

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07 FLCB placed on one of the incoming feeders.

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08 Remote monitoring set-up for FLCB pilot.

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09 Authorities in London are testing ABB's new FLCB.

Pilot installation results

ABB and UK Power Networks are currently carrying out a pilot evaluation of the FLCB in a London primary substation. The trial site was chosen because it has historically registered a relatively higher number of faults, space is available for the installation, and the fault level headroom is not far from the design limit. For this specific installation, the device was placed in three standard medium voltage panels, one for each phase. Throughout the trial, the FLCB will be evaluated both as a bus coupler and as a breaker on an incoming feeder, between the transformer and the busbar.

The pilot device will be remotely monitored by ABB throughout the study. The health status of various components together with transient system recordings will be automatically gathered and transmitted to ABB for analysis through the set-up →08. This will make it possible to study the long-term behavior of the device and to analyze the detailed outcome of protection

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Although continuous monitoring has been in effect, no faults have been registered in the system since its activation.

operations. Furthermore, these steps will allow specialized personnel to support the customer by responding rapidly to any possible malfunctions based on detailed diagnostics.

To date, although continuous monitoring has been in effect and the FLCB has been ready to respond to any fault, no faults have been registered in the system since its activation →09 [5]. ●

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CONNECTIVITY

Plugging ships and ports into a cleaner future

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Ports have a crucial role to play in facilitating the reduction of shipping emissions. ABB offers scalable and flexible frequency conversion technology that guarantees seamless, automated power transfer of a ship's load from its onboard power plant to an onshore source and back, thus meeting the needs of ship owners and ports. The result is a significant reduction in fuel use, pollution, vibrations, and noise.

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According to the Organization for Economic Co-operation and Development (OECD), 90 percent of traded goods are transported by sea [1]. Furthermore, as demand for global freight increases, maritime trade volumes are expected to triple by 2050. But while maritime shipping provides a cost-effective mode of moving goods over long distances, and is thus a source of prosperity, it is also a major source of pollution, accounting for approximately 30 percent of total global NO_x emissions and around 2.6 percent of total global greenhouse gas emissions.

According to a 2018 report by the International Transport Forum [2], an organization that is administratively integrated with the OECD, ports have a crucial role to play in facilitating the reduction of shipping emissions →01. The reason for this is that in the majority of ports, ships at berth use their diesel generators to run amenities, such

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PCS120 SFC

Main incoming substation   Power cables   Shoresides   Berth terminal   Onboard installation
                                            substation
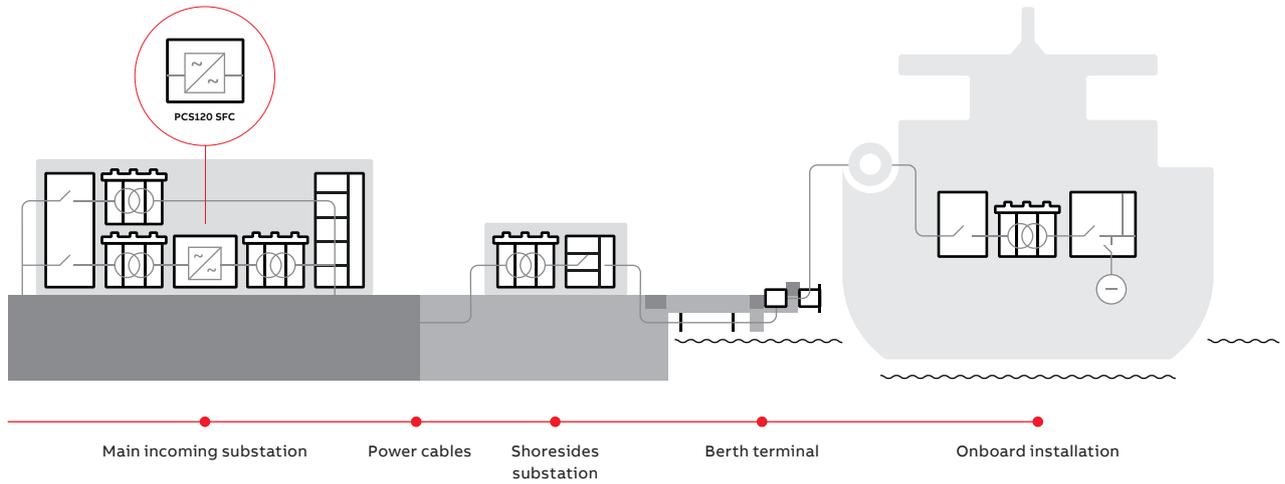
02

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01 Ports have a crucial
role to play in facilitat-
ing the reduction of
shipping emissions.

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02 Overview of a
shore-to-ship power
connection.

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03 Overview of an
onshore power
configuration.

as heating, ventilation, and cooling, as well as galley equipment. All of this not only has a negative impact on the environment, but also reduces the quality of life of local communities as a result of the noise and vibrations produced by ships.

Mounting pressures to reduce the pollution generated by the world's fleet have forced ship owners to adopt a proactive approach to measuring and monitoring combustion, which is reflected in such programs as marine fuel management (MFM). However, going green and becoming compliant with the demanding requirements of regulatory authorities, such as IMO/MARPOL and the EU, call for decisive steps. This is where advanced technology steps in.

Shore-to-ship power
ABB's new Static Frequency Converter (SFC) technology is the most reasonable and cost-effective choice for greener ports and fleets. The solution enables ships to shut down their diesel generators and plug into an onshore power source while berthed. However, most ships' power generation units operate at a frequency of 60 Hz, whereas the local grid in most parts of the world is 50 Hz. This means that providing ships with electricity requires a shore-side electricity supply arrangement →**02–03**. [3].

With this in mind, ABB offers static frequency converters that reliably and efficiently convert grid electricity to the appropriate load frequency. The company's leading-edge frequency conversion technology guarantees a seamless automated power transfer of the ship load from the onboard power plant to the onshore source and back. The result is a significant reduction in terms of fuel and lubrication oil consumption, which means less pollution and improved financial benefits. Shore-to-ship power is especially applicable to ships operating on dedicated routes, and vessels that consume large amounts

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ABB's solution enables ships to shut down their diesel generators and plug into an onshore power source while berthed.

of power while in port. This can offer concrete benefits for, eg, terminal operators whose ferries berth each day for a fixed number of hours.

Modular and scalable
ABB's SFC is a scalable, modular power converter system. It is comprised of multiple pairs of independent rectifiers and inverters managed by a system controller to provide a stable and reliable voltage and frequency source that can synchronize and regulate power when operating in parallel with other energy sources such as an onboard generation system. These features permit maximum flexibility in adjusting the system to suit the customer's needs. ABB's SFC portfolio includes the PCS100 (Power Converter System) and upcoming PCS120 →**04**, which is suited for low-power applications.
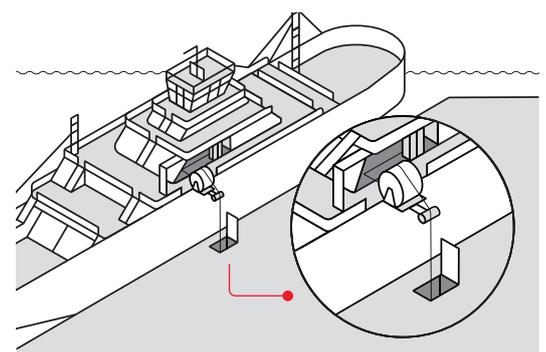
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04 ABB's PCS120 SFC.

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05 More and more
ports are reducing their
environmental impact
by allowing ships to tap
into grid power.

05a Pipavav Shipyard
Limited is the largest
shipyard in India.

05b Killybegs Fishery
Harbour Centre in
Donegal, on Ireland's
northwest coast.

05c The Bahrain port.

The modularity and scalability of these systems
enable multiple units to operate in parallel, which
makes the solution adaptable to the power
requirements of different ships and to a variety
of port infrastructures →05. If a unit is to be
placed outdoors, a suitable enclosure can be
delivered as part of the package if required. This
gives the customer flexibility when planning and
implementing the physical and spatial layout of
power converter systems so that they harmoni-
ously fit in with the surrounding environment.

Low operational impact
Another advantage of these systems is their
superior availability, which results from their
high reliability, robustness, and low maintenance
(PCS100 MTTR< 30 min / PCS120 SFC < 10 min)
– factors that lead to reduced operational costs.
The cost of ownership may be further reduced if
renewable energy sources, such as wind or hydro
power, solar panels or fuel cells are chosen as the
primary source of power. •

INDIA'S FIRST GREEN SHIPYARD

Pipavav Shipyard Limited (PSL) is
located on India's west coast in the
State of Gujarat and is the largest
shipyard in India. In addition, it is one
of the biggest drydocks in the world
and has a shipbuilding, ship repair
and offshore fabrication complex.
The shipyard has installed and com-
missioned some of the most modern
shipbuilding facilities available.

Thanks to its four 250 kVA PCS100
static frequency converters (SFCs)
from ABB, it is the first and only
"green shipyard" in India →**05a**. ABB's
leading-edge solution has helped the
shipyard to reduce emissions, pollu-
tion and noise levels while achieving
significant cost saving by allowing
ships to use grid power instead of
diesel generators. PSL also benefits
from improved availability and re-
liability compared to facilities that
use rotary frequency converters.

05a

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05b

IRELAND'S ATLANTIC FISHING FLEET: DEEP EMISSION CUTS

PCS100 Shore-to-ship static frequency converter (SFC) units from ABB are saving 96,000 liters of diesel fuel and cutting 2,000 tons of CO_2 emissions per year at Ireland's Department of Agriculture, Food and the Marine as they provide grid power to fishing boats at Killybegs Fishery Harbour Centre →**05b** in Donegal, on Ireland's north-west coast [4]. The converters – the first to operate in Ireland – are now boosting sustainability at 12 berths.

Killybegs is one of around 100 ports in Northern Europe where pelagic fish such as herring and mackerel can be landed. The port has a local fleet of around 25 large trawlers. Until recently, the trawlers relied on 70 kVA diesel deck generators when in port to power loads such as lighting, heating and electronic navigation and control equipment in the wheelhouse, as well as pre-heaters for starting the main engines.

Thanks to the port's new static frequency converters, however, the ships can power down their deck generators, reducing local emissions by the equivalent of removing nearly 500 cars per year from the road. The installation has also improved the harbor's quality of life by cutting noise emissions and reducing fire risk and maintenance requirements for trawlers.

The converters will future-proof the harbor by complying with legislation being introduced by the International Maritime Organization as it works toward its target of reducing shipping emissions by at least 50 percent by 2050 compared with 2008.

The converters draw power from the standard 400 V utility grid and are housed in a dedicated indoor plant room along with switchgear and safety systems. Trawlers connect via industrial sockets on the quayside, with access to power being controlled by the harbor master. Each converter provides remote monitoring for metering and can be isolated and switched individually between 50 and 60 Hz for flexibility.

BAHRAIN: CUTTING COSTS AND POLLUTION

Ships calling at Bahrain's port →**05c** can switch off their diesel engines and tap into cleaner onshore energy sources thanks to ABB's grid connection technology [5]. The three PCS100 SFCs (static frequency convertors) installed at the port can reduce a large ship's fuel consumption by up to 20 metric tons and reduce its CO_2 emissions by 60 metric tons during a 10-hour stay in port. ABB's grid connection technology makes it possible to feed shore-side power (typically 50 Hz) into ships' power generation units, which typically operate at a frequency of 60 Hz.

The port's Arab ShipBuilding & Repair Yard (ASRY) is a leading Middle East shipbuilding and repair company. For many years it relied on rotary frequency converters. However, the converters suffered from pollution, reliability, and equipment availability issues; moreover, their efficiency was generally around 75 percent. Today, thanks to the PCS100 SFCs, which have no rotating parts and therefore no need for mechanical maintenance, efficiency is up to 95 percent. As a result, equipment operational and maintenance costs have been sharply reduced, equipment availability has increased, and noise and vibration-related pollution have been eliminated.

ASRY is among the first shipyards in the world to receive ISO certifications for quality, management, environment, and health & safety systems, in addition to the ISPS code for Port Security.

05c

Multibody simulation

Multibody simulation tools support and speed the development of complex mechanical systems.

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Multibody simulation is a tool for the analysis of motion and forces in mechanical systems →01. Often confused with the finite element method (FEM), multibody methodology provides information on motion and forces, whereas the FEM deals with deformation and strength.

A basic slider-crank mechanism – as found in the internal combustion engine – transforms the rotation of a motor's crank into a vertical movement of the piston and thus provides a simple example of a multibody system. For given loads, multibody simulation can evaluate the motion of this system and all the reaction forces in the joints. Conversely, the simulation can also tell how loads react to a given motion.

Moreover, the mechanism model can be built parametrically and the influence of these parameters on system dynamics can be investigated →02. This feature is vital in the first stages of product development, in which different dimensions of mechanism are simulated until the required performance is reached. Later in the development, parametric analysis is used to define the influence of production and assembly tolerances and, thus, answer the critical question: "will the mechanism perform as required even with the imperfections introduced during production?"

A very important – and usually unavoidable – mechanical parameter studied using multibody simulation is play in joints. Play often has a significant influence on product performance and, because of its nonlinearity, cannot be modeled by simple analytics.

So far, the assumption was made that the mechanism's links were rigid – ie, they cannot deform. So, what about the deformation and strength of mechanical links? Nowadays, multibody tools can describe well the behavior of mechanisms with flexible parts – if the parts are simple. More complicated parts yield less precise results, so FEM tools must be deployed if precise deformation or strength information is sought. FEM set-up and simulation can be expensive and time-consuming, but there is a
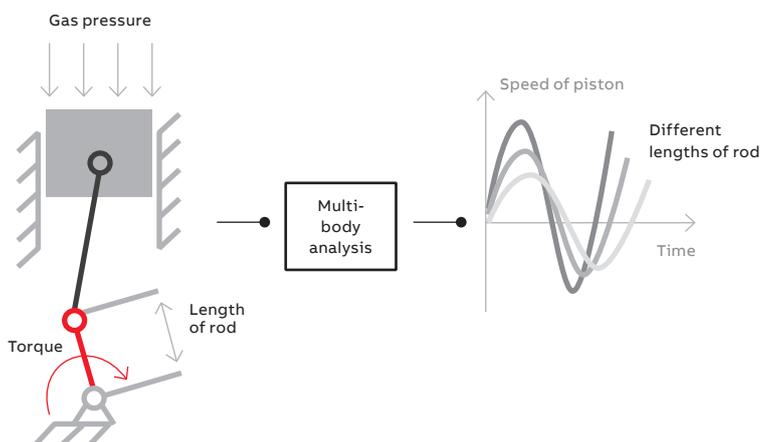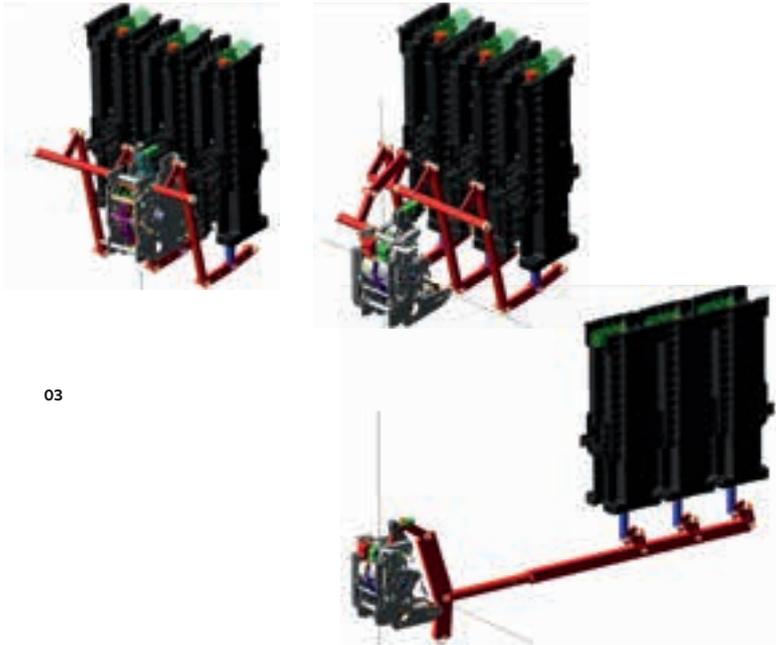
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01 Multibody simulation is invaluable for fast and reliable design of products with complex mechanics, such as this pantograph.

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02 Parametric analysis of a mechanical system.

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03 Multibody models of different topologies of a medium-voltage circuit breaker.

smart and fast option: Simulate the mechanism in a multibody tool and simulate only the critical part in the FEM tool, with input from the multibody simulation.

Circuit-breaker design is one area where ABB puts multibody simulation to good use. Circuit breakers are very complex mechanical systems that can be described by analytic formulas only in a limited way. A multibody tool is a must if the dynamics of such a complex system need to be analyzed →03. Using a multibody tool, it was possible to compare three circuit-breaker topologies within two months. Without the tool, three demonstrators would have had to be built – a costly and lengthy process.

Multibody simulation tools provide valuable support during the development of complicated mechanical systems. The tools accelerate the development process significantly and help avoid any unpleasant surprises during production by characterizing the influence of production tolerances. •

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Next 04/2021
Logistics

Logistics is the activity where business plans are tested against operational results. The latest digital technologies can help deliver those results faster, more profitably, and more sustainably. The next issue of ABB Review will reveal how companies are using digital processes and tools to turn tests into opportunities.

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