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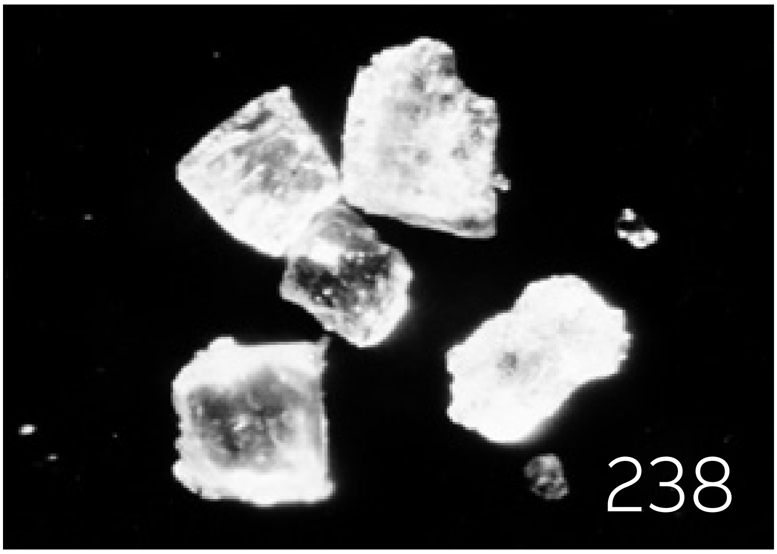
04|2023 en

review

Detection and analytics



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Page numbering

Many readers will be pleased to notice that from this year we have returned to classic scientific journal page numbering. Hopefully this makes referencing easier for the scientific community. Please see also the keyword index on pp. 301–303 of this edition of ABB Review.

Share articles

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

Corrigenda

"Klabin-ABB partnership: From planted forests to package – sustainably", ABB Review 03/2023, pp. 200–205. On page 203, for "800,000 MWh to Brazil's power grid," read "800,000 MWh annually to Brazil's power grid."

"Electric switch: Improving sustainability by switching to electric vehicles," ABB Review 03/2023, pp. 168–171. On page 171, for "ABB has been sponsoring the series since its inception," read "ABB has been title sponsor of the series since 2018, and is also official charging partner." Caption of Fig. 4 should read "ABB is title partner of the ABB FIA Formula E World Championship." In caption of Fig. 5, for "is used in the ABB Formula E-supporting Jaguar I-Pace eTrophy", read "was used in the ABB Formula E-supporting Jaguar I-Pace eTrophy from 2018-2020."

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Detection and analytics

What technology innovations of today will be considered business standards of tomorrow? This issue of ABB Review starts with a look back in time at ASEA – the "A" in ABB – and explores the many firsts this pioneering company achieved in areas including power transmission, robotics, and even synthetic diamonds. In the same spirit, this edition also captures some of the latest solutions ABB is innovating to sense data and then put them to work using AI. Inventing the future never stops.

Coming up in the next edition: **Innovation**

EDITORIAL

Detection and analytics

Dear Reader,

Sensors are the ears and eyes of industrial operations. They track the heartbeat of processes and enable better decisions. In this issue of ABB Review, we present examples of ABB technologies detecting, analyzing and contextualizing many different kinds of information – ranging from objects floating at sea, to impurities in gas flows, to cyber threats. The insights gained enable better decisions, contributing to higher productivity while protecting equipment, humans and the environment.

2023 marks a very special anniversary for ABB. It was 140 years ago that the inventor, Jonas Wenström, got together with the financier, Ludvig Fredholm to form a company that later became known as ASEA – the "A" of today's ABB. ASEA created numerous inventions and initiated activities that are still at the heart of ABB today. In this issue of ABB Review, we dedicate a section to this extraordinary journey of pioneering and entrepreneurship.

Enjoy your reading,

Björn Rosengren
Chief Executive Officer, ABB Group

Share this editorial

PERPETUAL PIONEERING

140 years of ASEA

It is almost impossible to imagine what life would be like without electricity. And yet, only as recently as the childhoods of our grandparents and great-grandparents, electric power was a luxury few people had access to, and many had never even heard of. This article examines how the spirit of curiosity and invention, sparked in the late 19th century by two entrepreneurs from Sweden, gave rise to innovations that changed the world, both in the realm of electricity and beyond – and set the stage for the formation of today's ABB; a company that now employs over 100,000 people and has sales of more than $30 billion.

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Writer and journalist
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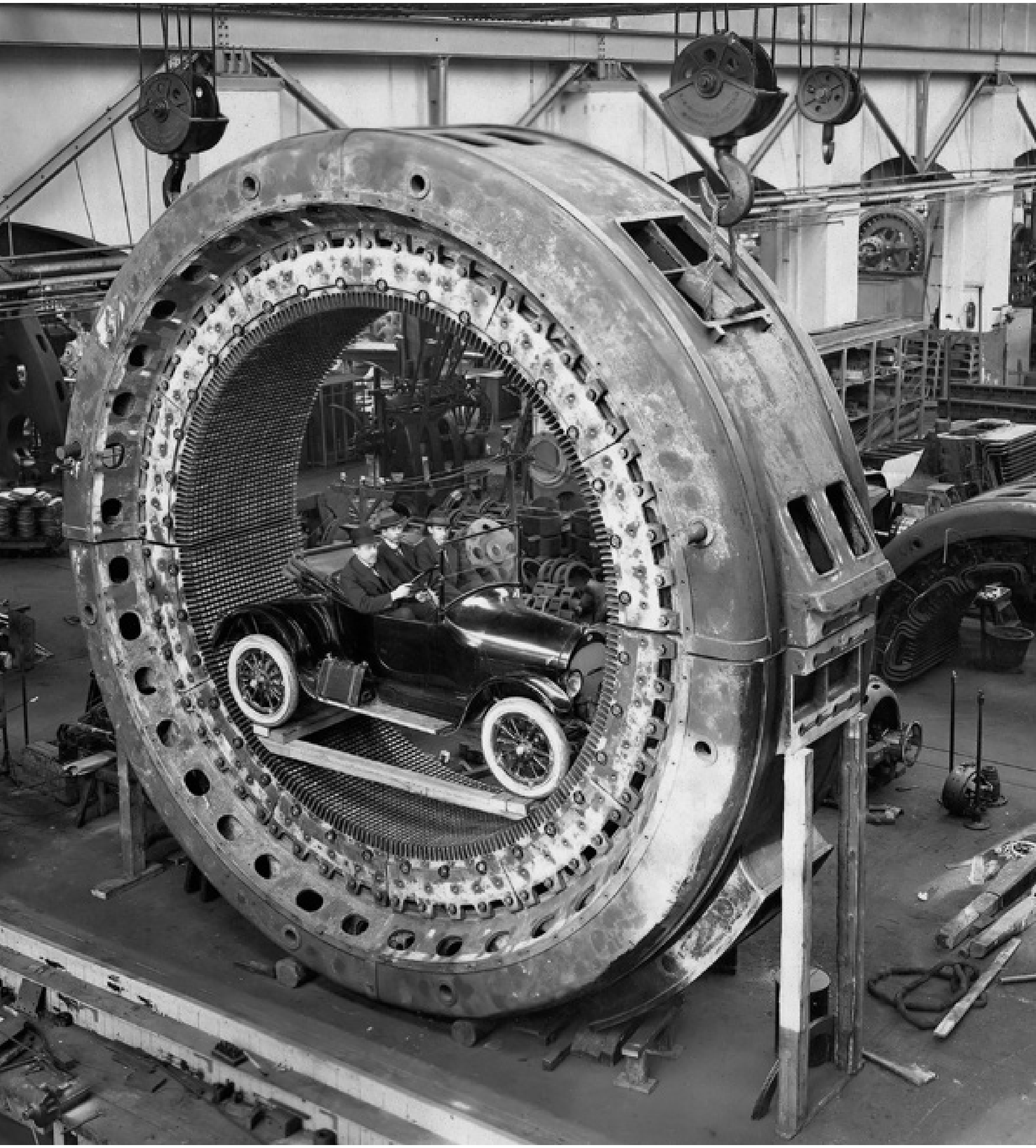
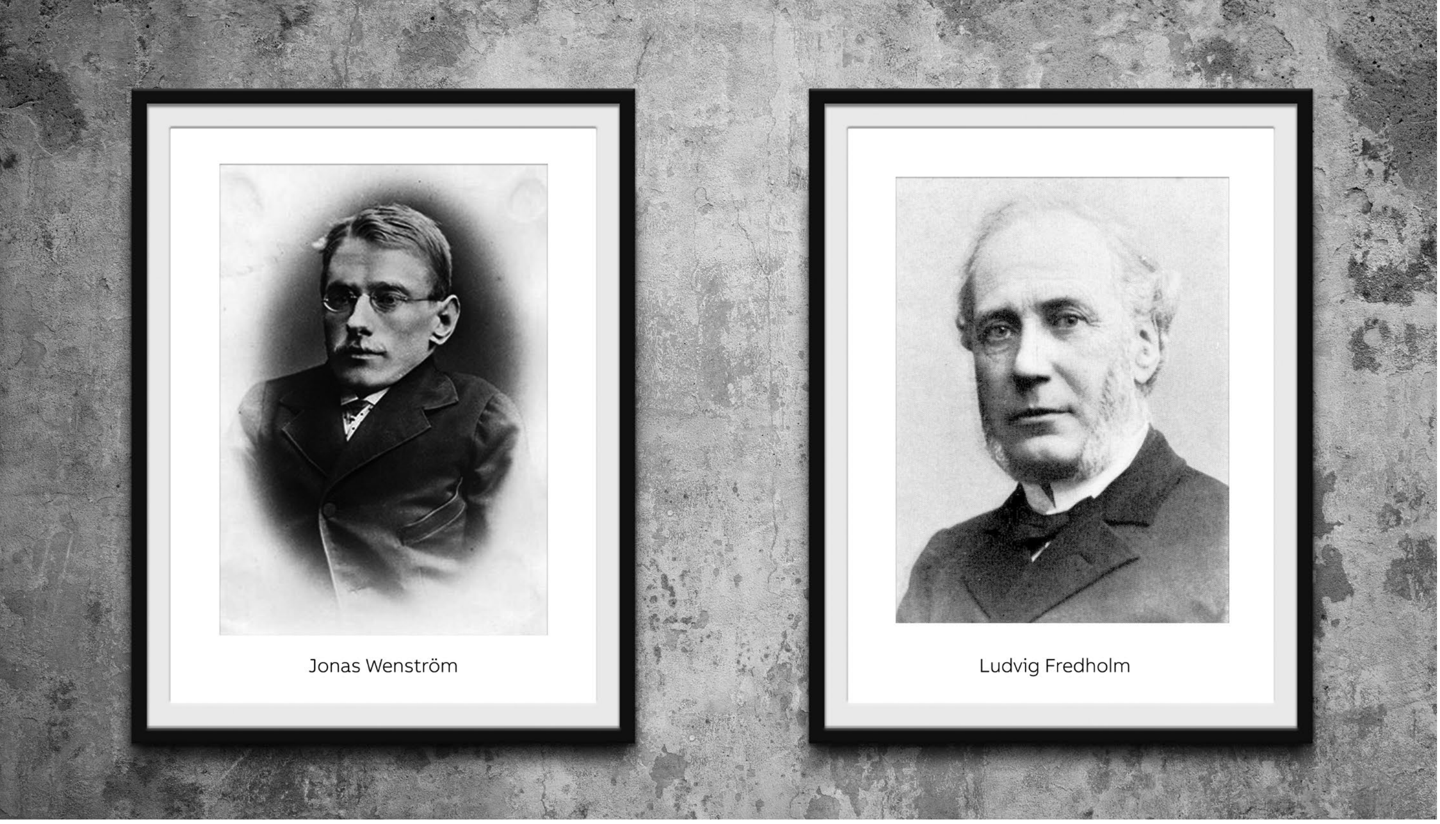




01

Only by chance did the gifted inventor, Jonas Wenström, meet businessman Ludvig Fredholm →01. The two men founded Elektriska Aktiebolaget on January 17, 1883, in Stockholm. Seven years later, in 1890, Elektriska merged with Wenström's brother's company to become Allmänna Svenska Elektriska Aktiebolaget, later shortened to ASEA (which eventually became the A in ABB).

Wenström, driven by incessant curiosity and entrepreneurship, became one of the leading pioneers of electrical transmission →02. His inventions enabled the construction of power plants and transmission lines as well as the electrification of cities and factories →03. As early as 1893, the young company built Sweden's first three-phase electrical transmission, a 15 km, 9.5 kV line from a hydro plant at Hällsjön to a mine in Grängesberg [1]. Tragically, Wenström died of pneumonia that same year, aged only 38.

—

By the time it merged with Brown, Boveri & Cie (BBC) in 1988 to form ABB, ASEA had grown into an industrial giant.

Wenström's spirit of creativity and innovation lived on at ASEA. The company supplied locomotives and power supplies for railways, including the 1926 electrification of the Stockholm to Gothenburg railway. Starting in 1978, ASEA supplied AEM-7 electric locomotives to Amtrak (United States).

Research was valued highly at ASEA. As early as 1916, and well ahead of the trend of industrial corporations doing so, ASEA opened a dedicated Central Research Laboratory in Västerås, Sweden [2]. The company's endeavors included the first commercial HVDC transmission →04, and the first synthetic diamonds →05.

In 1952, ASEA completed the world's first 380 kV AC transmission line, linking Harsprånget to Hallsberg (Sweden), a distance of about 1,000 km with 500 MW capacity [3,4]. This voltage class was later adopted internationally for long-distance transmission, and is still widely used today.

ASEA built Sweden's first nuclear power plant in 1972, and went on to build nine of the country's 12 reactors.

By the time it merged with Brown, Boveri & Cie (BBC) in 1988 to form ABB →06, ASEA had grown into an industrial giant and had become one of the world's ten largest groups in the electrical field and a world leader in HVDC technology.

Today, ABB is a major player in the world of industrial robotics. This journey began in 1974, when ASEA launched one of the world's first industrial robots, the IRB 6 →07.

What follows is but a tiny selection of the company's manifold achievements and lasting legacy.

—
01 Jonas Wenström (1855–1893) and Ludvig Fredholm (1830–1891).

—
02 Three-phase pioneers.

02a Hand-written, note from Thomas Edison to Jonas Wenström, enquiring about the availabilty of Thorite.
Source: Från Wenström till Amtrak, Västerås 1983.

02b Assembling a large three-phase transformer in an ASEA factory.

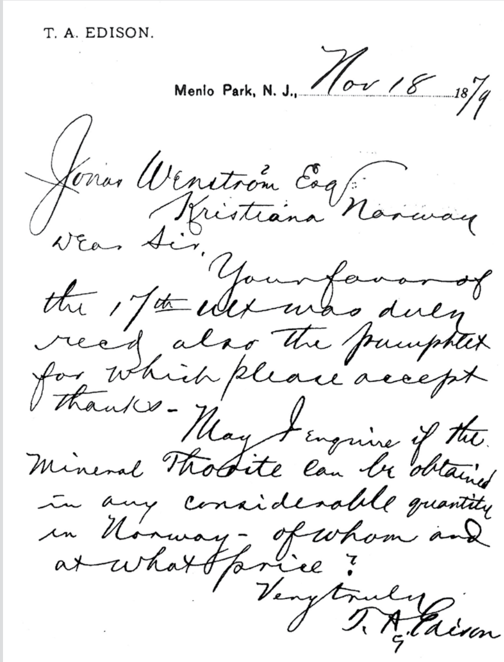
THREE-PHASE PIONEERS

Throughout the history of technology there have been windows during which radical new opportunities have arisen, and progress has shifted to a higher speed. The 1970s and 1980s, for example, saw such a revolution transform personal computing. Similarly, the early 2000s witnessed the boom of the Internet and social networks. Such technological revolutions are golden ages for entrepreneurship, offering seemingly unlimited opportunities for bold and creative minds – people who change the world forever. This is what happened to electricity in the 1880s and 1890s →02a.

Early commercial electric motors had mostly used DC. The increasing adoption of (single-phase) AC in transmission in the 1880s (initially predominantly for lighting) encouraged inventors to pursue viable AC motors. One drawback of single-phase AC was that it is not easy to create a rotating magnetic field – the basis of an induction motor. Another is that in a single-phase motor, power transfer is not constant, leading to torque fluctuations and vibrations.

In 1885, the Italian physicist, Galileo Ferraris, demonstrated a two-phase alternator. The second phase was effectively a separate circuit whose phase angle was shifted by a quarter period. At this phase difference, the two phases between them permitted a constant power transfer as well as a smoothly-rotating electric field.

In the years that followed, numerous inventors pursued the polyphase concept. These included Nikola Tesla (working for Westinghouse in the USA), Mikhail Dolivo-Dobrovolsky (working


T. A. EDISON.
Menlo Park, N. J., Nov 18 1879
Jonas Wenström Esq
Kristiania Norway
Dear Sir,
Your favor of the 17th ult was duly recd also the pamphlet for which please accept thanks - May I enquire if the Mineral Thorite can be obtained in any considerable quantity in Norway - of whom and at what price?
Very truly
T. A. Edison

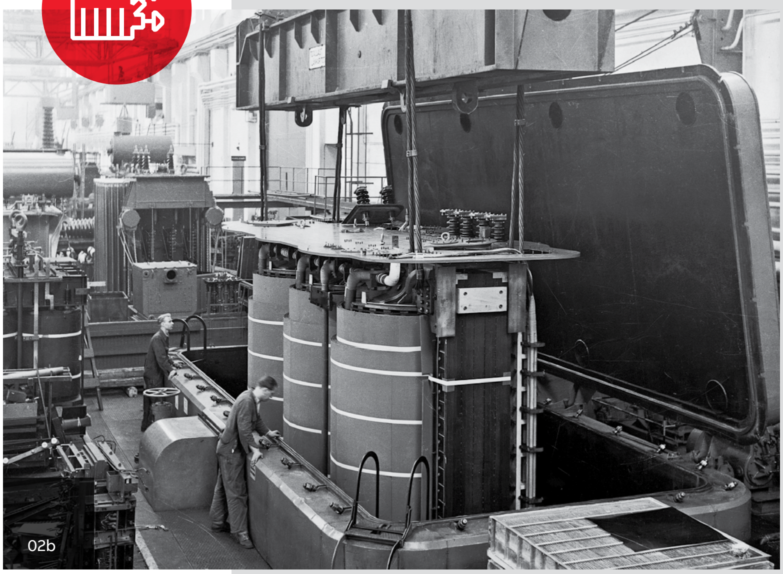
02a

for AEG in Germany) and, in Sweden, Jonas Wenström.

These inventors all adopted the three-phase system. As with two-phase, three-phase machines permit a constant transfer of power. Additionally, because the sum of the voltages of the three phases is zero, the neutral cable can be eliminated for balanced loads. Three cables can thus carry three times the power that a single-phase system based on two cables can carry, opening the door to huge savings in construction costs for transmission lines.

As a side note, while working for AEG, Dolivo-Dobrovolsky, partnered with another pioneer, Charles E.L. Brown, working for MFO (Maschinenfabrik Oerlikon, Switzerland) to build a three-phase transmission for the International Electrotechnical Exhibition of 1891, held at Frankfurt, Germany. Electricity was supplied by a 175 km, 15 kV three-phase link from a generator located in Lauffen am Neckar. This installation became a landmark achievement in the history of electrical engineering, demonstrating the viability of high-voltage three-phase transmission.

That same year, Brown left MFO and, together with Walter Boveri, started his own company, Brown Boveri & Cie (BBC). BBC acquired MFO in 1970, and merged with ASEA to form ABB in 1988. In 1989 the transmission and distribution business of Westinghouse was also acquired. ABB could thus lay claim to the heritage of several of the great pioneers →02b.


02b

02

—
03 One of Wenström's patents (source: scan from Google Patents). Motors and generators remain an important part of ABB's portfolio today.

—
04 First commercial HVDC.

04a Installation of the Gotland cable.

04b Uno Lamm (seated), pioneer of HVDC, in the Gotland control room.

UNITED STATES PATENT OFFICE.

JONAS WENSTRÖM, OF ÖREBRO, SWEDEN.

DYNAMO-ELECTRIC MACHINE.

SPECIFICATION forming part of Letters Patent No. 292,079, dated January 15, 1884.

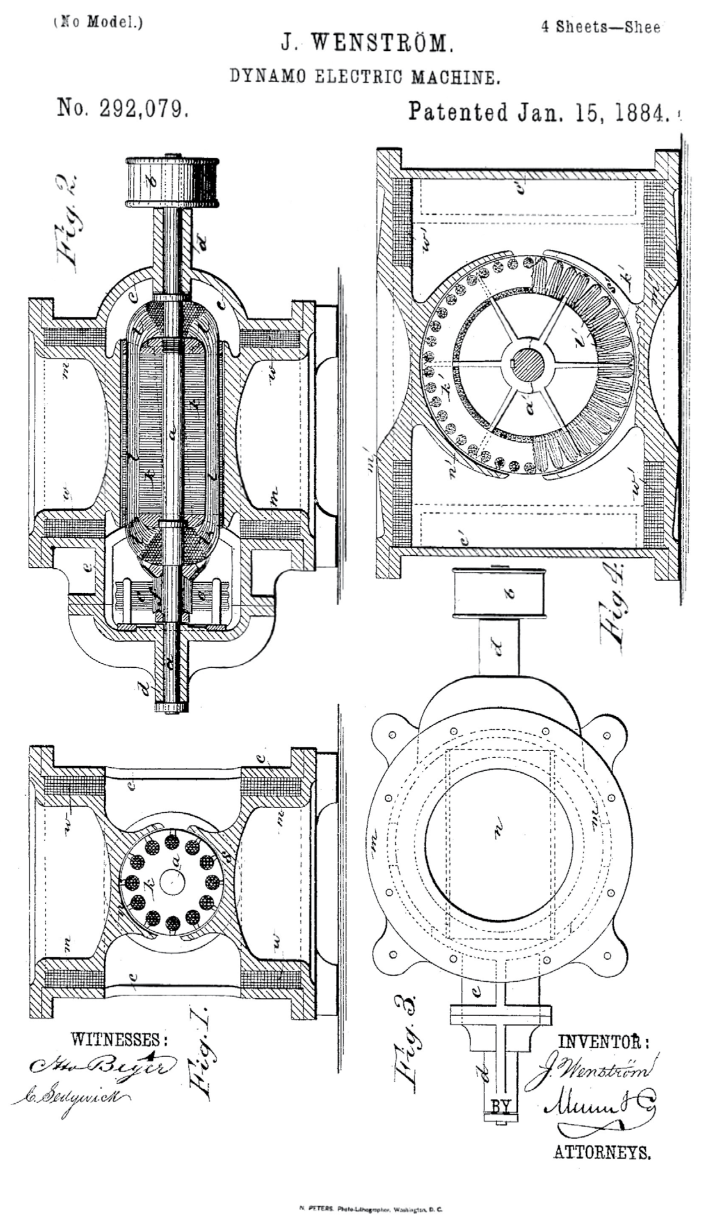
Application filed December 7, 1882. (No model.) Patented in England October 10, 1882, No. 4,819; in France November 9, 1882, No. 151,999; in Sweden November 25, 1882, No. 409; in Belgium November 27, 1882, No. 59,676; in Austria-Hungary March 28, 1883, No. 11,903 and No. 21,432, and in Norway May 23, 1883.

To all whom it may concern:

Be it known that I, JONAS WENSTRÖM, of Örebro, Sweden, have invented a new and Improved Dynamo-Electric Machine, of which the following is a full, clear, and exact description.

The object of my invention is to utilize the excited magnetism more completely than is done in machines constructed heretofore, and by so doing I am able to reduce the quantity of wire upon the field-magnets and the resistance in the same, whereby I obtain the same result with less velocity and power, and consequently at a less cost of construction and operation than in any other machine in use

shaft *a* is rotated by a belt running over a pulley, *b*, mounted on the said shaft *a*. The electro-magnets used heretofore generally consisted of iron cores covered with wire. In such machines a large quantity of magnetism is excited around them, and as this magnetism is not used it causes a great loss. In my improved machine, on the contrary, the bulk of wire is enveloped in iron, and the excited magnetism will in all directions meet iron for conducting it to the place where it is wanted and will be advantageous. The excited iron at the same time serves as a frame-connection between all parts of the machinery, allowing the armature to move freely between the polar



03

04a

FIRST COMMERCIAL HVDC

High-voltage DC (HVDC) is a form of electrical transmission especially suitable for underwater and underground cables, as well as for very long-distance overhead lines. Starting in the late 1920s, ASEA became first a research pioneer, and then a world leader in this technology. The first commercial application was the 100 kV, 200 A link

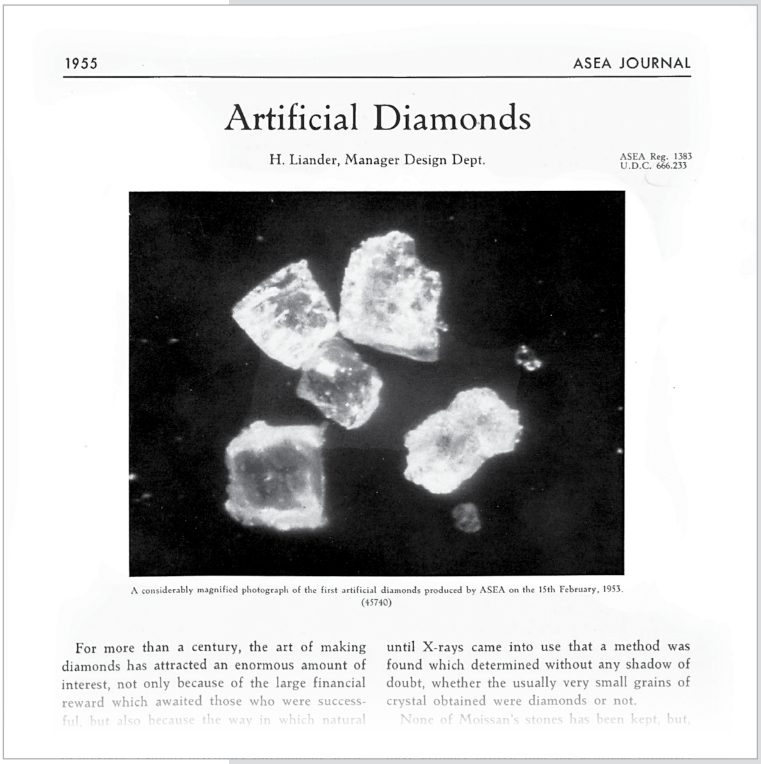
The first commercial application of HVDC was a 100 kV, 200 A link to Gotland, inaugurated in 1954.

to the Swedish island of Gotland, inaugurated in 1954 →04a [5-7]. The link's converter stations used mercury arc valves. At the time (and for many years after) ASEA was the only company in the world able to supply valves of a high enough voltage. Uno Lamm, often called the father of HVDC →04b, had been able to increase their blocking voltage by using grading electrodes to limit the spontaneous triggering of arcs.

Following the success of the Gotland project, further HVDC links followed, achieving ever higher voltages and power ratings. From the late 1960s, solid-state valves using silicon began to displace mercury. ASEA took on a leading role in developing thyristors capable of handling the required currents and voltages [8-10].

04b

In a move designed to refocus the company, ABB sold its high-voltage transmission activities, both AC and DC, to Hitachi in 2020. Medium and low-voltage AC and DC distribution remain central components of ABB's portfolio today.



1955 ASEA JOURNAL

Artificial Diamonds

H. Liander, Manager Design Dept.

ASEA Reg. 1383
U.D.C. 666.233

A considerably magnified photograph of the first artificial diamonds produced by ASEA on the 15th February, 1953.
(45740)

For more than a century, the art of making diamonds has attracted an enormous amount of interest, not only because of the large financial reward which awaited those who were successful, but also because the way in which natural until X-rays came into use that a method was found which determined without any shadow of doubt, whether the usually very small grains of crystal obtained were diamonds or not.

None of Moissan's stones has been kept, but,

05a

Download the 1955 ASEA Journal article

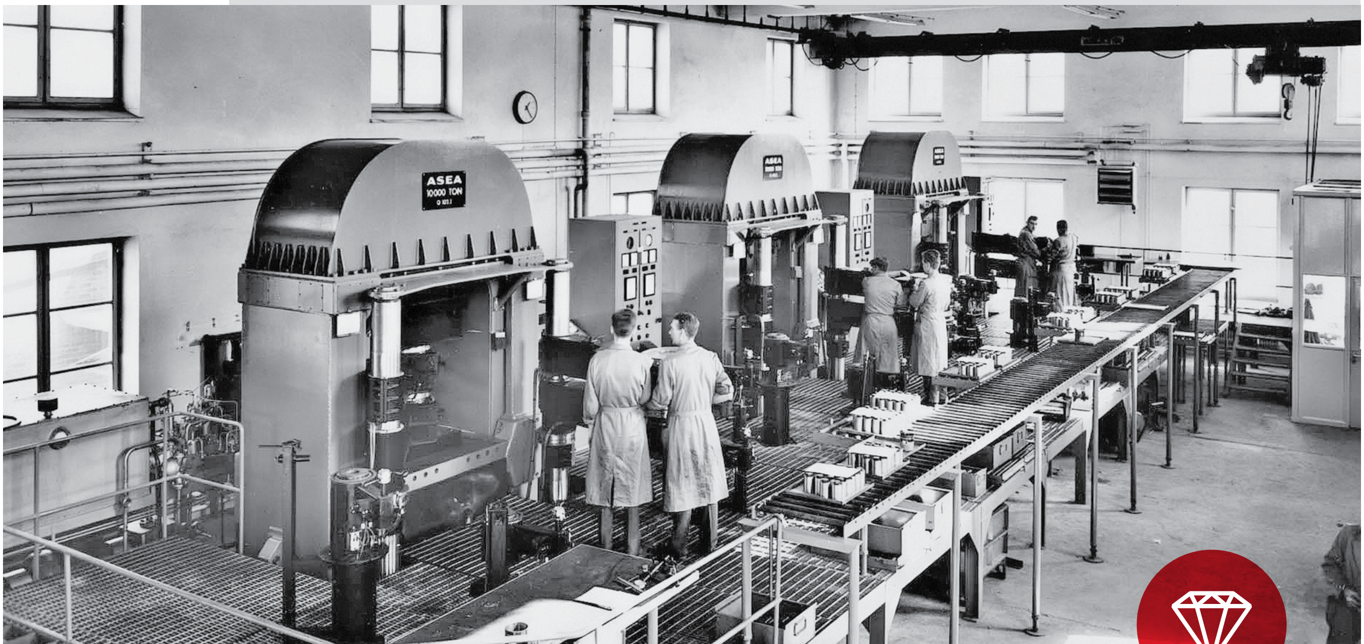
WORLD'S FIRST SYNTHETIC DIAMONDS

Following the discovery in the late 18th century that diamonds are made of carbon, there had over the years been numerous unsuccessful attempts to create them synthetically. The Swedish inventor, Baltzar von Platen, took up the challenge in 1937, realizing that the solution lay in building up sufficient pressure. In 1942 he convinced ASEA to provide financing and researchers. The project, code named 'Quintus,' was kept top-secret. Von Platen left the project in 1952, but ASEA continued the work with a team of five scientists under the leadership of Erik Lundblad [11].

Success was achieved on February 16th, 1953 at the team's lab in Stockholm, when a pressure of 8.4 GPa and a temperature of 2,200 °C were maintained for an hour, creating about 40 tiny crystals with a size of about 0.1 mm each. Four of these were sent to Stockholm University, where they were certified by X-ray investigation to be diamonds. The experiment was repeated with similar outcome on 24th May and again on 25th November.

As ASEA's goal was to perfect the process before making an announcement, the breakthrough was initially kept secret. The company's hand was forced when GE created its own diamonds in December 1954, publicizing this in February 1955. Unaware of ASEA's success, GE was claiming to be the first. ASEA responded by announcing its accomplishment in April [12], later also reporting it in ASEA Journal (a predecessor of ABB Review) →05a [13].

ASEA's diamonds were primarily used in industrial cutting tools. Production was transferred from the lab in Stockholm to a factory in Robertsfors, Sweden, in 1962 →05b. ASEA later entered a joint venture with De Beers, selling its participation entirely in 1975.



05b

05

06a

THE MERGER

In 1986, two years before ASEA merged with Brown, Boveri & Cie (BBC) →06a, ASEA employed 71,000 people, reported revenues of $6.8 billion and had an after-tax income of $370 million →06b. BBC employed 97,000 people, reported revenues of $8.5 billion, and had an after-tax income of $132 million. Seeing a vast range of matching business interests and technological synergies, ASEA and BBC agreed to merge and form a new company – Asea Brown Boveri (ABB), with headquarters in Zurich, Switzerland.

06b

06

—
05 World's first synthetic diamonds.

05a ASEA Journal article of 1955, announcing the successful production of synthetic diamonds.

05b Presses used for the production of diamonds in Roberts-fors, Sweden, 1964. According to J. Asplund [11], the employees in the photo were positioned to obscure sensitive aspects of the installation.

—
06 The merger.

06a The merger of ASEA and BBC to form ABB took effect on 5th January 1988.

06b A motor being assembled in an ASEA factory.

—

07 Robot Revolution.

07a Leif Jönsson of Magnusson AB and Lennart Benz of ASEA demonstrated the IRB 6 robot in 1974. Magnusson became ASEA's first external robot customer, using the robot to polish stainless steel pipes for the food industry.

07b The SAAB Model 99 of 1975 was an early spot-welding application.

07c ASEA's IRB 2000 arc-welding robot grabbed industry-wide attention when it hatched out of an egg at a show in Brussels in 1986.

07d ABB's FlexPicker robots are designed for quick and agile movements in picking and placing tasks (this is the FlexPicker IRB 360).

07e Launched in 2015, ABB's YuMi is designed to work alongside humans.

—

ROBOT REVOLUTION

Today, industrial robots can be found in discrete manufacturing and handling environments everywhere. The advances they have made possible in terms of increased productivity, consistency, quality and workplace safety have been astounding. But one machine in particular stands out:

—

ASEA's IRB 6 was the world's first all-electric microprocessor-controlled industrial robot.

ASEA's IRB 6, the world's first all-electric, microprocessor-controlled, commercially available industrial robot →07a. Introduced in 1974, the IRB 6 was revolutionary. Until then, hydraulics had dominated robotics. But the new machine with its 6 kg capacity, was unique not only in terms of its drive system but also in terms of its anthropomorphic configuration and its innovative use of a microprocessor for accurate control – it used an 8-bit Intel 8008 microprocessor. The new machine also set new standards in footprint size, speed of movement and repeatability.

In the decades that followed, the scope of robot applications grew, as did the range and capabilities of robots. Today, ABB is one of the world's leading robotics and machine automation suppliers →07b-e. [14-17]

07

07a

07d

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References

[1] T. Fogelberg, Å. Carlsson, "Transforming history: The ABB power transformer story," *ABB Review* 03/2007, pp. 80–86.

[2] A. Johnson, "Brainforce one: 100 years of ABB's first Corporate Research Center," *ABB Review* 03/2016, pp. 13–15.

[3] "The Swedish 380 kV System in Operation", *ASEA Journal* 1952, p. 43.

[4] "The Swedish 380 kV System", *ASEA Journal* 1953, pp. 27–29.

[5] U. Lamm, "High Voltage D.C. Power Transmission – a Pioneer Project", *ASEA Journal* 1950, pp. 172–174.

[6] U. Lamm, "The first High Voltage D.C Transmission with Static Converters: Some Notes on the Development," *ASEA Journal* 1954, pp. 139–140.

[7] G. Asplund, L. Carlsson, O. Tollerz, "50 Years of HVDC transmission: Part I, ABB – from pioneer to world leader," *ABB Review* 04/2003, pp. 06–09.

[8] G. Asplund, L. Carlsson, O. Tollerz, "50 Years of HVDC transmission: Part II, The semiconductor 'takeover'," *ABB Review* 04/2003, pp. 10–13.

[9] A. Moglestue, "From mercury arc to hybrid breaker: 100 years in power electronics," *ABB Review* 02/2013, pp. 70–78.

[10] A. Moglestue, "60 years of HVDC: ABB's road from pioneer to market leader," *ABB Review* 02/2014, pp. 32–41.

[11] J. Asplund, "The end of an era: Jan Asplund gives an overview of synthetic diamond production in Sweden," *Gems and Jewellery*, May – June 2015, pp. 24–27.

[12] J. Asplund, "The Truth, The Tales, The Disinformation and The Lies – a study on the written history on the first synthetic diamonds," self-published, January 2015.

[13] H. Liander, "Artificial diamonds," *ASEA Journal* 1955, pp. 97–98 (see also QR code on p. 244 of present article).

[14] B. Rooks, "Thirty years in robotics," *ABB Review Special report Robotics*, 2005, pp. 06–09.

[15] D. Marshall, N. Chambers, "Rise of the robot: Celebrating 40 years of industrial robotics at ABB," *ABB Review* 02/2014, pp. 24–31.

[16] P. Crowther, "YuMi: Introducing the world's first truly collaborative dual-arm robot that will radically change assembly lines," *ABB Review* 03/2015, pp. 06–11.

[17] T. Lagerberg, J. Jonson, "Robot bio: The life and times of the electrical industrial robot," *ABB Review* 03/2016, pp. 41–44.

07b

07c

07e

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FURTHER READING

On the history of ASEA

Från Wenström till Amtrak: profiler och händelser ur Aseas historia, ASEA AB, Västerås 1983.

A. Moglestue, "From the ASEA archives: Looking back on more than a century in print," *ABB Review* 01/2015, pp. 62–66 (QR code below).

On the history of BBC

T. Lang, .N. Wildi, Industriewelt; Historische Werkfotos der BBC, NZZ-Libro, Zurich 2006.

D. Siegrist, "125 years and a centennial: ABB celebrates 125 years' existence in Switzerland and 100 years of corporate research," *ABB Review* 03/2016, pp. 06–12 (QR code below).

On industrial robots

L. Westerlund, The Extended Arm of Man: A History of the Industrial Robot, Informationsförlaget, 2000.

Watch a video on the anniversary

Share this article

Photo fig. 07b: SAAB AB

Vision and detection

Can new technologies see and collect more actionable data from industrial facilities and work sites? Yes, but it takes experience, industry knowledge, and the application of cybersecurity and oversight to turn that data into performance and sustainability benefits. That innovation is going on today, and it's producing successes that could be tomorrow's standards.

250	**Change the way you look** How a vision system can tirelessly support ships' lookouts
256	**One-stop analyzer** Real-time measurement of gas contaminants using laser-based spectroscopic analysis
262	**Twin benefits** Optimizing the operation of variable speed drive systems
268	**Integrated solutions** The future of mine electrification
274	**Extending the safety net** Bringing cyber security into the OT domain with SIEM

HOW A VISION SYSTEM CAN TIRELESSLY SUPPORT SHIPS' LOOKOUTS

Change the way you look

Ports are busy, and getting busier. Merchant vessels are getting bigger. According to figures published by the United Nations Conference on Trade and Development (UNCTAD), between 2020 and 2021, median vessel turnaround time in port increased by 14 percent [1] while the average annual growth rate of cargo shipping is estimated at around 2.1 percent between 2023 and 2027 [2]. An ABB research program helps navigate the uncertainties.

Congested ports and crowded shipping lanes bring higher risks to vessels and added pressure on crews. Augmenting the crew's skills with technology brings safety benefits both to commercial vessels applying the technology and pleasure crafts sailing the same waters.

Modern navigation is heavily reliant on human perception. However, human senses are sub-optimal for slow, continuous, or wide-angle observations [3]. Research shows that despite their excellent ability to handle uncertainty, solve problems with creativity, and apply their knowledge and experience in making judgements, mortals are, nevertheless, fallible. A significant percentage of marine accidents are, to some extent, caused by human lapses[4]. Causes include crew fatigue, which can be improved by adopting new technology. To enable ships to see and monitor their surroundings – a pre-requisite for remote control and autonomous operations – several technologies are employed together to deliver a viable and trustworthy solution. Such solutions further enhance human experience and support crews in their safe vessel handling and accident avoidance.

One central navigational task is the lookout: the continuosly observing the surroundings with the purpose of early detection of any hazard to navigation. Human lookout is done by the crew, aided by binoculars. Other technologies contributing to safe navigation include Automatic Identification System (AIS) and marine radar. The current practice has some evident limitations. The lookout on duty may miss a nearby vessel due to the challenges of detecting slow and gradual change, or by having to focus on multiple targets simultaneously or for an extended time. Small craft may not be equipped with an AIS and may also be missed by the radar due to a low radar signature. Moreover, bigger vessel's radars typically have blind areas in close-range around the vessel since the radar is meant to detect targets far and early rather than close and last-minute. Radar is most often positioned on top of the bridge and has limited vertical field of view (FOV), so it will inevitably have a minimum range that is typically several hundreds of meters. History shows us that to increase safety, we need to look at things differently. As the author Wayne Dyer wrote "If you change the way you look at things, the things you look at change [5] In →01b a smaller vessel is depicted docked alongside a larger vessel and is therefore difficult to distinguish with a marine radar, but by changing the way we look at the scene, the things we are looking at have changed: the vision-based system is able to detect both the small and the large vessels.

—

Human senses are sub-optimal for slow, continuous, or wide-angle observations.

Leveraging machine perception and automation systems can change the way we look at things, enabling safer, more efficient maritime operations. A system of cameras and machine perception algorithms can fill current gaps by providing continuous, relentless, lookout, water clearance functionalities (WCF), detect small obstacles and cover blind zones not visible from the bridge.

An important task vital to navigation is accurate determination of water clearance: calculating the distances from the hull outline of the ego-ship to obstacles. This is particularly relevant during maneuvering in the harbor or navigating in confined waters. This could be done by relying on a global navigation satellite system (GNSS) and accurate charts. However, loss of GNSS would leave the ship without vital information and, depending on the frequency and precision of survey data, charts can vary greatly in their accuracy. Restricted bridge visibility requires additional crew during docking and tug operations; the bridge crew relies on subjective data about size and distance of obstacles, communicated via walkie-talkie.

Monocular-vision system

Today, novel algorithms empowered by modern hardware allow machines to process visual input and to perform complex perception tasks. State-of-the-art deep learning methods rely on neural networks with millions of parameters. The architecture of neural networks is tailored to the specific detection task. Modern hardware enables training of such huge neural networks. The resulting model can fulfil perception tasks including object detection and semantic segmentation. Machine learning methods are then used in combination with computer vision and signal processing techniques to bring value to the end user and support crew safety.

This research focuses on a monocular-vision system, ie, a single-camera system. This technology has been chosen in order to focus on bringing additional value to existing onboard cameras. Often a single camera is already installed and ABB's technology can utilize this. This simple and relatively inexpensive hardware has the benefit of being easily understood by humans, as well as being usable by computers. The systems presented here are comprised of multiple components, and one of the main challenges was to

—
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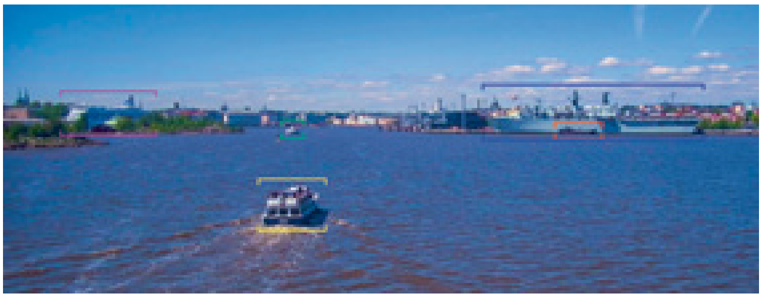

01b

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ensure that all of them operate in real time. This kind of functionality requires careful management of data flows from multiple sensors and balancing of algorithm execution between the main CPU and graphical processing units.

Convolutional neural networks
Object detection and semantic segmentation technologies are related to computer vision and image processing. The cutting-edge of these technologies are models based on convolutional neural networks. These networks are based on many convolution kernels that slide along the input feature maps and provide the output feature maps. As these kernels have many parameters that need to be tuned, a large quantity of images are required. To address this challenge, ABB collected and annotated tens of thousands of domain-specific images [PAT-1]. To improve the generalization, the images were recorded in different conditions and locations, both onboard and offboard. The vessel from which the onboard recordings are made and where the electronic lookout and WCF are operating is referred to as the 'ego-vessel'. When possible, a proprietary software was used to record images. The time of the day, the location and speed of the ego-vessel were used to start and to stop the recording process.

The goal of object detection is to detect all instances of objects from one or more classes. When it comes to marine applications, object detection is often used to detect different types of vessels and marine objects. They include but are not limited to sailing vessels, passenger vessels, and cargo vessels. Furthermore, sailing vessels may include engine and non-engine powered vessels. Differentiation between them is important for collision avoidance applications since engine and non-engine powered vessels behave differently and should be treated differently in line with the COLREGs rules.[1)]

—

"If you change the way you look at things, the things you look at change."
Wayne Dyer

Semantic segmentation is of vital importance for WCF as it enables the assigning of a class label for each pixel in the image. For example, this technology allows to the differentiation between pixels that belong to the following classes: vessel, water or land. Segmentation of water is used to estimate the water clearance, while joint segmentation of vessels and water is used in combination with object detection for vessel-water interface localization [PAT-2]. This interface is used to estimate locations of target vessels in the world coordinate system.

Camera calibration
A monocular imaging system is used to estimate locations of target vessels in a world coordinate system. As this system is calibrated with respect to the sea plane, image points on the vessel-water interface are back-projected from the camera to the sea plane. The back-projected points define the location of each target vessel. In this step, it is important that the camera is calibrated. Camera calibration entails both intrinsic and extrinsic parameters. Intrinsic parameters are usually calibrated in a lab. Extrinsic parameters need to be calibrated after installing the camera onboard, during commissioning of the system [PAT-4]. Any ship motions during operation need to be accounted for to ensure accurate back-projection. This may be done by utilization of an inertial measurement unit (IMU) or with a vision-based attitude estimation algorithm [PAT-5].

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Footnote

[1)] COLREGs stands for the Convention on the International Regulations for Preventing Collisions at Sea; it was adopted in 1972 and entered force on July 15, 1977.

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01 Examples of images recorded by the lookout camera installed on Suomenlinna II, a small passenger ferry connecting Helsinki to Suomenlinna Island.

01a Many targets, some small and not transmitting AIS, are moving ahead of the navigating vessel.

01b Ahead, a small support vessel is docked on the side of a larger navy vessel.

01c Small and very fast recreational jet skis are unpredictably maneuvering in the vicinity of the navigating vessel.

—

02 Example of images from MS Finlandia while approaching Helsinki, in which a vessel navigates from the port to the starboard side of the ego-vessel.

—

03 Range and bearing estimated with the monocular system. Comparison of estimated value with AIS-based ground truth.

—

04 SOG and COG estimated with the monocular system. Comparison of estimated value with AIS-based ground truth.

The locations of the target vessels are fed to a multiple target tracker. Each target is tracked with a filter able to capture target dynamics and provide estimates of target position, speed over ground (SOG), and course over ground (COG). Such estimated quantities can be used, for example, to determine the closest point of approach (CPA) and time to closest point of approach (TCPA) of target vessels in relation to the ego-vessel.

The marine environment poses some unique challenges to a digital vision system. Atmospheric conditions including harsh light conditions, dense fog, and heavy rain limit the capabilities of cameras. Other sensing technologies including non-visible wavelengths could be chosen in such scenarios in the future.

Electronic lookout

The images at →01 are from the Suomenlinna II, a small passenger ferry connecting Helsinki, Finland, to Suomenlinna Island. The camera is installed on the vessel at a height of approximately 10 meters above the water line and has a horizontal field-of-view of approximately 60 degrees. The images exemplify some of the situations where an electronic lookout can bring significant value: in →01a many targets are moving ahead of the own vessel, several of those are small targets which are not transmitting AIS and may be undetected to radar; →01b ahead a small support vessel is docked on the side of a larger navy vessel. A radar would hardly be able to distinguish the two targets, but the vision-based system is able to do so. On the left a ferry ship is detected despite being partly occluded by an island; →01c small and very fast recreational jet skis are maneuvering unpredictably in the vicinity of the ego-vessel, electronic lookout can monitor them continuously.

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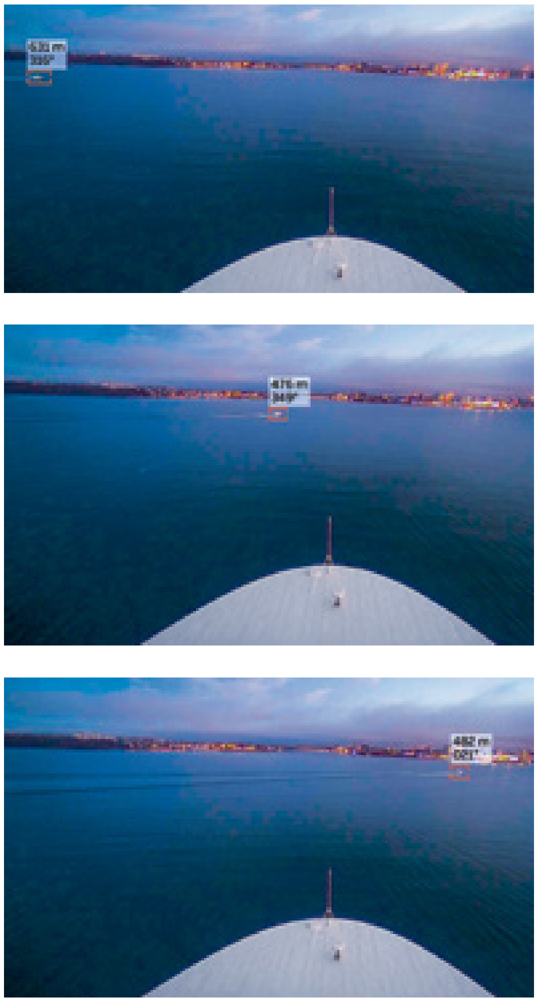
Today, novel algorithms allow machines to process visual input and to perform complex perception tasks.

At →02, depicted are a sequence of images from the lookout camera of Merchant Ship (MS) Finlandia, a ROPAX (roll on – roll off passenger vessel) that operates between Tallinn, Estonia and Helsinki, Finland. The camera is installed at a height of approximately 30 meters and has a horizontal field-of-view of approximately 115 degrees. In the sequence, a motorboat



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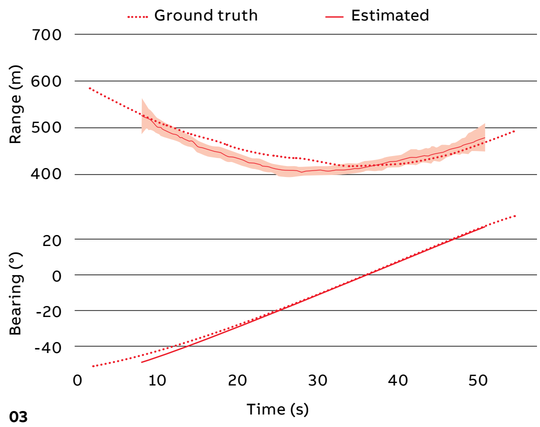

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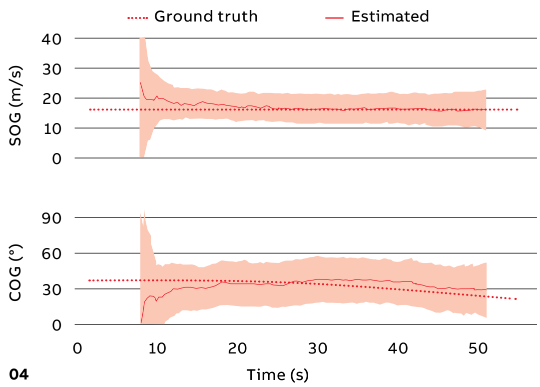

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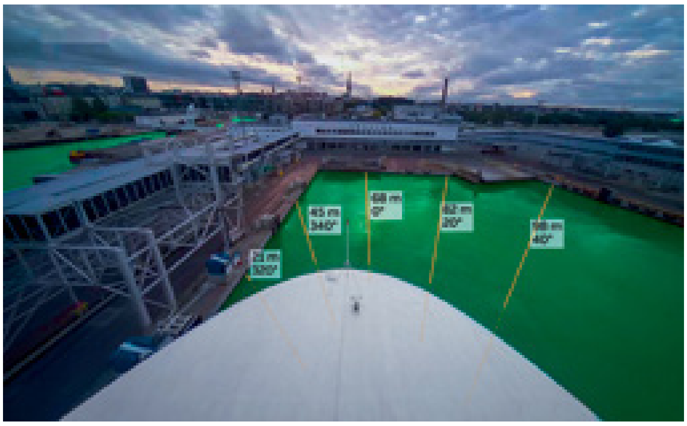

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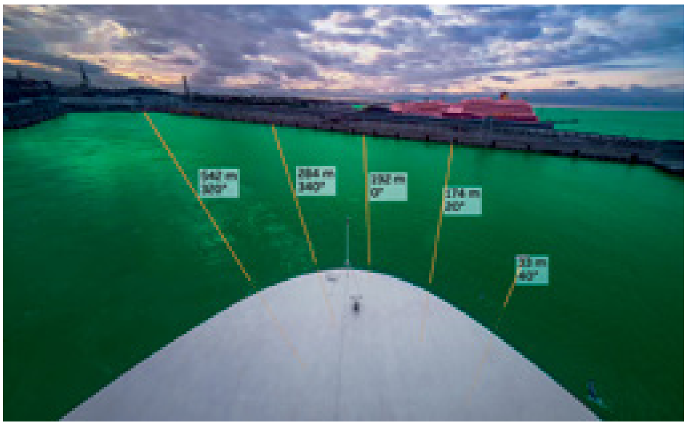

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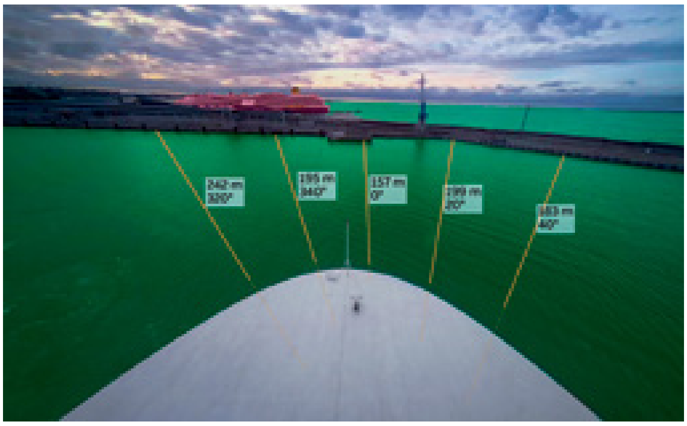

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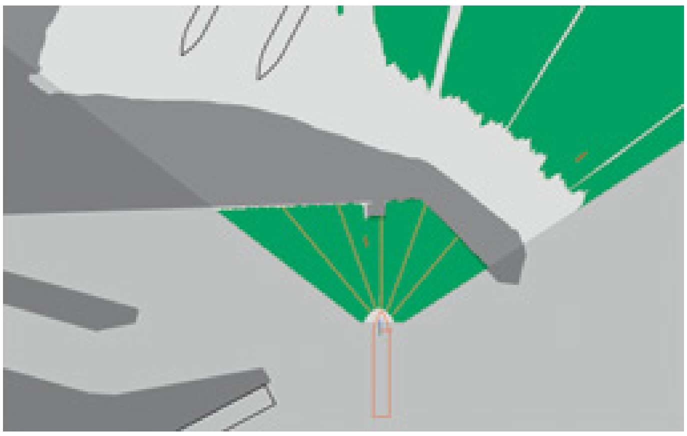

06

navigates from the port to the starboard side of the ego-vessel. The motorboat is detected. Bounding boxes depict the corresponding detections. Furthermore, the detected vessel is tracked by the vision system while within the field of view. The resulting track is compared to the corresponding AIS track. The comparison of range and bearing can be seen at →03, while →04 shows the comparison for SOG and COG. In both →03 and →04 the shaded area represents the uncertainty from the tracking filter (one standard deviation). The distance of the target vessel in this example ranges from approximately 400 m to approximately 600 m, while the SOG of the target vessel is approximately 15 m/s. The error in the estimated range is below 10 percent. SOG and COG estimates provide the input needed for CPA and TCPA calculations.

Water clearance

A sequence of images captured from the lookout camera of MS Finlandia while leaving Tallinn harbor are shown at →05. The ship is docked bow first and while exiting the harbor, she reverses and makes a 180 degree turn within the harbor. In the sequence of figures, the water is depicted in green, corresponding to the output of the segmentation network. Orange lines and their respective labels show the clearance between

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A monocular imaging system is used to estimate locations of target vessels in a world coordinate system.

the hull and the first obstacle along pre-defined directions. →06 shows a map of the water overlaid with the harbor structures. Such visual and numerical information about water clearance can provide valuable input to the crew during maneuvering or it can be used to further improve safety of autonomous operations.

The estimated clearance along the centerline is compared with the ground truth in →07. Ground truth is computed from charts and GPS-based ego-vessel position. The relative error is below 5 percent, accepted as more than sufficient in many applications. The small discrepancy, around 300 seconds, is due to a loading ramp that is not present in the charts used for the evaluation. This shows an advantage of this technology compared to relying on charts, which may be outdated at the time of use. Another advantage lies in the reduced cost of this technology compared to a LIDAR-based alternative.

05 A sequence taken from the lookout camera of MS Finlandia while leaving one of Tallinn's ports. The water clearance map and the directional clearances are computed in real time from the camera stream.

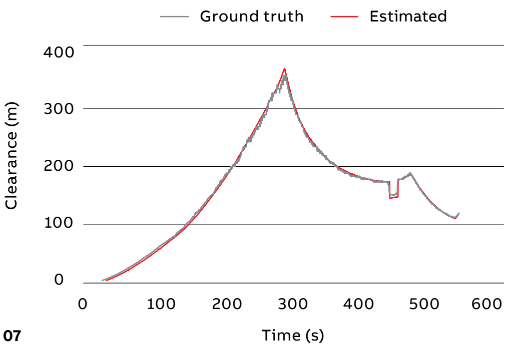
05a MS Finlandia about to cast off.

05b MS Finlandia just after casting off.

05c MS Finlandia commencing turn to starboard, within one of Tallinn's ports, towards exit.

06 Water clearance map corresponding to →05b. Water is depicted in green. For comparison, harbor structures from the nautical chart are shown in dark gray.

07 Estimated water clearance and ground truth along centerline for the sequence shown in →05.



07

Marine Pilot Vision
The research presented in this article is central to the development of more autonomous solutions for vessels. ABB Ability™ Marine Pilot Vision is part of the ABB autonomous solutions portfolio. It provides enhanced situational awareness by combining information from a range of sensors and other information sources for both the human operator and for autonomous control functions.

ABB Ability™ Marine Pilot Vision can provide a solution that does not rely on any external infrastructure. Image stream from cameras can be analyzed, and the map of the water clearance around the vessel can be calculated. Clearance from the hull to the closest quay or floating obstacle can be defined [PAT-3].

Vision-based water clearance is used for docking assistance and harbor maneuvering, providing clearance measurements from desired points on the hull's waterline towards desired directions. Docking cameras allow monitoring of areas not visible from the bridge. Water clearances can be visualized in Marine Pilot Vision's Chart and Camera Views. Vision-based vessel detection is used to support other target sensing functions (eg, AIS and radar), to extend detection coverage to vessels without AIS, vessels with low radar signature and to sectors which the human user is not observing constantly. Detections can be used for Lookout Assistance and for Target Tracking in short ranges. Localized detections are visualized as part of Lookout Assistance in Marine Pilot Vision's Chart and Camera Views.

The way ahead
The first functionalities resulting from this research are already being demonstrated in pilot projects on ferries in Scandinavia and tugs in the US. These projects allow a great deal of data to be collected and learning to be made to further the development of these systems, enabling a wide-scale commercial use of such products. There is a clear interest of progressive vessel operators to support the day-to-day operations of their crew with situational awareness systems. Yet, there is still a way to go from a regulatory standpoint before such technology can be viewed as a tool that can be considered as a full crew member.[2)] The research will enable the potential of vision-based solutions, in this case a monocular-vison system, and their benefits when integrated into the suite of marine safety systems. In addition to bolstering marine safety, such vision-based solutions are an enabler for increasing future autonomy in the shipping industry. •

First functionalities resulting from this research are being demonstrated in pilot projects in Scandinavia and the US.

Footnote

[2)] ABB and the One Sea partners use the expertise they gain through the development of these technologies to identify regulatory requirements of electronic lookouts and other situational awareness systems towards the International Maritime Organisation (IMO). This supports the development of the regulatory framework that will be released in 2028. One Sea Association is a non-profit global alliance of leading commercial manufacturers, integrators and operators of maritime technology, digital solutions and automated and autonomous systems. The association engages in the development of the international legal framework and participates in the standardization work [6].

References

[1] United Nations Conference on Trade and Development. (2022). (rep.). *Review of Maritime Transport* (p. 62). Geneva.

[2] United Nations Conference on Trade and Development. (2022). (rep.). *Review of Maritime Transport* (p. xvii). Geneva.

[3] K. Tervo, "Navigating the future", *ABB Review* 02/2022, pp. 10–17.

[4] R. Hamann & P. C. Sames (2022) Updated and expanded casualty analysis of container vessels, Ship Technology Research, DOI: 10.1080/09377255.2022.2106218

[5] D. W. Dyer, *Power of Intention: Change the Way You Look at Things and the Things You Look at Will Change*. Hay House Uk Ltd, 2004.

[6] https://one-sea.org/

[PAT-1] "Method for labelling a water surface within an image, method for providing a training dataset for training, validating, and/or testing a machine learning algorithm, machine learning algorithm for detecting a water surface in an image, and water surface detection system", European Patent Application no. EP22180133.5, Filed June 21, 2022.

[PAT-2] "Method for determining a vessel-water interface, and method and system for determining a positional relationship between an ego vessel and a target vessel", European Patent Application no. EP22180131.9, Filed June 21, 2022.

[PAT-3] "Method and system for determining a region of water clearance of a water", European Patent Application no. EP22212496.8, Filed Dec. 9, 2022.

[PAT-4] "Method and a system for calibrating a camera", European Patent Application no. EP22200130.7, Filed Oct. 6, 2022.

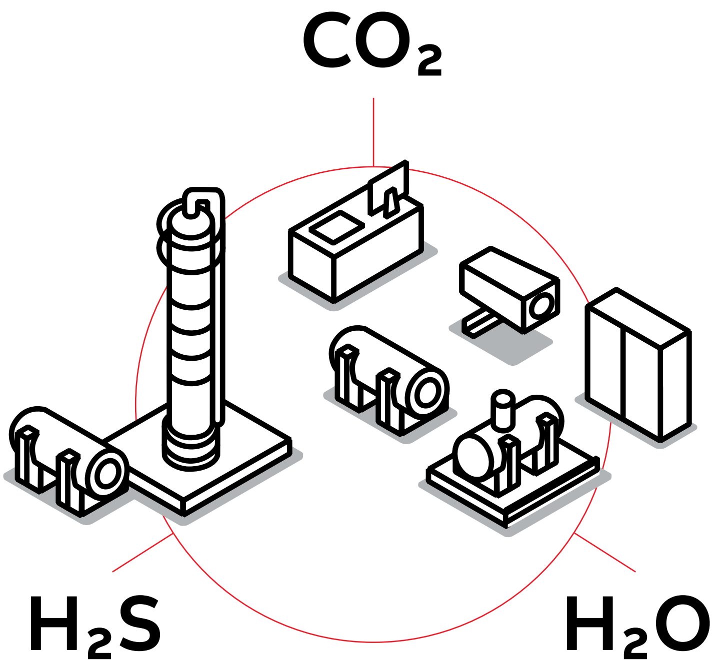
[PAT-5] "Method and system for determining a precise value of at least one pose parameter of an ego vessel", European Patent Application no. EP23158743.7, Filed Feb. 27, 2023.

Share this article

REAL-TIME MEASUREMENT OF GAS CONTAMINANTS USING LASER-BASED SPECTROSCOPIC ANALYSIS

One-stop analyzer

ABB has introduced Sensi+™, a compact natural gas contaminants analyzer that is based on a unique tunable diode laser (TDL) technology known as Off-Axis Integrated Cavity Output Spectroscopy (OA-ICOS). The technology accurately, reliably and simultaneously measures corrosive substances such as hydrogen sulfide, carbon dioxide and water →**01-02** in real time in complex and time-varying natural gas streams.



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01 Sensi+ protects natural gas pipelines, storage facilities, and other mission-critical assets.

Pipeline operators are often caught in a bind. On the one hand, they must ensure that contaminants in natural gas transmission networks are minimized because they can cause corrosion and thus potentially pose a significant hazard to an operator's business. On the other hand,

—
Hydrogen sulfide (H_2S), carbon dioxide (CO_2), and water (H_2O) represent both a safety and a pipeline integrity risk.

mitigating the risk of natural gas contaminants can often be a source of frustration, as companies are typically required to manage numerous technologies and devices to detect contaminants independently. This legacy approach is complex, failure-prone and expensive, as each contaminant requires its own analyzer, maintenance schedule and specific skill set to operate and validate.

Natural gas contaminants such as hydrogen sulfide (H_2S), carbon dioxide (CO_2) and water (H_2O) represent both a safety and a pipeline integrity risk. Left undetected, they can cause internal corrosion within the natural gas infrastructure, notably in gas pipelines and storage facilities as well as other mission-critical assets, ultimately cascading into pipeline failures. As a result, requirements in custody transfer mandate continuous measurement of these target substances. Moreover, industrial production processes cannot tolerate excessive concentrations of these substances, meaning that gas quality monitoring and control is required to meet operational objectives and production yield.

Yet today's analyzers often offer sub-optimal measurements and instrument reliability, false readings (especially during process upsets), and tedious, time-consuming maintenance in remote locations due to the use of legacy technologies (see below), such as lead acetate tape, UV analyzers, conventional TDLs and chilled mirror-based analyzers.

What follows is a look at the three major contaminants and the technologies that have been used until now to detect them.

H_2S
Raw, untreated, natural gas contains H_2S, a gas that can damage pipelines, storage facilities and gas turbines, and that poses a threat to human safety. Although the concentration of H_2S in natural gas varies geographically (from parts-per-million to percent levels), due to its toxicity, flammability and corrosiveness, H_2S must be monitored at all stages from the wellhead to the customer.

Conventional analyzers based on lead acetate tape are capable of detecting H_2S but have high maintenance requirements associated with replacing and disposing of the tapes in an environmentally safe manner and can suffer from

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02

reliability issues. On-line gas chromatographs take three to six minutes between measurement updates and therefore cannot sense rapid changes in H_2S. In addition, gas chromatographs require consumables such as carrier gas and flame fuel cylinder gases. Analyzers that employ broadband UV light sources and narrow bandpass filters are prone to interference from variations in background gas concentrations. Moreover, their lamp lifetimes are relatively short. Conventional TDL-based methods often rely on chemical scrubbing methods and a priori knowledge of the stream to operate, yet fail to offer comparable speed, sensitivity, selectivity, or accuracy and are unable to detect the variety of measured contaminant gases in a single enclosure as ABB's offering.

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Carbon dioxide can react with H_2S and H_2O to form compounds that can corrode steel pipelines.

CO_2

Carbon dioxide naturally occurs as a dilutant in oil and gas reservoirs and can react with H_2S and H_2O to form compounds that can corrode steel pipelines. In addition, excessive CO_2 levels reduce the heating value of natural gas. Thus, CO_2 levels in pipelines must be monitored and controlled when needed. Wellhead natural gas can contain as much as 30 percent carbon dioxide. Removal of CO_2 from natural gas utilizes membrane technologies or large amine plants.

Measuring carbon dioxide concentrations is required at processing plants and at natural gas custody transfer points to ensure that levels are low enough to meet quality specifications for pipeline transportation.

To date, approaches for CO_2 analysis in natural gas have included gas chromatography and absorption spectroscopy using infrared light sources or diode lasers. As mentioned elsewhere, gas chromatographs suffer from the need for

—
02 Sensi+ is a compact natural gas contaminant analyzer that accurately, reliably and simultaneously measures the three major contaminants in natural gas flows.

—
03 Representation of OA-ICOS technology in which the laser is injected off-axis into the cavity where its light reflects back and forth between highly reflective mirrors, thus interacting with the sample gas over a very long effective path length. This technique enables robust, sensitive measurements.

consumables and are slow to respond, while IR-based analyses lack sufficient sensitivity. Traditional TDL-based methods are typically single-gas analyzers that can suffer from cross sensitivity effects.

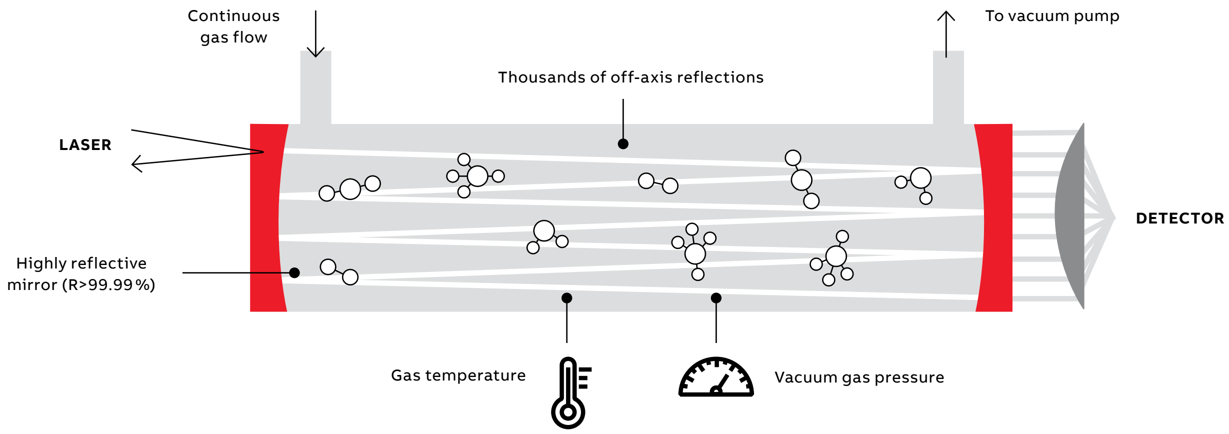
H_2O
H_2O in natural gas corrodes pipelines and exacerbates the presence of other contaminants by combining to produce acids that attack carbon-steel piping, valves and other equipment to cause internal corrosion and metal loss over time. Moreover, phase changes in water, due to temperature and pressure variations, can accelerate internal pipe corrosion.

—
Sensi+ functions automatically in a wide range of natural gas blends without any field calibration.

The measurement technologies that are traditionally employed to measure water vapor in natural gas pipelines include electrochemical and electromechanical approaches, as well as conventional TDL-based methods. However, these methods have significant limitations. For instance, electrochemical sensors are prone to drift, cross sensitivity, contamination and frequent maintenance or replacement. Quartz crystal microbalance and chilled mirror sensors are very sensitive but cannot differentiate water from other molecules that condense and are also sensitive to corrosion as the sensor is in direct contact with the gas. Chilled mirror sensors are slow to respond to and recover from upsets due to thermal equilibration timescales. In addition, similar to H_2S sensors, conventional TDL-based methods for H_2O often rely on chemical scrubbing in order to distinguish H_2O from background gases.

The Sensi+ solution
With a view to ensuring the detection of H_2S, CO_2 and H_2O, ABB has introduced Sensi+, a compact natural gas contaminant analyzer that accurately, reliably and simultaneously measures the above-mentioned substances in real time in natural gas streams. In contrast to legacy solutions, which have many drawbacks, Sensi+ offers a significant reduction in capital equipment expenditures (CAPEX) and operational expenses (OPEX), as well as space requirements. Sensi+ also functions automatically in a wide range of natural gas blends without any field calibration. In addition, the analyzer's low sample flow rate results in a very low emission rate.

ABB's unique laser gas absorption technology →03-04, which is called Off-Axis Integrated Cavity Output Spectroscopy (OA-ICOS™), enables sensitive measurements due to the kilometers of effective path length in the small cavity, while being more robust than traditional multi-pass or cavity techniques. The analyzer's modular design, modern user interface, and comprehensive system health metrics make it easy to use and troubleshoot remotely, thus reducing the need



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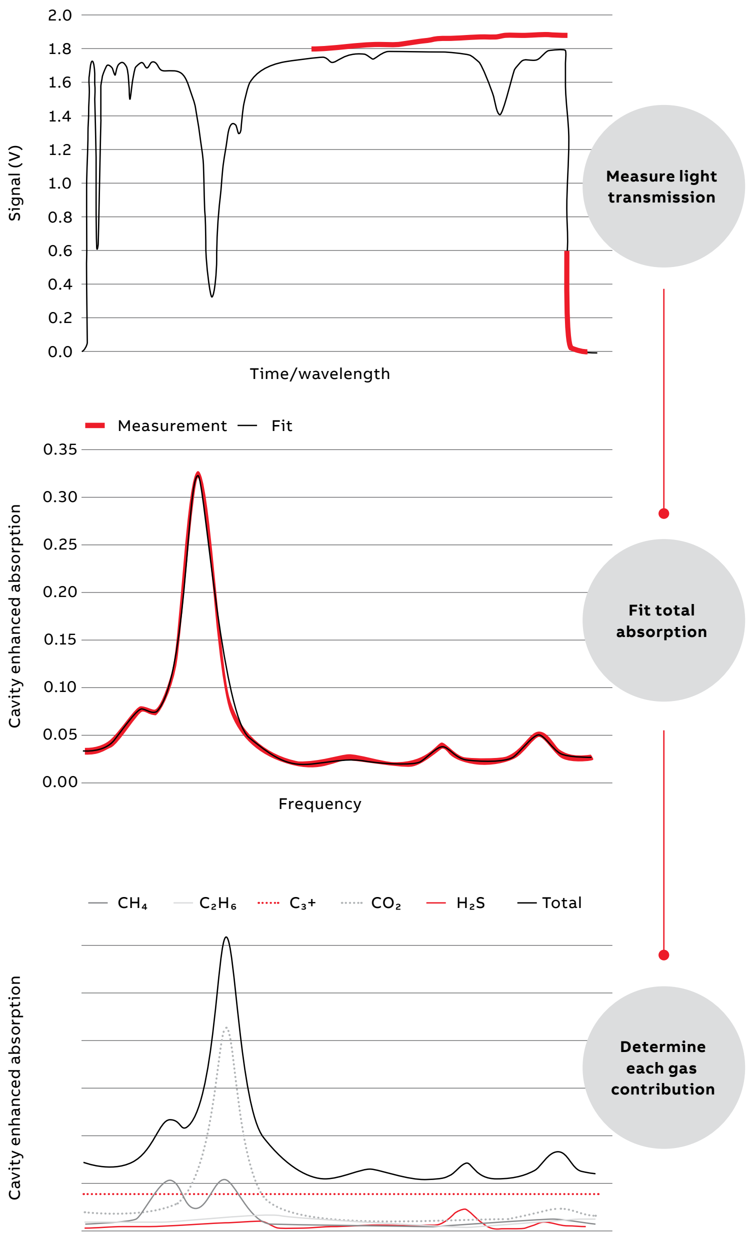

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for expensive, time-consuming nuisance site visits. This step change in analyzer design, coupled with built-in hardware redundancy features and remote diagnostics, can significantly reduce both unnecessary downtime and costly onsite intervention.

Sensi+ offers the following advantages:

- Simultaneous measurements of up to three gas contaminants. A single, compact analyzer based on multiplexed laser absorption spectroscopy saves space and obviates the need for multiple analyzers while simplifying deployment, operation and service without compromising performance.

- Fast response and recovery minimize product waste, maximize uptime and ensure facility safety and productivity. Rapid flow time response allows operators to react to process anomalies and redirect pipeline gas that contains abnormally high levels of contaminants. The analyzer recovers quickly after exposure to flows with elevated concentrations of contaminants.

- Proven laser-based technology combined with recent advances in spectroscopic analyses provide the highest accuracy, precision,

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Multiplexed laser absorption spectroscopy saves space and obviates the need for multiple analyzers while simplifying service.

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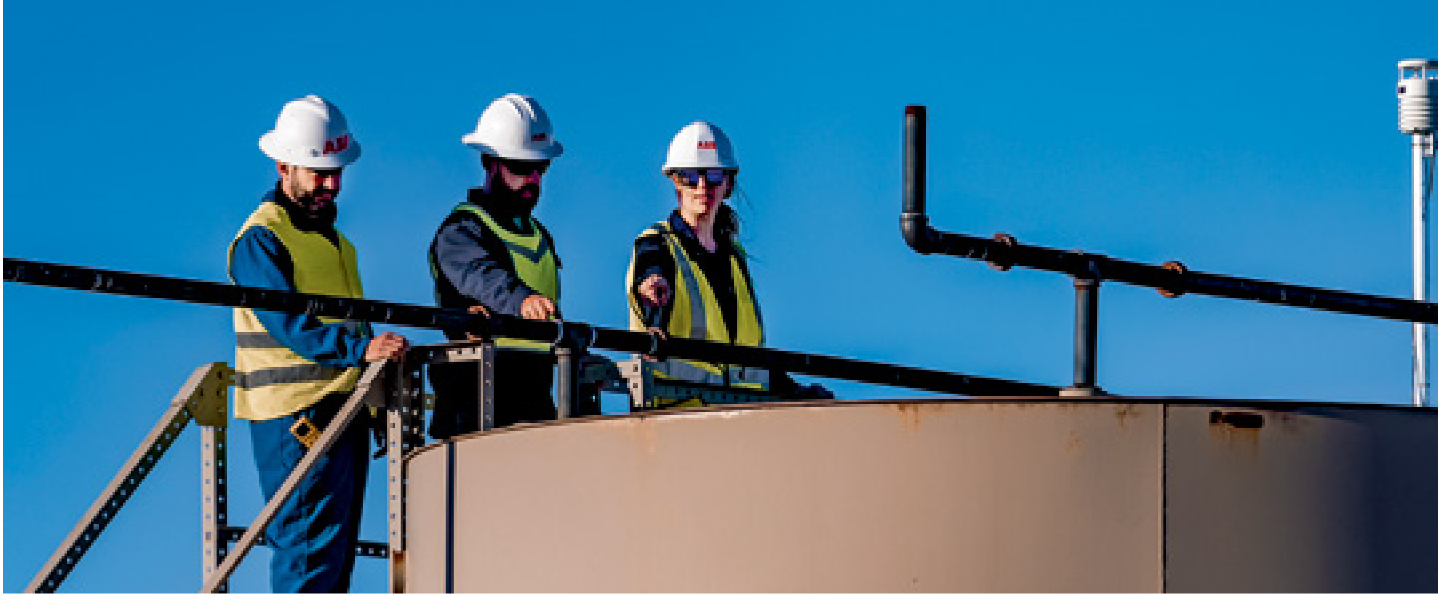

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04 Thanks to the sensitivity of OA-ICOS, coupled with advanced spectroscopic algorithms, complex natural gas absorption spectra can be separated into individual gas contributions.

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05 The Sensi+ user interface provides continuous, detailed digital health metrics in real time.

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06 Thanks to remote diagnostics, Sensi+ can significantly reduce the need for onsite intervention.

sensitivity and reliability. For over 15 years, ABB's LGR-ICOS laser absorption technology has been at the core of the world's most reliable gas analyzers used for applications requiring the highest overall performance. This technology has now been updated with customized electronics and an enclosure design suitable for hazardous area installation, along with advances in spectroscopic analysis algorithms, to yield accurate measurements in complex and time-varying natural gas blends with minimal cross interferences without any requirements for chemical scrubbers [1].

- High dynamic range allows reliable gas concentration measurements over several orders of magnitude. No other technology allows reliable measurements of contaminants at both very low and high concentrations, thus allowing reliable measurement of a wide range of applications with a single instrument.

- Rugged laser technology eliminates the need for light source replacement. ABB analyzers employ near-infrared diode lasers that provide many years of reliable continuous operation regardless of environmental conditions.

- The Sensi+ explosion-proof enclosure has been designed for easy deployment and installation in hazardous environments. Its dual seal certified feature obviates the need for an extra process seal. Furthermore, the analyzer satisfies critical global area classifications for the natural gas industry: Class I, Division 1, Groups B, C, D T6; Class I, Zone 1, AEx/Ex db IIB + H2 T6 Gb, Ex db IIB + H2 T6 Gb, ATEX/UKCA II 2 G Ex db IIB + H2 T6 Gb.

- A simple and comprehensive user interface →05 provides continuous detailed digital health metrics in real time. Modern UI design provides users with confidence regarding system health and allows fast, easy service.

- Convenient and cybersecure connectivity allows 24/7 remote monitoring using industry standard communications protocols. A secure ethernet-enabled web (HTTP) interface provides comprehensive diagnostics, instrumentation, configuration, and measurement information.

All in all, ABB's LGR-ICOS™ laser technology ensures unsurpassed measurement precision and accuracy under all process conditions while providing the highest analyzer reliability and uptime, as well as the lowest cost of ownership →06. Coupled with ABB's market-leading natural gas chromatograph (NGC) series, the introduction of Sensi+ makes ABB the first company to offer a complete gas quality solution that combines composition and contaminant measurements into a comprehensive, compact and economical measurement system. •

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No other technology allows reliable measurement of contaminants at low and high concentrations with a single instrument.

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Reference

[1] "Sensi+ GLA533-NG: Take immediate action with fast instrument response times," (ABB white paper), Available: https://search.abb.com/library/Download.aspx?DocumentID=WP%2FSensiPlus%2FGLA533-NG_ResponseTime_EN_Letter [Accessed September 13, 2023.]

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OPTIMIZING THE OPERATION OF VARIABLE SPEED DRIVE SYSTEMS

Twin benefits

How will a variable speed drive (VSD) system respond to sudden changes in its operating conditions? What is the potential risk of damage to an asset if the source and or the load change? Until now, questions like these have bedeviled engineers and forced companies to build and test expensive models. Now, however, ABB's medium voltage drive simulation twins (ST) can remove the uncertainty and risk associated with testing live hardware and ensure that nothing detrimental happens to a real-world system →01.

01

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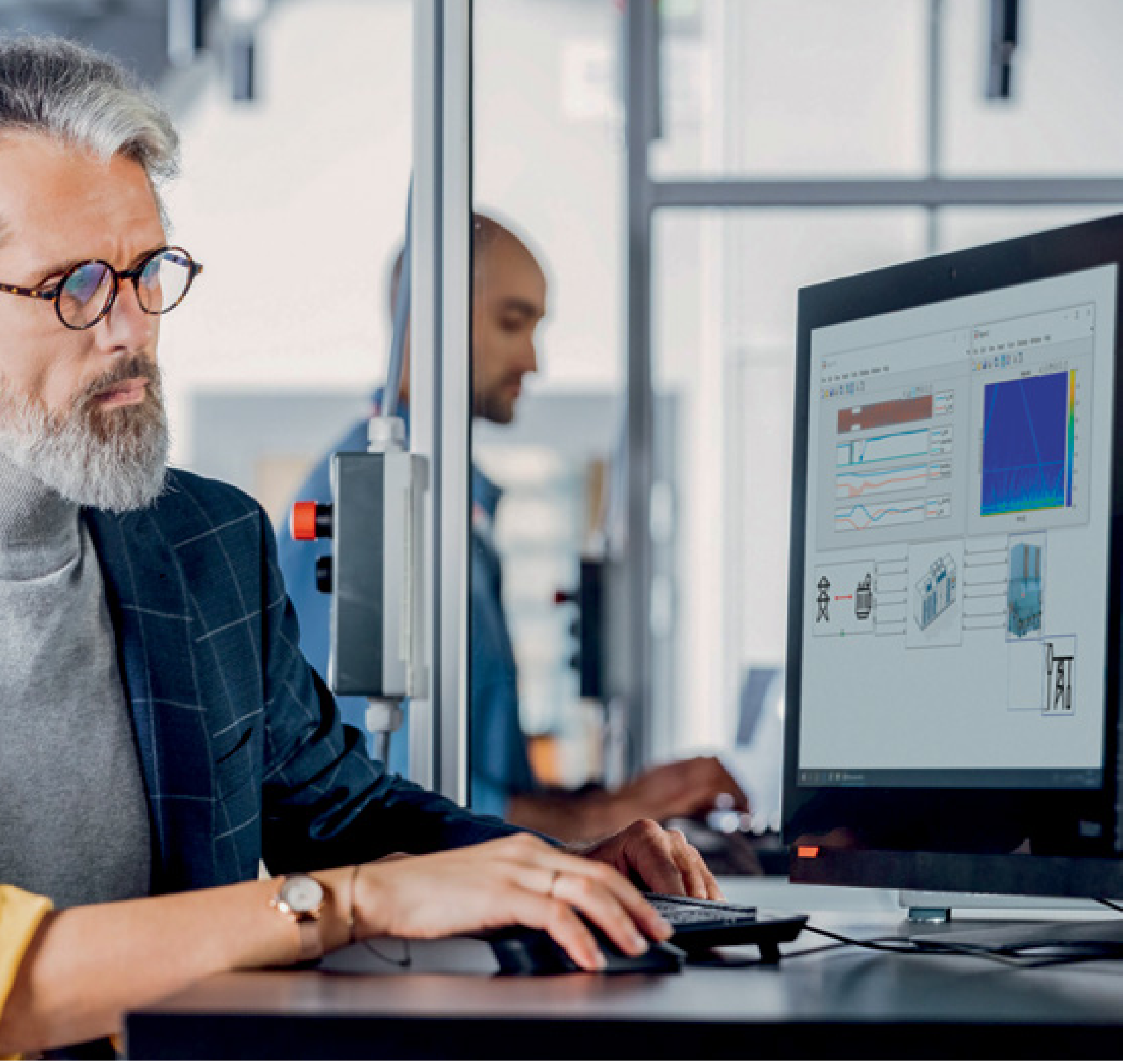
Variable speed drives are the backbone of industrial applications, transportation and energy infrastuctures – in short, most major mission critical applications →02. But with the focus generally being on the power conversion process (AC to DC and vice versa) it is easy to lose sight of complex system interactions →03 and concentrate on a single electric drive. In view of this, engineers are turning to simulation twins as the solution of choice to assess, validate and improve plant-wide performance.

A simulation twin combines a system's digital aspects with real-time aspects of how it is operated and maintained.

A simulation twin is a complete and operational virtual representation of an asset, subsystem, or system, that combines digital aspects of how equipment is built with real-time aspects of how it is operated and maintained. STs provide a safe environment to de-risk new drive system installations, expand existing plants and modernize installed equipment to the next level of performance. Be it for complex string testing, optimizing drive parameters, studying the interaction between drives and other electromechanical components, or performing power flow analyses, ABB has developed a wide spectrum of ST solutions that can match customer needs.



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01 Engineers are turning to digital twins to validate and improve plant-wide performance requirements.

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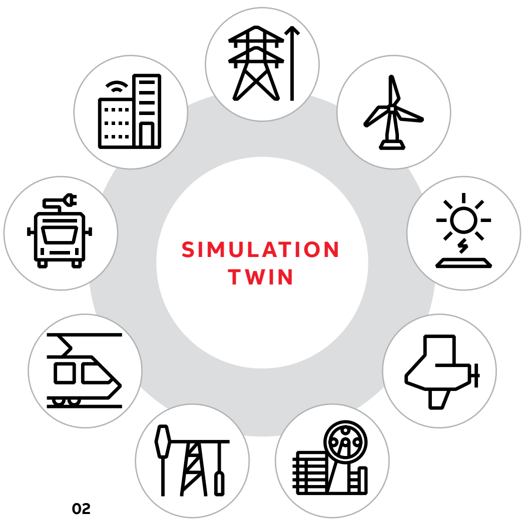
02 Mission-critical applications that benefit from the ST capabilities.

Comprehensive offering
Using a simulation twin in place of a real drivetrain system avoids excessive set-up and pre-tuning costs. It mitigates risk since any faults merely halt the simulation twin, thereby avoiding any damage that might otherwise have been inflicted if real equipment had been used. Furthermore, training of personnel to understand real hardware is simplified and less costly.

Simulation twins can also be offered as a service, whereby ABB carries out the drivetrain analysis and delivers a ready-to-use package to the customer. Alternatively, a simulation twin can be supplied to customers who wish to perform their own simulations. Whichever option is chosen, ABB experts can help determine the right solution.



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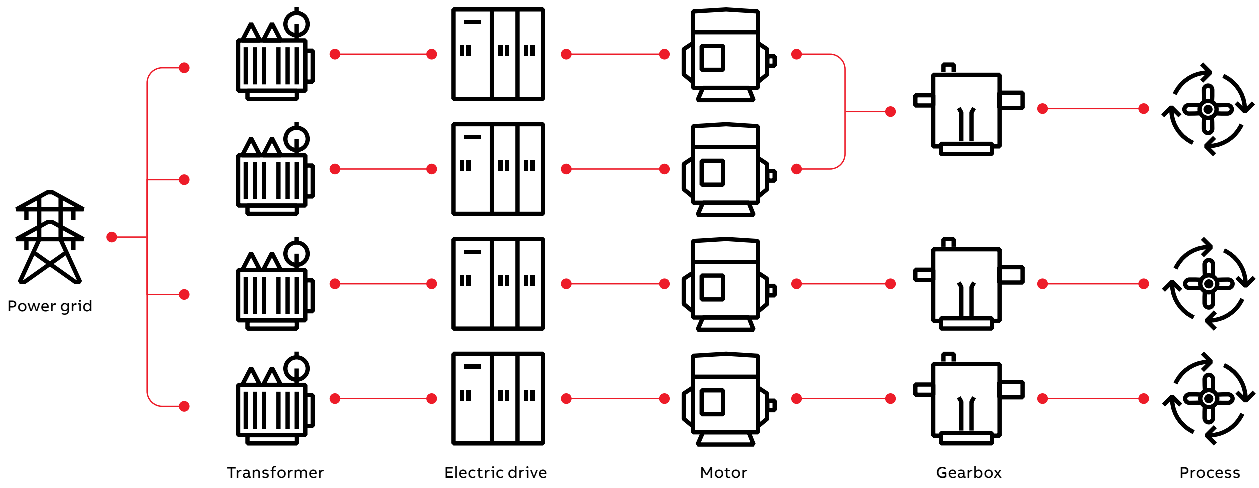

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Three simulation twins are available for medium voltage drives →04, each of which can be scaled according to the complexity of the drivetrain application and the depth of the required testing:
- Real-time simulation twin
- Virtual-time simulation twin
- Behavioral simulation twin.

These solutions present the perfect tradeoff between modelling complexity, fidelity to the real systems they represent, and portability. In each case, ABB experts support customers in picking the solution that best meets their needs.

Real-time simulation twin
At the heart of ABB's offering is the real-time simulation twin →05. This solution represents the closest physical and behavioral replica of the customer's installed asset. It is typically used in high-risk environments such as oil and gas facilities and in testing facilities where safety and the time associated with trialing equipment could prove prohibitive. The real-time simulation twin comprises a modular cabinet that provides a live, one-to-one representation of the drivetrain control and protection hardware and software. It also provides a high-fidelity simulation of the physical system, including grid, transformer, drive, motor and process. Moreover, it can be interfaced to an overriding system emulation or another twin installation. By pre-testing and verifying a complete drivetrain system, the real-time simulation twin de-risks and speeds up the entire testing process, providing results that are the closest possible to those of its real system counterpart.

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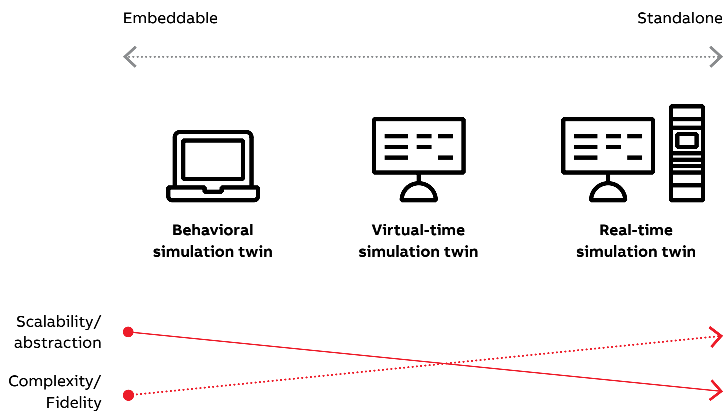
The real-time simulation twin represents the closest physical and behavioral replica of the customer's installed asset.

Virtual-time simulation twin
The virtual-time simulation twin is a PC-based equivalent of the real-time version. Here, the control hardware and software, as well as the physical drivetrain system, are fully simulated. This twin, therefore, operates in virtual time as opposed to the real-time response of a physical system. It is an ideal solution for customers in any industry that can benefit from a plant-wide analysis or assessment, especially when testing new concepts before a project is installed. It is also suitable for training personnel to understand the functionality of a real drive system and to operate equipment. The virtual-time simulation twin can be seamlessly scaled to multi-drivetrain system installations.

Behavioral simulation twin
The behavioral simulation twin provides a standalone software model that simulates any customer-defined abstraction of drivetrain functionalities, such as simplified system models and control layers. These models can be embedded into a larger simulation, for example, where power grid analysis is carried out, comprising several drives that are part of a complete network. This version can be scaled up to several hundred units and seamlessly embedded into a larger simulation environment, such as Matlab/Simulink or Power Factory, in the form of a functional mockup unit (FMU).



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03 A typical complex plant setup with several variable speed drives running multiple processes.

—
04 ABB offers three simulation twin solutions. Behavioral STs and virtual-time STs are PC-based products; real-time STs are a mixture of hardware-in-the-loop and software.

—
05 Simulation Twin control units are characterized by a modular structure.

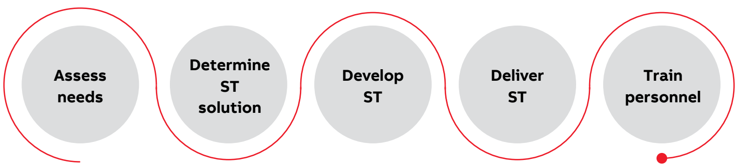
—
06 Customer journey from assessing need to delivering the ST solution and training.

Assessing which twin to choose

The first step in determining which ST best suits a customer's needs is a thorough assessment. As part of the solution development process, prior information regarding the installation is integrated into the solution. This information considers factors such as onsite operational experience, grid behavior, process requirements, and operational needs. Once the assessment has been completed, a decision is made as to which ST solution will be needed. Subsequent to this, ABB specialists model the solution, adapt the solution's software to the customer's setting, deliver the solution, and train the equipment's users →06.

Application example 1: low grid-voltage ride-through

As mentioned above, simulation twins offer a range of advantages when planning and upgrading energy and power conversion infrastructures. With the growing complexity of grid requirements and the increasing demand for power quality on installation sites, operators are often interested in analyzing and optimizing the behavior of a drive system in terms of its transient grid behaviors. For example, low voltage ride-through (LVRT) →07 is a typical metric for which conditions cannot be readily generated onsite during commissioning. Here, STs can offer the perfect environment for safe investigation and tuning of system behavior to such events.



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Application example 2: electromechanical system interaction

Variable speed drives are a key enabler of higher efficiency operations in processes based on rotating equipment – processes in which the interplay of electromechanical systems is usually so underplayed that it is lumped together as the inertia of the full drivetrain. In this case, STs can be used to simulate the drivetrain elements →08 to an extremely high degree of fidelity and hence provide detailed insights and understanding regarding various system interactions and effects on and from the grid. An example is the analysis of the torsional oscillations →09

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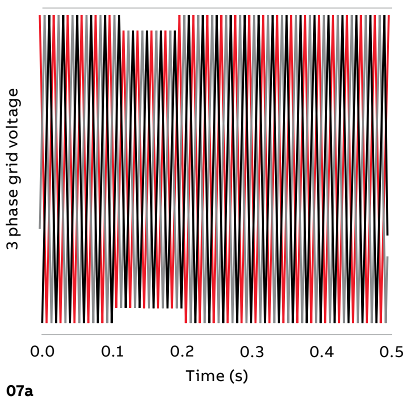
STs can offer the perfect environment for safe investigation and tuning of system behavior for events such as LVRT.



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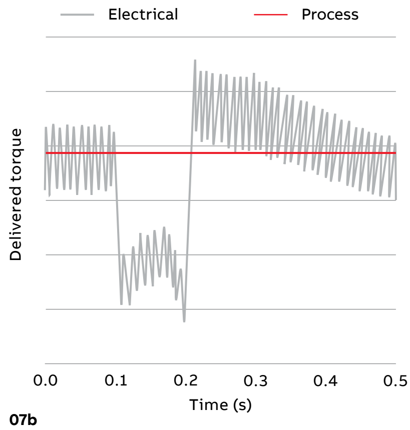

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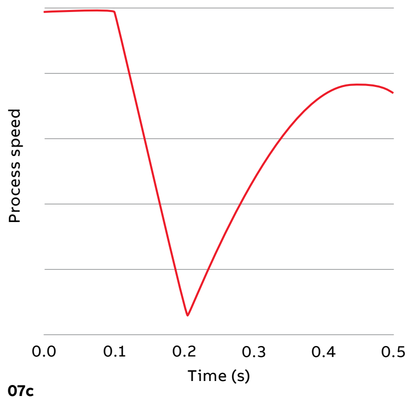

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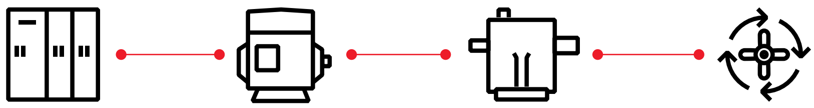

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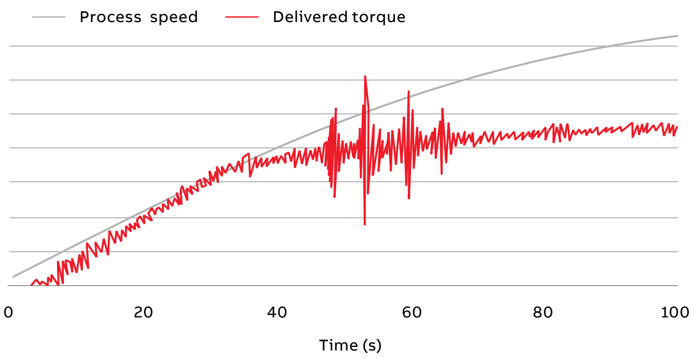

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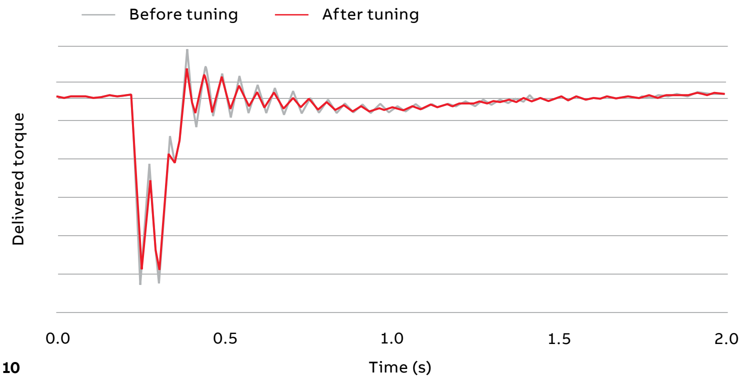

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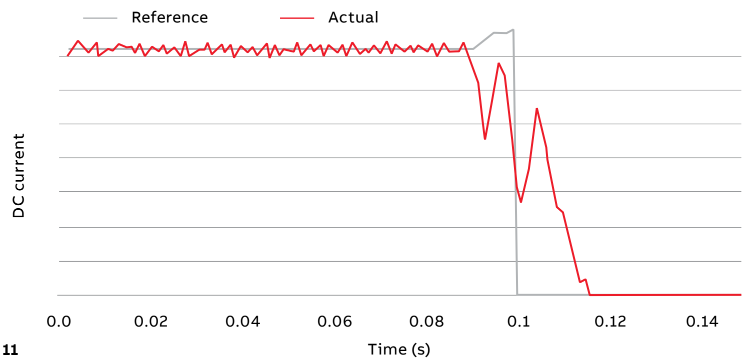

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resulting from a process speed ramp-up along any segment of a drivetrain. Once this has been achieved, STs can be used to optimize tuning of the associated controller parameters with a view to minimizing mechanical vibrations →10.

Advantage 1: Rapid anomaly identification and resolution

Maximizing uptime is a key requirement for mission-critical applications. STs can play a major role in this regard by resolving onsite issues in an efficient way. For instance, given data logger information on an issue →11, a scenario can be

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STs can be used to achieve the optimized tuning of controller parameters with a view to minimizing mechanical vibrations.

replicated in a one-to-one fashion using an ST, thus providing a high level of insight into the time-series signals from the twin model and the twin software. Experts can then evaluate the information and recommend the fastest path to resolving the issue.

Advantage 2: Integration into larger simulations

Behavioral or virtual-time STs are ideal for investigating power grid behavior in connection with disturbances, particularly because large 10–100 MW VSD loads can be a key player in overall grid behavior. For example, several versions of STs in the form of functional mock-up units

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07 Example of a low voltage ride-through behavior on MEGADRIVE-LCI: After a drop in line voltage, delivered torque to the process is reduced, resulting in a process speed transient dip.

07a Line voltage

07b Delivered torque

07c Process speed

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08 Drivetrain modelling, including electric drive, motor, gearbox, and process.

—
09 STs can provide insights regarding torsional oscillations resulting from a process speed ramp-up.

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10 ST-based optimization of damping mechanical oscillations. Proper tuning can reduce overall torque ripple during transients.

—
11 Time series from a VSD data logger showing behavior induced by an excessive grid transient event.

—
12 STs can significantly enhance the operational knowledge of technical personnel.

12

(FMUs) can be integrated into larger simulations in order to investigate events such as load flow anomalies, short circuits and harmonic network behavior.

Advantage 3: Training
STs can significantly accelerate the hands-on experience and operational knowledge of technical personnel →12. Employees can gain vast knowledge and explore a range of operational scenarios using STs, all in a safe environment. For example, it is possible to extract and visualize many signals from a system model and/or control software to gain better understanding of the various modes of steady-state or transient behavior of a drive system or fleets thereof.

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Soon, simulation twins will be trained online using streaming data and used to detect anomalies or impending plant failures.

Conclusion
As variable speed drive systems and their associated processes become increasingly complex and as grid standards become more and more demanding, simulation twins can become the solution for assessing and improving their performance. Furthermore, as their underlying models are refined over time to provide a perfect replica of installed equipment, simulation twins can become the building blocks of each new installation.

Looking ahead, simulation twins will be trained online using streaming data and used to detect anomalies or impending plant failures. This will open the door to better planning and much higher levels of plant availability. •

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THE FUTURE OF MINE ELECTRIFICATION

Integrated solutions

The mining industry is responsible for up to seven percent of all global greenhouse gas emissions. In view of this, although electrification is not an easy choice for the industry, it is not optional. Decarbonizing this sector will require an unprecedented acceleration of automation and digitization – interrelated factors that electrification is enabling.

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Mining is an energy intensive industry that requires a stable electric supply. But as the quality of ore grades diminishes and demand for raw materials increases, the industry's demand for energy is expected to increase dramatically. On the other hand, driven by the need to decarbonize their operations, mining companies are moving away from fossil fuels and increasingly

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Power quality plays a key role in the mining business in terms of ensuring equipment performance and lifespan.

investing in electrification, automation, and battery storage technologies to drive their hauling fleets, heavy machinery, and in-mine ventilation systems →01.

As these trends evolve, mining companies are relying on electric mains substations to step up the voltage from the mains power grid to supply the levels of reliable electrical power required for continuous operations. By providing a stable and consistent power supply, such stations minimize the risk of power outages or voltage fluctuations that could disrupt the activities of safety-critical electrical equipment and systems.

Naturally, associated power distribution systems are designed to accommodate future growth and increased power demand. As mining operations expand or new mines are developed, substations can be upgraded to meet evolving electricity requirements. This scalability ensures that mining operations can adapt to changing needs while maximizing production capabilities. This is of paramount importance when it comes to power quality, which plays a key role in the mining business in terms of ensuring equipment performance and lifespan.

Mining operations rely on a wide range of electrical equipment, including crushers, conveyors, pumps, and motors. These machines are sensitive to variations in power quality, such as voltage sags, harmonics, and voltage fluctuations. Poor power quality can lead to reduced equipment performance, increased downtime, and premature equipment failure, resulting in significant financial losses for the mining business.

In addition, mining operations are subject to various regulations and standards related to power quality. Adhering to these requirements is crucial to ensuring compliance and avoiding penalties.

Furthermore, in the context of an environment that is increasingly reliant on renewable sources of energy, as well as ores that are increasingly located in remote locations, power quality is all the more important because more materials need to be extracted, loaded, hauled and processed. In short, the integration of renewable energy has become a must in the ecosystem and needs to be embedded in mine design.

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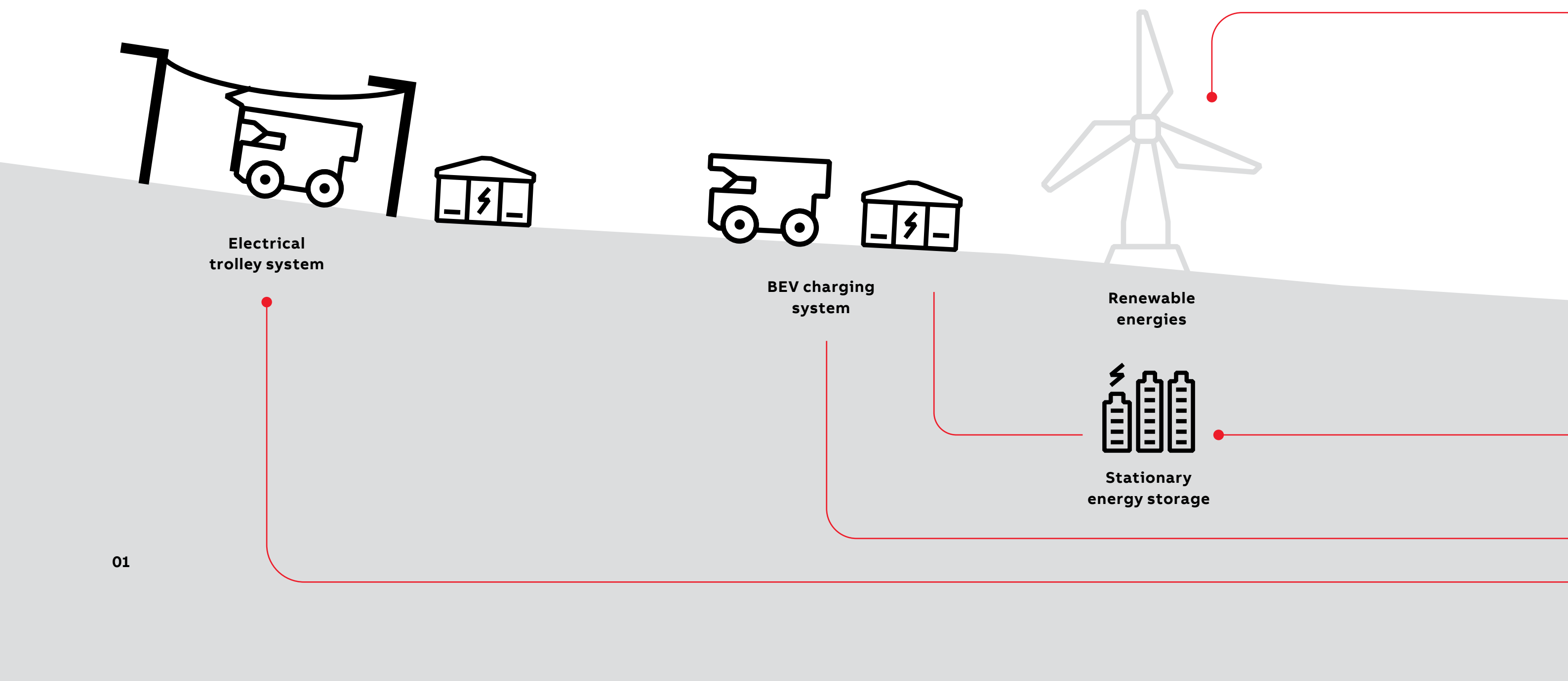
The implementation of renewable energy and energy storage systems depends on the stability and reliability of power systems.

Round-the-clock operations
Most mines operate on a largely uninterrupted schedule, requiring a continuous energy supply for consistent 24/7 load requirements. However, some key renewables, such as wind and solar energy, are variable and would benefit greatly from battery electric storage technologies. These technologies are improving rapidly and are approaching commercial viability. But they currently still suffer from high costs, limited lifespans, and an unproven ability to be scaled.

This limits the capacity of renewables that can be integrated into mining operations. In addition, achieving the successful implementation of renewable energy and energy storage systems depends on the stability and reliability of power systems, as well as a host of evolving technologies, not to mention the energy supply chain infrastructure.

These factors add up to one very clear conclusion: Power quality is of the utmost importance in the integration of renewable energy sources into the electrical grid. Furthermore, power quality measures ensure that the integration of variable energy sources does not compromise the stability and reliability of the grid. Power quality measures are essential for managing voltage and frequency levels within acceptable limits. Renewable energy sources, especially when interconnected at a large scale, can impact grid voltages and frequencies if not properly controlled. Deviations from standard voltage and frequency levels can cause equipment malfunction, damage, or even system-wide blackouts.

Effective power quality management ensures that renewable energy sources are integrated



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01 Conceptual overview of the future of eMine solutions. Decarbonization is based on the electrification of hauling fleets plus the integration of renewable energy sources.

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02 Decarbonizing mining operations requires profoundly rethinking how mines operate. Screenshot taken from ABB eMine solution video. Watch the full video on YouTube:

seamlessly, thus maintaining grid stability and avoiding voltage and frequency fluctuations.

Harmonic mitigation
The connection of renewable energy systems, particularly those based on power electronics, can introduce harmonics into the grid. Harmonics are unwanted distortions in the electrical waveform that can adversely affect the performance of other connected devices and equipment. Power quality measures involve

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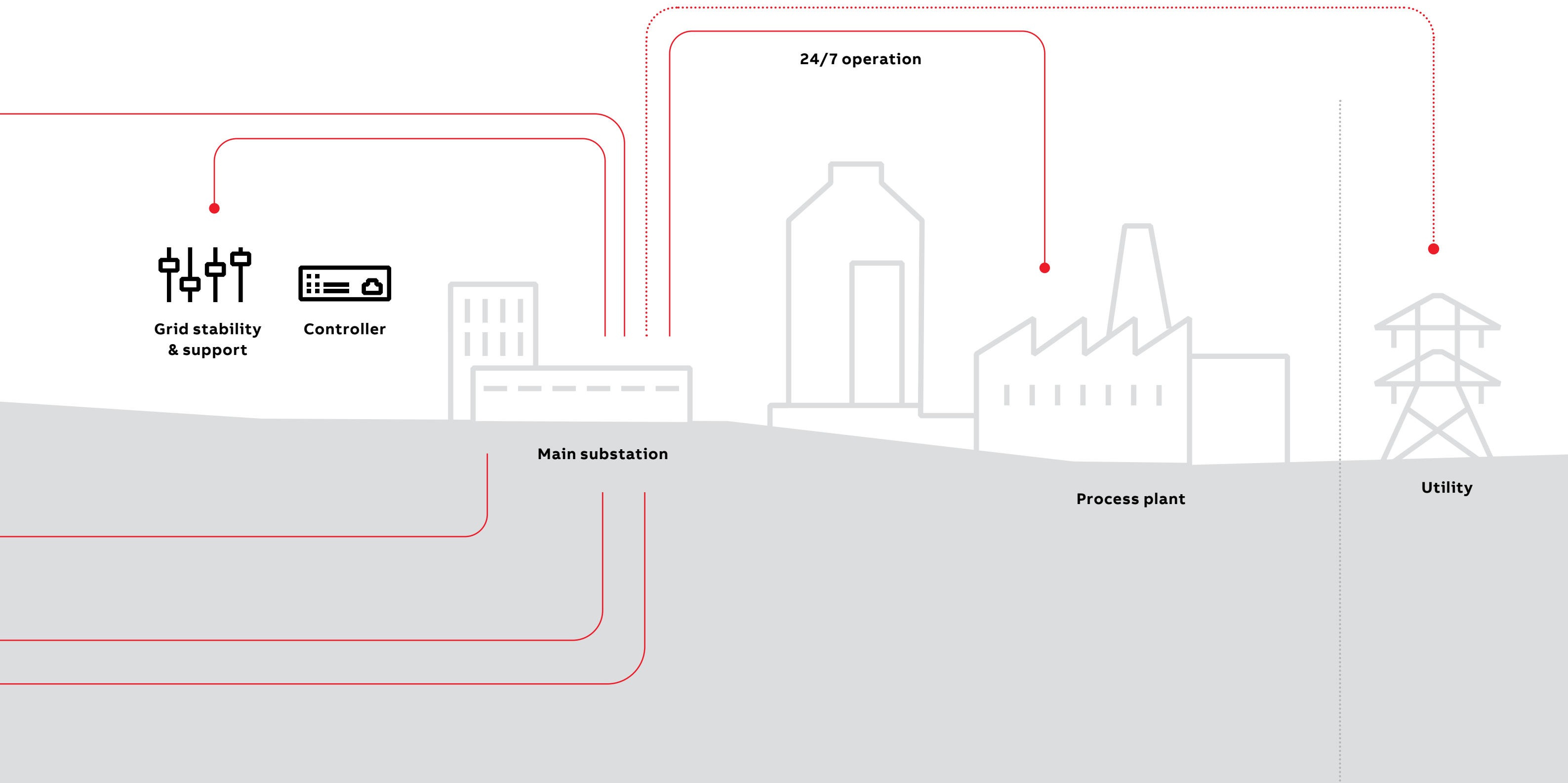
Power quality measures involve the use of harmonic filters, active power conditioners, and appropriate system design.

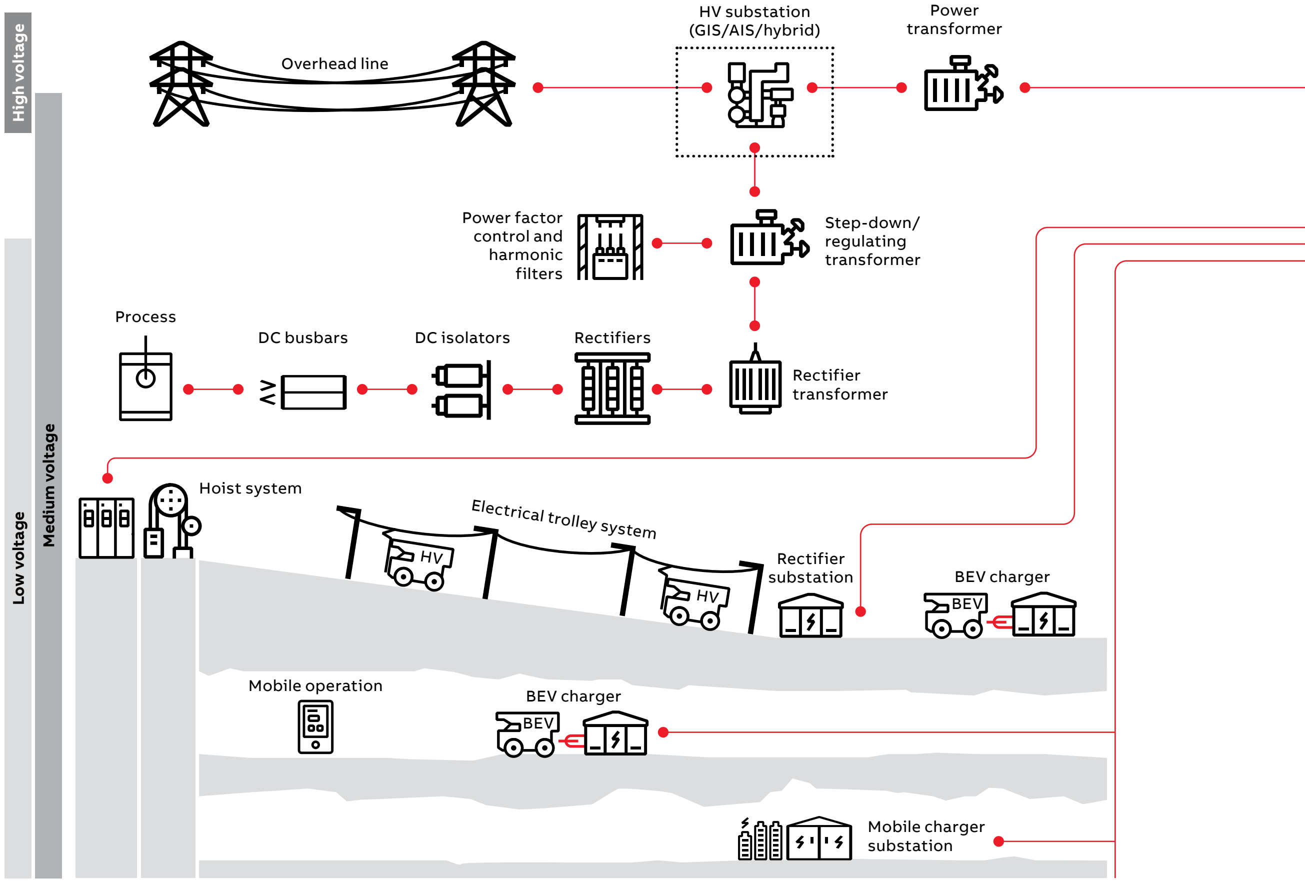
the use of harmonic filters, active power conditioners, and appropriate system design to minimize harmonics and maintain a clean electrical waveform. In a nutshell, power quality is vital to the integration of renewable energy sources as it ensures grid stability, voltage and frequency control, power factor correction and harmonic mitigation. By maintaining high power quality standards, renewable energy systems can be seamlessly integrated into the grid in mining

02

plants, thus promoting sustainable and reliable energy generation while minimizing disruptions to the electrical system.

Electrification is the enabler
Decarbonizing mining operations requires profoundly rethinking mines' connectivity, monitoring, cycle times and safety while collaborating with multiple partners and OEMs to ensure interoperability →02. Cutting this challenge into bite-sized problems, as well as a willingness to work together across the industry to ensure wide compatibility, has been the key to delivering this innovation.





03

One of the clearest realizations to have come from these steps has been that mines must be decoupled from diesel fuel. But this is more easily said than done. Decoupling requires development of a technology road map that can guide the planning of new or updated mines with a view to incorporating technology options as they mature, become scalable and cost effective. It is a journey based on a series of well-planned steps – practical, short-term actionable projects, designed to gradually transform mining operations.

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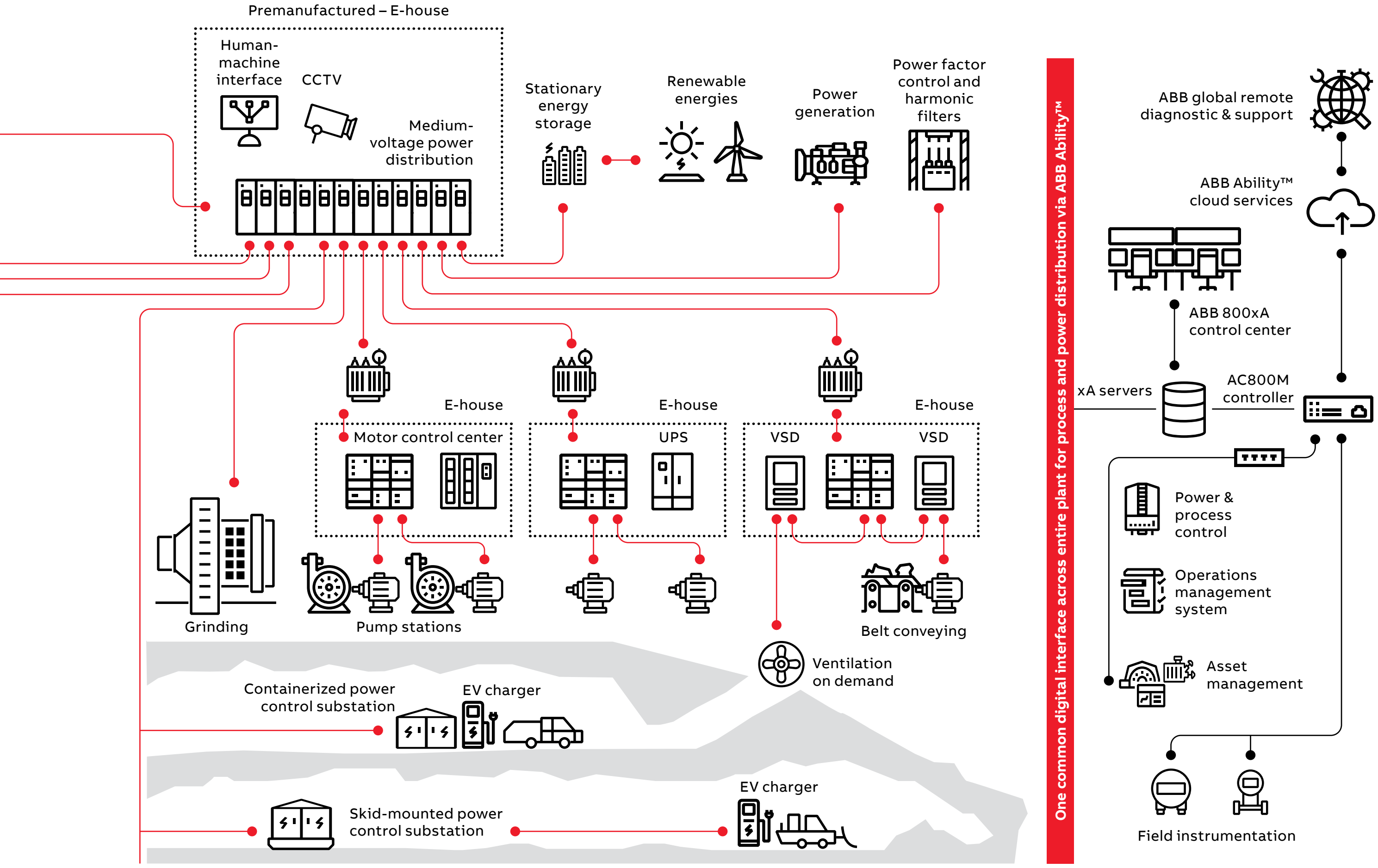
The decarbonization of mines involves transitioning from diesel-powered equipment to electrically powered machinery.

The decarbonization of mines typically requires an increase in electrical energy usage, primarily due to the replacement of fossil fuel-powered equipment with electric alternatives. It involves transitioning from diesel-powered equipment to electric vehicles, electric-powered haul trucks, loaders, drill rigs, and other mining machinery. Such equipment requires a battery charging infrastructure, including charging stations that are strategically placed throughout a mine site. The development of an extensive charging infrastructure necessitates additional electrical energy to meet the charging needs of electric fleets.

Decarbonization efforts also involve implementing energy efficiency measures to optimize energy usage and minimize waste. These measures may include upgrading lighting systems, improving insulation, and implementing advanced control systems. Although these measures are designed to reduce overall energy consumption, they can sometimes be offset by the increased energy demands of electrified equipment. It is therefore important to take a holistic view and consider the overall impact of decarbonization efforts on electrical energy demand. This will depend on



UPS: Uninterruptible power supply
VSD: Variable-speed drive
AIS: Air-insulated switchgear
GIS: Gas-insulated switchgear
BEV: Battery electric vehicle
HV: Hybrid vehicle (diesel + electric)

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03 ABB's portfolio of mining technologies extends from electrification and automation to renewable energy integration and strategic energy management practices.

various factors, such as the scale of a mining operation, the extent of electrification, the integration of renewable energy, and the implementation of energy efficiency measures.

Strategies for managing the increased demand for electrical energy may involve a combination of on-site renewable energy generation, energy storage systems, and demand management practices. Ultimately, the transition toward decarbonization in mines often leads to a higher demand for electrical energy, as it becomes the primary power source for electrified equipment. However, this increased demand can be addressed through a combination of renewable energy integration, energy efficiency measures and strategic energy management practices →03, ensuring a more sustainable and environmentally friendly mining industry.

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A critical and comprehensive assessment of the mining industry's technological and economic needs must be conducted.

Considering the above-mentioned trends in decarbonization and the growing demand for integration of renewable energy in the mining industry, there is no time to waste. A critical and comprehensive assessment of the mining industry's technological and economic needs based on comparative simulation studies must be conducted. Such studies must take the unique needs of different mining operations into account. Only in this way can solutions be developed that provide guidance for practical, customized, best-fit project decisions. •

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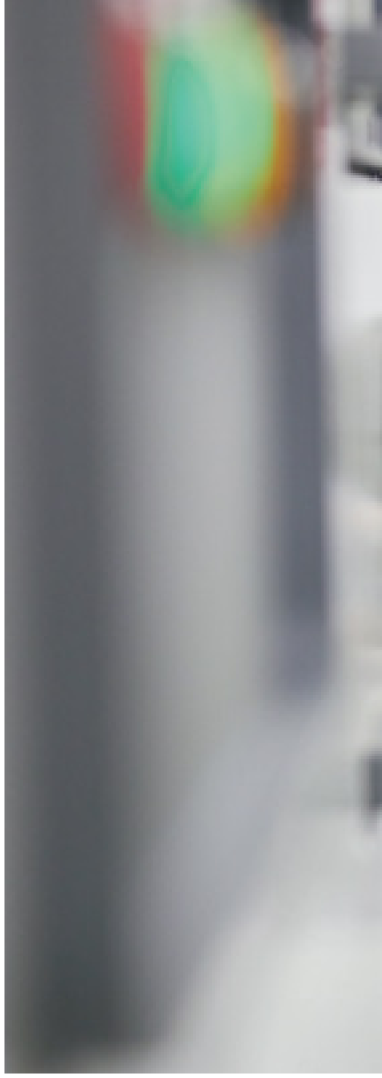
BRINGING CYBER SECURITY INTO THE OT DOMAIN WITH SIEM

Extending the safety net

Converging industrial operational technology (OT) and IT networks – and ever more sophisticated systems, devices and protocols – offer countless benefits. Such enhancements, however, also make such systems vulnerable to cyber attacks. ABB is researching methods that further improve the security of customer installations.



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Industrial systems are becoming increasingly connected. This connectivity offers many benefits, such as improved productivity and flexibility, but also increases the attack surface available to malicious actors, giving them more opportunities to exploit flaws and vulnerabilities. At the same time, convergence of OT and IT networks is driving an increase in the complexity of industrial setups, devices and protocols. If these sophisticated, interconnected systems are not secured, they become prime targets for cyber attackers →01. Indeed, in 2021, manufacturing became the most attacked sector amid a growing number of intrusions into OT-connected industries in general [1].

One prominent method used to counter cyber threats in complex industrial setups is SIEM.

The impact of cyber incursions may include unwelcome disclosure of confidential information, extended production downtime, financial impairment or loss of property or even life. Affected organizations incur additional costs for remediation as well as reputational damage. Moreover, many organizations must meet certain cyber security requirements for regulatory or standards compliance and may be obligated to report any breaches and suffer associated penalties.

To respond to these risks and ensure compliance, proactive cyber security solutions that can monitor and detect threats to complex industrial setups are required. One prominent method used to counter cyber threats is security information and event management (SIEM).

Introduction to SIEM

The term SIEM was introduced by Mark Nicolett and Amrit Williams of Gartner in 2005 [2]. SIEM combines two concepts: Security information management (SIM), which involves the collation of security information at a central location for further analysis, and security event management (SEM), which is the real-time evaluation of event data.

The central idea of SIEM is the monitoring and evaluation of event data from various sources such as applications, network components, servers, or any other event-logging entities to

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01 Convergence of industrial OT and IT setups and increased connectivity demand the very best cyber security.

discover patterns of potential security-related irregularities. The results of the monitoring and evaluation process can either be reported on alert-enabled dashboards or directly funneled

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SIEM tools collect event data at a central location and apply security rules to it.

into a security orchestration automation and response (SOAR) system to trigger automated responses to a threat.

SIEM tools collect event data at a central location and apply security rules to it. The evaluation of the event data happens in real-time, which means that the rules are permanently applied to find individual events as well as aggregations and correlations of events within given time frames. SIEM tools can be established as on-premise solutions or as cloud services.

SIEM rules are configurable – for instance, concerning parameters that are specific to the automation system they are applied to, such as user accounts, individual IP addresses or allow-listed external domains to which the system may connect. Safety-critical tags are also important parameters that contextualize the rules and these are also specific to each instance of the control system. Changes in critical tags can be monitored by SIEM tools.

Each commercial SIEM product has its own rule specification, which impedes rule-interoperability across vendors. An open-source initiative, SIGMA, tries to overcome this barrier by introducing a generic rule specification and offering conversion tools to translate the general rules for different target SIEM products.

Challenges for SIEM adoption
The benefits of digitalization are driving businesses to rethink OT and IT strategies, enabling previously disconnected systems to connect to enterprise networks and cloud services. Here, SIEM is essential to ensure that security is maintained by detecting malicious activity. Adoption of SIEM in OT environments is, however, currently uncommon – one of the challenges to its implementation being that lessons learned from the classic IT world often do not apply in the OT area. Moreover, each OT network is individual and assumes unique operating states that should not

02

be interpreted as attacks. This dilemma results in a trade-off between the generality of SIEM rule sets, which implies maintainability, and customization, which ensures practicality.

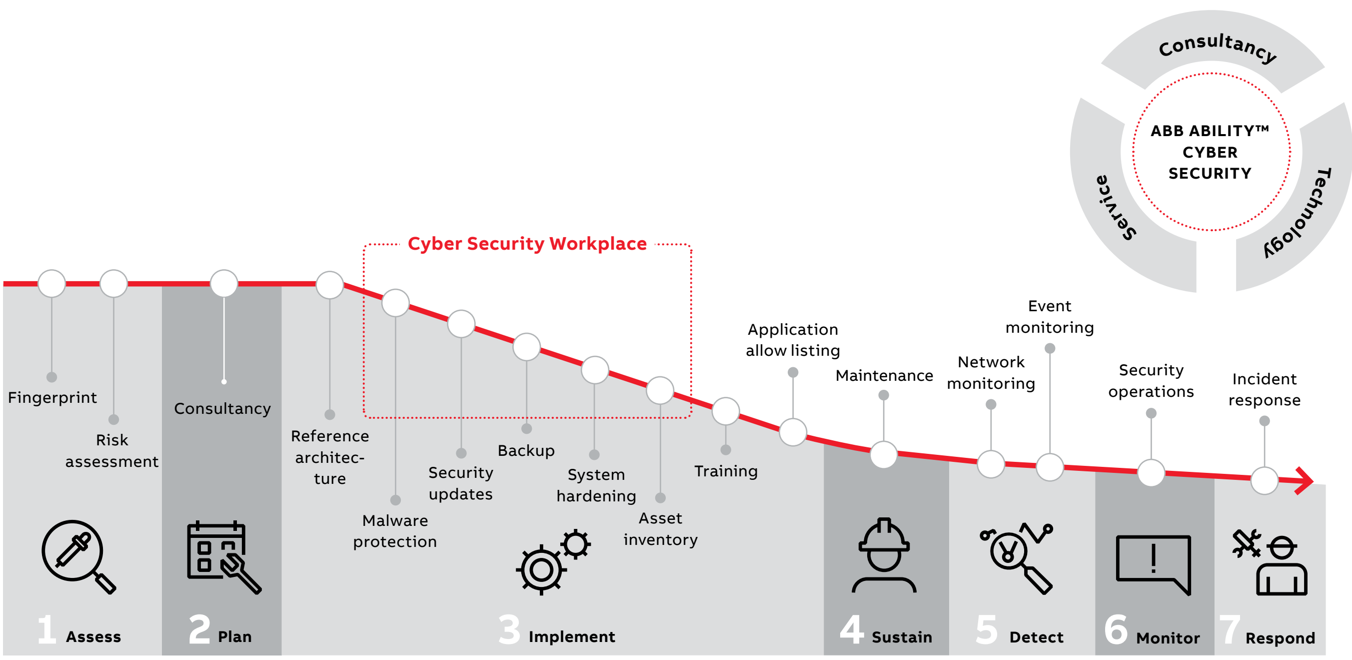
A further complicating factor is that the OT umbrella also covers (resource-constrained) embedded devices that do not have monitoring capabilities.

Another obstacle impeding the application of SIEM technology to the OT domain is the potentially high rate of false alarms that results from the fact that OT systems have frequent changes in production setups and show recurring regular operator interventions. Maintenance and safety-oriented operator interventions might also share similarities with attacks. This complicates general monitoring rules that separate good and malicious activities. Judging these situations is time-consuming and requires plant familiarity and security knowledge.

Further drivers for employing SIEM
The demand for better cyber security in industrial contexts has increased in the past few years and continues to do so. As well as the negative impacts of a cyber breach mentioned above, demand is also fueled by another significant consideration: emerging standards and laws. These include:

> The demand for better cyber security in industrial contexts has increased in the past few years and continues to do so.

- The German Federal Security Information Act (BSIG). In its current form, the BSIG established the obligation, from May 2023, to use attack-detection methods that continuously and automatically record and evaluate suitable parameter characteristics from ongoing operations.
- The IEC 62443 set of security standards, which requires a business entity to have the ability to identify failed and successful cyber security



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02 The four pillars of ABB's approach to cyber security.

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03 ABB's risk reduction roadmap.

attacks or breaches and the capacity to identify and respond to incidents. A further requirement is the capability to centrally manage a system-wide audit trail and make it available to an analysis instrument such as a SIEM tool.
- The ISO 27001:2013 and ISO 27019:2017 standards, which stipulate the necessity of event logging and assessments of events as well as the extent of the capability to respond to cyber incidents.

ABB's approach to cyber security
Care and collaboration are part of ABB's core values, which means ABB helps customers build and maintain safe and secure operations and supports them in meeting best practices and adhering to regulations. ABB also partners with established SIEM tool vendors to supply and build upon market-accepted solutions and ecosystems.

Cyber security at ABB is composed of four connected pillars: cyber security solutions, services associated with these services, cyber security consulting and intelligence – ie, ABB's unique expertise as market leader in automation technology – that underpins this edifice →02. Bringing cyber security to the customer is based on six steps:

- Assessment of the cyber security situation.
- Planning the activities, tools and services needed.
- Implementation of tools and services, including activities such as system hardening, implementation of a security architecture and security training.
- Maintenance – for example, software patches or updates. Here, the ABB Ability™ Cyber Security Workplace™ can ensure patches against known exploits are installed as quickly as they become available. The operator is informed about update progress and told which systems are missing updates [3].
- Ongoing threat monitoring, detection and response.

→03 shows ABB's risk reduction roadmap. In this process, ABB builds especially on its knowledge of control systems and their deterministic nature. By using the information in the control system, ABB can tailor cyber security to the specific needs of particular industrial facilities.

Ongoing research
Current cyber security offerings are comprehensive and follow established good practices. Nevertheless, there are still open questions and problems to be solved in this field. Two such aspects are actively studied at ABB.

Firstly, there is context and event annotation. As described above, the state of the OT environment can be very "colorful" due to factors such as on-demand adjustments to schedules, interventions by operators to return to the steady state, or maintenance activities. Judging cases without this context can be difficult and time-consuming. Adding annotations to events to contextualize them can simplify handling and facilitate automation that accommodates SIEM rule adjustment.

Secondly, devices, down to the smallest sensors, in converging OT/IT networks are becoming more complex and more capable. In the future, it will be important to monitor these devices for security-relevant information and integrate them into a SIEM tool, just like any other asset.

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ABB helps customers build and maintain safe and secure operations and supports them in meeting best practices.

This evolution brings several challenges as these devices are usually heavily resource-constrained and embedded and, as is commonly the case with existing devices, not designed to support monitoring functionality. ABB is investigating ways to integrate this type of device into SIEM structures. One potential approach is to deploy monitoring agents directly on the device itself and securely transmit the information they gather to a SIEM tool based on standard protocols, where possible, to ensure interoperability with existing security infrastructure. For legacy devices and heterogeneous environments, ABB is investigating ways to monitor and extract security-relevant information external to the devices, avoiding the need to modify them or the software or protocols they use.

These improvements can help obtain much more security-relevant information from industrial installations and annotate it, based on operational context – ultimately supporting ABB customers in making the right cyber security decisions when faced with threats. •

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References

[1] IBM, "X-Force Threat Intelligence Index 2022." Available: https://www.ibm.com/downloads/cas/ADLMYLAZ. [Accessed March 14, 2023.]

[2] Williams A. and Nicolett M., "Improve IT security with vulnerability management," Gartner Research publication, ID G00127481 (2005). Available: https://www.gartner.com/en/documents/480703. [Accessed March 14, 2023.]

[3] K. van Overveld and M. Virostek, "Safe cyber space – ABB Ability™ Cyber Security Workplace," *ABB Review*, 02/2023, pp. 112–117.

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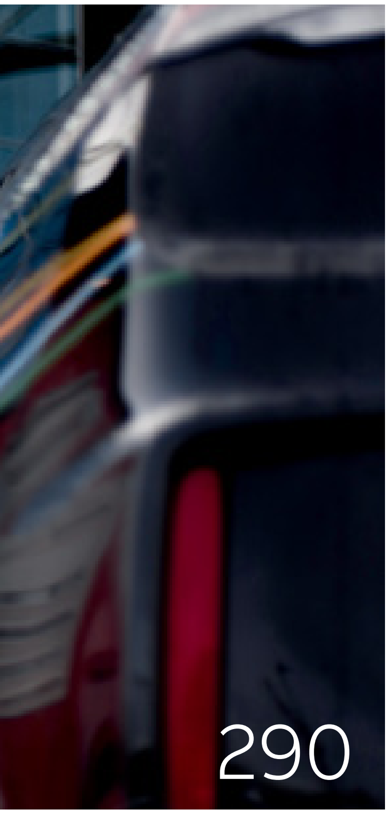
Applying AI

ABB puts AI to work as a core component of business operations, doing things like keeping energy grids efficient and safe, optimizing pricing for EV charging, and providing state-aware oversight for chemical processes. It is likely that integrating AI in such ways will be common in the future. The following articles document how it's getting done today.

280 **Edgy distribution**
The application of IoT technologies to distribution automation

290 **Unlocking the price**
Grid-informed dynamic pricing for EV charging using reinforcement learning (RL)

296 **Beware of the state**
State-aware lane assistance enables better continuous processes



THE APPLICATION OF IOT TECHNOLOGIES TO DISTRIBUTION AUTOMATION

Edgy distribution

ABB's EDGEPRO framework will enable grid edge computing devices to provide distributed intelligence and fast response to time-critical grid issues. Designed for today and to accommodate a hierarchical distribution future, EDGEPRO provides state-of-the-art protection, automation and control technologies to safeguard the grid as the energy transition unfolds.

—
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The recent proliferation of Internet-of-Things (IoT)-based technologies has led to massive improvements in digital computing hardware and software technologies; this translates to lower cost for comparatively higher computation and storage capability, compact-sized hardware, and compatibility with a larger selection of operating systems (OS). Additionally, communication protocols have increased the penetration of single board computers in many consumer and industrial applications. Such profound innovations could positively impact the energy sector. The application of a state-of-the-art edge computing infrastructure to the electrical power distribution grid would provide distributed intelligence and rapid response to time-critical grid issues, eg, fault detection, isolation, and restoration [1]. As more distributed energy resources (DERs) are integrated, the power distribution system becomes increasingly complex: Potentially destabilizing events, such as temporary and permanent faults [2], loss of measurement data, and cyber-attacks are well-known concerns [1]. To address these issues, ABB conducted a small-scale experimental validation of edge computing in power distribution automation. The resulting framework, Economical, Data Fusion-based Grid Edge Processor (EDGEPRO), presented below, can be used for classifying different faults, detecting anomalies in the grid, measurement data recovery, and other advanced analytics techniques. EDGEPRO has been designed for today's distribution applications and to accommodate future hierarchical distribution.

—
As more DERs are integrated into the grid, the power distribution system becomes increasingly complex and less stable.

Software framework for EDGEPRO
Because multiple data sources from different devices are at the core of smart grid platform integration, ABB needed to provide a scalable and secure platform for edge computing applications to accommodate various industrialization

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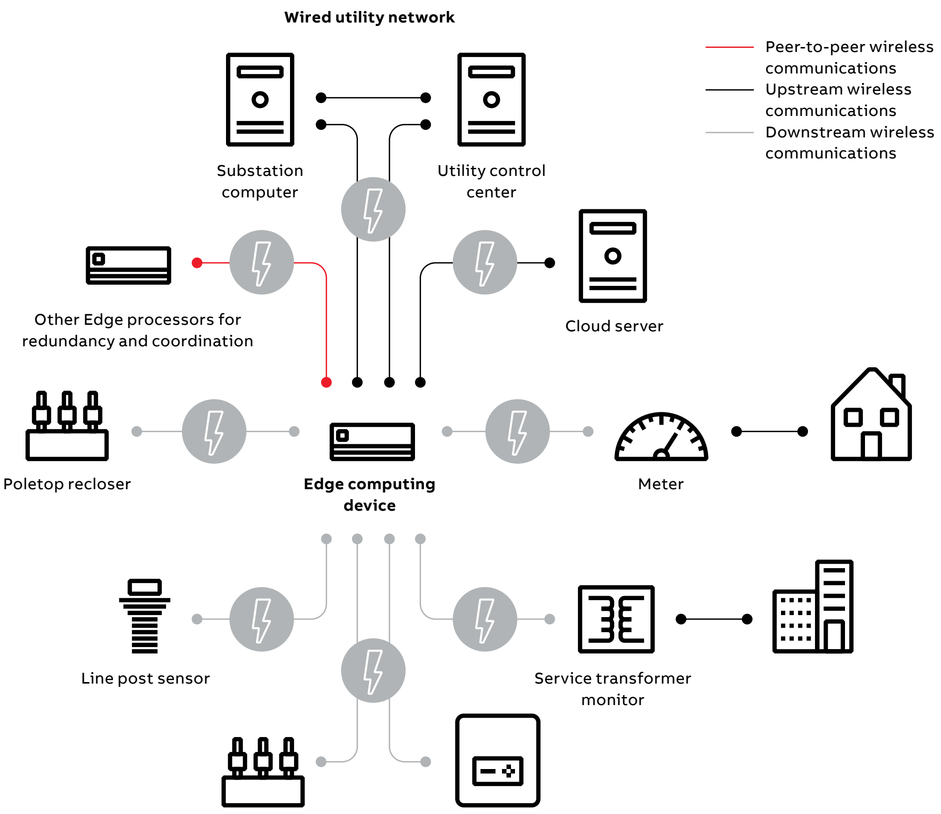
01 Edge computing device connections are illustrated schematically.



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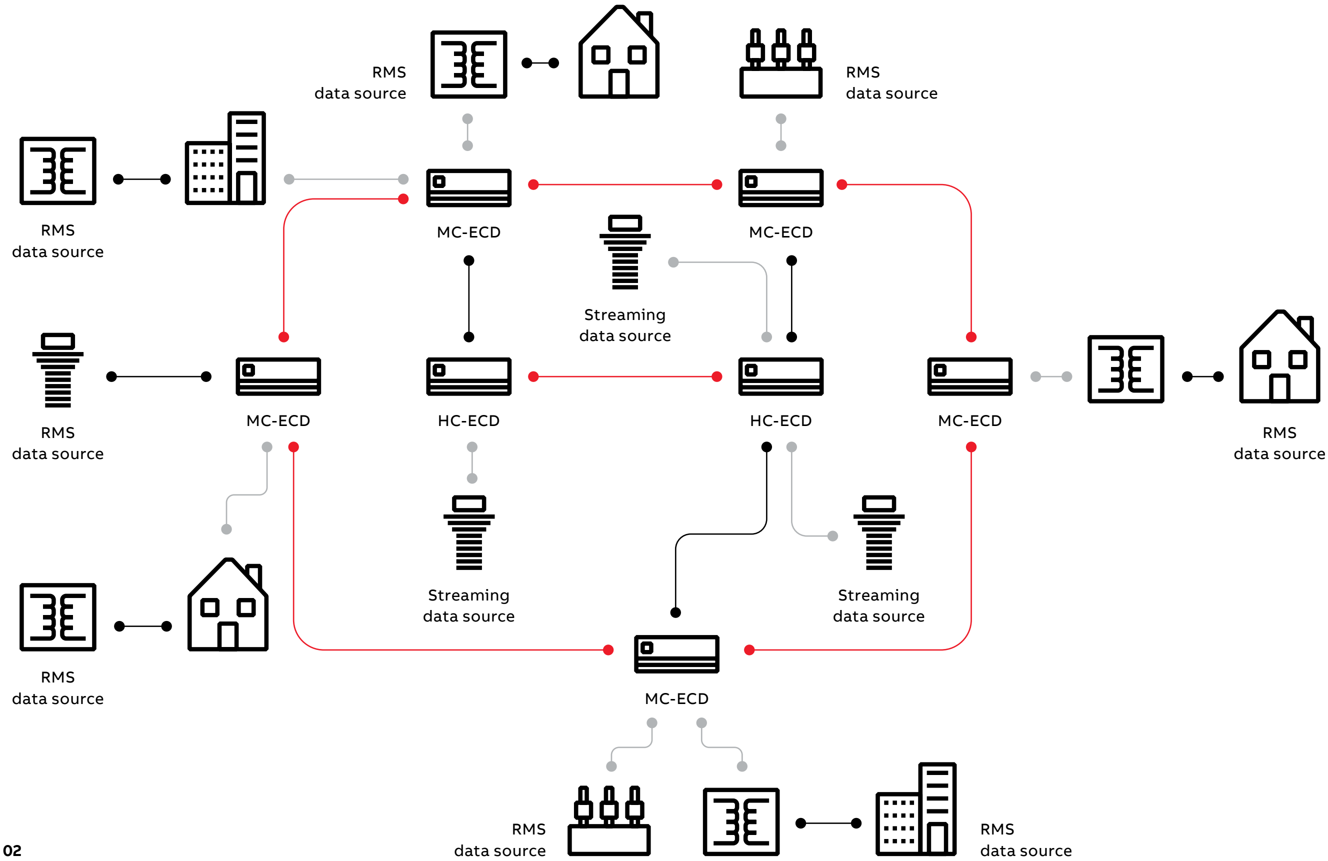

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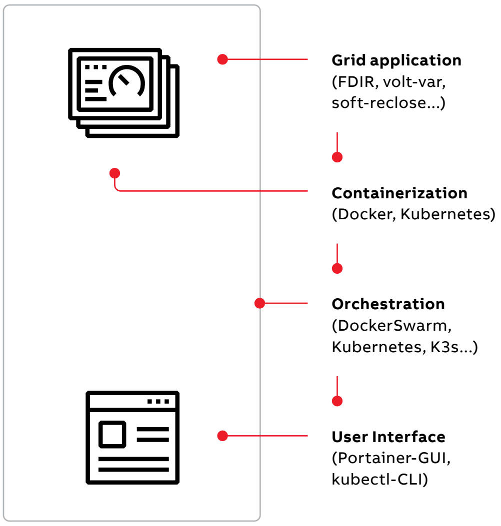


03

and commercialization options: the EDGEPRO embedded framework does this by supporting both Windows and Linux OSs. Such flexibility is crucial as communication libraries, eg, industrial communication, Web server, protection, and control proprietary software, are generally hosted in Windows OS, whereas novel secure VPN technologies, mesh wireless libraries, and machine learning (ML) applications are easiest to evaluate and implement in Linux.

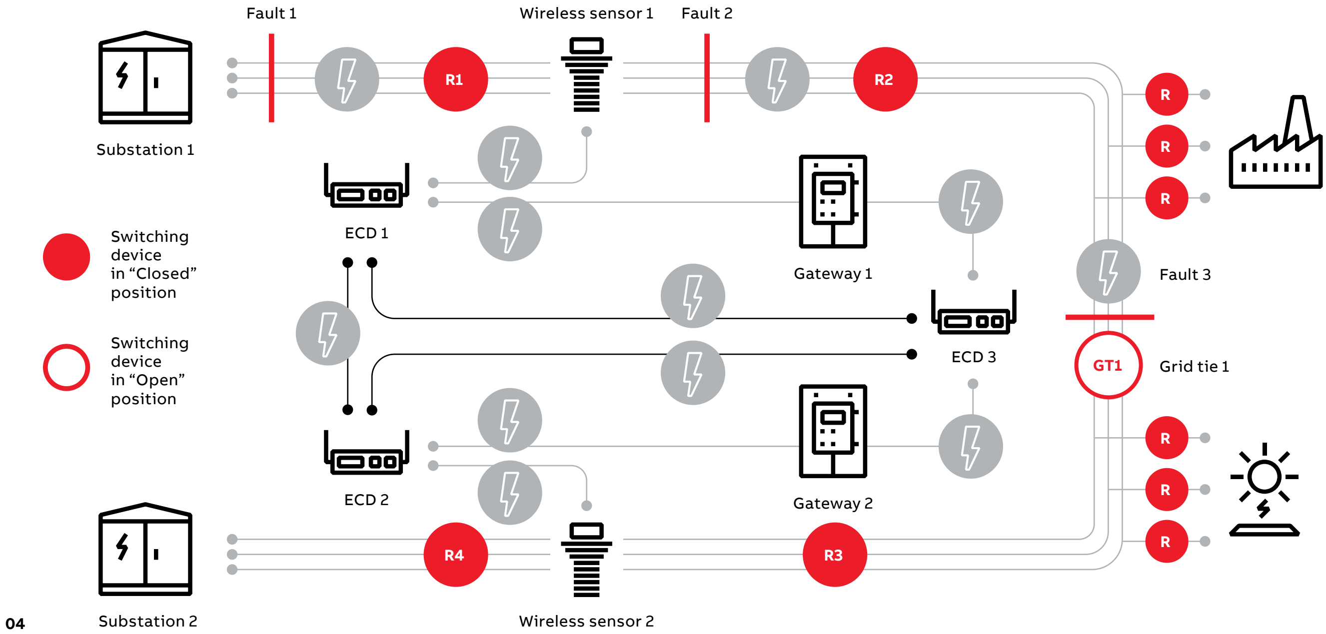
How does the EDGEPRO device →01 or device network →02 function? Since it can implement a multi-layered hierarchical architecture with different edge computing devices (high-, medium-, low-cost) the network features a main EDGEPRO device with management capabilities for pushing applications to individual devices. A container registry hosted on the highest level

—

ABB conducted a small-scale experimental validation of edge computing in power distribution automation.

EDGEPRO device, or in the cloud, provides image repositories for the applications hosted on each computing device. Repositories might contain various tagged versions of container images, and the lower-level EDGEPRO devices can pull down the required image by requesting device- or configuration-specific tags.

The management bus implements control functions; the container image pulls over secure protocols, featuring a broker that communicates over publish-subscribe-type message queuing protocols (MQTT, AMQP, etc.). Each application



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EDGEPRO embedded framework supports both Windows and Linux OSs, thereby providing crucial flexibility.

supports the receiving of message commands to start and stop application processes, receive configuration descriptive files that coordinate grouping with other devices and zone configurations. This interface manages pushing updates to deployed applications, syncing databases at each individual device for distributed applications, and any updates to security- or Public Key Infrastructure (PKI) technologies. The EDGEPRO lower-level devices regularly check for updates to individual device configuration- and zone configuration files exchanged over a JavaScript Object Notation (JSON) or equivalent. Thus, EDGEPRO can perform the necessary control functions.

Building containerized grid applications
For field applications, containerization and workflow orchestration – well-known in cloud computing – were adapted to the edge computing. ABB devised a simplified process for converting standalone grid applications into containers, which isolate applications into smaller units, and for deploying, managing, deleting, and updating

—
02 ABB's proposed edge computing architecture for power distribution applications is displayed. MC-ECD is a medium-cost edge computing device, HC-ECD is a high-cost edge computing device.

—
03 Simplified process for building a containerized grid application on the edge computing platform is shown. While ABB selected K3s for orchestration, other tools such as Kubernetes (K8s) and Dockerswarm could be used according to resource constraints.

—
04 Example FDIR scheme for validating the proposed edge processor-based container orchestration is illustrated. The scheme consists of two substations with a typical five-recloser loop, including multiple loads, voltage and current sensors, four protection recloser controllers, one grid-tie switch, three ECDs, and two gateway devices. For redundancy and backup, the gateway devices communicate with multiple ECDs.

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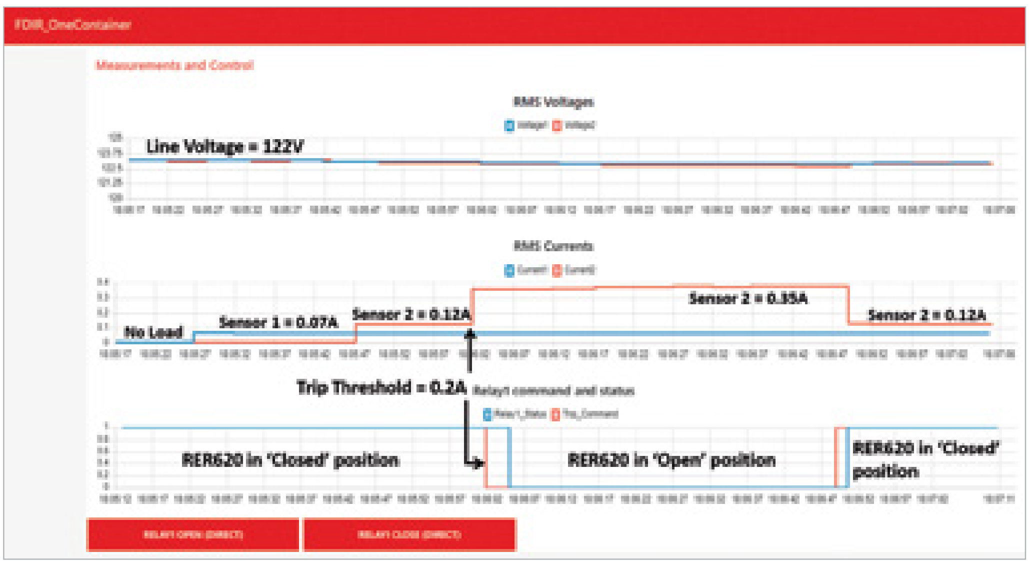
05 Example results of the demonstrations used to validate the EDGEPRO platform are shown: GUI panel on the supervisor EDGEPRO showing the waveforms measured by multiple wireless sensors in the network.



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these containers across many EDGEPRO devices →03. Docker Engine was selected to containerize the application due to its OS compatibility with Windows and Linux and implementation simplicity, while K3s, the simplest and least resource-consuming platform tool considered, was selected for container orchestration →03.

Experimental prototype design
To validate the EDGEPRO embedded framework, ABB developed a fault detection, isolation, and restoration (FDIR) application scheme →04, in which the ECDs communicate with Intelligent Electronic Devices (IEDs) and sensors, and other edge computing devices in the hierarchy.

Simulations were performed using Node-RED: a JavaScript-based Web server tool that enables the creation of logical and communication nodes representing different components in the FDIR scheme. Critically, this allows interactive simulation demonstrations to run inside the ECD3, or supervisor EDGEPRO device, where each logical state represents the state of the electrical system.

—
EDGEPRO can be used for classifying different faults, detecting anomalies in the grid, measurement data recovery, etc.

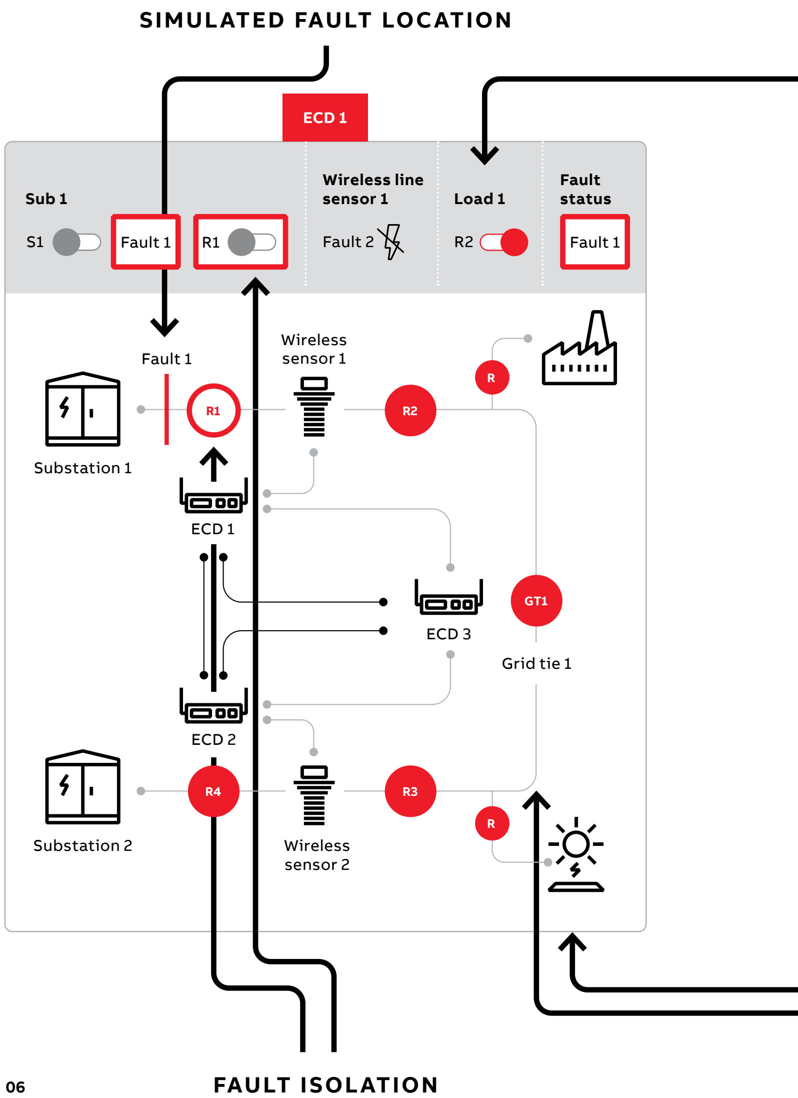
The final FDIR demonstration used container orchestration with three HPE EL10 devices that formed a K3s cluster. Master and agent tool was installed on respective ECDs to enable the orchestration of containers across all the ECD devices. A YAML file defined the container configuration for each ECD, and the FDIR container image was developed on an x86 platform and uploaded to the DockerHub public repository. After deploying the YAML file, the Node-RED application automatically started in all ECDs, which ran a specific part of the image based on identification.

The hardware setup featured actual recloser controllers (ABB RER620) and emulators, simplified software switches in Node-RED for other relay devices, commercially available wireless sensors and TI DSP-based sensor data acquisition and wireless modules. Additionally, to move the data and commands between ECD devices, ABB used MQTT, while Modbus TCP protocol communicated with IED RER620. It is noteworthy that other protocols are also supported eg, DNP3 and IEC 61850.

EDGEPRO platform validation results
To validate the EDGEPRO platform, ABB created multiple demonstrations →05. First, wireless sensors were connected to the actual electrical load, and the supervisor EDGEPRO device (ECD2) was set to trip the relay when the current exceeded 0.2 A. Having measured the load voltage and current, the sensors relayed the data to the respective EDGEPRO device, which then tripped the relay opening the recloser relay when the current exceeded the threshold. Once the fault cleared, the systems returned to normal operation →05.

This simple demonstration validated various aspects of the EDGEPRO platform, eg, connecting and collecting data from wireless sensors, and connectivity with ABB protection relay products →05.

A further demonstration implemented a simplified FDIR scheme for power distribution →06. In this case, containerization of the FDIR grid



06

application was validated through the ECDs' GUI panels →06. The containerized application was uploaded to a private repository on the internet and deployed using the K3s container orchestration tool to ensure that performance metrics were always met. Importantly, fault status indicators, system status, parameters, and waveforms were displayed on the GUI panels of all edge devices →06. The system successfully simulated faults at different system locations via GUI buttons and restored normal operation once the fault cleared (pre-fault load on faulted circuits was used to check the load before restoration).

Led by objectives

Due to the heterogeneity and multi-sources of data, ABB deployed the data fusion technique [3] on the edge processor platform. Two main objectives were addressed: "Fixing problematic data" for data-source quality issues, eg, inconsistency, imperfection, etc. and "Extracting higher-level information" to obtain knowledge from multiple data sources. Hence, ABB developed two main applications in the edge processor framework: event classification and data recovery.

Event classification

To help differentiate between permanent events (ie, cable/conductor faults, animal contacts, and equipment failures) and temporary fault events (vegetation management issues, lightning strikes, and switching transients), it was necessary to perform distribution grid event classification. Here, ABB developed and introduced ML-based and domain expertise-based methods.

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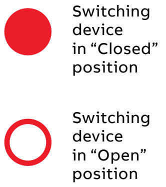
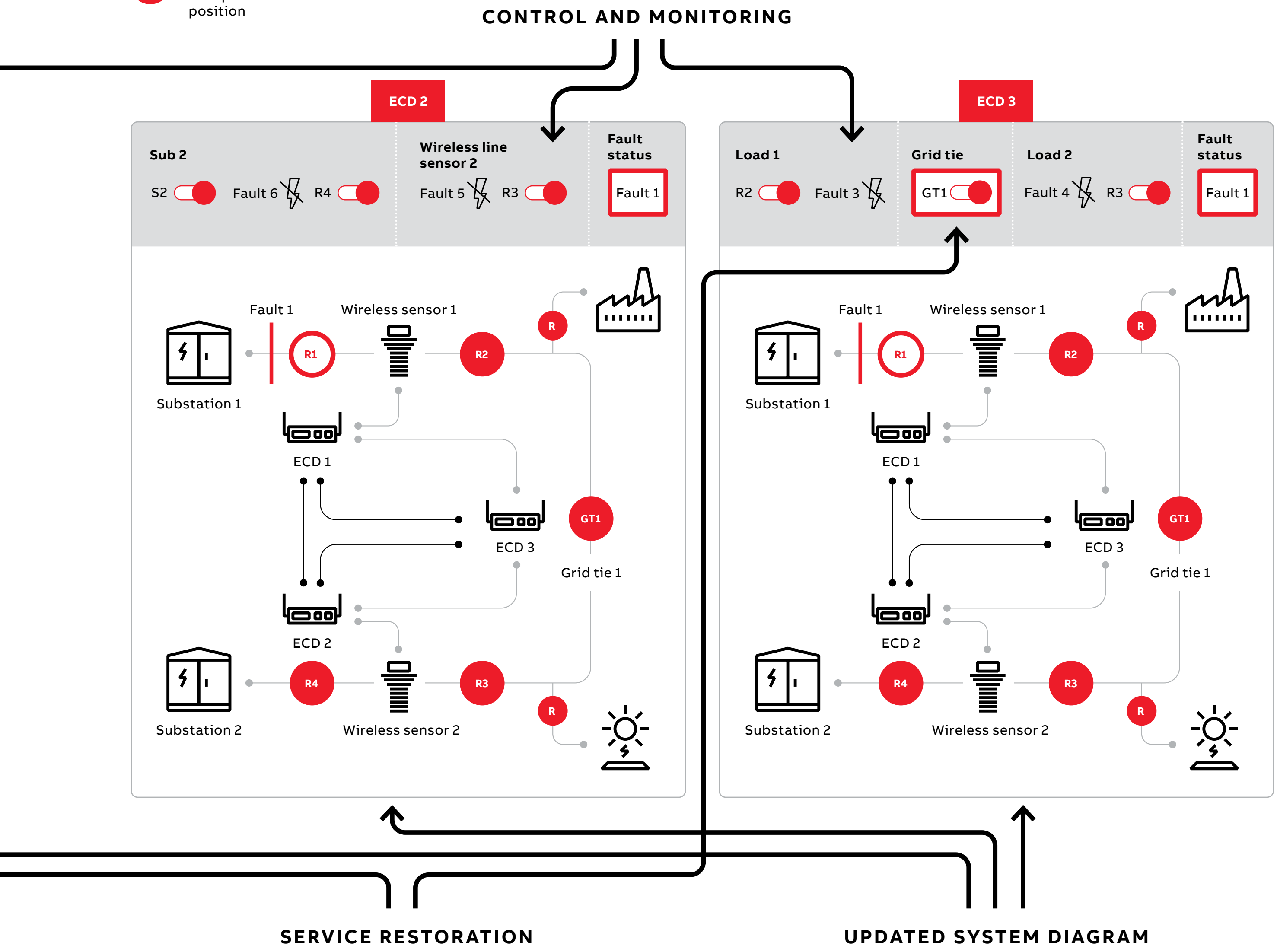
At the grid edge, basic to slightly advanced applications can be deployed, which range from low- to high-cost ECDs.





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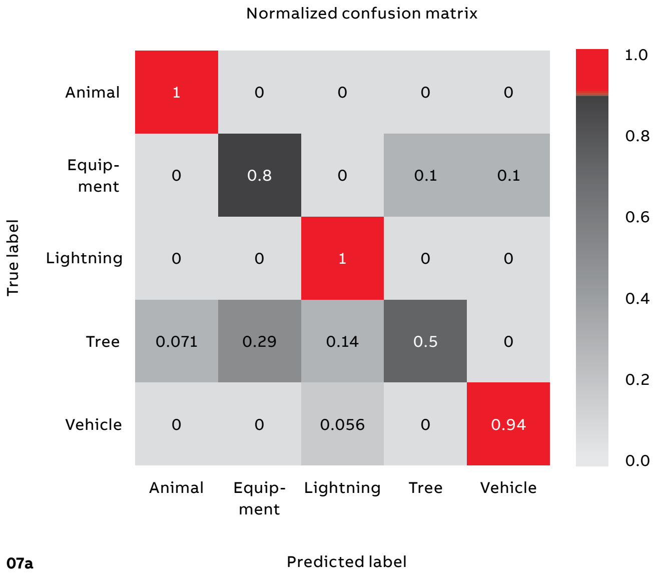
06 Graphical panels of all three Edge devices (ECD1, ECD2 and ECD3) showing near real-time system parameters/ information in a simplified manner based on the solution depicted in →04.



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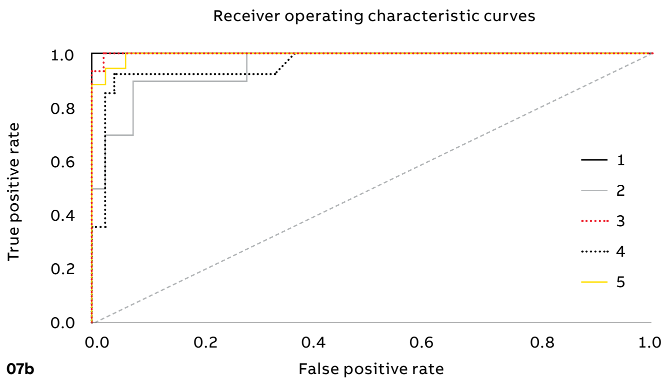

07b

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07 The results of event classification are displayed.

07a Normalized confusion matrix (support: 69, Accuracy: 87 percent) is shown.

07b The receiver operating characteristic curves (ROC) and the area under the ROC curves (AUC) are presented. Here, AUC for class 1: 1.0, AUC for class 2: 0.956, AUC for class 3: 0.999, AUC for class 4: 0.964, and AUC for class 5: 0.996.

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08 Proposed edge computing architecture for power distribution applications at a high level using advanced analytics.

For the ML-based fault classification technique, data was sourced from the National Infrastructure for Artificial Intelligence (AI) on the grid (NI4AI), led by PingThings [4,5] with University of California, Berkeley. The infrastructure, including data, analytics platform, and user-community was provided to catalyze the use of artificial intelligence on the grid.

For event classification, 155 datasets were assigned to one of five classes: animal (15 datasets), lightning (24 datasets), vehicle (18 datasets), tree (43 datasets), and equipment (55 datasets) with differing data points (from 50 to 30,000) and sampling rates (from 50 to 1000 µs). Possible attributes included: time, voltage (V) Va, Vb, Vc; current (I) Ia, Ib, Ic, and In. The three phase currents Ia, Ib, and Ic of individual cases were concatenated to extract features using the Python package “tsfresh”, which automatically calculates a large number (773 in this case) of time series characteristics.

To improve imbalanced classification performance, a known challenge of ML techniques applied to classification datasets, ABB employed the Synthetic Minority Oversampling Technique (SMOTE). This resulted in 55 instances for each class. For the data set, 75 percent of the data was used for training while 25 percent was kept for test/validation purposes. Because the best-suited algorithm for solving the ML problem was unknown at the outset, ten promising classification algorithms were investigated using spot-checking:

- Two linear algorithms: Logistic Regression (LR) and Linear Discriminant Analysis (LDA)
- Four nonlinear algorithms: k-Nearest Neighbors (KNN), Naïve Bayes (NB), Classification Trees (CART), and Support Vector Machines (SVM)
- Four ensemble algorithms: Random Forest (RF) and Extra Trees (ET); AdaBoost (AB) and Stochastic Gradient Boosting (GBM)

Having estimated the skill of these ML models with the classification metric, 10 fold cross validation, and accuracy, ABB selected the ensemble algorithm, ET, for classification as it outperformed the other models after data standardization. Subsequently, a grid search algorithm, hyper parameter optimization, which serves to tune the algorithm, was applied to find the optimal number of “trees” (best results with n-estimators = 300). The results of the event classification using the tuned ET algorithm and standardized data →07 demonstrate the success of the application.

Data recovery for state estimation

As the grid transitions to an intelligent electrical power grid, integrating ever more DERs, the real-time monitoring and control of the system is critical. Synchrophasor measurements using rapid time-stamped devices, or Phasor measurement units (PMU), can address this challenge by determining the state of the system [6].

The first step was to reconstruct the missing data. Data were sampled at synchronized instants and correlated with measurements of nearby PMUs based on the power system topology. PMU data exhibited low-dimensional structure despite the high-dimensionality of raw data. The resulting matrix contains measurements of nearby PMUs of approximately low rank. Because ABB determined that reconstructing missing PMU data could be formulated as a low-rank

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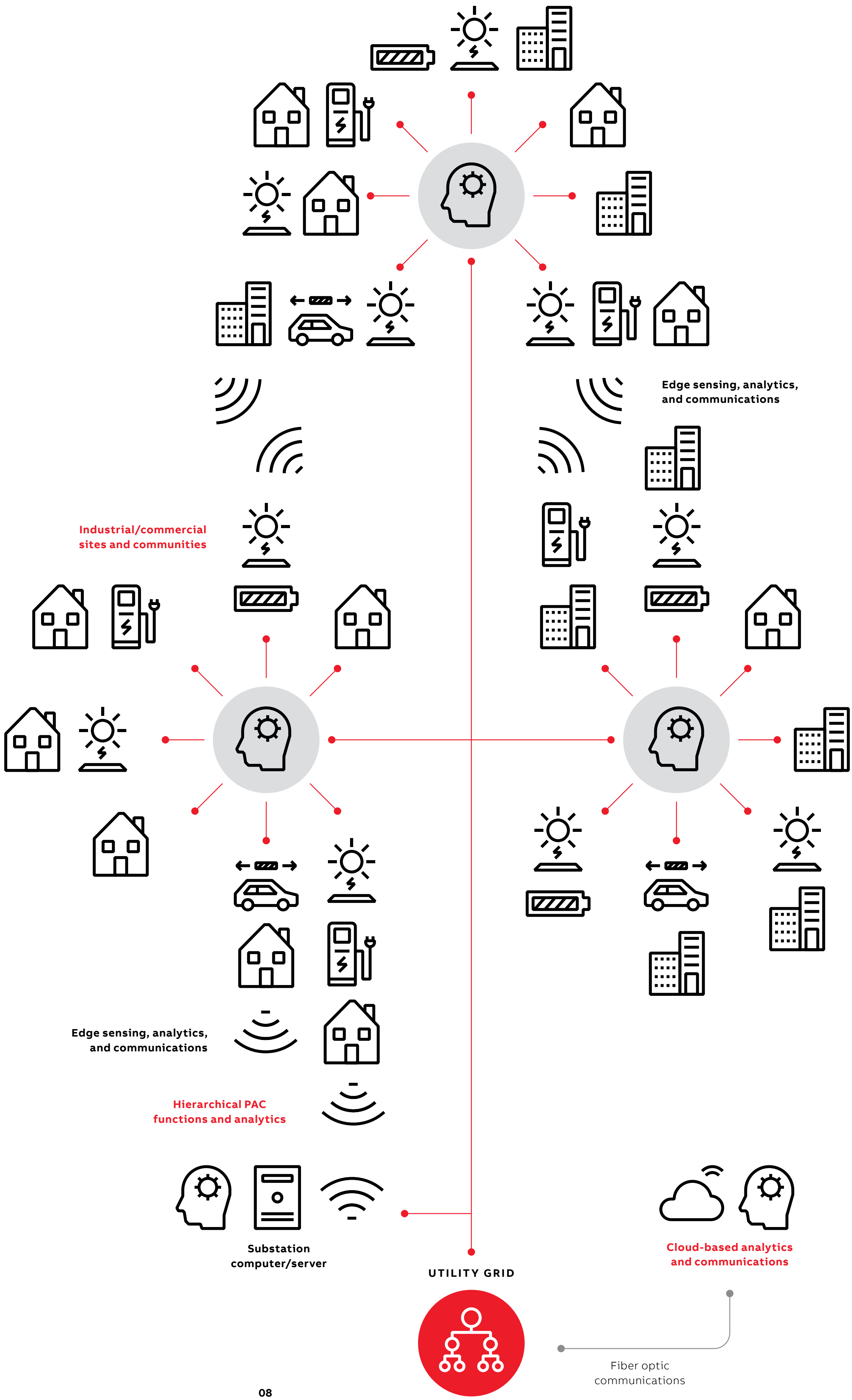
ML methods suit low cost ECDs, while deep/reinforcement learning-based methods suit a substation computer or the cloud.



Edge sensing, analytics, and communications
Industrial/commercial sites and communities
Edge sensing, analytics, and communications
Hierarchical PAC functions and analytics
Substation computer/server
UTILITY GRID
Cloud-based analytics and communications
Fiber optic communications
08

VIRTUALIZED CENTRALIZED PROTECTION AND CONTROL

Virtualized centralized protection and control is a new technology that can leverage the edge computing and advanced communication infrastructure for enhanced hierarchical grid intelligence. A virtual platform entails the implementation of the PAC functions on a server (ie, in software) that resides in the substation. The flexibility to provide enhanced PAC applications, analytics, and cyber-security methods, on top of the existing virtualized PAC functions is advantageous. By implementing PAC functions on a server instead of on a substation computer more advanced ML-based applications can be implemented. Moreover, if 5G and IEC 61850 communications are utilized with the virtual platform, then real-time sampling at the field device level can be achieved. The result is a comprehensive view of the system in real-time, a more advanced and comprehensive PAC functions that will span the distribution grid.

09

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09 Enhanced hierarchical grid funtion with virtualized protection and control is examined.

—
10 ABB's EDGEPRO will provide for distributed intelligence to support distributed automation and grid management as the grid evolves.

matrix completion problem, matrix completion methods, eg, nuclear, Hankel, and total variation norm minimization, were introduced and developed based on convex optimization technique to recover both randomly and temporally missing data with applications to synchrophasor (PMU) data recovery for state estimation [7]. In this way, ABB showed that EDGEPRO can be successfully used in power distribution automation for data recovery and state estimation.

The future is hierarchical

The edge computing concept presented here focuses on distributed intelligence, and yet the concept of hierarchical grid intelligence is likely the future of grid protection, automation, and control architecture. ABB's EDGEPRO framework is designed for today's use and to accommodate this hierarchical distribution future.

Grid edge computing devices will provide distributed intelligence and fast response to time-critical grid issues (eg, fault detection, isolation, and restoration), communicating pertinent data to devices at the substation level (eg, substation computers, high-end ECDs) and providing another layer of protection, automation, and control (PAC). Moreover, such devices can potentially provide a sanity check that the ECD-based control decisions made were indeed correct. Further, by interfacing and coordinating with the cloud and end-customer application-based IoT systems, a comprehensive picture of the effects of grid events can be obtained. This level of communication enables the link from the utility, and others, to the consumer and industrial and commercial sites.

Advanced analytics is another application that can be applied at all levels of ABB's framework to provide more hierarchical intelligence →08. At the grid edge, basic to slightly advanced applications, eg, fault detection, isolation, and restoration, can be deployed; the type of ECD whether high- or low cost, will determine the level of deployable advanced application →08.

At the substation and cloud levels, where computation power and capabilities are greater, more advanced applications are possible. For example,

—
ABB's proposed concept offers faster response to grid events than centralized or substation-based solutions.

ML-based applications are deployable at all levels; the technique complexity and data models will determine the deployment hardware platform. A simpler ML method could be deployed on low cost-ECDs, whereas a more complex method, eg, deep/reinforcement learning-based method, would be needed on a substation computer or the cloud.

Such a flexible deployment architecture provides the basis for a hierarchical grid intelligence framework, allowing for dynamic protection, control, and an automation system that can accommodate many new sub-systems to the grid (eg, DERs, energy storage).

More future applications

Considering ABB's proposed architecture →08, further applications are possible, including site-specific (eg, event analysis and detection) to broader system-level applications (eg, DER monitoring and control), as existing technologies, eg, data fusion, ML/AI, and 5G real-time communications, expand; thereby enabling a paradigm shift in distribution PAC functionality. While data fusion merges various data sources and types to manipulate data and provide useful

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inputs to end applications, ML techniques use supervised, unsupervised, and reinforcement learning methods to solve traditional and new distribution protection, automation, and control applications. The deployment of 5G and other advanced, real-time communication systems will enable the deployment of applications that could only be realized on paper 20 years ago →09.

Looking to the future, but grounded in the present, ABB's proposed concept provides for a faster response to grid events than centralized or substation-based solutions: coordination with SCADA, distribution management systems and substation computers is feasible. Such new wave technology can provide significant benefits to the utility distribution grid, distribution automation, overall grid management, advanced analytics, DER monitoring and control, and asset management. The merging of edge computing technology, the ubiquitous communication medium and protocols, and advanced analytics will provide strong distributed intelligence platforms to support the next generation of distribution automation and grid management products →10. •

10

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References

[1] R. Rodrigues, et al., "Applying edge computing to distribution automation", *2023 IEEE Conference & Exposition (Grid Edge)*, PES IEEE April, 2023, Available: https://ieeexplore.ieee.org/document/10102738 [Accessed Aug. 3, 2023.]

[2] P. Perani, "In Grid we trust", in *ABB Review* 03/2023, pp. 172–179.

[3] Y. Zhang et al., "Information fusion for edge intelligence: A survey", in *Information Fusion*, vol 81, 2022, pp.171–186, Available: https://www.sciencedirect.com/science/article/abs/pii/S1566253521002438 [Accessed Aug. 3, 2023.]

[4] PingThings Website, [Online] Available: https://ni4ai.org/info [Accessed Aug. 3, 2023.]

[5] DOE/EPRI National Database Repository of Power System Events, [Online] Available: https://pqmon.epri.com/see_all.html [Accessed Aug. 3, 2023.]

[6] P. Joshi and H. Verma, "Synchrophasor measurement applications and optimal PMU placement: A review" in *Electric Power Systems Research*, vol 199, 2021, Available: https://www.sciencedirect.com/science/article/abs/pii/S0378779621004090 [Accessed Aug. 3, 2023.]

[7] A. Primadianto, and C. Lu. "A review on distribution system state estimation" In *IEEE Transactions on Power Systems*, vol 32, 5, 2016, pp. 3875–3883.

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GRID-INFORMED DYNAMIC PRICING FOR EV CHARGING USING REINFORCEMENT LEARNING (RL)

Unlocking the price

To help balance load and power generation that ensue from the electrification of transportation and the increased connection of variable power sources to the grid, ABB has developed an RL-based dynamic price model for electric vehicle (EV) charging with the required flexibility to respond to changing grid conditions.

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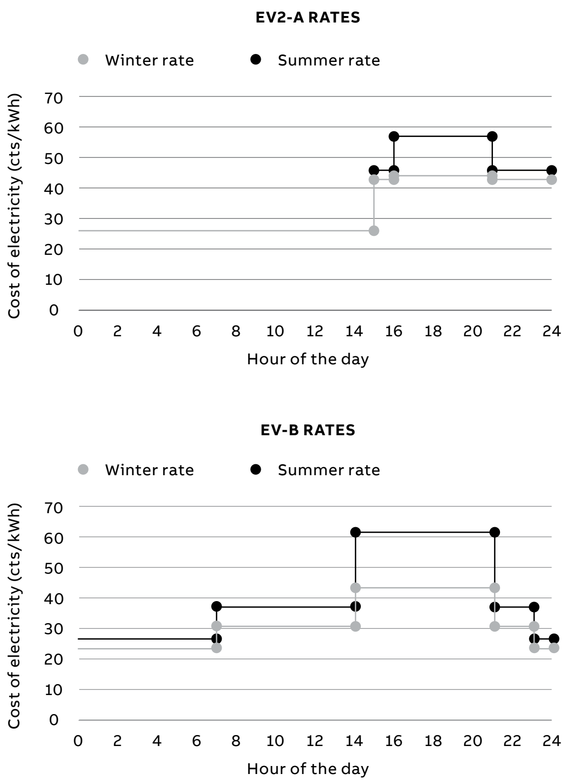
The electric grid of the future must handle increased loads from the accelerated electrification of transportation as well as variable generation from distributed energy resources (DERs). Balancing load and generation requires a combination of location-specific grid-responsive solutions. Recognizing this key challenge, ABB proposes a free market approach to influence EV charging decisions by varying the price of EV charging in response to grid conditions. The resultant solution will lower the cost of delivering power to the end customer and help utilities maintain grid stability.

Shifting to electric vehicles

The electric grid is in the process of undergoing a major transformation. The world has largely recognized the need to shift away from fossil fuel-based energy, especially for transportation. The resulting rapid increase in EVs is projected to lead to a heightened demand for power and energy. This increase, along with the expansion of distributed energy sources connected to the grid, leads to increased variability in power generation. Two ways to handle the subsequent balancing act between power generation and load would be to add more energy storage and, or, to reinforce the grid. However, this comes with significant capital expenditure. While such infrastructure-based improvements are welcome and have already begun [1], the scale of the problem is potentially alarming. For example, in September 2022, residents of twelve California counties were requested to reduce power consumption or face rolling blackouts due to higher power demand than usual resulting from an extreme heat wave [2]. Such scenarios indicate the need to implement a broader combination of approaches.

—
The rapid increase in EV's is projected to lead to an increased demand for power and thus energy.

One obvious consideration is to evaluate the future of EV charging, which has been growing at an ever higher rate due to increased customer demand. To help meet this demand, ABB launched the world's fastest EV charger, the Terra 360, in 2021. With a maximum output of 360 kW, an electric car can be charged in less than 15 minutes, delivering 100 km of range in less than three minutes [3]. And once the capability to charge rapidly is developed further and installed, it would be more than unfortunate if the speed of charging needed to be artificially and forcibly curtailed. Such actions might be required to maintain grid stability and ensure the security of power supply.



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ABB, the world leader in EV infrastructure, offering the full range of charging and electrification solutions for EVs of all kinds, is collaborating with partners in the utilities, and academia, to provide technical solutions to address these future challenges in the real-world. ABB's Electrification Mosaic Platform for Grid-Informed Smart Charging Management (eMosaic), is one such project, that was initiated in 2020 to provide a combined view of multiple charging sites, levels, and types of EV charging for utility-informed smart charging management.

Time-of-use rates – a locked-in structural solution

A traditional free market approach to handle the load to generation mismatch, especially in areas where solar energy generation is strong, has been the use of time-of-use rates. Electric utility companies, such as PG&E in California, USA, already have EV time-of-use rates in their rate structure [4] →01 which means that the price that end consumers pay better reflects the time varying costs of generating electricity. Beneficially, time-of-use rates have a daily and seasonal aspect, in which different rates are applied to night and day as well as to summer and winter to account for various factors, eg, variability in solar generation. Moreover, there are different rates depending on whether the power is for the entire home, without separate metering for EV charging (EV2-A rates), or only for EV charging (EV-B rates). Such pricing is expected to incentivize customers to charge during specific hours of the day. Even

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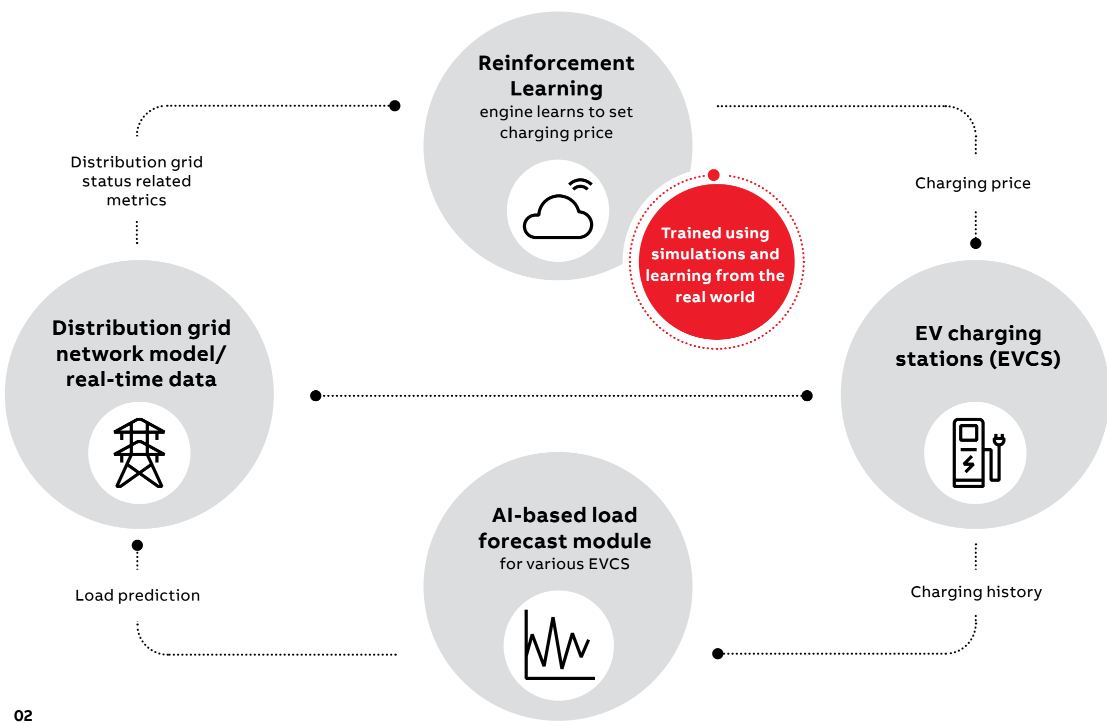
Time-of-use rates are a free market way to handle the load generation mismatch where solar energy generation is strong.



02

Reinforcement learning components	
Agent	Q-learning for small problems, deep Q-learning for larger problems
Environment	Distribution grid connected to multiple EV sites with the capability to react to or communicate charging price to the EV user, capturing user behavior
Action	Setting a price factor to modify base price at each EV site, changing hourly
State	Voltages and currents of interest at the distribution level on a per unit basis
Reward	Constraints on voltages and currents of interest Minimize cost of power delivery

03

—
01 An example of time-of-use rates.

—
02 RL agent price setting overview.

—
03 The table defines the RL components used in ABB's study.

so, EV customers are free to charge their car during peak hours, albeit at more than double the cost of the off-peak rate. Despite this seemingly logical solution, time-of-use rate structures are fixed and therefore unresponsive to changing grid conditions, such as unexpected peak use due to extreme temperature conditions, thereby reducing the effectiveness of this rate structure. While the certainty of such a pricing structure is positive, changing grid conditions and even weather could reduce its effectiveness.

Dynamic pricing

The next extension of time-of-use rates is to introduce grid-informed dynamic pricing, wherein the price of EV charging is responsive to what has happened historically and what the grid is currently experiencing. While this approach lacks the certainty of time-of-use rates, it provides the flexibility to respond to changing grid conditions through a free market approach. With the ever-increasing demand for power and energy, rapidly changing loads, and expansion of distributed energy resources, the future grid will face more variability. Dynamic pricing is another tool that could be used to help balance generation and load. According to the dynamic pricing approach, the EV user is rewarded with a lower price of charging during times when it is favorable to the grid (and in turn to the EV site owner) yet has to pay a higher price during high-demand situations. Nevertheless, there are many technical challenges to resolve before dynamic pricing can become a reality.

Setting the best price

Capturing the complex interaction between dynamic EV charging price, EV charging user behavior, electric load, and distribution grid dynamics is a formidable challenge. The goal is to provide benefits to the grid while simultaneously reducing the cost of delivering power to the EV or EV charging site owner. For a positive impact, the pricing approach must not only be flexible, it must be tailored to the location-based dynamics of the EV charging site. And, herein lies the rub: the rapidly increasing and changing EV penetration complicates the issue. Clearly, the dynamic price setting mechanism must be automated, but how? Smart grids can help solve the supply issues originating from the burgeoning number of rooftop solar and EV battery power sources operating in real-time by balancing demand from customer devices (air conditioners, water heaters, batteries, EVs). Dynamic pricing in real time would remove the pressure from the load, but how is this possible? The solution lies in the use of artificial intelligence (AI), specifically the field of reinforcement learning.

RL for dynamic pricing

The RL technique is based on the ability to learn the optimal behavior in a certain environment for maximum reward. Heavy research ensued after groundbreaking results were achieved in 2016 when AlphaGo, an RL-based computer program, beat the world Go[1] champion, Lee Sedol. Since then, there has been deepening research into RL and its use in industrial applications eg, for data center cooling, robotics, etc., with good success [5]. Recently at ABB, RL has been used to capture

—
ABB's grid-informed dynamic pricing has been successfully developed using RL models.

complicated interactions between EVs and the grid to dynamically set the charging price of electricity, as a follow-up step to the time-of-use electricity pricing in current use [6].

In this case, the RL agent can be thought of as a controller that takes the grid status as input and generates a charging price or charging price factor as output. This output is communicated to the EV charging station, which in turn transmits this information to the EV end-user.

In framing and developing an RL-based solution for any problem, the RL components must be defined →03. For the distribution grid, ABB used an IEEE 34-bus distribution system model with multiple EV charging stations at different nodes.

The next step involved training the RL agent to perform this price setting function. During the training process, the RL agent learns by interacting with the environment and trying different actions, which in this case are different price points, and determining how it affects the reward (a combination of grid health constraints and cost of total power delivery).

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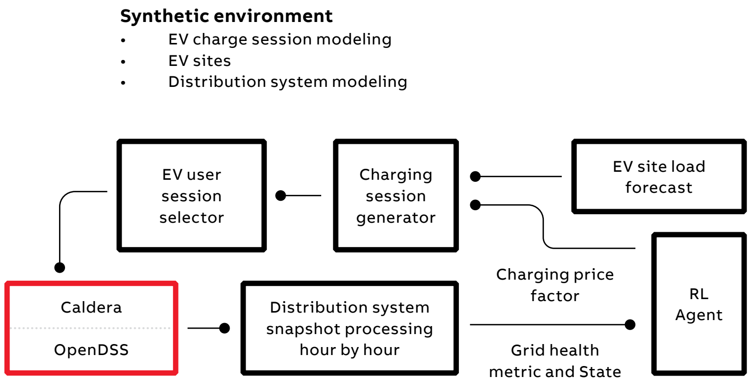
Footnote

[1] Go is a board game, invented in China, with over 2.1×10^{170} legal positions on the board.



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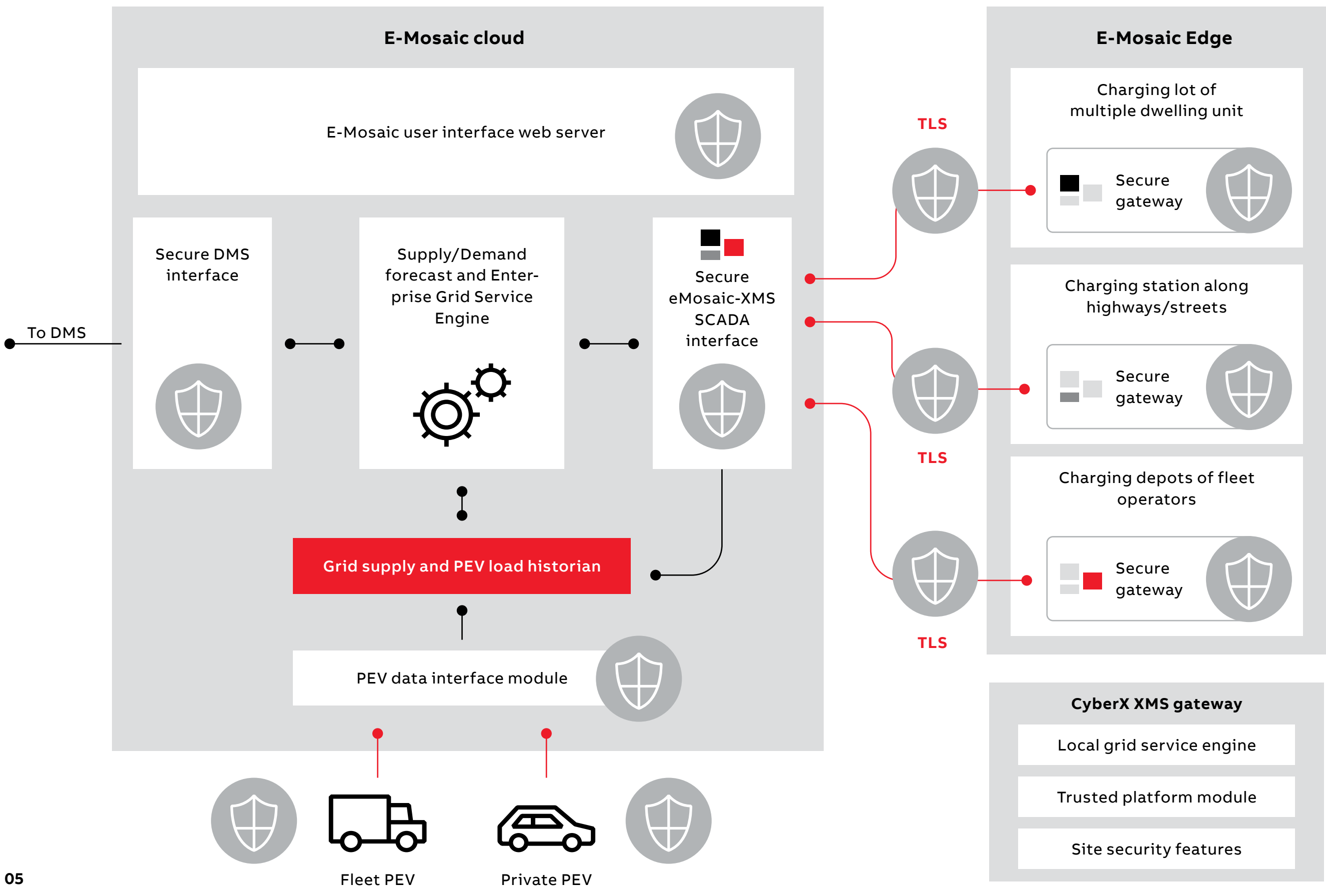
Ideally, to learn about its environment, the RL agent should train in the real world where it receives reality-based feedback for its actions. The drawback is the well-known exploration-exploitation trade-off. To learn, the RL agent needs to be able to explore the impact of different actions; during this time, its performance may be severely suboptimal. Moreover, the amount of time required to learn could be unreasonable for many real-world applications. To circumvent these drawbacks, a synthetic environment, which is similar to, yet distinct from a simulation twin, is created to represent the real world. In this way, the RL agent explores the effects of its actions in simulation before it is deployed and fine-tuned, using feedback, in the real world.

Synthetic environment for training
Allowing the RL agent to explore a virtual synthetic environment prior to deployment, makes it possible to use RL to solve complex problems. Ultimately, the closer the simulated environment is to the real world, the better the agent will perform once it is deployed. To this end, ABB developed and employed various tools and routines to simulate different aspects of EV charging, electrical grid dynamics, and load environment as well as end user behavior. The key tools and routines employed are:

- Caldera, an infrastructure simulation platform, developed by Idaho National Laboratory, which simulates the EV charging sessions and EV site electrical dynamics [7].
- OpenDSS, from the Electric Power Research Institute, which is used to simulate the IEEE 34 bus distribution system.
- Other routines developed in-house in Python, eg, EV site load forecaster, which predicts the day-ahead EV charging load for a charging site using multiple time horizons to capture the usage pattern and EV penetration dynamics using only past EV metering data [6]; EV



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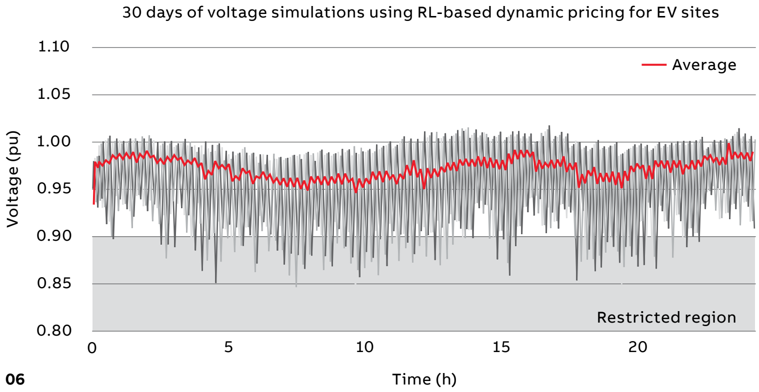

06

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04 Synthetic environment used to train the RL agent.

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05 An overview of the eMosaic architecture for secure communications. Please note that the Enterprise Grid Service Engine processes data and generates control signals to provide grid service such as supply and demand forecast based on historic data and that XMS refers to an XFC management system or charging station management system.

—

06 An example of voltage deviations seen at one node of a stressed distribution feeder. The diagram contains 30 plots of data for 30 days (one for each day). Each plot spans 24 hours and extends one more hour to the next day, hence 25 hours are depicted. The red curve is the average voltage deviation for the 30 days.

user session selector, which models user response to price signals; and charging session generator, which stochastically generates charging sessions based on a day-ahead prediction of EV behavior.

In ABB's case, the synthetic environment interacts with the RL agent →04, wherein it obtains the grid health metrics from the synthetic environment every hour and modifies the changing price accordingly.

Communication architecture

Dynamic pricing requires the underlying communication infrastructure to assure a flawless exchange of information. ABB determined that this infrastructure needed to be updated. This was accomplished as part of ABB's eMosaic project. Here, ABB developed and established secure communications between the EV site, the eMosaic cloud and different users →05.

Training and testing in the synthetic environment

The RL agent was trained in the developed synthetic environment for over 900 episodes (each episode is equivalent to 24 hours of charging). The training process takes about 5 days on a medium duty desktop computer server. To complete this training process in the real world, it would take about two and a half years. To generate the necessary performance metrics, the stochastic simulation was run to collect 30 days' worth of data: Voltages and currents were captured from distribution grid simulations →06. Here, it is to be noted that the grid has been deliberately loaded to reproduce the anticipated stress on the grid caused by EV charging. To compare performance, a constant pricing use case (baseline) with a similar price for energy delivery as the average dynamic price was simulated. The dynamic pricing use case demonstrated a nearly 50 percent reduction in the time spent in the restricted voltage region (less than 0.9 per unit). These results are extremely promising.

—

Having trained and tested the model, ABB will implement this pricing strategy at a demonstration site with project partners.

Future steps

Having defined the required algorithms, models and completed simulations to train and test this dynamic price model, ABB's next step is to implement this pricing strategy in a demonstration site with project partners. This will include a utility company and a university in the United States. Thus, the impact of dynamic pricing with real EV users can be rigorously tested, so that dynamic pricing will be ready to serve EV charging end customers and the utilities. After all it is only through balancing the needs of energy producers and consumers alike that the electrical grid can maintain a secure supply of energy as the electrification of transportation expands. •

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References

[1] P. Perani, "In grid we trust", *ABB Review* 03/2023, pp. 172–179.

[2] D. Smith, "California sent a scary text message urging residents to cut their power use and it worked", *The Sacramento BEE*, Sept, 2022 [Online] Available: https://www.sacbee.com/news/local/article265446471.html [Accessed May 17, 2023.]

[3] ABB Website, "ABB launches the world's fastest electric car charger", Available: https://global.abb/group/en/calendar/2021/terra-360 [Accessed May 17, 2023.]

[4] PG&E Website, "Electric Vehicle (EV) Rate Plans", Available: https://www.pge.com/en_US/residential/rate-plans/rate-plan-options/electric-vehicle-base-plan/electric-vehicle-base-plan.page [Accessed May 17, 2023.]

[5] J. Luo, "Controlling Commercial Cooling Systems Using Reinforcement Learning" in *arXiv*, November 2022, [Online] Available: https://arxiv.org/abs/2211.07357 [Accessed May 17, 2023.]

[6] H. Suryanarayana and A. Brissette, "EV charging site day-ahead load prediction in a synthetic environment for RL based grid-informed charging", 2023 IEEE Transportation Electrification Conference & Expo ITEC, June, 2023, pp. 1–5,

[7] Idaho National Laboratory Website, "Caldera: EV infra-structure simulation platform", Available: https://cet.inl.gov/caldera/SitePages/Caldera.aspx [Accessed May 17, 2023.]

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STATE-AWARE LANE ASSISTANCE ENABLES BETTER CONTINUOUS PROCESSES

Beware of the state

Because various operating states exist in continuous production processes with distinguishing characteristics, data-driven solutions must take into account states and substates of the system to derive useful insights. ABB provides the ultimate state-aware solution to better support operators.

01

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Despite the emergence of machine learning (ML) techniques in a variety of industries that can handle dynamic and complex processes based on the proliferation of available data, the chemical process industry is not always able to use this data optimally in their continuous production processes. Even though the increased abundance of available historical time series data from various plant operating states, eg, startup, shutdown, half-load or full-load, might be available as the Internet of Things (IoT) devices proliferate, determining state is no easy matter. There are many reasons for this. For example, manual operations can cause a change in the operating state; the signature of various states usually coexist within a large amount of data, making identification of these states difficult. Moreover, a number of substates could exist within one operating state, thereby further complicating state determination.

—
ABB set out to provide a means to accurately identify and calculate the process state and substates.

ABB set out to resolve such challenges by providing a means to accurately identify and calculate the process state and substates to enable operators to more accurately evaluate and correct production processes.

Why determine the state?
Imagine that the feed flow rates of multiple types of fuel gas influence the operating status of a gas-fired power plant. When analyzing data from such processes, it is critical to incorporate information about process state because the exact same behavior exhibited by the data in one state can be normal, yet indicate a fault in another state. It follows that the optimal way to operate the process in question can deviate dramatically depending on the operating states. In addition to contributing to safe operations, the occurrence and the characteristics of each operating state could be relevant for experts in their evaluation

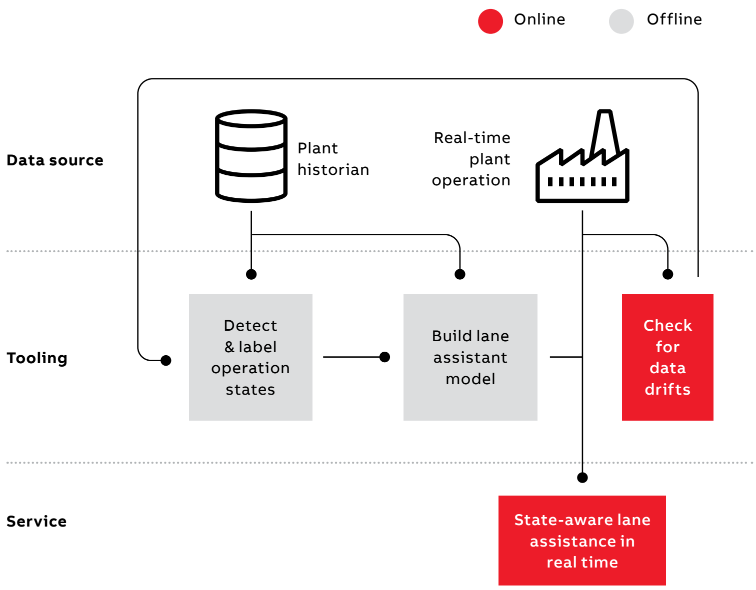
—
01 Because continuous processes are a mainstay of the chemical industry, operating state determination is critical for automation .

of the performance of the process to enable more efficient and sustainable operation →01.

Providing the correct and optimal support to a specific determined scenario is critical. Therefore, ML models, which are configured to support operators in such processes, should be state-aware. In turn, this means that the information about operating states should be included as a prerequisite for data analysis and ML model building. Such determination is demanding for a myriad of reasons: The process operating states might not be explicitly documented, or if documented the format could be difficult to process for data analysis and ML model configuration. Moreover, the root cause of the change of operating states could make identification challenging because of the sheer number of manual operations present during the production process in question.

—
Information about operating states should be included as a prerequisite for data analysis and ML model building.

Solution architecture
In a rigorous effort to address these challenges, ABB developed an innovative architecture using ML-based techniques →02. In offline training of the model, this data-driven solution utilizes signatures of the varying operating states to



02

identify the states derived from the unlabeled, historical time series data and to label them accordingly. For example, the generated power is correlated with the power plant load; a high value for generated power would indicate that the process is in the full-load state while less generated power might indicate that the process is running at a half-load state.

ABB's solution can successfully identify states with simple signatures and such that are more complex. With the operating states identified, the solution then analyzes the operation and configures state-aware ML models that generate the operating lanes for all, or, the most important operating states individually.

When deployed for online operator support, this solution labels the currently active operating state in the process using the available online data and applies the corresponding ML model to generate operating lanes for operator support

—

This innovative ML-based architecture solution is part of the ABB Ability™ PlantInsight Operator Assist platform.

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

ABB's innovative solution is part of ABB Ability™ PlantInsight Operator Assist, which provides a compact overview of complex plants and appropriate support for operating personnel in these plants. The solution is developed for and has been verified in several customer use cases with real-life datasets from various processes, such as chemical production, oil refineries and power plants.

Data-driven state identification

In the first step of the workflow, the historical time series data are segmented and clustered using unsupervised time series clustering algorithms such as the well-known time-series KMeans and Toeplitz Inverse Covariance-Based Clustering (TICC) [1]. The clusters of the segment should represent various operating states. An example of the identified states is given in →03, namely "running", "not running", "startup" and "shutdown", from the unlabeled time series data. The "running" and "not running" states can be easily distinguished from one another by evaluating the time trends, ie, all process variables had non-zero values when the process was in the "running" state as exhibited by the pink-colored area in →03 while all variables have almost zero values when the process was "not running" as displayed by the yellow area in →03. In the case of a short period when a shut-down occurred, followed by a startup, ABB's solution successfully identified the short but significant transition periods of "startup" (orange area) and "shutdown" (green area) →03.

Because the major states, ie, "running" and "not running" are identified during the process, even though the process was constantly running, the possible existence of substates within the major states are indicated in this case. By applying the time series clustering algorithm to the time windows identified to be one or more specific major states, ABB's solution enables the identification of possible substates. In one instance, the substates correspond to the flow rates of two different types of fuels (indicated by red and blue lines on the graph), and the ratio between these rates, which are being supplied during the process under investigation. In this example, the yellow-colored period indicates when the "red" fuel was dominant and the "blue" fuel was insignificant; whereas the green-colored period is identified as the time in which the "blue" fuel was more dominant than the "red" fuel.

Thus, ABB's ML-based fully automated solution identifies the operating states and substates existing in the process under investigation rapidly, accurately, and easily. The task of identification of the states by a human expert would, in contrast, be tedious, time-consuming and therefore less efficient.

—
02 The schematic provides an overview of the workflow for the state-aware operator support.

—
03 An example of identified operating states from the historical data. Pink region: “running” state; yellow region: “not running” state; orange region: “startup” state; green region: “shutdown” state.

—
04 Substates identified during the process: the blue curve and red curve are a measure of the flow rates of two different types of fuels. The gaps between the colored periods belong to the “not running” state identified previously; they were removed from this analysis.

Analysis of the states

Once operating states are identified, ABB’s solution goes one step further by analyzing the operating states to generate additional useful insights regarding the historical performance of production. For example, the statistics of the identified states and corresponding periods represented in the historical data can be calculated.

—

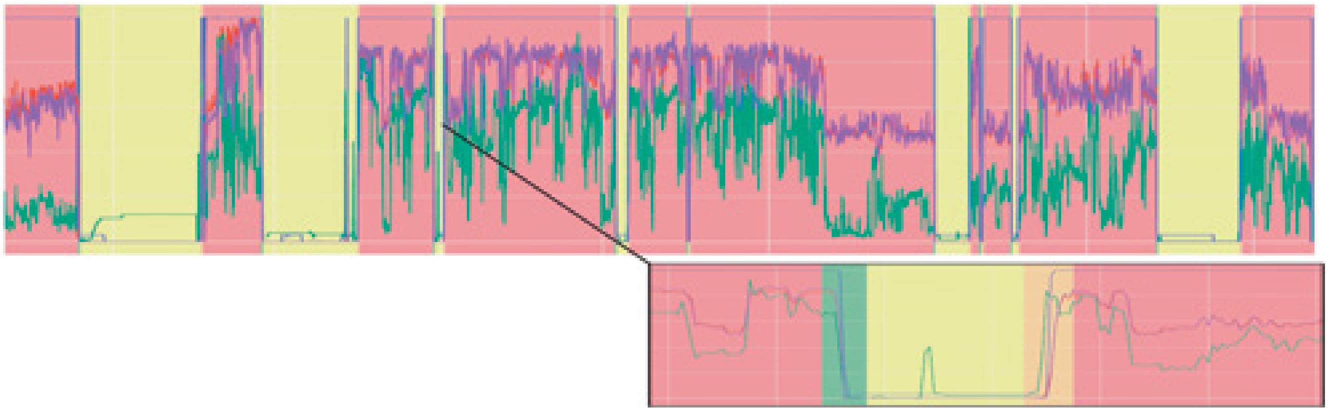
ABB’s solution analyzes the operation and configures state-aware ML models that generate operating lanes.

Two examples of the statistics employed do just that →05, namely to analyze the duration of each operating state and the frequency of the transitions between the states. The conclusion could be that the running time is around 65 percent and the not-running time is 20 percent, approximately, over the given period. Additionally, a typical operation sequence can be identified from the frequency analysis that such a sequence makes: “running” → “shutdown” → “not-running” → “startup” → “running” (R→D, D→N, N→U, U→R) →05. It is noteworthy that the transition from “startup” to “not running” occurred once; this might indicate an unsuccessful attempt to startup. Such information would be relevant in regard to a retrospective analysis of the production performance.

Moreover, the labels generated by the unsupervised time series clustering algorithm can be further leveraged and explained by XAI (explainable AI) methods [2], which will soon become mandatory in the EU, to extract rules for process operation. For example, for the “running” state presented in →03, the rule would be: when the blue curve is above a certain threshold value, which fits well with the empirical knowledge of the process experts, such that: when the process is running normally, a key process variable should be nonzero. Such rules not only enhance the confidence of domain experts in data-driven solutions, a challenge in sophisticated data-driven solutions, but will also yield insights when labeling of the operating states occurs in real-time.

State-aware lane assistance

To present information to the operator in an intuitive and efficient way, ABB Ability™ Plant-Insight Operator Assist adopts the concept of operating “lanes” as if the operator was driving their process and, as such, they should remain in the lane to guarantee safe, sustainable and efficient production→06. The lane is presented as a dynamic, adaptive band around the time trend of selected process variables.



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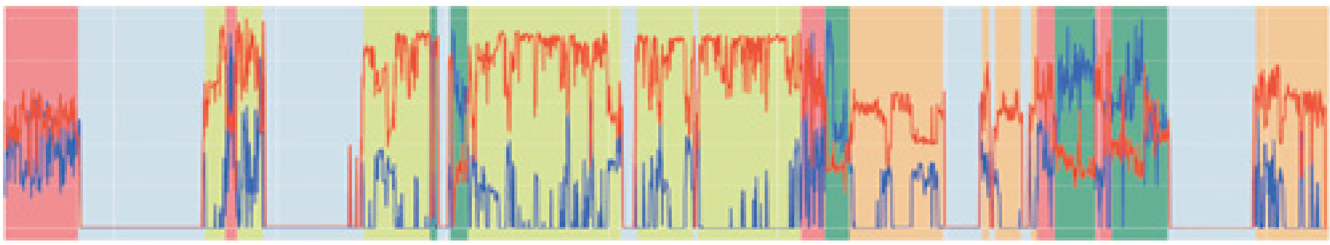

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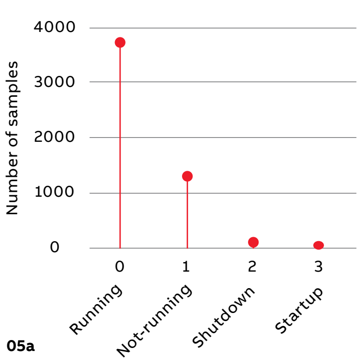

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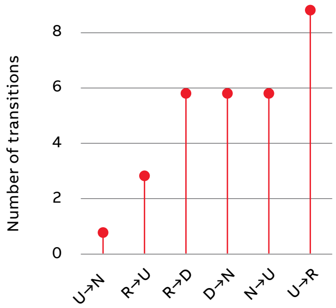

05b

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05 Statistical results of the operating states.

05a Duration of each operating state is shown.

05b Transition frequencies between the states are shown (R: "running"; N: "not-running"; U: "startup"; D: "shutdown").

—
06 The schematic provides an overview of the workflow for the state-aware operator support from the ABB Ability™ PlantInsight Operator Assist.

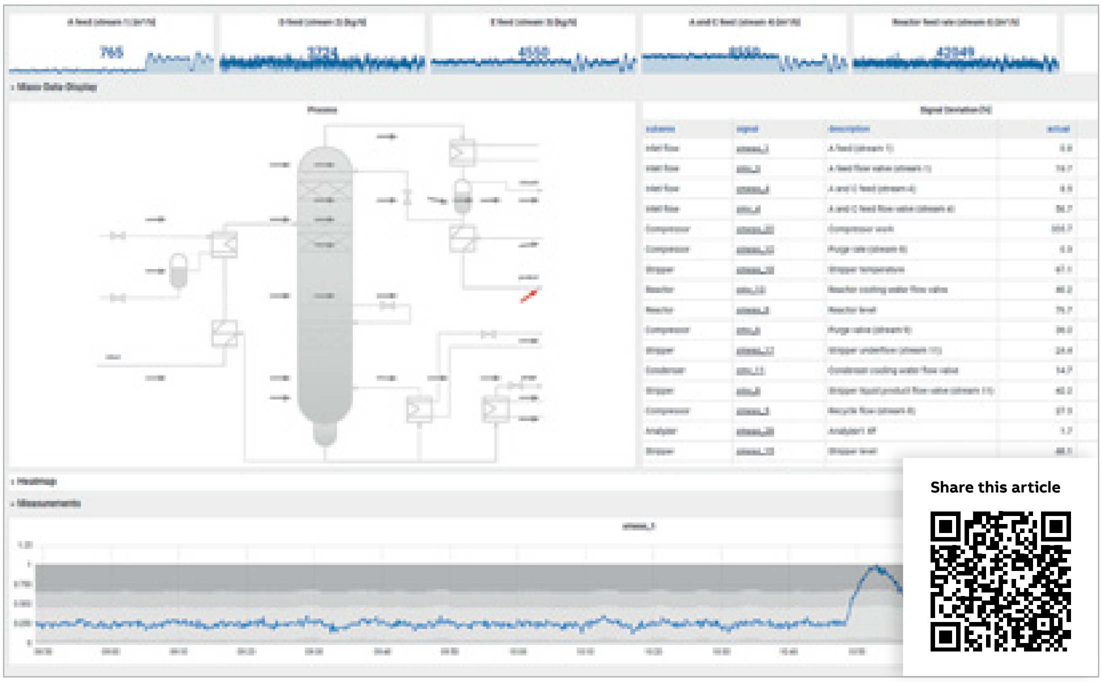
ABB's solution further empowers the configuration of the operating lanes via multivariate, state-aware ML models. One way to accomplish this task is to train one ML model, eg, an autoencoder, for each important operating state using data collected from this state only. Such ML

—
With state-aware support, operators can better understand and evaluate the production operation and performance.

models can capture the behavior of the process in a given state better than a general model that is trained using data from a variety of states [3]. The ML models are then used to calculate the operating lanes; such lanes take into account both the current process state and the relationship between several process variables. Compared to the bandwidth of conventional static alarm limits of process variables, such lanes are much more adaptive and can be much narrower; this can enable early detection of even minor deviations of the process from the ideal production.

It is essential for both the operators and the operator support systems to be aware of the historical and present operating state, eg, the loading conditions, the input materials, and the expected grade of end product that may exist in their processes. Only in this way can they properly evaluate performance and make the right decisions accordingly. ABB's ML-based solution addresses these needs by providing a fully automated, unsupervised workflow to enable the identification of the operating states and substates from time series data. Not stopping there, ABB's innovative digital solution provides additional useful insights by deriving and presenting the historical states. The state information is incorporated in training state-aware ML models that generate operating lanes to detect deviations from optimal production.

With the state-aware support this solution offers, operators will be able to better understand and evaluate the production operation and performance in their specific processes, both historically and in the present, thereby maintaining a safe, sustainable, and efficient production. •



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References

[1] D. Hallac, et al., Toeplitz "Inverse Covariance-Based Clustering of Multivariate Time Series Data" in *arXiv*, 2018, Available: https://arxiv.org/abs/1706.03161v2 [Accessed July 17, 2023.]

[2] The Royal Society "Explainable AI: the basics policy briefing", 2019, [Online] Available: https://ec.europa.eu/futurium/en/system/files/ged/ai-and-interpretability-policy-briefing_creative_commons.pdf [Accessed July 17, 2023.]

[3] R. Tan, et al., "An on-line framework for monitoring nonlinear processes with multiple operating modes" in *Journal of Process Control*, Vol. 89, 2020, pp. 119–130.

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BUZZWORD DEMYSTIFIER

Gaia-X

Although the term sounds simple enough, much ambiguity and misunderstandings surround the topic of data spaces. What are they for? And what have Gaia-X and Catena-X to do with it all?

—

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Put simply, the intention behind data spaces is to enable the sharing of data across different domains and organizations to foster new business models of data-driven services by overcoming limitations in terms of trust in existing infrastructures and accessibility of data. Having set this goal, initiatives – such as the International Data Space Association (IDSA) [1] and Gaia-X [2] – are working out relevant principles, standards and technical solutions. Catena-X [3] is an example of a first adoption of a data space emerging from this work.

When explaining data spaces, one should first clarify what they are not:

- Data spaces, such as Gaia-X, have been erroneously depicted as the European cloud-provider alternative to Google, Amazon, etc. They are not.
- Data spaces are neither just a collection of cloud storage services, nor a shared database creating a big data lake.
- Another common misunderstanding is that participation in a data space will simply make data accessible to anyone within this space. This assumption conflicts with one of the core principles of data spaces: data sovereignty.

So, what are data spaces, then? Data spaces are regulated environments that facilitate the provision and consumption of data and data-driven services while respecting core principles – such as openness, transparency, trust, data sovereignty, security and decentralization. Openness allows any party to join the space, while data sovereignty guarantees every data provider will keep full control of their data and any sharing thereof.

Considering Gaia-X as representative, the initiative develops technological and legal guardrails for future data-space concepts. The contributions are governed by a collection of documented principles, regulations and standards for technical solutions to connect data and services providers with consumers.

Participants in a data space must verify themselves and their offerings against the regulations by documentation, technical proof and audits to ensure trust towards other participants.

Initiatives such as Gaia-X specify generic technology building blocks, that allow the realization of data spaces. These blocks comprise so-called Federation Services and reference implementations. Federation Services help establish mutual trust between participants, create data or service contracts and facilitate rule-based data exchange. Federation Services are hosted by elected participants from the data space (not Gaia-X itself) who neither have access to any operational data nor can interfere with the bilateral data exchange between participants.

—

Gaia-X creates technological and legal guardrails for future data space concepts.

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Apart from IDSA and Gaia-X, who ar the “rules of the game,” early adopters already exist: The most prominent of these being Catena-X, a data space focused on automotive supply chain participants. Catena-X relies heavily on open-source software – eg, Eclipse Dataspace Components (EDC) [5], which prepares technology blueprints for upcoming data spaces.

The maturity of Gaia-X and most adoptions, except Catena-X, is limited and it remains to be seen how implementations and uses of data spaces will evolve. One potential candidate of interest to ABB’s key industries is the up-and-coming Manufacturing-X, which will help establish a flexible, trusted and sovereign data ecosystem that allows the many advantages of digitalization – manifested by, for example, Industry 4.0 – to be fully exploited. •

References

[1] IDSA publications: https://internationaldataspaces.org/publications/about-idsa/

[2] Gaia-X, “Vision & Mission.” Available: https://gaia-x.eu/what-is-gaia-x/vision-and-mission/. [Accessed July 1, 2023.]

[3] Catena-X, “The Vision of Catena-X.” Available: https://catena-x.net/en/vision-goals. [Accessed July 5, 2023.]

[4] Sovereign Cloud Stack, “About Sovereign Cloud Stack.” Available: https://scs.community/about/. [Accessed July 5, 2023.]

[5] Eclipse Foundation, “Eclipse Dataspace Components.” Available: https://projects.eclipse.org/projects/technology.edc. [Accessed July 5, 2023.]

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FRENCH AND SPANISH TRANSLATIONS

ABB has discontinued the publication of the French and Spanish versions of ABB Review from issue 01/2023. From 01/2023 forward, only English, German and Chinese versions will be provided. The editorial staff apologizes for this decision. Subscribers of the discontinued translations are being supplied with the English version if no other preference is expressed. Readers wishing to change their preference are invited to indicate this on abb.com/abbreview

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