review

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Page numbering

Readers will be pleased to notice that from this year we have returned to academic journal page numbering, meaning page numbers run contiguously throughout the four editions of the year. Our intention is to make referencing easier for the scientific community.

Corrigendum

"The shoulders of giants", *ABB Review* 1/23 pp. 9–15: On page 11 (caption of fig 02) and page 13 (first paragraph), the name of ASEA's technology publication should read ASEA Journal, not ASEA Review.

"Cutting the cables", *ABB Review* 1/23 pp. 34–39: The following co-author was omitted: Abdulkadir Karaagac, ABB Corporate Research Ladenburg, Germany, abdulkadir.karaagac@de.abb.com. On page 38 the acknowledgments should read: "The authors wish to acknowledge the outstanding contributions of colleagues from ABB Corporate Research, Västerås, Sweden and of colleagues in Ericsson R&D"

The authors and editors of ABB Review apologize for these errors.

Enhanced knowledge

As businesses collect more data, the challenge is to inform and integrate it with past experience, make it available wherever and whenever it's needed, and constantly update and improve it. This issue of ABB Review explores how the resulting enhanced knowledge helps deliver savings and performance improvements. What's next? Make sure to get a free subscription to print, online, and/or newsletter content by scanning the QR code.

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

EDITORIAL

Enhanced knowledge

Dear Reader,

In an increasingly competitive and fast-changing market environment, industries have come to expect their production systems to be installed and updated quickly and efficiently with a minimum of disruption to their operations. As equipment and processes become more complex and versatile, these expectations can only be fulfilled with sophisticated tools that support planning, configuration and operation.

In this issue of ABB Review, we look at how advanced software is speeding up and streamlining maintenance, upgrading and processing in industrial operations from substations to food-and-beverage applications. Among the highlights is a toolkit that simplifies the setting up of robots and a solution that consolidates multiple cyber-security controls.

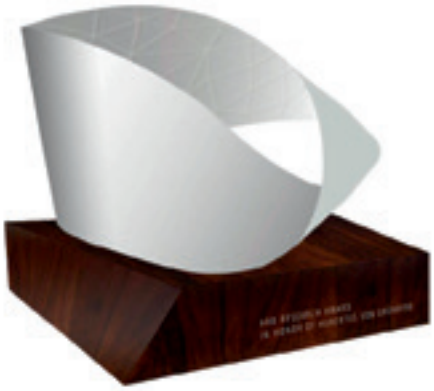
Enjoy your reading,

Björn Rosengren
Chief Executive Officer, ABB Group

PRESTIGIOUS AWARD FOR WORK ON CONNECTED DEVICE SECURITY

2022 ABB Research Award

The 2022 ABB Research Award in Honor of Hubertus von Grünberg has been awarded to Dr. Utsav Banerjee. This triennial award comes with a $300,000 grant to support Dr. Banerjee's work on integrated circuits and systems for increased security on the Internet of Things (IoT) and connected devices.



Alf Isaksson
ABB Corporate Research
Västerås, Sweden

alf.isaksson@se.abb.com

The ABB Research Award in Honor of Hubertus von Grünberg is bestowed only every third year and is intended to distinguish external researchers. The award is named after Hubertus von Grünberg →01, a former Chairman of the Board of Directors of ABB. The winner is selected from many submissions by a jury composed of prominent academics, Dr. Bernhard Eschermann, Chief Technology Officer of ABB Process Automation and Dr. Hubertus von Grünberg.

This sum represents one of the world's highest-endowed research prizes to be offered by a company.

The award winner receives a $300,000 grant to support their research over a three-year period. This sum represents one of the world's highest-endowed research prizes to be offered by a company. The award is bestowed by the ABB CEO at a special ceremony →02.

The award is intended to encourage world-class research in ABB's main fields of operation:

HUBERTUS VON GRÜNBERG

Hubertus von Grünberg, a theoretical physicist who wrote his doctoral dissertation in 1970 on Albert Einstein's theory of relativity, was instrumental in setting ABB on a path to sustainable growth and in cementing its reputation as a leader in technological innovation. His steadfast support for research, both at universities and within the company, established it as one of ABB's strategic imperatives.

During his tenure as ABB Chairman from 2007 to 2015, the company achieved notable technological breakthroughs, such as the hybrid high-voltage direct current (HVDC) circuit breaker, which solved a 100-year-old engineering puzzle, and paves the way for an easy-to-manage DC grid. Today, the ABB group invests some $1.3 billion annually in R&D and operates numerous research centers around the world, underlining ABB's claim to be one of the most innovative companies worldwide in driving the digital transformation of industries.

01

02

electrification and automation. The award recognizes outstanding postdoctoral research – in particular, work that makes creative use of software, electronics or new materials to pave the way for groundbreaking industrial solutions →03.

The 2022 winner
Even as a schoolboy in India, Utsav Banerjee was fascinated by the latest developments in electronics. Now, after having received an MSc and a doctorate from the Massachusetts Institute of Technology (MIT), he is pushing the boundaries of technology.

As an Assistant Professor at the Indian Institute of Science, in Bengaluru, Dr. Banerjee's work addresses security and privacy issues in the IoT. The aim is to bridge the gap between complex theoretical concepts and practical implementation to enable efficient hardware solutions for secure edge computing. This area of research involves complex mathematics and sophisticated electronic circuit design, especially relating to silicon chip architecture. The field is becoming increasingly important as more and more components connect to the internet and exchange data across companies' sites.

Faster and better encryption using less power
Complex algorithms are used to encrypt data passing between connected devices in the process and automation sectors. However, this encryption requires hefty computing muscle. Dr. Banerjee's research aims to improve and speed up the encryption and authentication of data while reducing the computational power needed for these tasks.

An enabler for other breakthroughs
Dr. Banerjee's research will lead to new implementation-level advances in secure computation. Results from this research are expected to inspire breakthroughs in the field of privacy-preserving computation, taking one further step toward the goal of strong, affordable and high-efficiency data security.

"Our hope is that we will be able to embed high-performance, low-power hardware into tiny devices and that all the data collected by these devices will be encrypted and will remain so even during subsequent computation in the cloud,"

—
This research is expected to inspire breakthroughs in the field of privacy-preserving computation.

explains Dr. Banerjee. "This award will help me research hardware security and how to enable the hardware systems that will perform computations on encrypted data. These investigations will involve software and hardware components and custom chip design."

Dr. Banerjee chose to conduct his research at the Indian Institute of Science because it is the leading institute in the country. He adds, "Being in India, I still stay close to my roots and I have an opportunity to contribute back to my society through research and teaching."

ABB Review will publish a full-length article on Dr. Bannerjee's work in a later edition. •

PAST LAUREATES

The 2019 prize was awarded to Ambuj Varshney of Uppsala University, Sweden, in recognition of his work on sustainable networked embedded systems (NESs). Varshney developed an ultra-low-power and long-range communication system (LoRea) for battery-free sensors that harvest small amounts of energy from the ambient environment. He has demonstrated their ability to communicate over distances of up to a few kilometers while consuming only tens of microwatts [1].

The 2016 prize was awarded to Jef Beerten from the University of Leuven, Belgium, for research on the modeling and control of DC grids.

03

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01 Former ABB Chairman, Hubertus von Grünberg, drove innovation in the company.

—
02 ABB CEO Björn Rosengren, awardee Dr. Utsav Banerjee and Hubertus von Grünberg, former ABB Chairman, at the ABB Research Award ceremony in Baden, Switzerland.

—
03 Past winners of the Hubertus von Grünberg award.

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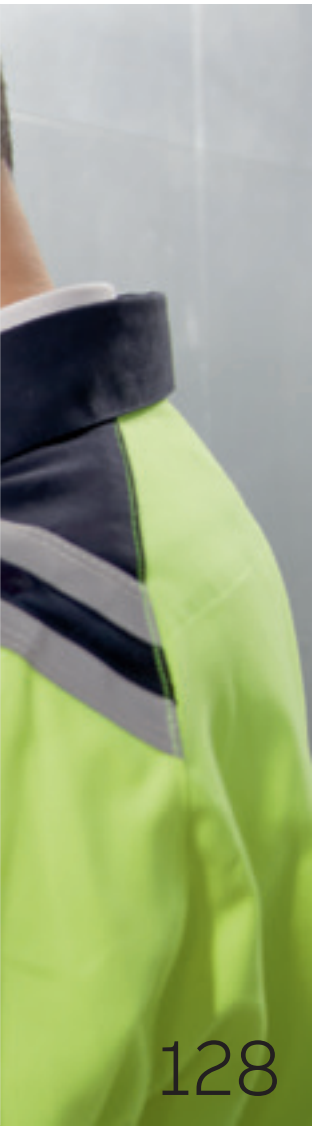
References

[1] R. Schoenrock, "Prestigious award for network researcher", *ABB Review* 2/2020, pp28-29.

Photo fig. 02: ©Selina Meier/ABB

Enhanced knowledge

Change is inherent in any operation, and enhanced real-time knowledge bridges the gap between mind-boggling new tech and achieving mind-boggling results. ABB helps customers put that knowledge to work every minute of every day in robots, VR goggles, factory processes, and systems overall.



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01

HIGH SPEED ALIGNMENT – VISUAL SERVOING TECHNOLOGY FOR ULTRA-HIGH PRECISION ASSEMBLY

For greater results

Released in 2022, High Speed Alignment is the first software package on the market to provide 4- and 6-axis robots with visual servoing technology. Accuracy is increased by 50 percent and productivity by 70 percent – just what the precision assembly electronics industry needs.

Sales of smartphones, and other high-tech devices are growing, paralleling recent advances in electronics. As such, devices are becoming smaller and more powerful. Consequently, new automation solutions are required to quickly and accurately pick and place components in electronic production lines [1]. But this is more easily said than done. There is a well-known process trade-off between accuracy and speed if high-level performance is to be achieved.

ABB's articulated 6-axis robots, for example, are designed for such automation solutions. Flexible and able to handle complex tasks in tight spaces, such robots can perform a variety of meticulous placement tasks. ABB experts wondered if it was possible to push alignment accuracy and speed beyond the current limits in such cases. The result is ABB's High Speed Alignment[1)] software with visual servoing technology – designed and developed to explore new

—
01 ABB's breakthrough robot alignment software, introduced in 2022, is demonstrated.

—
02 Schematics that illustrate the traditional alignment method and the visual servoing method.

02a The traditional alignment method is shown. Here, processing of data occurs before the robot moves; and before checks are made about whether the robot has been aligned in the correct position. If not, another snapshot is taken and the robot is rerun, once proper alignment is completed, the robot jumps to the next task.

02b ABB's new visual servoing method creates a continuous loop of data processing and servoing, which includes checks for alignment performance, before the robot proceeds with future tasks.

limits for alignment accuracy and speed, while also achieving reduced cycle times →01.

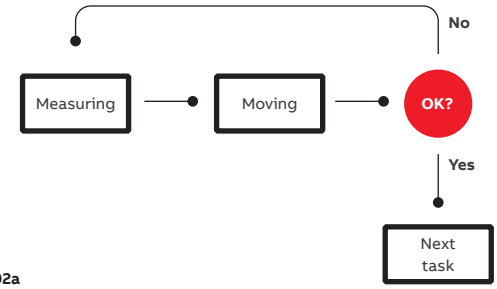
High Speed Alignment: past, present and future
Traditionally, robots were pre-programmed – ready to execute orders on command and work in determinate environments. A high degree of technical competence was required for both calibration and commissioning. Using an iterative look-then-move approach for robotic alignment, the robot had to first stop before the vision system could take snapshots, process the data and then determine and execute the necessary action. The robot then repeated this course of action, over and over again as needed →02a.

In recent years, shifts in paradigms have led to a new approach to robot alignment. Nowadays, systems are generally smarter, able to sense uncertainties and the dynamics of the environments in which the robots operate; this is due to the aid of various sensors, significantly, vision sensors. As a result, a more adaptive approach to alignment, one that is much less deterministic, is possible. Sensor feedback is now tied to the operation of the robot →02b. This means that while sensor input is collected, data is processed simultaneously; feedback is directed at the same time to the robot system, thereby allowing commands to be executed almost instantaneously. By combining this real-time sensor data capability with built-in smart algorithms, simultaneous prediction is now possible. Every forthcoming robotic movement can be predicted; instructions can be provided while, or even before, the next feedback loop is being processed. Use of this approach results in greatly shortened repetitive cycle times for: collecting input data, processing the data and executing tasks, as well as increasing the robustness of the robotic system. Thus, users can reach the desired high accuracy and speed they need – high speed alignment during operation is now possible.

ABB's High Speed Alignment achieves increased system reliability, while it reduces cycle times and increases accuracy.

Thanks to this paradigm shift, it is estimated that by 2025 more than 30 percent of new robots will be equipped with vision sensors. These sensors will allow robots not only to accomplish more advanced tasks, the new visual capabilities will boost robot performance. By combining the fields of robotics with vision and artificial intelligence (AI) the way in which robots work and interact with their environment will change rapidly.

Technology and business-driven product development
Previous research on high-speed alignment focused primarily on improving the controllers' range of stability and robustness to system errors. However, in industrial applications →03, besides system accuracy and stability, cost and efficiency must be considered whenever new products are developed. For these reasons, ABB relied on real customer cases from the electronics industry and immediately began their investigation of the production line challenges that customers face on a day-to-day basis; the



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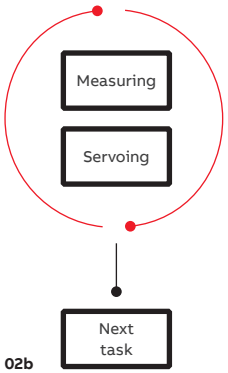

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Diamond Dong
JiaFan Zhang
ABB Robotics and Discrete Automation Research and Development
Shanghai, China

diamond-daimeng.dong@cn.abb.com
jiafan.zhang@cn.abb.com

Xiaolong Feng
ABB Robotics and Discrete Automation Research and Development
Västerås, Sweden

xiaolong.feng@se.abb.com

Qi Lu
York Qian
ABB Robotics and Discrete Automation
Shanghai, China

qi.lu@cn.abb.com
york-yingjie.qian@cn.abb.com

03

aim has been to develop a system that satisfies industry's needs.

Giving demonstrations at robotics fairs, and performing in-house demonstrations based on real-world customer cases has allowed ABB to enhance the technology development phase. Observed holistically, an interactive process between ongoing research and business-case studies has formed a sound foundation for development. This ultimately ended with a high-level classified technical readiness prototype. Thus, the technical effort needed for the research and development function during the productization phase could be greatly reduced. And, as an added bonus, customer pilot tests, which ran successful validation studies in parallel to ABB's development project, helped ABB to secure orders for the software even before the official launch of the product.

—

By including an auto-tuning feature, ABB has reduced deployment time from an entire shift to just an hour.

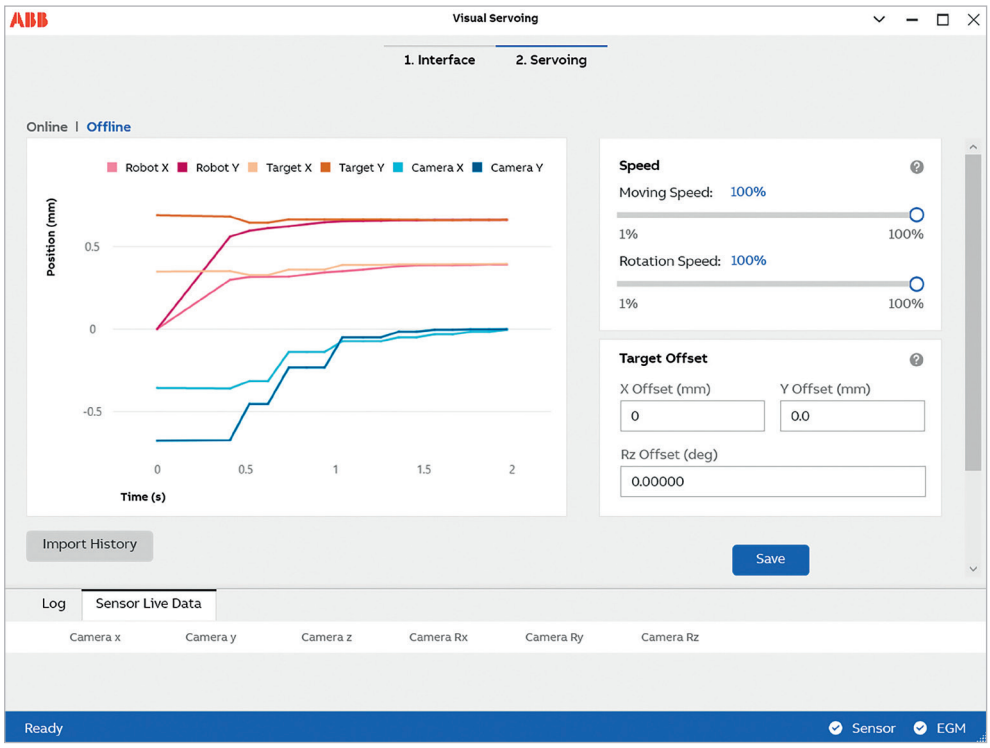
Speeding up productivity while reaching high accuracy

Developed for ultra-high precision assembly tasks and successfully tested using customer setups, ABB's High Speed Alignment not only achieves increased system reliability, but this unmatched technology also reduces cycle times by 70 percent, from ~5.6 s to ~1.7 s, while increasing accuracy by 50 percent, from 20 µ to 10 µ.

How does High Speed Alignment achieve such phenomenal results? A comparison of the traditional look-then-move approach with ABB's new technology provides answers →05-06: In the traditional approach, cycle times are dependent on the number of loops that are required for the sensor system to recognize the designated objects, with a single loop lasting approximately

—
03 ABB's High Speed Alignment software is compatible with ABB's IRB 1100 and IRB 120 industrial robots.

—
04 The screenshot shows the user-friendly nature of servoing with the auto tuning feature; it illustrates the ability for users to focus on either speed or accuracy.



04

2 seconds →05. Here, there is a certain amount of luck involved in the determination of just how many cycles will be required. In contrast, with High Speed Alignment, this recognition process occurs continuously, whether the previous robotic motion has finished or not. And, by fusing the data acquired by the sensor together with the feedback data of the robot at the same time, the target motion of the robot can be updated – in as little as 4 ms. Significantly, this means that a much larger spread of values is created, and the system does not need to wait on the completition of full cycles →06.

System complexity

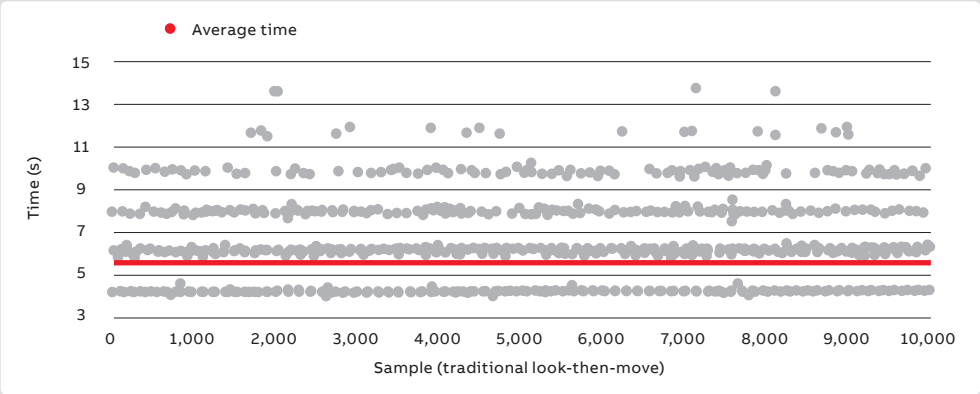
It is noteworthy that tests for both the look-then-move and High Speed Alignment approaches were conducted in a simple system set-up with one or two vision sensors. Would the cycle times be different if the system complexity is increased? To test this notion, two additional sensors were added to the set-up, thereby increasing complexity. In the case of the look-then-move approach, any misalignment requires the system to rerun the entire alignment cycle, thereby greatly increasing cycle times. Further, this would increase the possibility of system failure before proper alignment is achieved – a clear disadvantage. In contrast, adding increased complexity to visual servoing technology did not impact alignment cycles since all areas are rectified simultaneously. In other words, the cycling times remain unchanged. Thus, ABB's High Speed Alignment system with visual servoing technology – using a simple vision sensor system – enables precision of robotic movements to achieve 10 µ levels while greatly improving speed.

Ease-of-use is key

ABB designed the ease-of-use software and interface with the knowledge that by sacrificing either accuracy or speed, it is possible to push the other entity to an even greater level. By simply tuning either accuracy or speed, the converging time of the robot alignment, or the cycle time can be modified, respectively →04. As a result of the easy-to-use software, in combination with the intuitive user interface, only minimal expertise is required to operate the system.

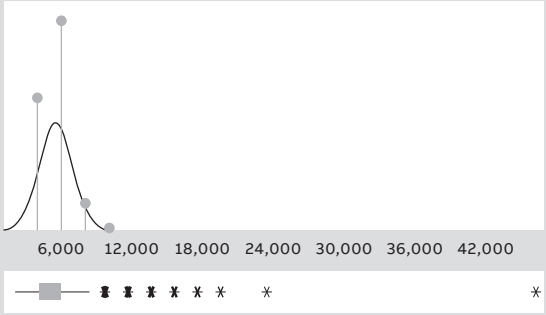
—
The alignment software was originally developed for use in the computer, communications and electronics industry.

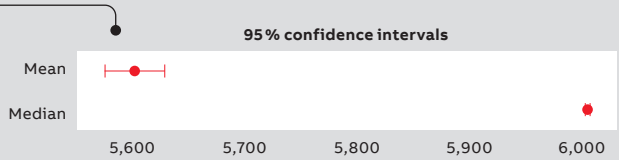
High Speed Alignment has also been designed for effortless commissioning as well as ease of system alignment so that inexperienced users



ROBOT	IRB120
Times run	10,000
Passed	9,994
Passed %	99.94%
Failed	6
Failed %	0.06%
Avg. time (ms)	5,603
Min. time (ms)	2,211
Max. time (ms)	13,845

Q1 = 4,158
Median = 6,005
Q3 = 6,091
IQRange = 1,933
Whiskers to:
2,211.8476
N = 10,000



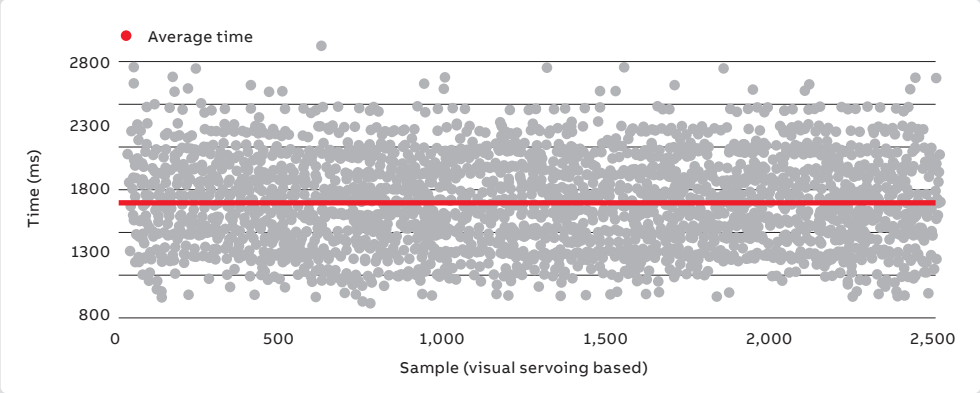


Anderson-Darling normality test

A-squared	817.47
P-value	<0.005
Mean	5,602.9
StDev	1,378.5
Variance	1,900,226.6
Skewness	3.9763
Kurtosis	82.8112
N	10,000
Minimum	2,211.0
1st quartile	4,158.0
Median	6,005.0
3rd quartile	6,091.0
Maximum	45,991.0

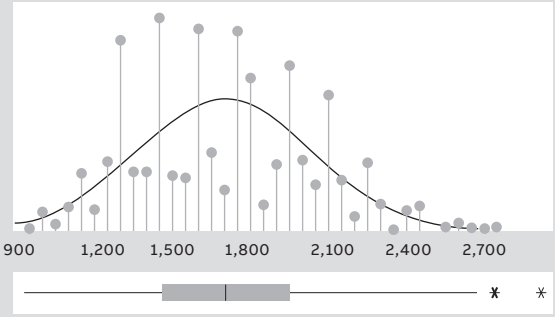
95% confidence interval for mean	
5,575.8	5,629.9
95% confidence interval for median	
6,004.0	6,007.0
95% confidence interval for StDev	
1,359.6	1,397.9

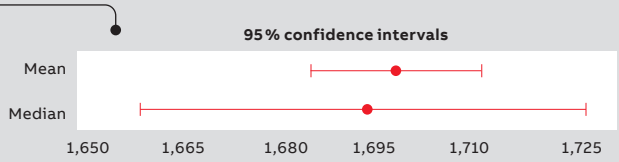
05



ROBOT	IRB1100
Times run	2,500
Passed	2,500
Passed %	100%
Failed	0
Failed %	0%
Avg. time (ms)	1,698
Min. time (ms)	932
Max. time (ms)	2,910

Q1 = 1,455
Median = 1,693.5
Q3 = 1,944
IQRange = 489
Whiskers to:
932.2669
N = 2,500





Anderson-Darling normality test

A-squared	9.51
P-value	<0.005
Mean	1,697.9
StDev	339.6
Variance	115,359.5
Skewness	0.240467
Kurtosis	-0.412036
N	2,500
Minimum	932.0
1st quartile	1,455.0
Median	1,693.5
3rd quartile	1,944.0
Maximum	2,910.0

95% confidence interval for mean	
1,684.6	1,711.3
95% confidence interval for median	
1,658.0	1,727.5
95% confidence interval for StDev	
330.5	349.3

06

—
05 Test results for the traditional method with a static target and 0.02 mm accuracy. The alignment time for 10,000 cycles, averaging at 5.6s is shown above. Below, a 95 percent confidence interval for the mean, residing between 5.58s and 5.63s is displayed.

—
06 Test results for the visual servoing method with a static target and 0.01 mm accuracy. The alignment time for 2,500 cycles, averaging at 1.7s is shown above. Below, a 95 percent confidence interval for mean residing between 1.68s and 1.71s.

—
07 The schematic illustrates the project's scope for ABB's visual servoing technology.

can operate the system. By using vision-guided motion, a combination of machine vision and precision motion control, which is the core technology behind High Speed Alignment, the flexibility of the alignment

—

ABB relied on real customer cases to investigate the production line challenges that customers face on a day-to-day basis.

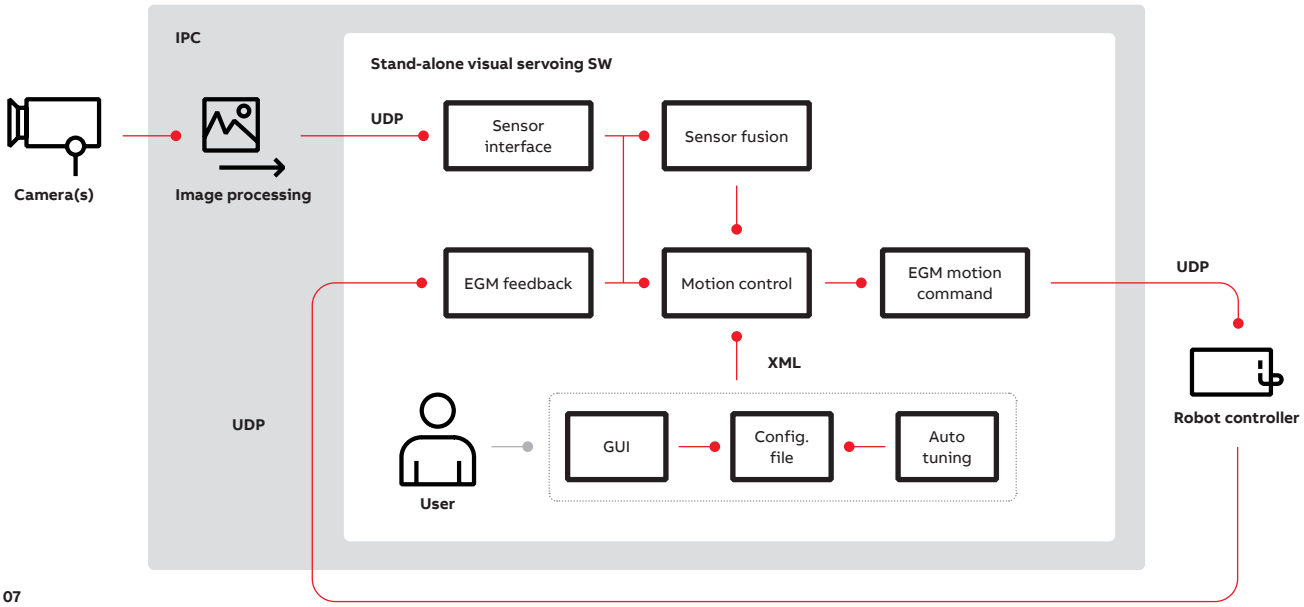
process is improved. Previously, to implement a high-performance controller, users required tremendous effort (expertise) to tune the control parameters for the servoing, generating greater costs. Thanks to High Speed Alignment this is no longer the case.

For these aforementioned reasons, ABB included an auto-tuning feature. In contrast to traditional systems, in which users had to consider the time delay of sensors, filter buffer length, control gain, delay of robot and dead zones etc., ABB's solution allows all of these parameters to be calculated automatically. Users need only drag the tuning sliders and observe the alignment performance. This removes some of the skill barriers to interacting with the system to achieve desired alignment results. By including an auto-tuning feature, ABB effectively reduces commissioning time, reducing deployment time from an entire shift to just an hour.

Additionally, ABB's system allows users to select previously recorded servoing data for comparison whenever they tune new servoing parameters. Such functionality supports users, experts and novices alike, in all their efforts and reduces costs.

Expanding compatibility

Currently, High Speed Alignment is compatible with a wide range of cameras, IRC5 and OmniCore™ robot controllers for high flexibility. Although High Speed Alignment is independent of hardware and the image processing tool used, the type of communication protocol used is important. The solution supports any sensor if the data is transmitted in the correct format via a User Datagram Protocol (UDP) channel to the client →07. Nonetheless, there are plans to support Transmission Control Protocol (TCP) communication in the near future.



07

50 years
of robotics software expertise

10µ–20µ
accuracy levels for highly precise electronics assembly

70 %
increase in speed using 6 axis robots for alignment use cases

Easy-to-use software and intuitive user interface, little expertise required to operate the system

Compatible with a wide range of cameras, IRC5 and OmniCore robot controllers for **high flexibility**

8 → 1 hour
Reduction of deployment time by effortless commissioning with auto-calibration and tuning

The entire framework consists of a sensor (a camera in this case), a robot controller, an image processor and visual servoing technology →07. The latter technology and the image processor are included within the industrial PC. The camera is attached to the end effector of a robot to capture visual information in the task space. The resultant image stream is received by the image process, which computes the position of the target object relative to the camera. The robot controller, namely an IRC5 (or OmniCore™), controls the robot and provides an External Guided Motion (EGM) interface to communicate with visual servoing through the UDP datagram. Visual servoing then acquires data from both the EGM and the image processor and generates motion commands that are sent to the IRC5 through UDP. It is the feedback of the robot's information from the EGM interface that allows the performance of the visual servoing controller to be maintained at an optimal level [2].

The software includes visual servoing technology with cameras, and a computer vision system, to control the position of the robot.

New opportunities
ABB's High Speed Alignment software was originally developed for ultra-high precision tasks in the computer, communications, and consumer electronics industry, such as assembly in electronics manufacturing, alignment of components, picking or placing a work piece in a tool, and placing a part in a fixture. Other opportunities for potential applications include:

- For bottle-picking, eg, in breweries that rely on Causal State Splitting Reconstruction algorithms
- For gluing, sealing and tire assembly, and friction stir welding in the auto industry
- For seat assembly in Tier 1 industries; suppliers of parts or services to an original equipment manufacturer (OEM).

With High Speed Alignment, ABB has released the first software package in the market to provide visual servoing technology for 4- and 6-axis robots for ultra-high precision assembly tasks

—
08 A summary of the main benefits of ABB's High Speed Alignment with visual servoing.

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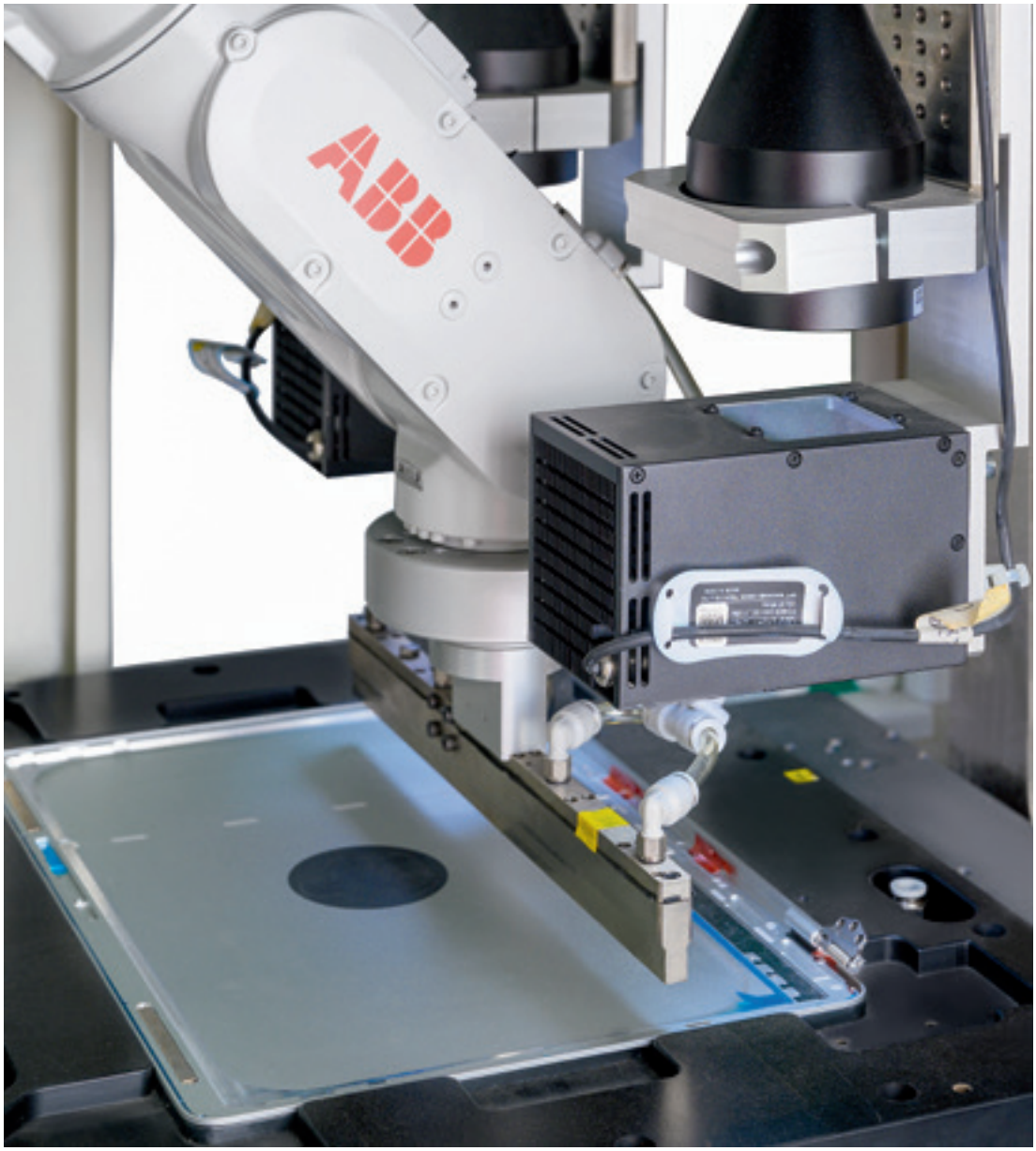
09 Using one or more cameras with a computer vision system to control the position of the robot's device or tool relative to the workpiece, High Speed Alignment achieves a phenomenal level of percision.



09

→08. Using one or more visual sensors and a computer vision system to control the position of the robot's device or tool relative to the workpiece in real-time, this technology satisfies industry's demand for higher alignment accuracy and speed →08-09. High Speed Alignment enables robotic movements to achieve 10 µ levels for precise electronics assembly while meeting industry's cost and efficiency demands. •

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High Speed Alignment is the first software package in the market to provide visual servoing technology for 6-axis robots.

Footnote
[1] Visual servoing for ultra-accurate alignment (also known as High Speed Alignment, High Accuracy Assembly, in text referred to as High Speed Alignment)

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References

[1] ABB press release, "ABB launches breakthrough robot alignment software increasing electronics manufacturing speed and accuracy", 12 April 2022, Available: https://new.abb.com/news/detail/89415/prsrl-abb-launches-breakthrough-robot-alignment-software-increasing-electronics-manufacturing-speed-and-accuracy [Accessed September 17, 2022.]

[2] Y. Mao et al., "Visual-Servoing Control Based on EGM Interface of an ABB Robot", IEEE Publication, Chinese Automation Conference, 2018, Available: https://ieeexplore.ieee.org/document/8623638 [Accessed March 14, 2023.]

SOFTWARE THAT OPTIMIZES ROBOT PERFORMANCE

The right moves

The integration and programming of robots represent a major part of any company's investment in automation. With this in mind, ABB's RobotStudio® [1] [2], the world's most used offline programming and simulation tool for robotics, includes software that can be used to design, test and refine entire production cells in the virtual world, thus opening the door to a dramatic simplification of how robots are programed and operated. The most recent addition to the RobotStudio platform is RobotStudio Cloud, which enables individuals and teams to collaborate in real time on cell designs from anywhere [3].

Magnus Seger
Simulation Software
Göteborg, Sweden

magnus.seger@
se.abb.com

Boxes are stacking up, space is tight. Time is short. Wouldn't it be nice to have robots that could just be told what to do without any ifs, ands, or buts? Although commissioning and assigning new tasks to robots is still far from simple, RobotStudio®'s desktop version makes it possible for users to do programming and simulation offline without disturbing ongoing production. Furthermore, RobotStudio®'s Augmented Reality Viewer app [4] enables users to visualize robots and solutions in a real environment or in a virtual room on any mobile device for free. In addition, associated software and applications enable teams to accelerate decision making and speed up the design and commissioning phase.

Users can visualize robots and solutions in a real environment or a virtual room on any mobile device for free.

Offline programming and visualization offer an ideal path to maximizing return on investment for robot systems; these techniques reduce risk and errors while eliminating downtime by programming outside of the production environment. Widely used by companies throughout multiple industries, ABB's RobotStudio® presents a wealth of possibilities for programming, designing and testing robots in a virtual environment. Below are ten examples of how it can boost customer facility performance [5] and enhance production.

Cable simulation
Designing robot cables and dress packs can be a challenge. Designers must consider the fact that the cables connected to industrial robots can undergo extensive wear and tear, resulting in a growing risk of collisions. With this in mind, RobotStudio offers cable simulation, enabling engineers to visualize →01 the movements of robots and their cables before implementation, thus reducing collision risks and increasing cable life span.

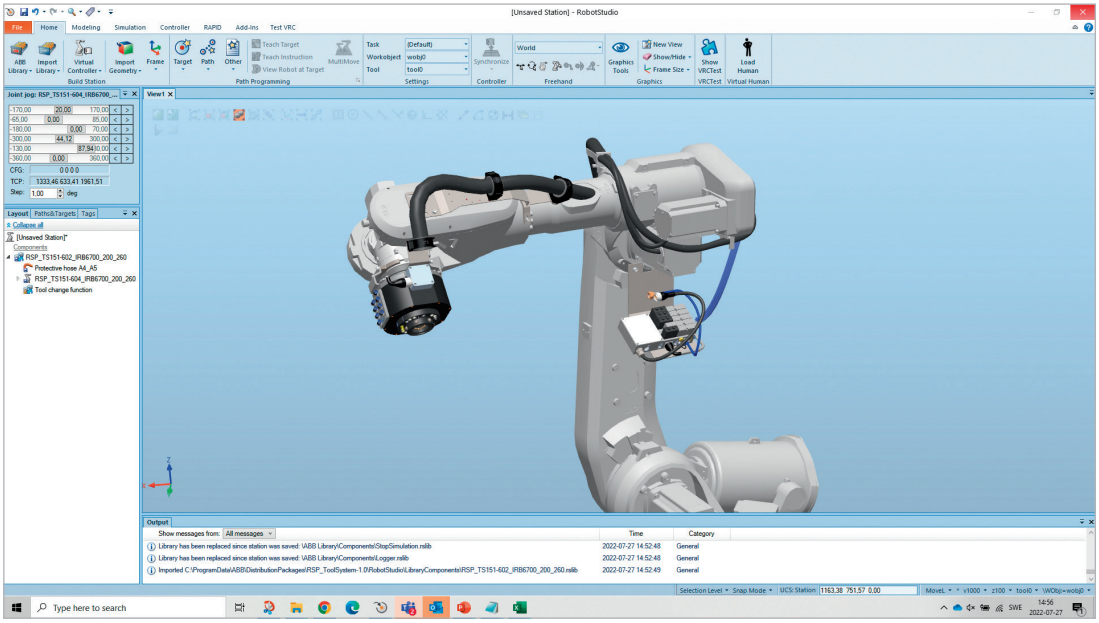
Swept volume
Figuring out the space that a robot requires to perform an operation can be tricky. This can make it difficult to predict how multiple robots might work with each other in a tight space, and where to set up fences and other boundaries where humans and robots intend to work together. RobotStudio can automatically and precisely calculate the swept volume of a robot and its tooling, covering the motion of the robot program. This can help to provide precise recommendations for where to place fences and safety zones, enabling automation process managers to prevent clashes, interferences, and potential accidents during actual production.

Signal analyzer
When retrieving, visualizing, and reviewing motion signals and I/O signals from a robot controller, these signals must come in the correct order. They must also have the correct time stamp to guarantee precision when tuning and optimizing the robot program, with the data received from real and virtual controllers.

—

RobotStudio can automatically create a swept volume of a robot and its tooling, covering the motion of the robot program.

This data is required from both the real and virtual robot controller to establish why a robot cannot reach a programmed speed, or how quality is being affected by slight adaptations or speed drops. Additionally, analyzing energy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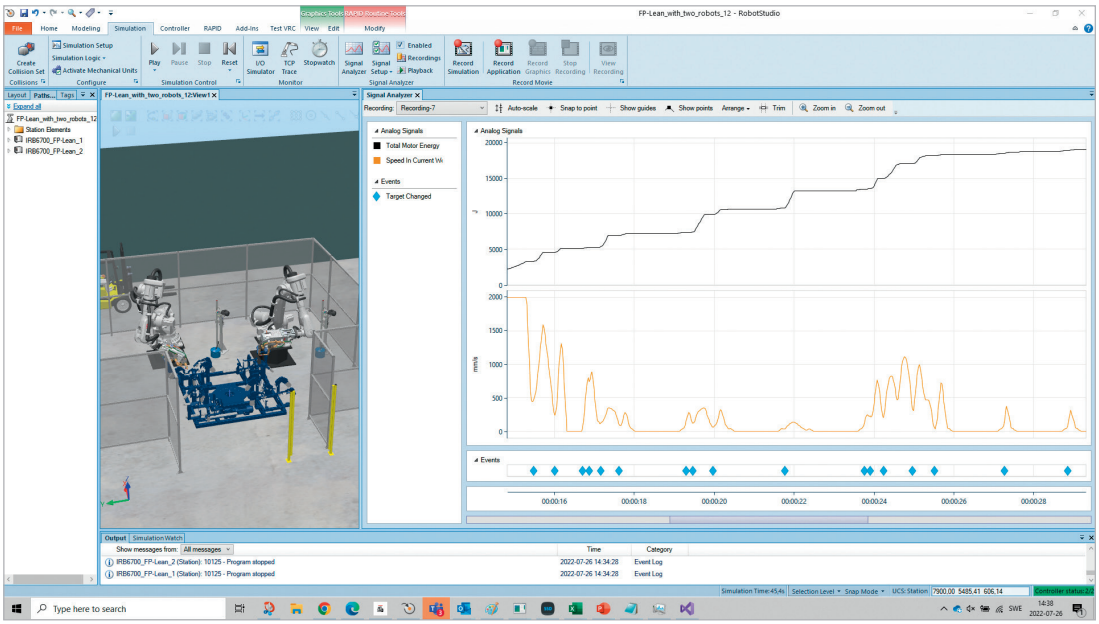
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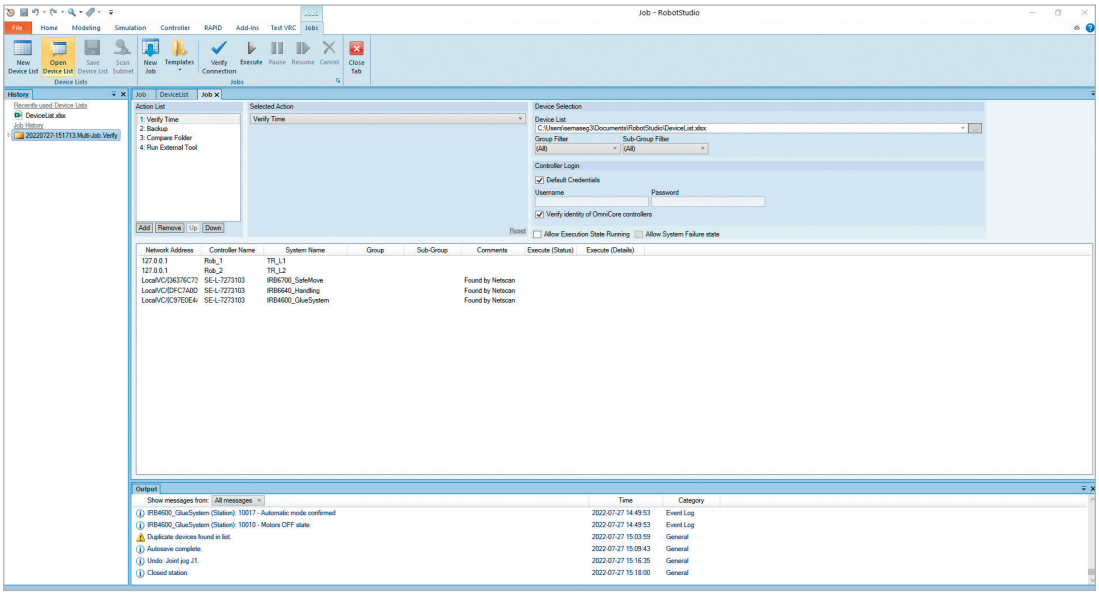
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History
Action List
Selected Action
Device Selection
Controller Login
Output

03

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01 Cable simulation reduces collision risks and helps to increase cable life span.

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02 Signal analyzer allows users to record and display all signals from a robot controller in one view.

—
03 The RobotStudio® Jobs feature permits simultaneous operation on a large population of robot controllers in a factory.

performance and efficiency during a cycle, and how variables can affect energy use, is becoming increasingly important for users.

RobotStudio's signal analyzer →02 allows users to record and display all signals from a robot controller (real or virtual) in one view. The dashboard allows users to optimize and adjust parameters with ease. Robot speed, power consumption levels, I/O signals, tool-center point (TCP) positions, joint values and more can all be recorded. By using the "go to" program or visualization, issues in the program can be identified with just one click.

CAD to path
Using a handheld device and joystick on the shop floor when moving a robot to the correct position to create a robot program is extremely complicated and time consuming. Usually, this will stop ongoing production and result in sub-optimal targets. However, by using a CAD-model of a part, it is possible to automatically generate a robot's positions on the edge of a shape.

—
The Auto-Configuration feature helps users to automatically define an optimized robot arm configuration.

In seconds, this will create perfectly oriented targets along the edge, which would have been otherwise cumbersome to achieve online by jogging and teaching the targets with a robot. RobotStudio's Auto-Configuration feature helps users to automatically define an optimized robot arm configuration for the complete path with just one click.

Jobs
Keeping an entire fleet of robots updated and running consistently is challenging. Traditionally, each robot would require operators to update and validate the installation manually, which is extremely time consuming. In the commissioning phase there can be multiple updates and changes happening at the same time. This makes it almost impossible to get an overview of which robots are installed and ready to go.

In view of these challenges, RobotStudio's Jobs feature →03 permits simultaneous operation on a large population of robot controllers in a factory, simply by connecting them to the factory's network. There are several actions that can be carried out, including backups, synchronizing the time on each robot, reading of RAPID data, updating user rights, retrieving system data, and sending them to external programs like Excel for further analysis, and much more.

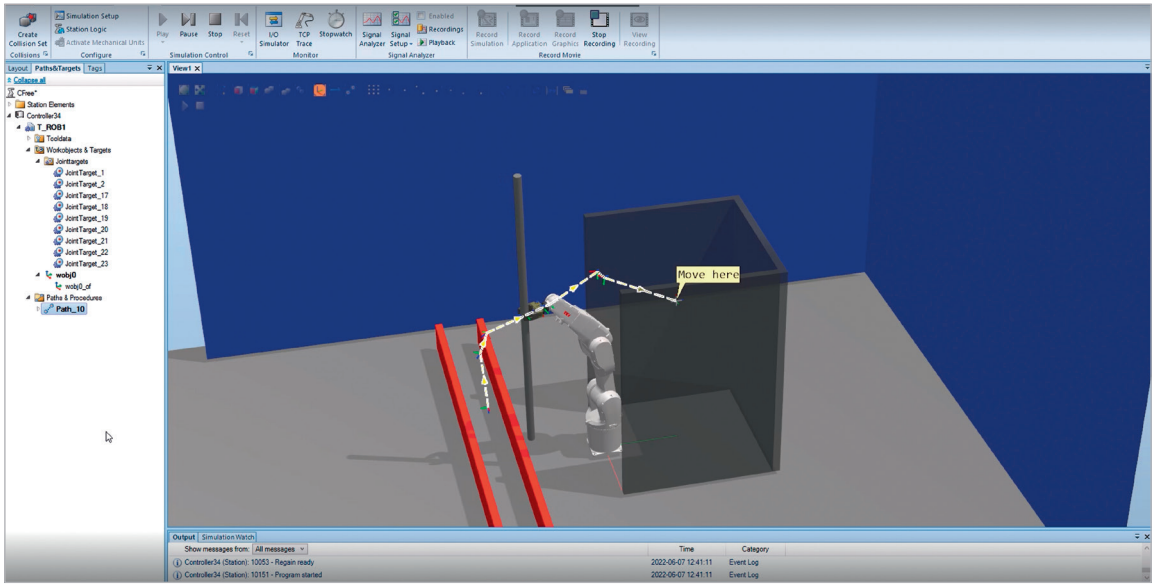
Automatic path planning
In a tight and crowded robot cell that contains a lot of equipment, it can be a highly complex and time-consuming task to create every robot movement, while also considering every obstacle on each movement path.

RobotStudio's automatic path planning feature →04 obviates the need to program all the steps to the final desired position. Instead, only the final position needs to be given, and the robot will swiftly follow a path that avoids all obstacles in its movement path automatically. This feature enables a collision-free path from start to finish within seconds, speeding up the engineering phase and time-to-market.

RAPID editing and debugging
Creating robot programs on a teach pendant is not ideal and typically requires downtime. This can be carried out on a PC or third-party simulation tool that emulates the robot code, however, this does not always provide sufficient context, nor does it allow testing and debugging of the program.

With RobotStudio's text editor, programs loaded into a robot can be viewed and edited either live or virtually. The editor features syntax and error highlighting, tooltips, automatic insertion of arguments, and context-sensitive help for robot instructions. There is also a data editor that allows tabular editing of the program data. The program can be debugged by setting breakpoints, while numerous other variables can also be monitored.

Station viewer
In the discovery and planning stage it is important for the supplier to be able to explain and communicate the proposed solution so that both the customer and the supplier are aligned, thus ensuring effective cooperation and collaboration. This is traditionally done by exchanging reams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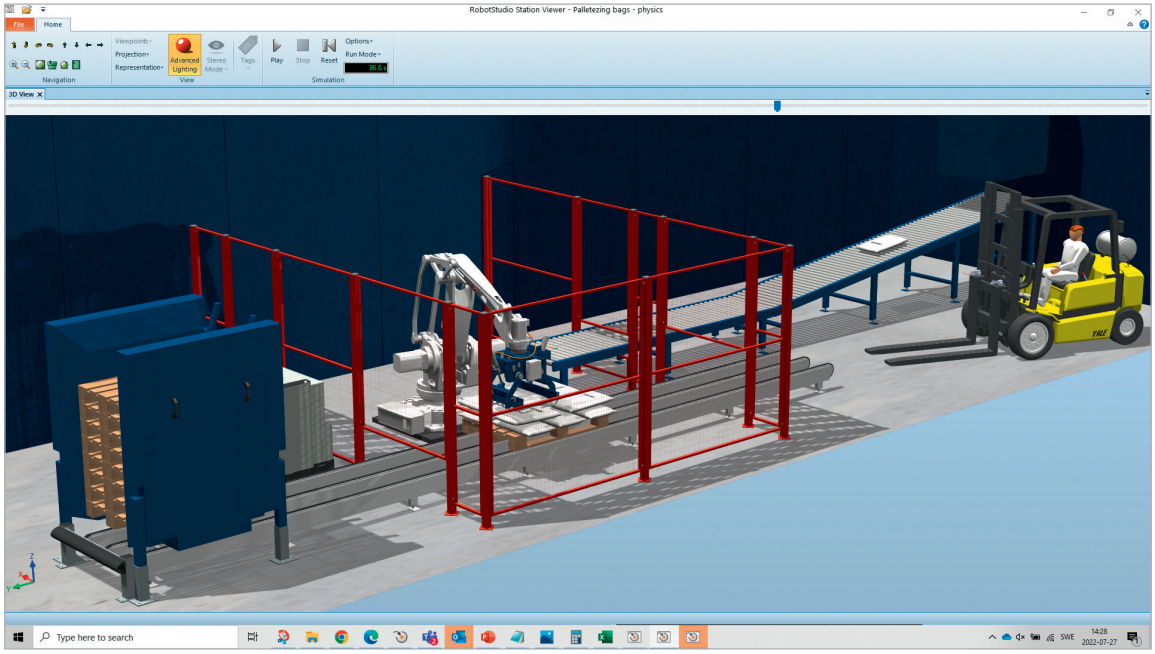
RobotStudio Station Viewer - Palletizing bags - physics

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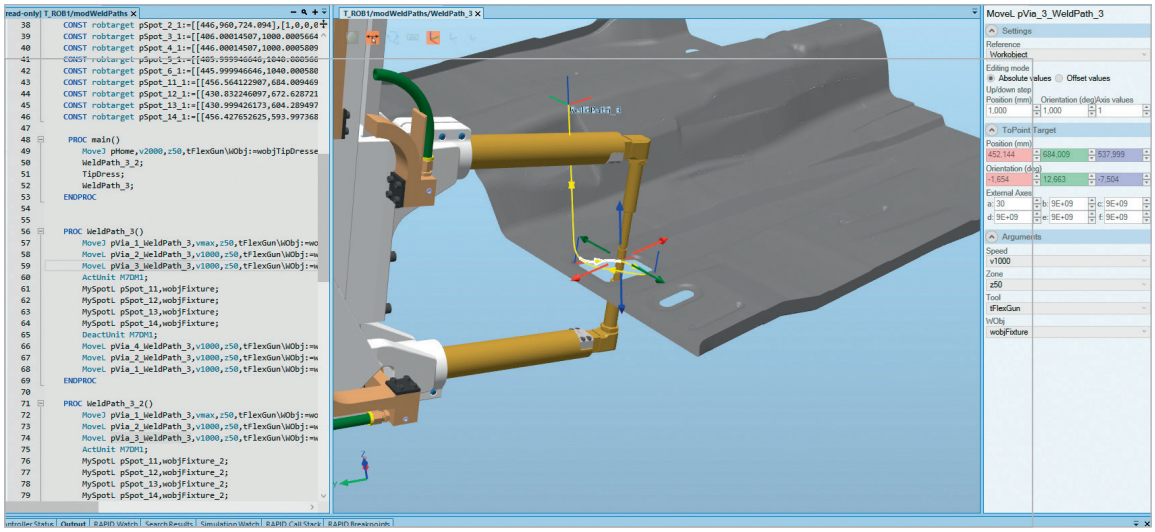

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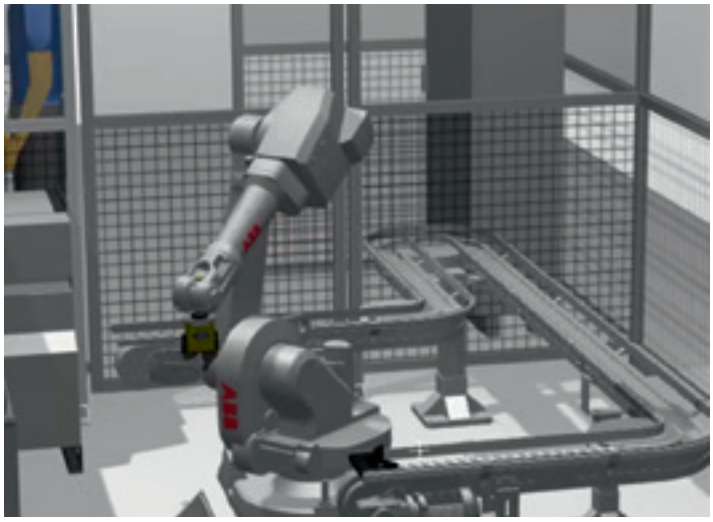

07a

07b

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04 Automatic path planning allows a robot to automatically follow a path that avoids all obstacles in its movement path.

—
05 Station viewer is a 3D interactive movie package for showing and sharing a RobotStudio® simulation to users who do not have the software installed.

—
06 Path editor's 3D views help users to edit individual or multiple targets at the same time.

—
07 Robot controller provides an exact copy of the real software that runs robots on the production floor.

07a Simulated production floor.

07b Actual production floor.

of documents, which are typically not easy to interpret and understand – a process that often leads to project delays and misunderstandings in the team.

Station viewer →05 is a 3D interactive movie package for showing and sharing a RobotStudio simulation to users who do not have the software installed. The package displays realistic graphics with accurate tooling, movements, and throughput, providing a better understanding of proposals and adjustments. The package also makes it possible to view projects in virtual reality, simply by plugging the headset into a computer.

—
Virtual controller allows users to be confident that what they see in the program is what they will get on the shop floor.

Path editor
Updating programs online is usually carried out through the teach pendant. However, editing multiple instructions or the complete process path can lead to errors and is a cumbersome process. It can also be difficult to achieve an accurate grasp of the necessary direction to move the positions to get the correct update of the targets. Furthermore, it can be difficult to go back and correct errors without losing previous edits.

RobotStudio's RAPID path editor →06 enables 3D views and ways to edit programs loaded into the robot controller, allowing users to edit individual or multiple targets at the same time, while the program is automatically updated. All changes can be undone before being loaded into the robot.

Virtual controller
Getting a system updated and running on the production floor can be time consuming and costly, particularly if easier options are available. Traditionally, offline programming systems have been used, but simulations are by their nature imperfect and do not always reflect reality.

RobotStudio's virtual robot controller →07a, 07b is an exact copy of the real software that runs robots on the production floor. It therefore provides more realistic simulations, using real robot programs and configuration files identical to those used on the shop floor, including safety zones. The virtual controller allows users to be fully confident that what they see in the program is what they will be getting on the shop floor. •

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References

[1] RobotStudio® Suite. Available: https://new.abb.com/products/robotstudio. [Accessed January 15, 2023.]

[2] RobotStudio®. Available: https://new.abb.com/products/robotics/robotstudio/robotstudio-desktop [Accessed January 15, 2023.]

[3] https://new.abb.com/news/detail/97646/prsrl-abb-robotstudior-takes-to-the-cloud-enabling-real-time-collaboration

[4] RobotStudio® AR Viewer. Available: https://new.abb.com/products/robotics/robotstudio/ar-viewer-app [Accessed January 15, 2023.]

[5] Customer stories. Available: https://new.abb.com/products/robotics/customer-stories [Accessed January 15, 2023.]

01

ENVISIONING THE FUTURE OF PROCESS AUTOMATION

The DCS of tomorrow

For more than four decades, ABB has been leading the way in the distributed control systems (DCSs) at the heart of the world's largest and most critical operations. How are ABB DCSs likely to evolve over the coming four decades to meet the demands of a rapidly changing digitalized industrial world?

Photo fig. 01: ©Getty Gallery/stock.adobe.com

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01 A fast-changing industrial world means DCSs have to evolve dramatically in the coming decades.

Since its introduction more than 40 years ago, the DCS has made enormous contributions to the safe, efficient and reliable operation of hundreds of thousands of industrial facilities. From the beginning, ABB has been a leader in the DCSs that drive large and critical operations in a wide range of settings, such as utilities, water, process industries, oil and chemicals, food and beverage, pharmaceuticals, marine and data centers. Today, safety, efficiency and reliability remain foundational requirements, but current practitioners require greater and more agile innovation to respond to the increasingly demanding and dynamic landscape of process industries. How should ABB DCSs evolve over the next 40 years to accommodate these requirements →01?

Ingo Mauritz
ABB Process Automation
Minden, Germany

ingo.mauritz@
de.abb.com

Future-proof, flexible architecture

ABB envisions that demands on future process automation systems will be reconciled through a process automation architecture that effectively enforces a differentiation between a robust evergreen core – where reliable, deterministic response is prioritized – and an extended, digitally enabled environment that performs tasks that are less time-critical while facilitating faster innovation and continuous performance improvements. Such an extended automation environment will enable secure connectivity with additional Industrial Internet of Things (IIoT) initiatives and allow for greater collaboration among people, systems and equipment →02.

—
Future process automation core and extended environments will be virtual, modular domains with cyber secure interfaces.

Consistent with the Open Process Automation Forum's vision of independent software modules with defined communication interfaces, future process automation core and extended environments will be virtual, modular domains with cyber secure interfaces based on industry-standard OPC UA information models and communications [1]. These containerized modules will be automatically orchestrated in accordance with the performance and security expectations placed on them. This strategy moves enforcement of authentication and authorization from the network perimeter toward a zero-trust approach at the core, where components will be required to digitally prove their identity and originality, as well as their authorization for specific tasks, in order to properly deal with the evolving threat landscape [2].

Because process controller and application software will exist as containerized functional entities independent of hardware, they will be flexibly deployable and dynamically available across purpose-built and industrial PC controllers, edge devices, on-premise servers and cloud platforms.

The orchestration environment will automate load balancing among hardware resources and simplify control application allocation. Advanced applications will run adjacent to the control core and be easily modified without impacting operations by virtue of their containerization.

Additionally, new functionalities will be tested and validated, via digital twin simulations online, prior to deployment.

Resilience will be assured by adjustable availability approaches designed to meet application needs, allowing users to optimize system availability with a cost-effective hardware footprint.

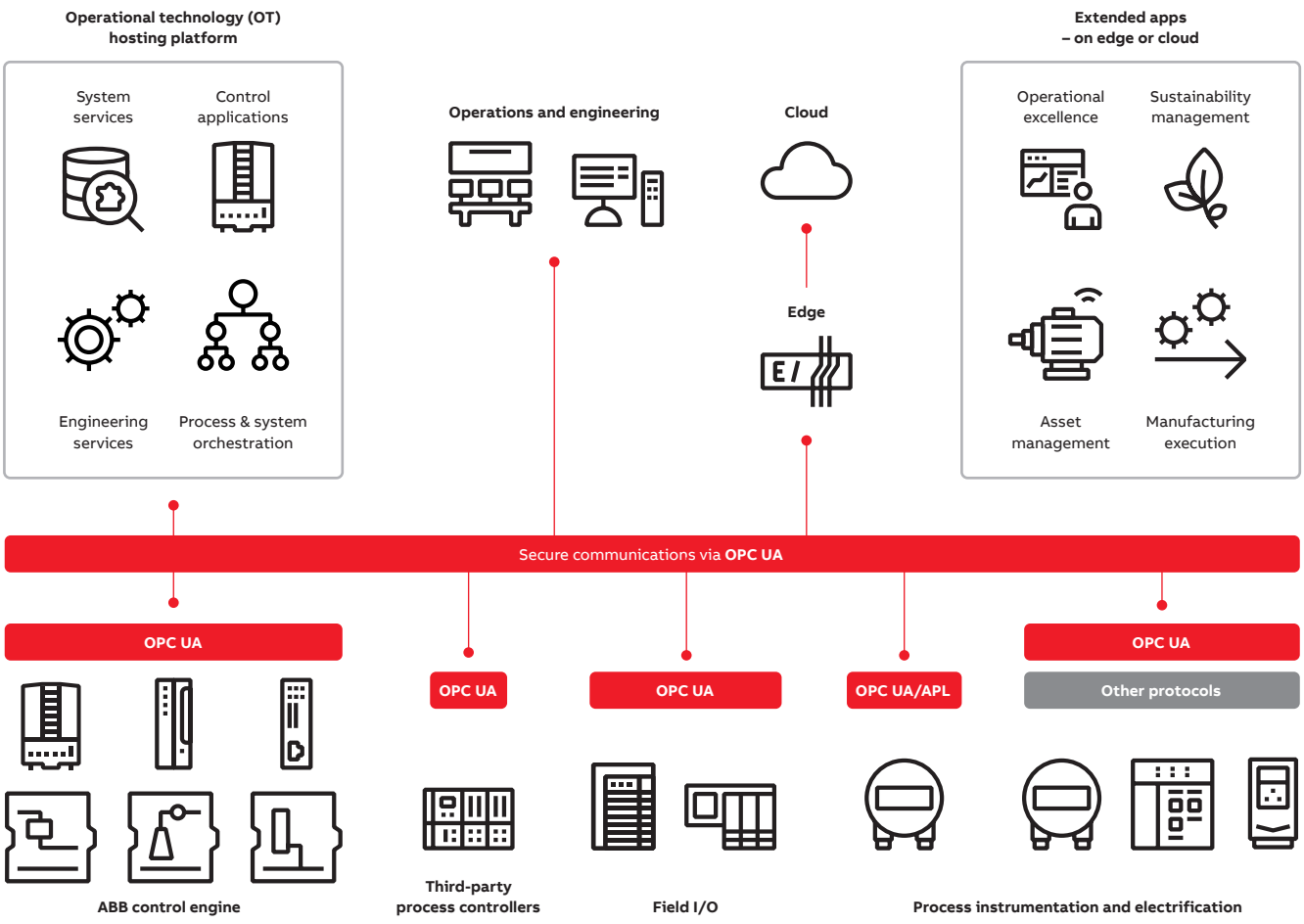
Orchestration automated, complexity hidden
The need for orchestration and management of modular, containerized control engines and applications represents a significant change for users of future process automation systems. IT departments might be accustomed to such tasks, but operation engineers are focused on running their processes, rather than managing the tools that control them. Hence, the need exists for automation of these activities.

Technology adoption with continuity
The future process automation system will be designed to enable current users to take advantage of new technology and solutions with minimal disruption to their existing setup. Protection of users' intellectual property and their investment in applications means they can retain their infrastructure while adopting new technology at their pace and as needs dictate.

New portability approaches and a layer of technology independence between software and hardware will ease inter-platform application transfer and minimize hardware life cycle concerns, providing a lower-cost, lower-risk method for the graceful evolution of current systems, keeping future automation evergreen.

Current users will be able to to take advantage of future technology with minimal disruption to their existing setup.

An architecture built to adapt
Strengthening the control system core also entails moving noncritical functionality that may



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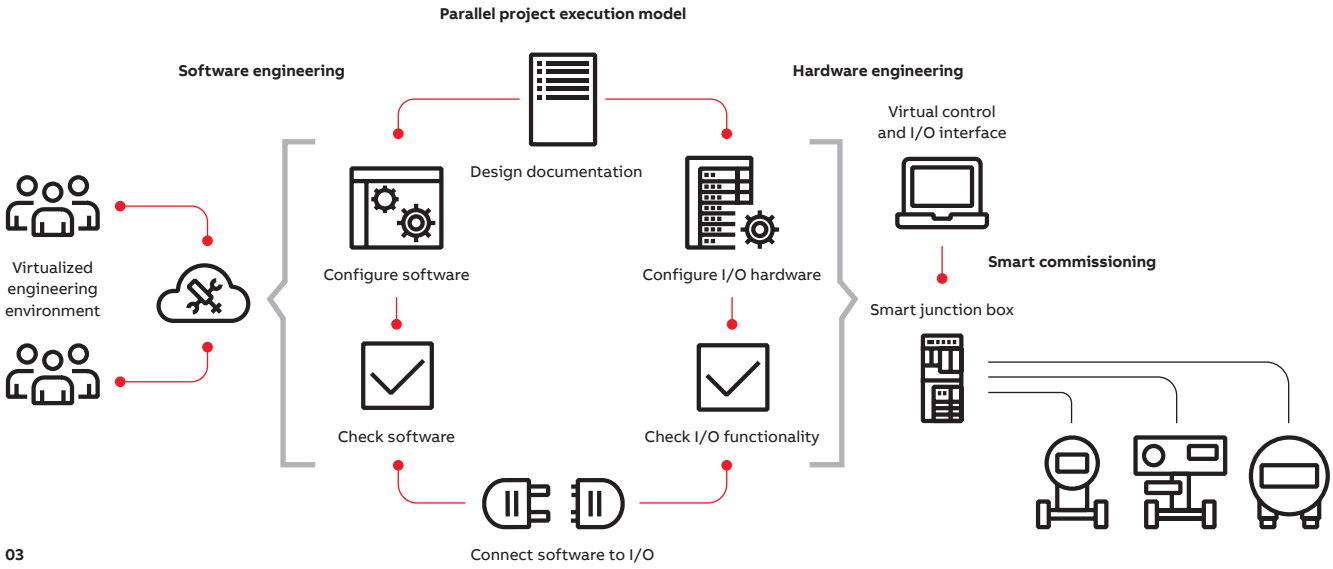

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02 One flexible, interoperable, modular and secure architecture aligned to user initiatives and emerging technologies.

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03 By separating hardware from software engineering, it is possible to decouple tasks and allow independent teams to work in parallel with precise and efficient late binding, thus reducing the impact of changes on the project schedule.

—
04 The future process automation system will be a holistic data-sharing digital ecosystem.

be updated more frequently onto an outward-facing platform. ABB's edge software is designed to provide this functionality, serving as a data-diode for secure core protection and providing a comprehensive application framework for monitoring and optimization. If edge capabilities are critical to core control functionality, the software can also be deployed as part of the core. The new process automation system environment delivers this flexibility.

Project execution and automation engineering transformed

Project execution can be streamlined by decoupling hardware engineering and software development, as is accomplished, for instance, by ABB Adaptive Execution™. This tool allows project tasks to be performed in parallel by different teams, in different locations and even in virtualized cloud engineering environments →03. For example, engineers can perform virtual application testing and commissioning with a combination of virtualization, emulation and simulation technologies, all implemented in the cloud as a digital twin. The digital twin recreates process dynamics, probing performance against functional specifications. This virtual commissioning helps to identify potential issues, resulting in smoother and faster start-ups, and can proceed in parallel with other project tasks.

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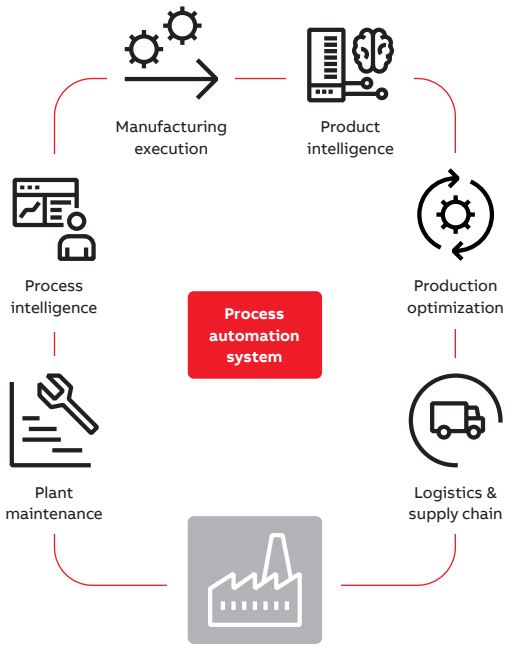
Project execution can be streamlined by decoupling hardware engineering and software development.

Libraries of modular, reusable code developed for particular types of processes or assets can further streamline project execution. Future process automation systems will use pre-made, pre-tested automation software modules that come complete with elements for control, visualization and associated services. Using well-defined communication interfaces for interaction with other modules will eliminate the need to develop "glue" logic to coordinate module behavior. Using pre-made modules also allows agile control strategy upgrades and process reconfiguration. Quality controls on pre-tested code will also help to ensure that the unit becomes operational quickly and without incident.



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Overall process orchestration of the software modules will be facilitated by the automation system, elevating the control engineer's tasks from programming control logic to configuring process-specific automation requirements. When designing a process unit for which a pre-tested module cannot be readily repurposed, automated engineering methods will shorten the distance between offline engineering tools and the direct development of code in the process automation system of the future.

Digitalization will bring about a new range of business models and services.

A digital ecosystem that fuels the IIoT
Among the functions of the extended, digitally enabled environment envisioned in future process automation systems is secure, simplified integration with other essential elements on the edge, on-premise or in the cloud. Such integration will provide users with safe, secure, application-level access to core control OT data – as well as data from other IIoT devices, applications and business structures – without disturbing core control operations →04.

The digital ecosystem will be built on emerging edge and cloud technologies. These technologies change the automation landscape by providing a flexible and secure computing infrastructure, including servers, data storage, development environments, business intelligence services, artificial intelligence (AI) and data analytics for improving risk management, optimizing productivity and achieving sustainability targets.

Optimization with data analytics
Data is at the heart of optimization at a process, plant or enterprise level. The challenge resides in collecting and combining the data from different sources, contextualizing it, transforming it into knowledgeable insights and delivering it to the appropriate persons for timely action. Here, flexible, edge-oriented solutions will predict issues and prescribe actions for better asset operations, superior predictive maintenance strategies and improved tuning of production processes.

Opening the door to new business models
Digitalization will bring about a new range of business models and services because, with the digital ecosystem separated from the critical core, extended applications can follow a separate software purchase process, allowing a much quicker pace and opening the door to Software-as-a-Service (SaaS) or Platform-as-a-service (PaaS) business models. This evolution will shift spending from capital to operational budgets.

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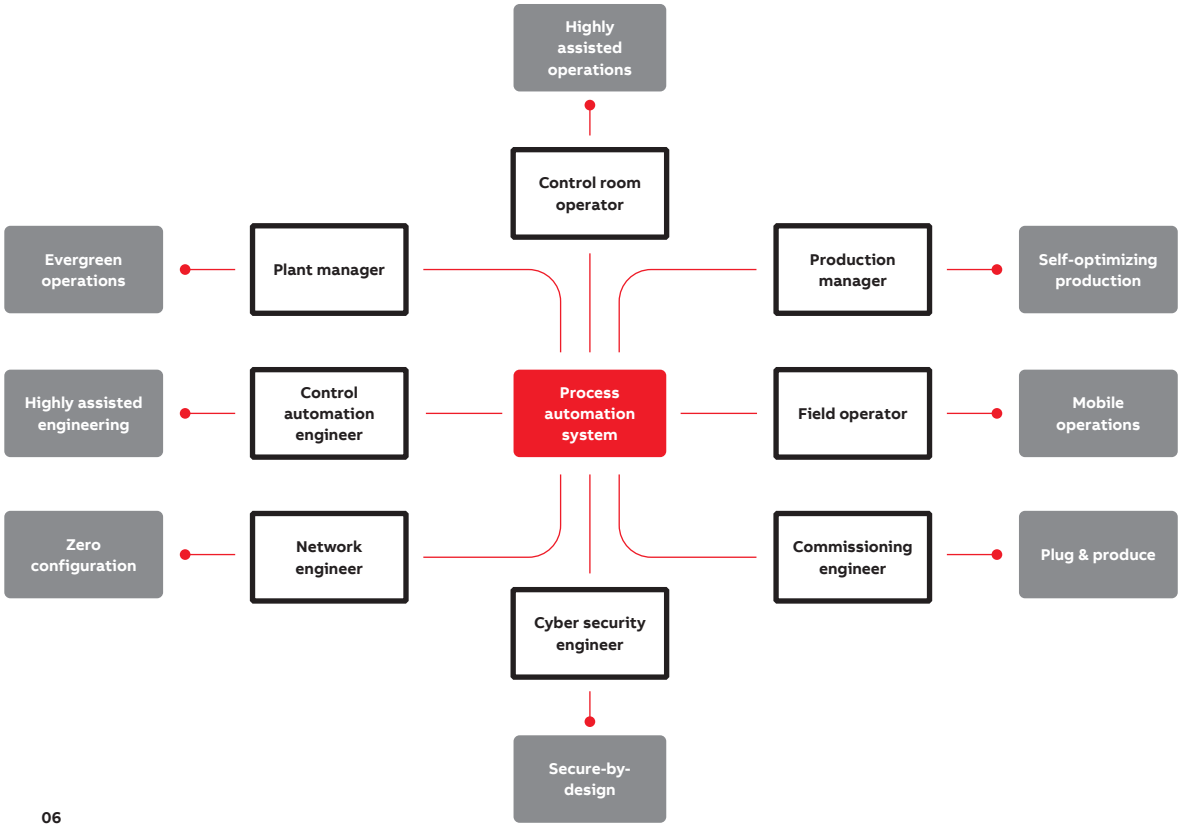

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05 Elevating human performance for all system users.

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06 Direct pathways for digital data to reach cloud applications without disrupting the control core.

Changing roles and processes for a digital industrial workforce

Along with the digital transformation of today's DCS, the roles and duties of plant personnel are going through a transformation of their own. While the effect on future work processes is far-reaching, the duties of the control room operator are perhaps the most directly affected.

In future process automation systems, autonomous operations and industrial AI will revolutionize work, not necessarily by replacing humans, but by augmenting human cognitive capabilities to amplify their potential and assist decision making →05. Experts will be freed from mundane, repetitive tasks and can then focus on higher-value activities. Thus, people and autonomous systems will partner, with humans making the final decision.

> People and autonomous systems will partner, with humans making the final decision.

In the field, sensor data collection and machine-learning algorithms will enhance operatives' senses via augmented reality (AR) tools for more efficient maintenance and commissioning. For engineers, a host of innovations will remove the complexity associated with managing today's integrated plant systems. These advances include self-configuring networks, evergreen operations, plug-and-produce insertion of new equipment modules and natively cyber secure components →06.

The journey ahead

The process automation system vision described in this article represents ABB's guide to simplify and accelerate DCS innovation, with continuity, over the next few decades. ABB envisions that the process automation systems of the future will empower industries to compete in a fast-changing world by delivering adaptable, reliable, integrated, modular and secure automation solutions with flexible, simpler and faster project engineering execution and commissioning [2]. This vision will facilitate digital transformation and collaboration between people, systems and equipment through secure OT/IT integration for autonomous operations and sustainable performance, thereby ensuring the safety of people and the environment and the continued commercial success of the enterprises that embark on this journey. •

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References

[1] M. Kiener, "Buzzword demystifier: OPC UA," *ABB Review*, 1/2023, pp. 80–81.

[2] ABB, "Envisioning future process automation systems: Enabling innovation while preserving continuity." Available: https://new.abb.com/control-systems/control-systems/envisioning-the-future-of-process-automation-systems. [Accessed February 14, 2023.]

ABB ABILITY™ CYBER SECURITY WORKPLACE

Safe cyber space

Title photo: ©Thomas Barwick via Getty Images

ABB Ability™ Cyber Security Workplace consolidates and presents data from multiple cyber security sources, enabling industrial operators to monitor the overall status of their security controls, perform associated maintenance activities and receive alerts that help remediate threats and reduce risk.

Kees van Overveld
Cyber Security Service Products
Etten-Leur,
The Netherlands

kees.overveld@nl.abb.com

Matthew Virostek
Cyber Security Service Portfolio
Cleveland OH,
United States

matthew.virostek@us.abb.com

With numerous assets, multiple control loops, a multitude of controllers and extensive IT and operational technology (OT) infrastructure, industrial plants can pose significant cyber security challenges. Indeed, cyber attacks against industrial plants are growing in frequency, level of sophistication and degree of harm inflicted. For example, some 450,000 new malicious program (malware) instances are detected each day [1]. To further exacerbate the problem, there are currently 3,500,000 unfilled cyber security jobs globally [2].

Although most enterprises know the consequences of lax cyber security, appropriate malware countermeasures often leave much to be desired. One common scenario is that the company purchases and implements one cyber security software solution for each system in the plant. So far, so good. However, because these solutions are manufactured by multiple, competing vendors, they are all different and the management, maintenance and monitoring of each platform independently is complicated,

Some 450,000 new malicious program instances are detected each day.

			Consequence			
			Acceptable	Tolerable	Unaccept-able	Intolerable
			Little or no effect	Effects are felt but low production impact	Serious impact to production	Breach of laws or regulations
Likelihood	Probable	Risk will occur	●	●	●	●
	Possible	Risk will likely occur	○	●	●	●
	Improbable	Risk unlikely to occur	○	●	●	●

01

cumbersome, costly and time-consuming. Team members can then often neglect to give these cyber security tools the attention they deserve and the inevitable happens: Cyber attackers penetrate IT and OT networks and cause catastrophic damage. The plant may have to shut down for weeks – with hefty financial losses – and brand reputation damage and regulatory fines may result. Here, the company's failings can be summarized as:

- Poor risk awareness and insufficient prioritization of cyber countermeasures →01.
- Lack of visibility into the security controls currently running.
- Limited time spent maintaining security controls.

ABB Ability Cyber Security Workplace makes it easy and cost-effective to reduce significantly cyber security risk.

What such a company needs is a way to simplify security by consolidating tools, automating risk detection and remediating risks sooner. This is exactly what ABB Ability Cyber Security Workplace does.

ABB Ability Cyber Security Workplace

ABB Ability Cyber Security Workplace automatically gives complete visibility of security controls by providing a consolidated view of all such countermeasures in a simple user interface.

Data from ABB and third-party cyber security solutions is collected by ABB Ability Cyber Security Workplace and forwarded to a consolidating native application. Operators can then seamlessly monitor the status of all their security controls, perform maintenance activities to increase resilience and receive alerts with actionable insights to remediate threats and reduce risks →02.

ABB Ability Cyber Security Workplace makes it easy and cost-effective to reduce significantly the risk to production from cyber security threats.

Simplify, consolidate and automate risk detection

In ABB Ability Cyber Security Workplace, traffic-light key performance indicators (KPIs) clearly flag an issue and its severity. Inbuilt root-cause analysis then evaluates the issue and suggests steps required to fix it. Such inbuilt intelligence reduces the expertise needed to maintain cyber control systems. Further, these step-by-step guides shorten remediation times, lowering overall operating costs.

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01 In cyber security, risk is a function of consequence and likelihood.

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02 ABB Ability Cyber Security Workplace provides users with a comprehensive view of their entire cyber security situation.

Because all alerts are consolidated in one console and are, thus, recognized quickly, the length of time that cyber risks are present in the production environment is minimized. Moreover, as all controls are accessible from one place, the labor costs required to maintain them are reduced.

Security controls status dashboard
At the core of ABB Ability Cyber Security Workplace is a single dashboard that monitors security controls, flags increased risks and guides the operator through the steps required to protect people, assets and processes →03-04.

Further, ABB Ability Cyber Security Workplace monitors the status of security patches continuously so that patches against known exploits are installed as soon as they become available. The operator is informed if an update succeeded, told which systems are missing updates and is alerted when a system reboot is required.

To protect the production environment against non-targeted threats, ABB Ability Cyber Security Workplace constantly monitors the status of malware protection and warns when an anti-malware deny list update is unsuccessful so the issue can be quickly corrected. An alert is also issued if anti-malware software is missing or has been forgotten – as can happen, for example, when a peripheral device is replaced. With ABB Ability Cyber Security Workplace, it is also possible to isolate chosen OT and IT environments to protect them from external intrusions.

ABB Ability Cyber Security Workplace installs security patches as soon as they become available.

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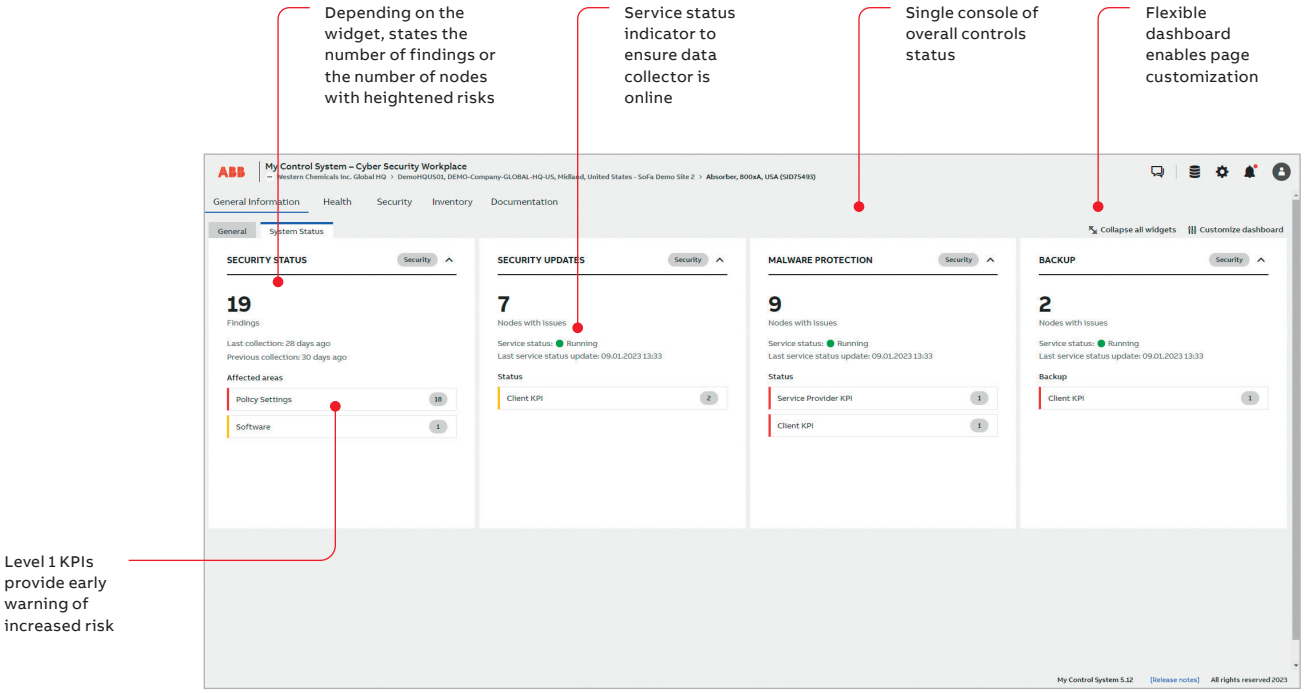

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Using a cyber-asset inventory and communication-flow intelligence, it is possible to monitor which devices are connected. If an asset in the monitored network were to start communicating with a hacker on another network (eg, with a command and control server) the operator would be informed →05.

ABB Ability Cyber Security Workplace also monitors the status of backups to ensure that adequate backups are on hand to restore to a known good state quickly. This precaution can mean the difference between recovering production in hours instead of days or weeks.

Remote access user management
Remote access is a very useful feature but can also be a liability. ABB Ability Cyber Security Workplace reduces the risks associated with remote access by managing user accounts and authentication. Once the operator is notified that a user wants to remotely access any system, they can activate or terminate that user's account at will and generate an audit history of management tasks performed by the user.

Consolidated cyber security
By bringing ABB and third-party cyber security solutions together into a consolidated native application, an operator can easily monitor the overall situation in their plant. Alerts with actionable insights ensure nothing is missed and that any imminent threat can be immediately recognized and countered.

ABB Ability Cyber Security Workplace also lowers costs by consolidating tools and improving security operations efficiency and, at the same time, increasing cyber resilience by cutting mean time to risk recognition and response.

A cyber asset inventory feature monitors which devices are connected, based on communication flows.

The last word is best left to a plant manager who has recently implemented ABB Ability Cyber Security Workplace: "Cyber security risk is one of the many areas I need to manage at my site. I task local engineers with implementing security controls across the site and must be reassured

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03 ABB Ability Cyber Security Workplace security controls dashboard.

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04 ABB Ability Cyber Security Workplace, typical screen.

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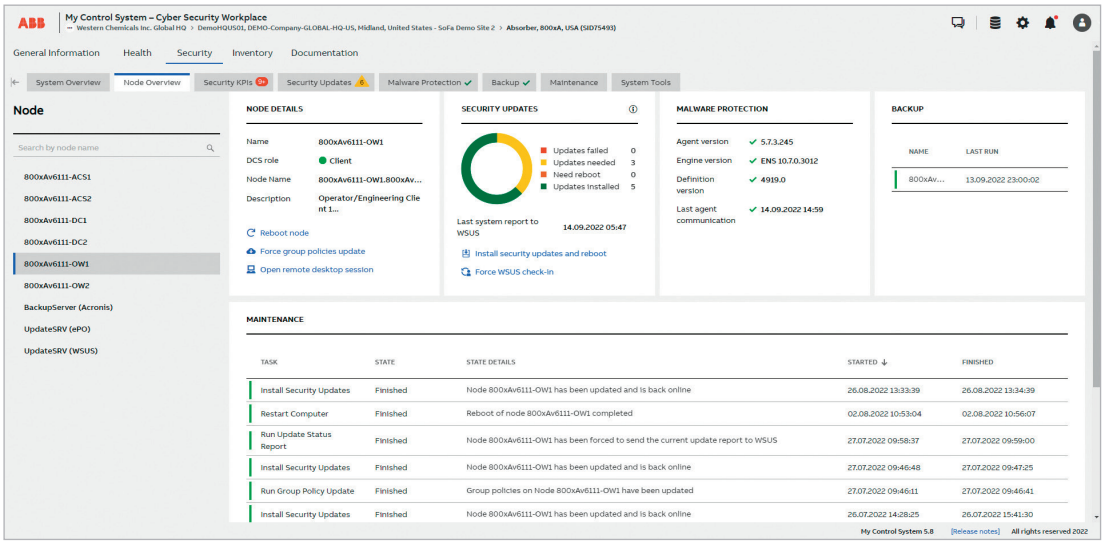
05 A typical cyber asset inventory display.



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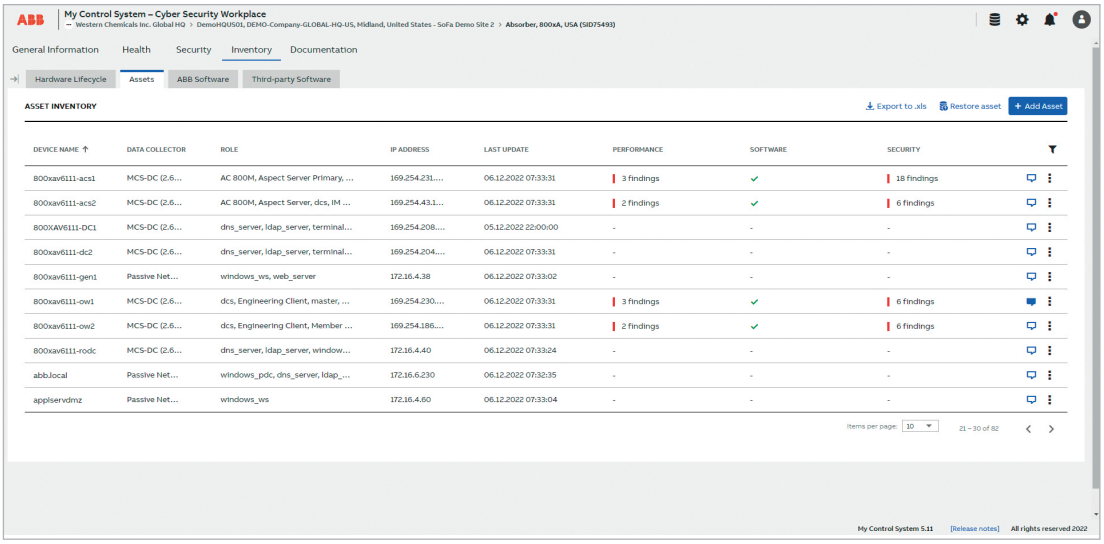

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that my systems have the right controls in place and are compliant with global policy. It is difficult and resource-intensive to know what and where

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"Any alert provides me with the data and analytics needed to investigate further and take remedial action, with ABB support."

my gaps are and how to sort them. I don't have access to internal cyber security expertise to implement and manage specialist tools. However, I don't have to be an expert to understand the status of my security controls with ABB's Cyber Security Workplace. This solution allows me to see gaps in my security controls from one interface. If there are any issues, I will get an alert that provides me with the data and analytics to investigate further and take appropriate remedial action with the support of ABB service engineers. The Cyber Security Workplace significantly reduces the effort required to manage and maintain my security controls and reduces my risk." •

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References

[1] AV-TEST Institute, "Malware Statistics & Trends Report." Available: https://www.av-test.org/en/statistics/malware/. [Accessed September 7, 2022.]

[2] Cybercrime Magazine, "Cybersecurity Jobs Report: 3.5 Million Openings In 2025." Available: https://cybersecurityventures.com/jobs/. [Accessed September 7, 2022.]

VIRTUAL PROTECTION AND CONTROL FOR MEDIUM-VOLTAGE SUBSTATIONS

The virtues of virtualization

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01 Virtualization helps solve many of the challenges faced in maintaining and updating hardware in substations, such as this one in Finland, where virtualization field tests took place.

01

—
Sandro Schönborn
Thanikesavan Sivanthi
ABB Corporate Research Center
Baden-Dättwil, Switzerland

sandro.schoenborn@ch.abb.com
thanikesavan.sivanthi@ch.abb.com

Anna Kulmala
Henry Niveri
ABB Distribution Solutions
Tampere, Finland

anna.kulmala@fi.abb.com
henry.x.niveri@fi.abb.com

Robert Birke
Former ABB employee

To adapt to the rapidly changing power grid environment, medium-voltage (MV) substation operators must reduce costs, simplify equipment maintenance and updates, and accommodate increasing numbers of distributed power sources. Virtualization helps solve these challenges.

Although they generally go unnoticed by most, MV substations are found everywhere there is any appreciable concentration of people or industry →01. Responsible for stepping down the voltage delivered by high-voltage (HV) transmission systems, substations are vital for the supply of electricity to industrial and residential customers.

Modern substations typically feature devices from multiple vendors. These devices run applications, on their proprietary hardware, that are essential to the functioning of the substation. However, maintaining and updating a myriad of proprietary devices is an expensive and challenging business. And substation operators face other challenges, too – for example, the rising numbers of distributed energy resources (DERs) on the distribution grid. This increase in DERs brings with it the need for further investment in intelligence and resilience across the grid. Moreover, the distribution system operators (DSOs) are under constant pressure to reduce capital expenditure (CAPEX) and operating expenses (OPEX) generally.

One effective way to address these challenges is to introduce a flexible and rapid deployment of applications in substations. The DSOs can then not only deploy applications from different vendors onto the same hardware but also add functionalities or upgrade existing functionalities on demand. The key to accomplishing flexible and rapid application deployment is virtualization.

Virtualization decouples software from hardware

The concept of decoupling software from the underlying hardware – ie, virtualization – has been very successful in the IT landscape over the past few decades. Indeed, virtualization technology is the workhorse that enables modern

—

The key to accomplishing flexible and rapid application deployment is virtualization.

cloud infrastructure as it reduces hardware costs and simplifies maintenance. With virtualization, applications run in a “virtual” environment, abstracted from the actual underlying platform and isolated from the other applications running

02

on that platform. Virtualization enables software to be deployed, executed, exchanged and migrated almost independently of the underlying platform →02. Virtualization also helps to achieve high availability and resiliency at a reasonable cost. These benefits of virtualization technology

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When applied to substation automation, virtualization technology faces challenges not seen in cloud computing.

can be exploited to assist DSOs in addressing the challenges and limitations they face in substation automation while also making it easier to deploy and scale new applications.

Customizing virtualization for substation automation

Virtualization in computing environments can take place at different levels:

- In hardware, in virtual machines (VMs) that provide the functionality of a physical computer without the developer having to deal with actual physical hardware.
- In the operating system (OS), in so-called containers. In contrast to a VM, which virtualizes an entire hardware machine, a container virtualizes the software levels above the level of the OS and can isolate processes and control the access of processes to CPUs, memory, etc.
- At the function level, as in serverless computing, where there are still servers involved, but these are abstracted away from the application, so the developers do not have to worry about provisioning or managing server infrastructure as this is handled by the cloud provider.

When applied to substation automation, virtualization technology faces challenges not seen in cloud computing. While the cloud has ample and scalable computing, storage and networking resources, the resources available in substation devices are more modest. Furthermore, the applications running on the devices are of mixed criticality (safety-critical and non-safety-critical) and some applications may require specific hardware configurations – for example, support for the Precision Time Protocol in a network card. Moreover, many substation applications have special timing and high availability requirements that must be met during operation.

These needs sharply differentiate virtualization when it is applied to distribution or substation automation. Consequently, careful resource assignment and provisioning are required when consolidating several VMs or containers onto

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02 Virtualization helps free software from its dependence on the underlying platform.

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03 Screenshot of one of the rare substation events showing how the multifrequency admittance-based earth fault protection operated at the same time (to the millisecond) across all three substation instances.

devices. Otherwise, resource contentions can result in non-deterministic delays that could compromise the real-time guarantees for the applications running in the VMs or containers.

ABB investigated the applicability of virtualization technology in MV substations, specifically the use of real-time protection and control applications in Linux containers that provide virtualization at the OS level. Multiple instances of centralized substation protection and control on the same host were run

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Resource provisioning and management are critical for an implementation of virtualization in substation automation.

and effective real-time performance of the control and protection applications using tailored resource provisioning and virtual networking solutions was demonstrated. The discussion below shows just how critical effective resource provisioning and management are for a successful implementation of virtualization in substation automation.

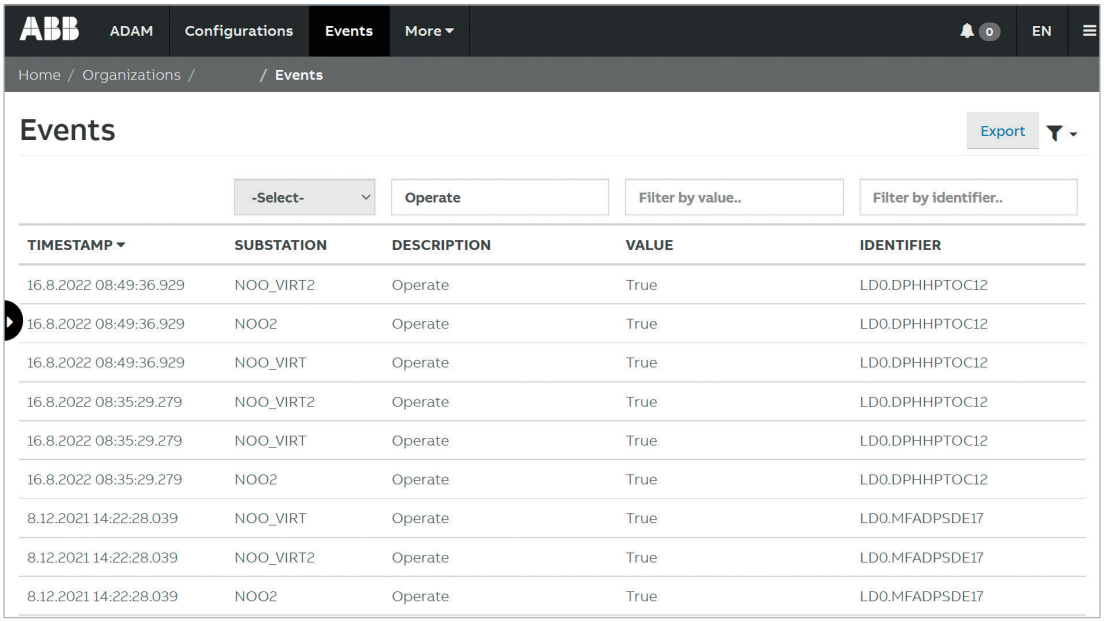
Implementation and resource management
ABB researched the applicability of running demanding real-time workloads in Linux, using not only OS-level virtualization with containers but also VMs. The basis of the test systems is a Linux kernel with a PREEMPT-RT patch for real-time operation. In essence, PREEMPT-RT is a Linux kernel patch that adds real-time capabilities. Although PREEMPT-RT may not be suitable for very fast real-time loads with latency requirements in the order of a few microseconds, in reality only the more realistically achievable millisecond latencies are needed for substation automation applications.

To achieve the real-time performance required in substation automation, the protection application must:

- Receive the incoming voltage and current measurements promptly.
- Have guaranteed access to the computing hardware when needed.
- Complete calculations within a limited period and be able to send out a response action in time.

These conditions create different challenges for a virtualized setup with multiple applications sharing the same host system.

Latent latency challenges
The first obstacle is retrieving process data from the merging units (MUs) in a timely manner. MUs act as interfaces that receive process data such as measurements from instrument transformers and switchgear alarms and indications. The focus here was placed on digital substations where process and control data are exchanged over an Ethernet network, as specified in the IEC 61850 standard. In such situations, multiple applications need to share the physical network access with virtualized networking technologies, such



TIMESTAMP	SUBSTATION	DESCRIPTION	VALUE	IDENTIFIER
16.8.2022 08:49:36.929	NOO_VIRT2	Operate	True	LD0.DPHHPTOC12
16.8.2022 08:49:36.929	NOO2	Operate	True	LD0.DPHHPTOC12
16.8.2022 08:49:36.929	NOO_VIRT	Operate	True	LD0.DPHHPTOC12
16.8.2022 08:35:29.279	NOO_VIRT2	Operate	True	LD0.DPHHPTOC12
16.8.2022 08:35:29.279	NOO_VIRT	Operate	True	LD0.DPHHPTOC12
16.8.2022 08:35:29.279	NOO2	Operate	True	LD0.DPHHPTOC12
8.12.2021 14:22:28.039	NOO_VIRT	Operate	True	LD0.MFADPSDE17
8.12.2021 14:22:28.039	NOO_VIRT2	Operate	True	LD0.MFADPSDE17
8.12.2021 14:22:28.039	NOO2	Operate	True	LD0.MFADPSDE17

03

as a virtual switch or macvlan (a network driver that presents software containers to the physical network as if they were physical devices). Therefore, various ways of attaching a virtual environment to the host physical network were studied. This investigation was performed using the virtual product known as ABB Ability™ Smart Substation Control and Protection for electrical systems SSC600 SW.

Scheduling performance is not significantly impacted by running the software inside containers on modern hardware.

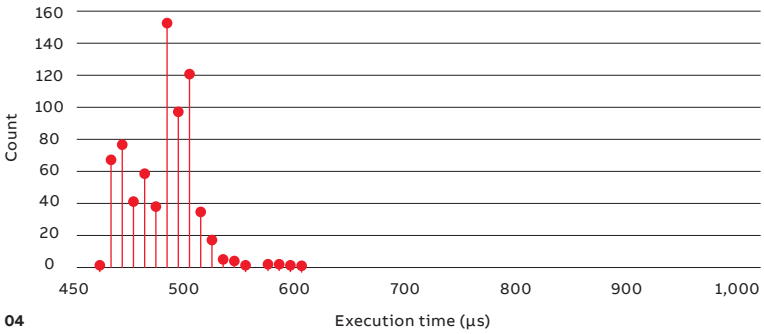
Since mainstream network virtualization approaches do not optimize for latency, substantial pitfalls for real-time operation (due to how network drivers defer work for later) were discovered. The final setup was optimized to avoid these pitfalls. Modern networking hardware can also help to improve the situation through explicit virtualization features.

Accessing the CPU as needed

With data arriving on time, the next step toward achieving real-time performance is to gain access to the CPU when needed. Scheduling process execution is a core task of any OS, and Linux with PREEMPT-RT offers multiple real-time policies and enables the protection software to preempt other applications.

It was found that scheduling performance – ie, getting the CPU exactly when requested – is not significantly impacted by running the software inside containers on modern server hardware and is not the main bottleneck on a properly configured system, at least for latencies above a few dozen microseconds. However, the protection process or a whole VM might still be blocked by another application with a similar priority or by one of the many OS housekeeping tasks. Different CPU core allocation policies were studied and potentially dangerous contentions were resolved by exclusive allocation of CPU cores to applications, including maximum isolation of the OS to dedicated CPU cores. Exclusive allocations further ensure proper sizing of host hardware to guarantee the availability of sufficient computational resources for all applications.

The policy chosen is also a good match to the high computational demand of protection algorithms and the mostly horizontal nature of



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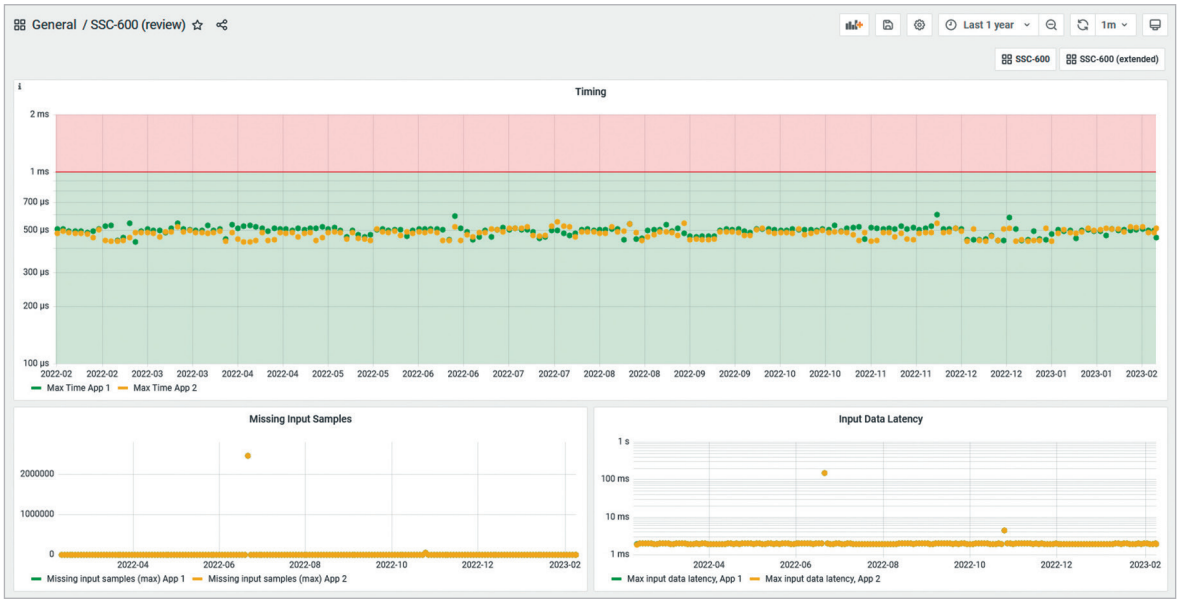

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04 Execution times show good compliance with requirements.

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05 Compliance with the internal cycle time: Execution times of the internal functions met the required deadline (red line) throughout a whole year of operation.

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06 Virtualization will help substation operators to reduce costs and successfully tackle the rapidly changing power grid topology.

scaling in modern hardware with its consistently increasing numbers of CPU cores.

Not forgetting memory considerations
Even with calculations started at the right time and dedicated CPU cores available, interference can still delay computations unacceptably. For data-intensive applications, such as protection and control, execution timings depend strongly on the transfer times of data between memory and CPU. A modern system employs multiple levels of fast intermediate memory (cache) to reduce retrieval times for frequently used data. Unfortunately, the cache size is limited and holds further potential for interference between applications with high data loads. Therefore, policies of cache partitioning and exclusive reservation of memory bandwidth were implemented.

With careful consideration of resource reservations, it becomes possible to fully isolate virtual real-time applications from each other and ensure steady operation with timely responses for all of them on the same platform.

Pilot installation and performance
The project work moved from early proof-of-concept studies to lab tests of virtual protection and control to validation of real-world deployments in the field.

In the laboratory, the team validated protection reaction times of the whole system running in different configurations and virtual environments, and with varying loads, against actual signal injection in hardware-in-the-loop tests and real-time network simulations. In all tests, the virtual setup succeeded and lived up to the timing and functional requirements of the equivalent dedicated embedded protection and control device.

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The test in Finland validates that the approach works for virtual protection and control in real substations.

Following the positive lab results, ABB moved to validation in the field in collaboration with one of Finland's leading DSOs. One IEC 61850 certified server was deployed in a research cabinet at a substation in Western Finland province →01. Using careful resource partitioning, this server can run two fully configured virtual SSC600 instances in parallel.

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Since the deployment in September 2021, the instances complied with all functional and timing requirements of the physical SSC600. Some (of the very few) events observed at the substation were captured and, by comparing event logs, it could be seen that the behavior of the virtual instances perfectly aligns with the behavior of the physical counterpart →03. →04 highlights a critical performance index: compliance with the internal cycle time. →05 shows how the execution times of the internal functions met the required deadline (red threshold). The carefully designed virtual network layer allowed the arrival of all the incoming sampled measurement value traffic in time with no late samples or other losses during normal operation. The only observed packet losses happened during external data disconnection events, unrelated to the virtual setup.

The field test in Finland successfully validates that the approach chosen is fit for purpose for virtual protection and control in substation automation in the real world. Virtualization provides substation operators with a way to reduce costs and make equipment maintenance easier as well as successfully take on board the rapidly rising numbers of renewable power sources appearing on the grid →06. •

Photo fig. 06: ©guruXOX/stock.adobe.com

BETTER SERVICE DECISIONS WITH ABB ABILITY™ SMART MASTER

Health monitor

Accuracy, compliance, status and failure diagnosis and prediction are critical aspects of field devices that need to be known and tracked. ABB Ability™ Smart Master is a performance management platform for field devices that takes care of these and other aspects.

Sabyasachi Bhattacharyya
ABB Instrumentation
Bangalore, India

sabyasachi.bhattacharyya@in.abb.com

Ayyanar Kavithasan
Measurement & Analytics
Bangalore, India

ayyanar.kavithasan@in.abb.com

Field devices are the unsung heroes of the industrial world. Without field devices working away in the background – measuring, monitoring and controlling – virtually every industry and process would grind to a halt →01. Because they are indispensable to so many industries, the number of field devices installed worldwide is colossal – and growing daily.

For example, it is estimated that the flow meter market alone will be worth over $10 billion by 2026, driven mainly by increasing global uptake of water and wastewater treatment, water consumption metering and focus on leakage reduction [1]. The market for level meters is expected to reach $3.5 billion by 2025 – a growth attributed to a rising demand for level transmitters in the pharmaceutical and food and beverage sectors [2]. By 2025 the temperature sensor market will likely exceed $7.8 billion, up from $5 billion in 2018 [3].

ABB's asset performance management platform for field devices is ABB Ability Smart Master.

When other common field devices – pressure sensors, valve positioners, etc. – are added in, it becomes clear that the global installed base of field devices is indeed enormous. ABB is a major supplier to this multibillion dollar market.

Accuracy, compliance, status reporting and failure handling are just some critical aspects of a field device's performance. To manage these aspects effectively in a large installed base and allow customers to focus on their core business operations, what is needed is a comprehensive asset performance management platform.

ABB's asset performance management platform for field devices is ABB Ability Smart Master.

ABB Ability Smart Master

The health of a measurement device is characterized by:

- Accuracy of the measurement.
- Compliance with industry regulatory guidelines.
- Legitimate operation limits.
- Valid installation.
- Effective diagnosis of existing device failures and prediction of potential future failures.

If a customer has access to comprehensive information regarding these characteristics, they can make an informed decision about when to service a device; know when a regulatory check is due; and have a good idea of when or how a future failure may occur. The customer can then plan their operations and maintenance much more effectively.

ABB Ability Smart Master makes this improved approach to service possible over the vast installed base of ABB measurement devices.

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01 Field devices are critical components in most industrial processes, such as the mixing in the pharmaceutical production line shown here.

Remote connectivity and remote monitoring are also facilitated – capabilities that are useful when remedial action or expert service analysis has to be rapid or when plant access is made difficult by, for example, geographical remoteness or travel restrictions.

Collecting data from the measurement devices, Smart Master provides a dashboard summary of connected devices and their health status, as well as insights into this status →02. This knowledge enables ABB service-assisted clients and self-service customers to plan service operations, spare part orders and device replacements. Data collection and analysis can be scheduled daily, weekly or monthly depending on the regulatory and operational sensitivity of the installation in which the devices are deployed.

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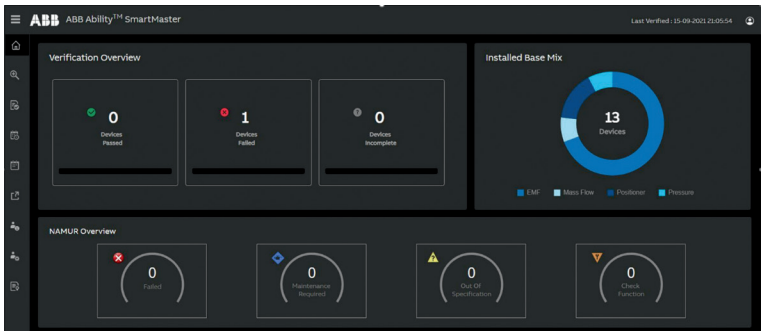
Smart Master provides a dashboard summary of connected devices and their health status.

Because operations and service personnel can forecast the need for spare parts and services much earlier, factory downtime can be reduced or even eliminated. If there is a pattern of device failures, a calendar view analysis and an analytical report provide a further understanding of the failure scenarios →03-04. For many problems, Smart Master can assist with fault tracing and remediation without the user resorting to leafing through manuals.

Regulatory compliance

To ensure that measurement quality or final product integrity is not compromised, devices must adhere to industry-specific regulatory compliance requirements. Such adherence involves significant costs. ABB Ability Smart Master helps mitigate these costs by enabling remote pre-compliance activities, thus reducing calibration or certification effort later in the delivery and commissioning schedule.



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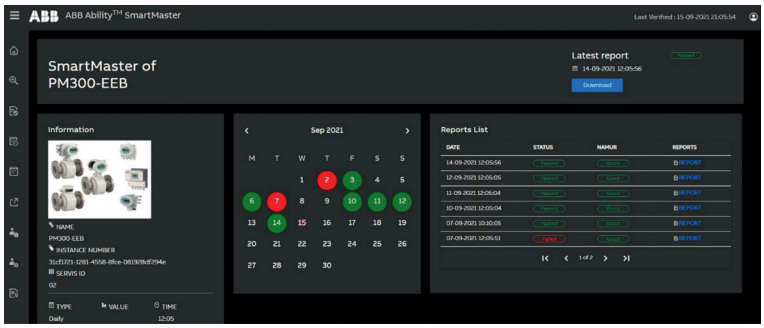

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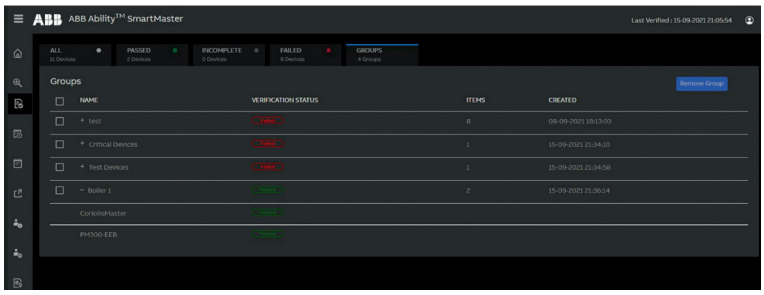

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Multi-tier solution
ABB Ability™ Smart Master provides a three-tier solution to monitor the health of installed devices:

- On-premise: Remote monitoring support with collected data managed within the customer network.
- Dedicated cloud: A dedicated link to each customer for monitoring. Collected data is managed securely in ABB's infrastructure devoted to the particular customer.
- Shared cloud: A global link to all customers for monitoring. Collected data is managed securely in ABB's common cloud infrastructure for all customers.

Connectivity
In many cases, measurement devices are deployed in an isolated location – for example, in a water distribution network – that lacks physical network connectivity. Devices can also be hidden deep under layers of the distributed control system (DCS). Reaching such isolated devices effectively with minimal wiring and little auxiliary hardware is essential if they are to be successfully included in the ongoing digital transformation of industry – a development that can ill afford a complete re-engineering of traditional networks.

Smart Master provides a comprehensive asset performance management platform that enables better service decisions.

In such cases, field device integration (FDI) technology can be used to integrate devices with Smart Master without additional wiring or disturbing current operations →05. Smart Master can also connect via 3G/4G and NB-IoT →06. In countries where there are restrictions on directly sending data to the cloud, data is transmitted through the telecom provider.

ABB Ability™ Smart Master can also integrate with devices through a smart human-machine interface (HMI), which is a technology that retains the instrument's connection to the control system as such but enables a parallel Bluetooth communication for digital solutions →07.

Better service decisions
With such a massive installed base of field devices, Smart Master provides a comprehensive asset performance management platform that enables ABB customers to make better service decisions regarding their ABB measurement devices.

With clear and concise interfaces, Smart Master surveys all connected field devices to deliver a complete overview of status, health and maintenance needs. Whether processed on-premise or in the cloud, the data collected and analyzed by Smart Master allows the customer to get on with their daily business, confident in the knowledge that the management of their field device service is in safe hands. •

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02 ABB Ability Smart Master provides a summary of devices connected and their health status in the dashboard.

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03 Insight into periodic device health failures or fluctuations is provided via a calendar view analysis and a detailed analytical report.

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04 Various Smart Master tabs display different device status information.

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05 ABB Ability Smart Master integrates with the FDI server to collect data.

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06 Smart Master integrates with remotely deployed devices such as flow meters via 3G/4G and NB-IoT communication.

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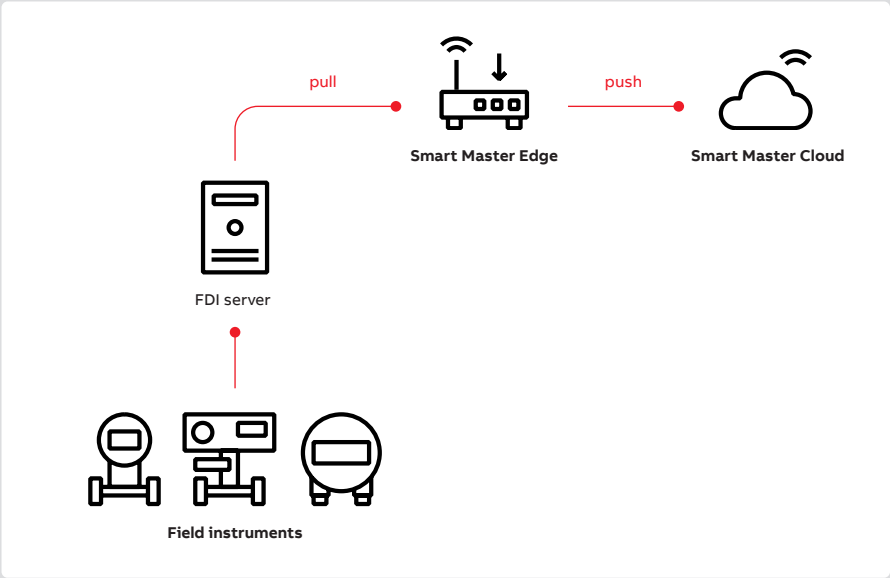
07 ABB Ability Smart Master integrates with devices via smart HMI.



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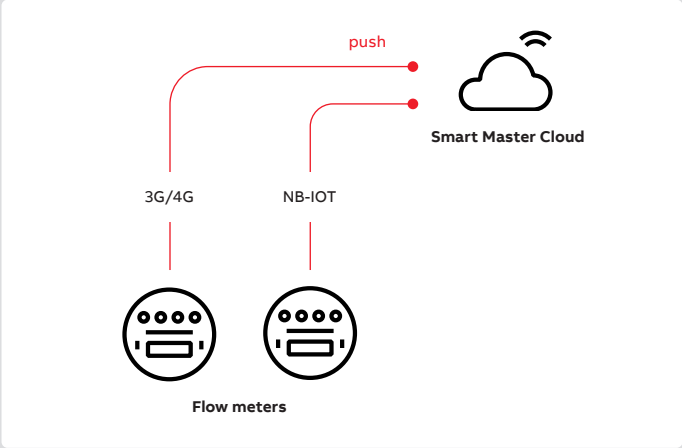

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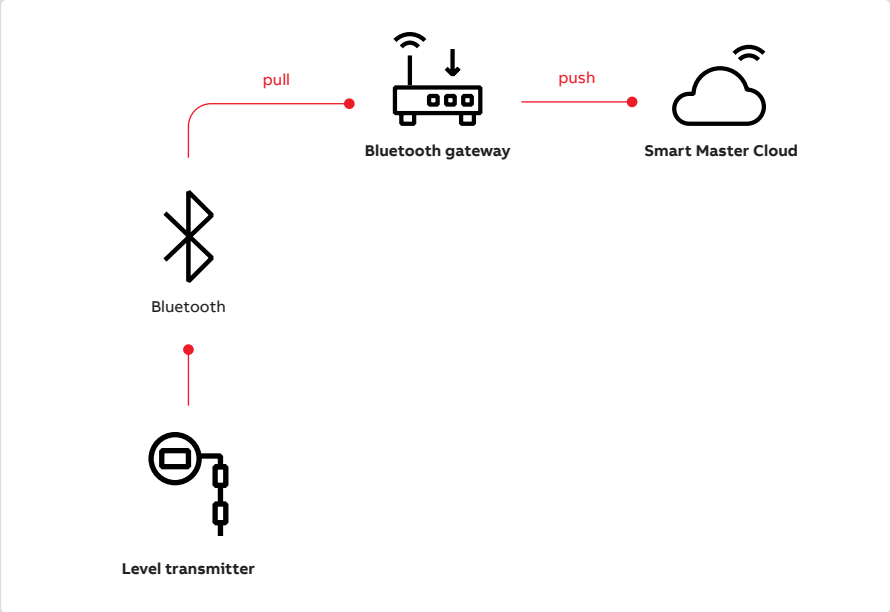

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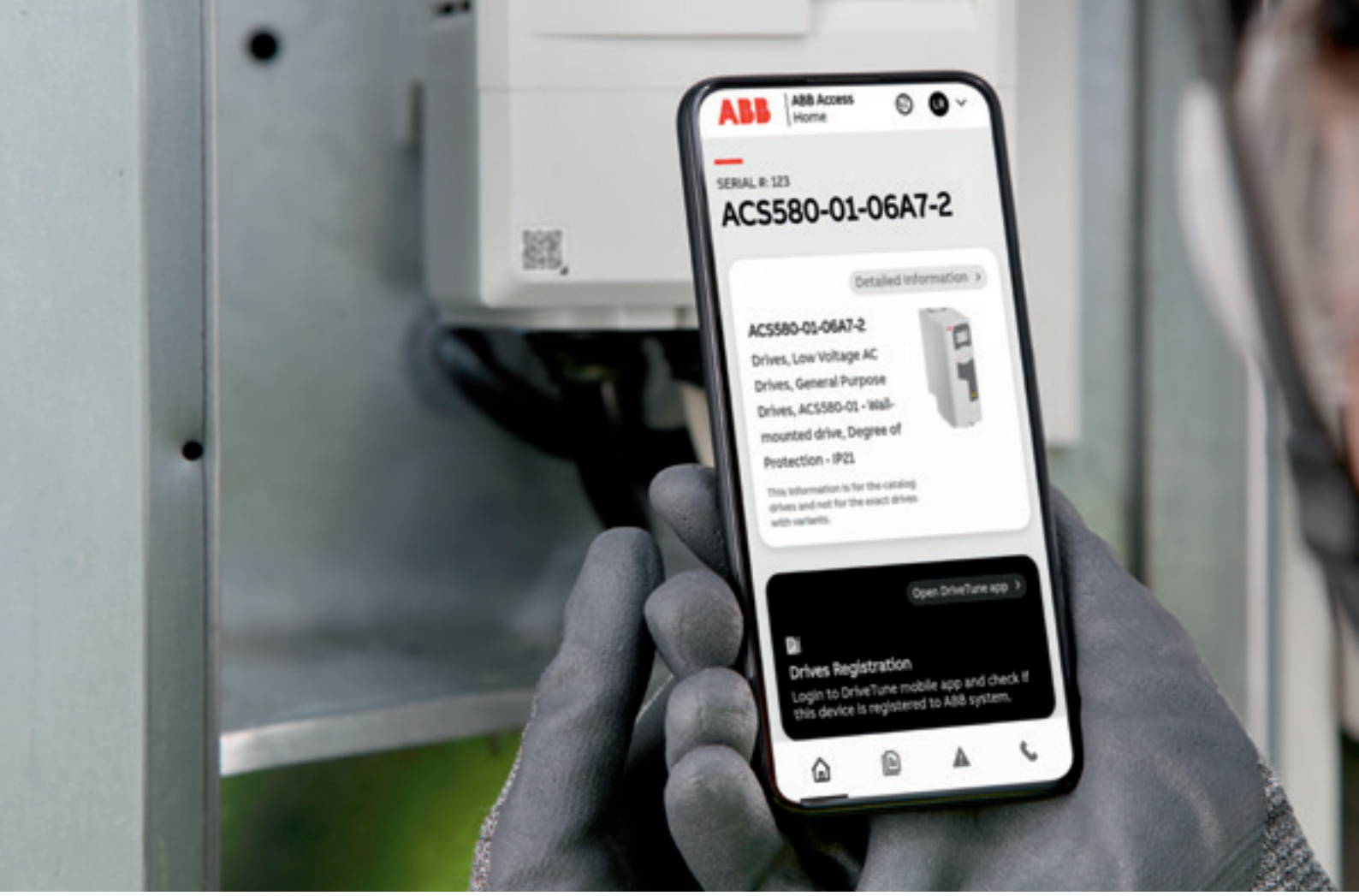
References

[1] Markets and Markets, “Flow Meters Market by Type.” Available: https://www.marketsandmarkets.com/Market-Reports/flow-meters-market-1191.html. [Accessed September 19, 2022.]

[2] Markets and Markets, “Level Transmitter Market by Technology.” Available: https://www.marketsandmarkets.com/Market-Reports/level-transmitter-market-23472700.html. [Accessed September 19, 2022.]

[3] Fortune Business Insights, “Temperature Sensor Market.” https://www.fortunebusinessinsights.com/temperature-sensor-market-102434. [Accessed September 19, 2022.]



01

Naveen Kumar
Motion-Device Products, software tools
Bangalore, India

naveenkumar.e@in.abb.com

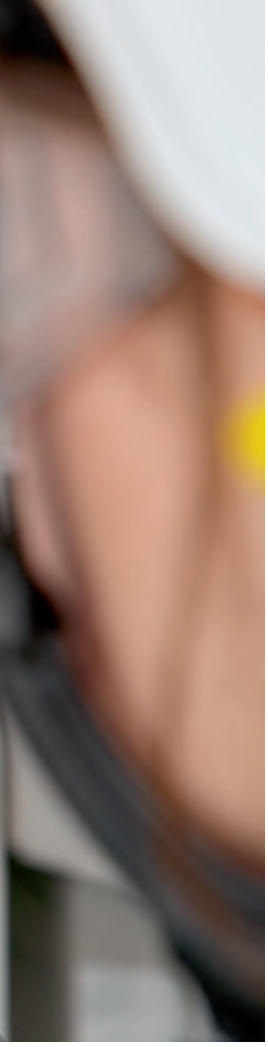
Sunil Kumar S
Motion-Device Products
Bangalore, India

Sunilkumar.x.s@in.abb.com

OPENING THE DOOR TO A WORLD OF INFORMATION

Access is everything

In compliance with European Union Ecodesign requirements, ABB has introduced a QR code-based digital platform designed to provide easy access to information regarding ABB products.



Thanks to a new platform, technicians, commissioning engineers, customers and distribution partners can now use a handheld device such as a mobile phone to access a world of information from their ABB drives, motors and PLCs by simply scanning a device's QR code →01. The key is ABB Access, a responsive web application that links users to product-specific information, such as manuals, installation guides, and step-by-step instructions regarding commissioning and troubleshooting.

> As the web application facilitates self-service, it allows more bandwidth for experts to handle challenging issues.

The responsive web application also allows users to rapidly and easily reach expert support from ABB to report and solve problems on-site.

Furthermore, ABB Access complies with DIN SPEC standard 91406:2019-12, thus making it easier for OEMs and end users to read QR codes using commercially available hardware and software. The result is faster troubleshooting, which results in higher uptime and lower downtime, as well as a unified user experience across a range of ABB products. As the web application facilitates self-service, troubleshooting can be performed by any user with basic knowledge, thus allowing more bandwidth for experts to handle challenging issues. In addition, ABB Access helps to reduce users' carbon footprint by avoiding hardcopy booklets, catalogs, manuals, hardware instructions, installation guides, etc. and by ensuring that the latest version of such information is instantly available, can be stored, secured and downloaded when needed to any authorized device.

A star is born

The new platform is the result of an extensive effort that included a QR code initiative and user interface design website prototype development. In this part of the project use cases were gathered covering areas ranging from system drives to

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01 ABB Access means device information can easily be accessed by QR code.

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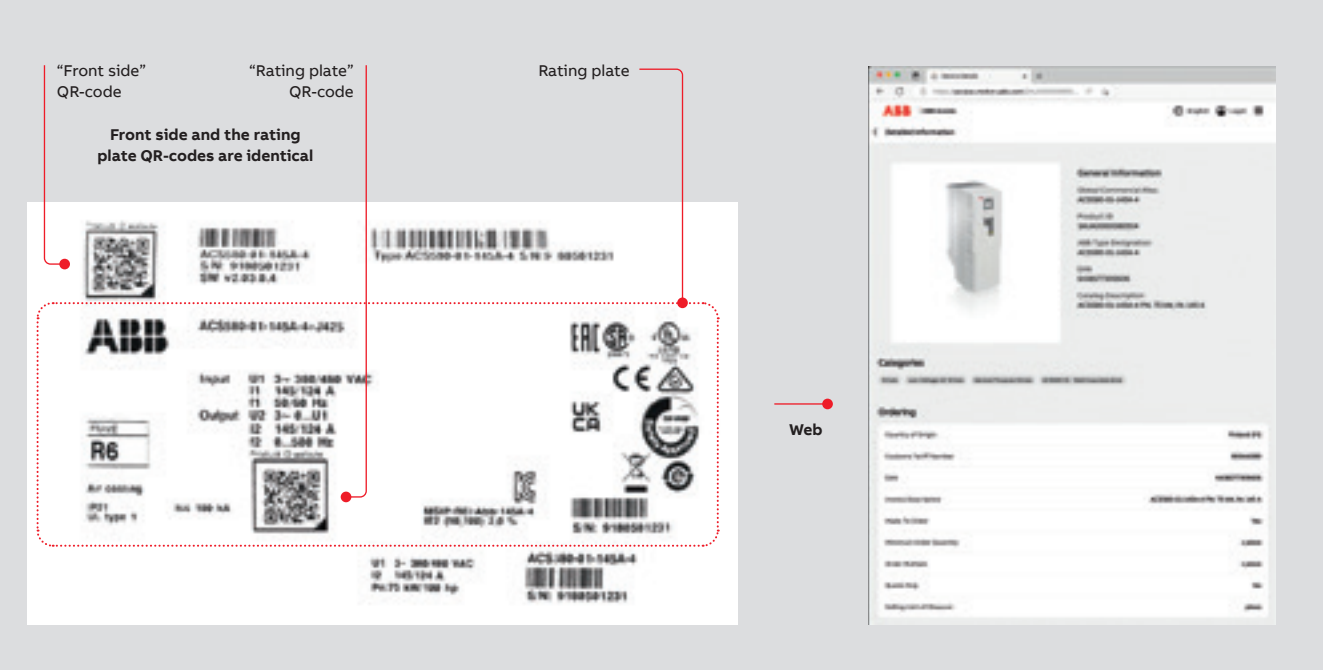
02 Device-specific QR codes are included during the product-manufacturing phase.



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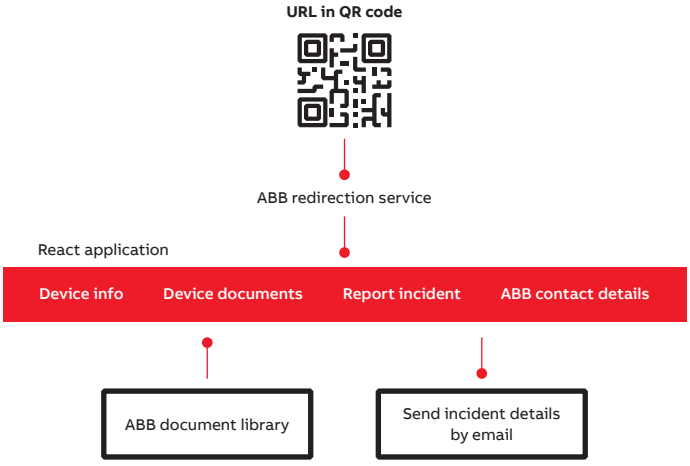


03

motors and generators. At the same time, design and development of the QR code landing prototype was performed and early mock-ups of the web application were created with a view to understanding which elements should be prioritized and how to build the customer experience flow.

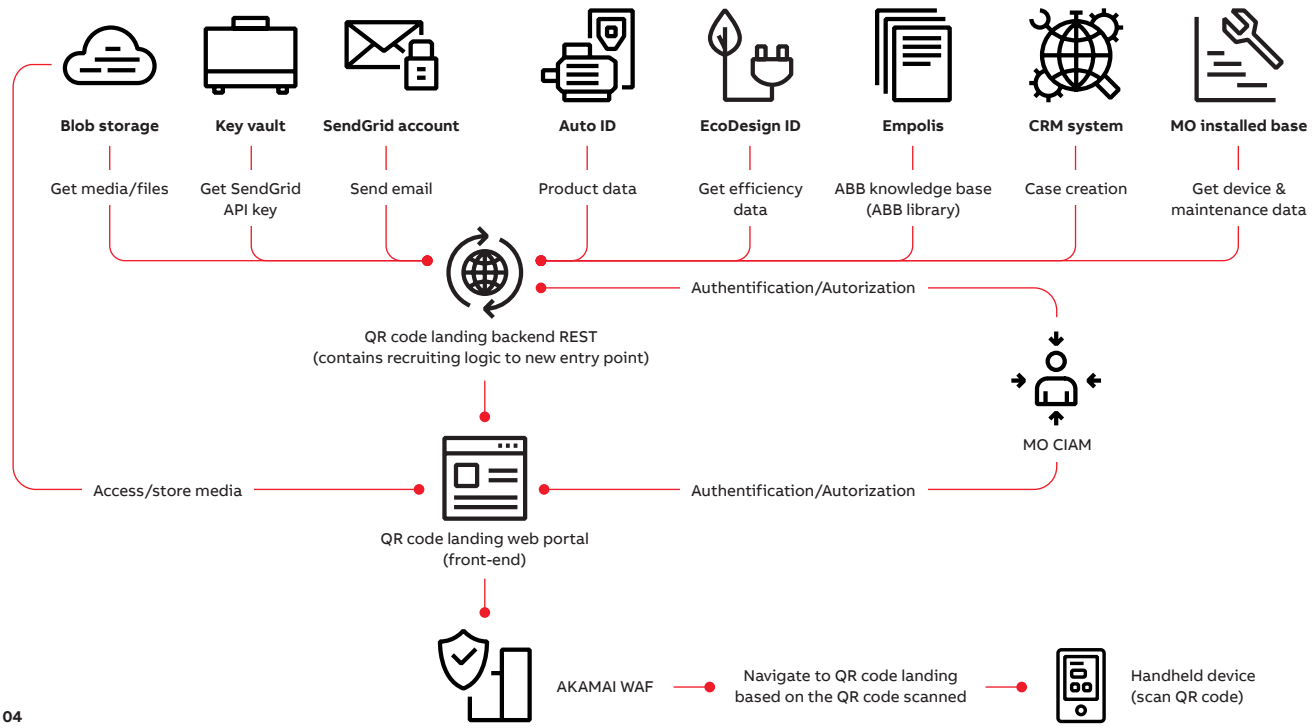
In late 2020 a working model was implemented. This enabled the flow of the customer experience from scanning a QR code to finding the correct documents pertaining to a target product type, reporting an incident, or finding the correct contact information for a specific site.

Approximately one year later an initial minimum viable product was piloted and tested. This provided a foundation for the implementation of the product as well as a comprehensive set of requirements for future expansion. The product's first release took place in early 2022.

How ABB Access works

The ABB Access web application is a channel for Motion Drives customers to access digital services through their everyday handheld devices. Scanning a QR code displayed on an ABB device connects the user to a page that offers relevant documentation, the possibility to report an issue to a product-specific organization and various other capabilities →02. Device-specific QR codes are included during the product-manufacturing phase.

ABB Access does not store any user information in its cache or databases, thus making it more reliable and secure.



04

05

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03 The QR code contains the target device's URL. The URL contains the device's product ID and serial number.

—
04 ABB Access architecture.

—
05 After scanning a QR code, the user is redirected to ABB Access using the Auto ID redirection feature.

The application offers two types of user flows, ie, anonymous user flow and authenticated user flow. For the anonymous user, no authentication is needed. Authenticated users are identified using motion customer identity and access management (MO CIAM) based on Open ID Connect identity, which is built on top of the OAuth 2.0 protocol, an open standard for access delegation.

—

Security is based on the Akamai WAF web access firewall, which is designed to prevent cyber, phishing and cross site attacks.

Although authorization is not applicable for anonymous users, authenticated users are provided with some extra information. For ABB internal users some additional documentation, such as electrical wiring diagrams etc., is visible. The web application itself is implemented using React frontend →03 running as an Azure App Service Static Web App, and a C# Dotnet backend running as Azure Function. The application communicates with the ABB knowledge base for device documentation and device manuals content.

Further enhancements are planned for upcoming releases to provide data related to the installed base, product master, service events, incident cases, and project documentation. In addition, the application will communicate with asset lifecycle management (ALM)to receive data from DIB, MoR, ServIS, BOL, PowerTrain and other databases.

Architecture and security

ABB Access architecture →04 is based on a representational state transfer application programming interface (REST API). After scanning a QR code, the user is redirected to ABB Access using the Auto ID redirection feature →05. Data is then made available using a responsive user interface. ABB Access also communicates with other ABB

internal data service providers by offering related information for different ABB products, all of which is in compliance with standard security

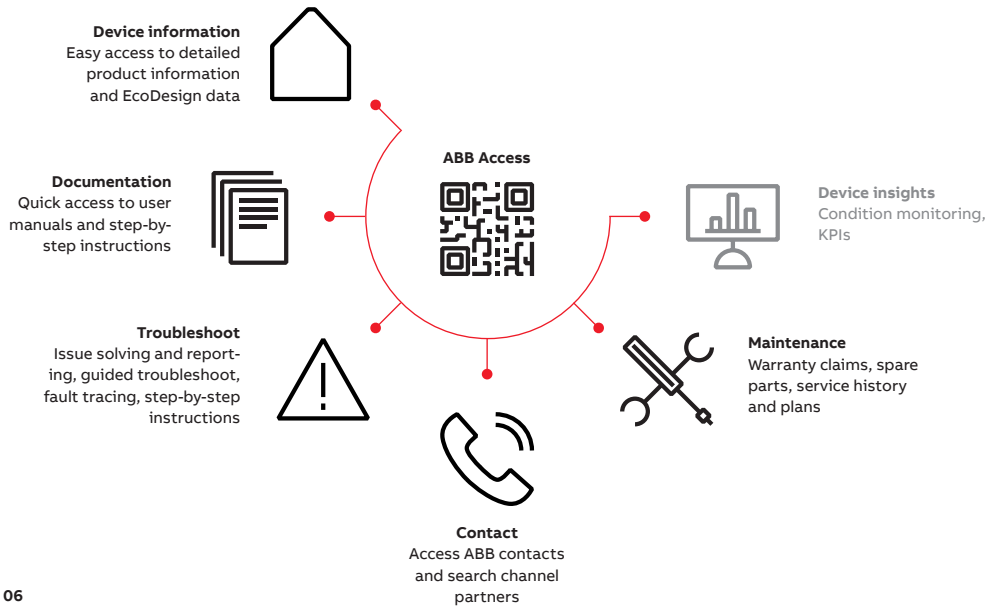
ABB's DriveTune Mobile app opens the door to wirelessly starting up, commisioning and troubleshooting the user's drives.

policies and principles. Furthermore, ABB Access does not store any user information in its cache or databases, thus making it more reliable and secure.

Security is based on the Akamai WAF web access firewall, which is designed to prevent cyber, phishing and cross site attacks, which might be caused by malware scams. In addition, before any major release to a production environment ABB Access undergoes DSAC, WAF, and WAS scans in order to detect potential threats or vulnerability issues.

The Device Information Page: A world of data
At the heart of ABB Access are five key sections: Device information, Documentation, Troubleshooting, Contact information, and Maintenance →06. All are available in six languages: English, Chinese, Spanish, French, German, and Italian. The Device Information Page helps users easily find up-to-date product information. This begins by downloading ABB's DriveTune Mobile app, which opens the door to wirelessly starting up, commissioning and troubleshooting the user's drives by means of a mobile device. Here, a detailed information tab provides access to product catalog information, catalog descriptions, ordering information. Also shown are technical specification details, such as country of origin, Cn8 values, customs tariff numbers, EAN values, invoice descriptions, minimum order quantities, order multiples, quote only, selling unit of measures, eco design data, marketing descriptions, short and long descriptions, etc., along with additional information, such as product dimensional data, classification information and environmental information.

Documents page
The Documents page provides easy access to data and manuals for fast problem solving. Here, ABB SmartGuides →07 are one of the handiest ways to get short, clear visual instructions. Simple and animated step-by-step instructions assist with wall mounting of drives, electrical installation, and drive programming. The page offers an advanced document search tab that allows users to view lists of all applicable documentation related to the scanned serial numbers of products or devices. Associated documentation may include firmware manuals, hardware manuals, catalogs, standards, operating procedures, safety precautions, preventive and maintenance checklists, user manuals, related communication modules and installation guides.



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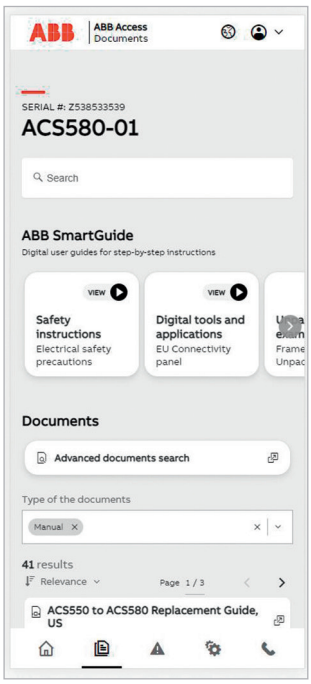

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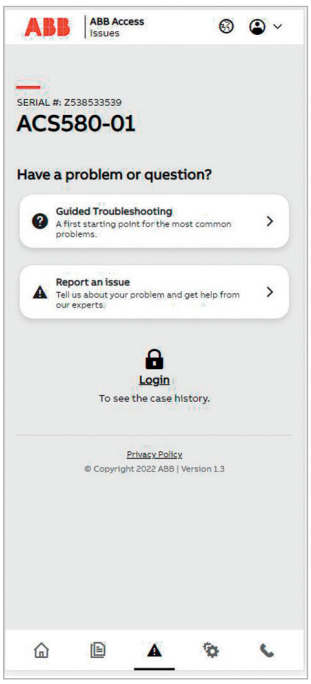

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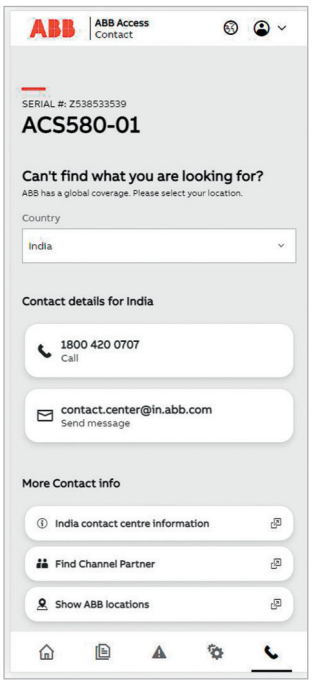

09

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06 ABB Access is divided into five key sections: Device information, documentation, troubleshooting, contact information and maintenance.

—
07 The Documents page's SmartGuides are one of the handiest ways to get short, clear visual instructions.

—
08 The Troubleshooting page offers step-by-step guidance to identify the root cause of an issue.

—
09 The Contact page offers country-specific assistance information.

Troubleshooting page
The Troubleshooting page →08 allows users to access support from experts by reporting an issue and logging in to see a case history. Here, a step-by-step guided troubleshooting procedure can be followed to identify the root cause of an issue, contact ABB service representatives, or enter a fault code or warning code to identify the reason behind a fault or warning in a drive or PLC and take appropriate action to resolve it.

Contact page
The Contact page →09 allows users to reach ABB and service contacts, locate detailed, country-specific contact information, find channel partner networks, and discover ABB locations globally with contact numbers and email IDs.

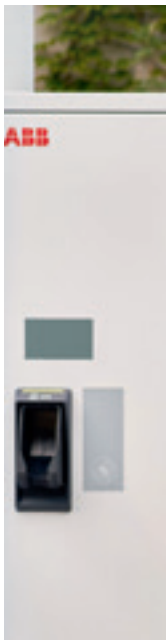
Maintenance page
The Maintenance page covers a wide range of information on ABB Motion products, including product maintenance history, warranty information, spare parts information, planned maintenance schedules, user classifications, digital passport gateway, and additional serial number-based information for special access users.

The number of ABB Access daily users has increased steadily. Since its first release in early 2022, the platform has logged 28,000 sessions, and the average number of daily users has been approximately 200. In fact, the platform has been so successful that plans call for it to soon begin covering other major business areas of ABB, which may include Industrial Automation and Robotics. •

—
The platform has been so successful that it may cover other business areas, such as Industrial Automation and Robotics.

Further information:
https://new.abb.com/drives/mobile-tools/abb-access

Assets in motion



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Mobile assets must be in motion to be working. To be able to work they need connections. Whether these connections optimize the charging of battery EVs, or are advanced perception systems connecting ships to their surroundings, these links are key to ensuring the assets can fulfill their purposes optimally. It's enhanced knowledge that makes a difference. The ABB difference.

136 **Clean machine**
Carbon emissions from EV battery production and use

140 **Plug-in mines**
World's first fully automated charging system for mining trucks

146 **Modeling flow**
Multiphysics-based reduced order model (ROM) for mine pollution control

CARBON EMISSIONS FROM EV BATTERY PRODUCTION AND USE

Clean machine

—
Daniel Chartouni,
ABB Corporate Research
Baden-Daettwil,
Switzerland

daniel.chartouni@
ch.abb.com

Srinidhi Sampath
ABB Corporate Research
Västerås, Sweden

srinidhi.sampath@
se.abb.com

Silvio Colombi
ABB ELSP Smart Power
Quartino, Switzerland

silvio.colombi@
ch.abb.com

01

Electrification of transport has turned the spotlight onto the sustainability credentials of the batteries powering battery electric vehicles (BEVs). How does the lifetime carbon footprint of a BEV, battery included, compare with that of an internal combustion engine (ICE) vehicle?

—
01 BEVs are rapidly overtaking ICE vehicles on the roads. But BEV batteries also have a carbon footprint.

The drive to decarbonize the world has prompted most automobile manufacturers to invest heavily in electrifying their product lines – a move expected to generate a future battery demand of hundreds of GWh annually.

However, ever since the introduction of BEVs, the sustainability aspect of battery production – as well as the sustainability of the production of the BEVs themselves – has been a hotly debated topic, although it must be borne in mind that a battery, though not necessarily a sustainable device in itself, can enable something else to operate sustainably. But the question remains: given the carbon footprint of both the BEV and battery production, are BEVs, over their lifetime, more sustainable than their traditional ICE counterparts →01?

—
ICE fuel and exhaust emissions were compared with BEV electricity use and emissions from battery manufacture.

To answer this question, ABB conducted a study on two passenger vehicles of similar size (five-seaters): an ICE vehicle, represented by a Volkswagen Golf GTD, and a BEV, represented by a Volkswagen ID.4. Life-cycle emissions of carbon dioxide (CO_2) were compared for the manufacture of each vehicle. Also, fuel "well-to-tank" and exhaust emission data for the ICE were collected, as was data related to emissions from BEV battery manufacture and the lifetime electricity consumption of a BEV [1,2].

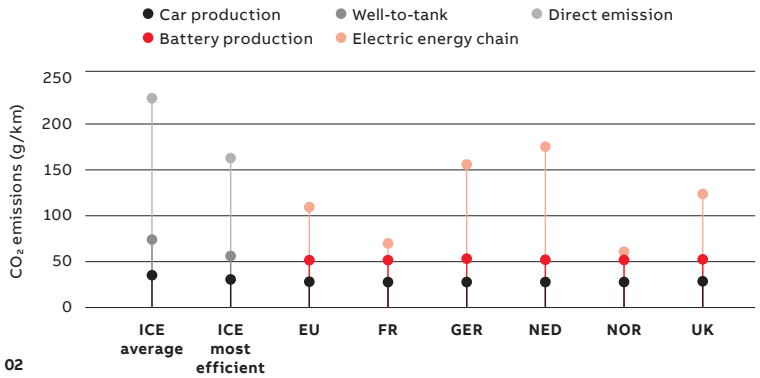
These emissions were converted into equivalent grams of CO_2 per kilometer driven (gCO_2eq/km), assuming a vehicle lifetime of 240,000 km. Average-efficiency and most-efficient ICE cars were taken and a steadily increasing BEV battery capacity up to the year 2030 was assumed. Published data was used where available [3], combined with ABB's estimation of trends from 2015 to 2030 →02-03. For instance, in car manufacturing and in direct emissions of ICEs, annual improvements of up to 1 percent were taken when estimating values up to 2030.

Battery production and use

Emissions arising during BEV battery production and BEV use were estimated in detail. A nickel manganese cobalt (NMC) type of lithium-ion battery chemistry was considered – NMC batteries are the most popular and have a higher energy density than other chemistries. Battery materials, cell manufacturing, and pack and module assembly were included in the study. Future scenarios were estimated based on an increasing battery energy density.

For the BEV use phase, power grid CO_2 emissions in the EU, USA and China were linearly extrapolated from 2020 to 2030 [4,5]. Since 2020 emissions were affected by the pandemic, values for this year were taken from a trend line based on 2000 to 2021.

A further 25 percent was added to emissions to account for upstream losses during electricity



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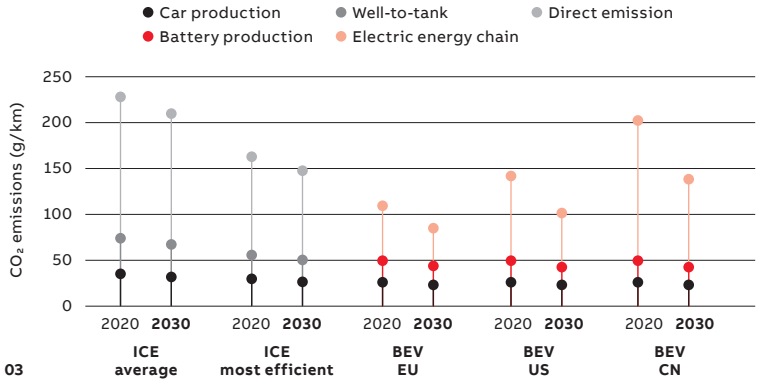

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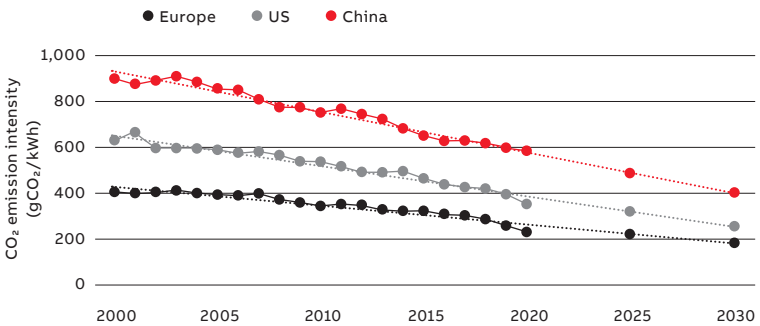

04

production [6], transmission and distribution; the same number was used for the fuel well-to-tank emissions. A 0.85 percent improvement per year for the electricity consumed as fuel during the use phase, coupled with a 92 percent efficiency during charging, was also assumed. These numbers and percentages reflect a realistic estimation of all the contributions to emissions during the life cycle of a passenger car.

The analysis presented here only looks at the CO_2 footprint in gCO_2/km over the lifetime of the car and does not include aspects that increase the attractiveness of BEVs such as:

- Air quality improvement in urban areas heavily affected by ICE vehicle emissions.
- Traffic congestion, where idling ICE vehicles create emissions.
- Other form of pollution – for example, NOx, carbon particles in exhaust fumes, dust from brakes (BEV regenerative braking reduces the amount of such dust), oil leaks, etc.

Data analysis

In both ICE and BEV vehicles, it was found that the primary contribution to emissions arises during the use phase. For ICE vehicles, it is "tailpipe" or direct emissions; for BEVs, it is the electricity energy chain. The emissions from the electricity chain show a decreasing trend due to an increasing renewable energy content, although with different trend slopes for the various regions and countries covered in this study →04.

For battery production, the main energy consumers are NMC powder production, the manufacture of the aluminum used in modules and packing, and drying and storage of the mixed and coated powders used in the battery [7-10].

This study found that the overall CO_2 emissions for BEV versus ICE vehicles depend on the region or country. For example, in the EU or USA, BEV vehicles are already better than the most efficient ICE vehicles, ie, emissions from BEVs are

In both ICE and BEV vehicles, the primary contribution to emissions arises during the use phase.

lower than emissions from the most efficient ICE vehicle. In China, BEVs are better than the average ICE today and will be better than the most efficient ICE by 2030. ABB made conservative assumptions in this study, so these projections could have an upside.

Some other considerations are not included in this study. For example, emissions from idling ICEs, mentioned above, but also the emissions saved by BEV regenerative braking and lower maintenance. Moreover, ABB believes there will be a plateau in ICE emissions as this technology is mature, whereas innovation will accelerate BEV emissions reduction. Also not considered are future technologies such as vehicle-to-grid, where the BEV participates in the national power grid as an energy source or storage device, thus

—
02 Life-cycle emissions over 240,000 km of electric and conventional vehicles in Europe in 2020. The way electricity is generated regionally accounts for the differences in EV emissions.

—
03 BEVs vs. ICE, overall CO_2 lifetime emission equivalent, projected progress.

—
04 Decarbonization of national power grids.

enabling emissions reduction in grid power generation. In other words, the picture for BEV emissions will most likely be rosier than that painted here.

Powering into the future

The question of whether an ICE vehicle is better than a BEV vehicle in terms of CO_2 emissions has been answered by a detailed study of cradle-to-gate life-cycle emissions conducted on comparable five-seater vehicles. This study took into account published life cycle analysis studies on manufacturing, battery production, fuel supply, electricity generation and distribution, as well as usage emissions. It was observed that BEVs already have lower emissions than the best ICE vehicles in the EU and USA; China lags somewhat but is catching up rapidly. Significantly, emissions were found to come mainly from the use stage of both types of vehicles. For BEVs, emission reductions are dominated by declines in power grid emissions, primarily brought about by grid decarbonization. The BEV value proposition will become even more attractive as countries adopt more renewable energy sources.

—
Lower BEV emissions come from declines in grid emissions, mostly brought about by decarbonization.

The study presented here does not include any impact on carbon footprint related to recycling either type of automobile or the BEV battery. The reuse or recycling of batteries is continuously and rapidly evolving, including so-called second-life uses, so any assumptions made may not be valid over the period of the estimation (2015-2030). However, a future study may revisit this topic to quantify the impact of carbon emissions in the post-use phase of the vehicles discussed. •

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References

[1] Cox B. et. al., "Life cycle environmental and cost comparison of current and future passenger cars under different energy scenarios," Applied Energy 269 (2020). Available: https://www.sciencedirect.com/science/article/pii/S030626192030533X. [Accessed January 24, 2023.]

[2] Hall D. et. al, "Effects of battery manufacturing on electric vehicle life cycle greenhouse gas emissions," ICCT Briefing, Feb 2018. Available: https://theicct.org/publication/effects-of-battery-manufacturing-on-electric-vehicle-life-cycle-green-house-gas-emissions/. [Accessed January 24, 2023.]

[3] Philippot M. et. al, "Eco Efficiency of a Lithium Ion Battery for Electric Vehicles: Influence of Manufacturing Country and Commodity Prices on GHG Emissions and Costs," Batteries 2019, doi:10.3390/batteries5010023. Available: https://www.researchgate.net/publication/331225913_Eco-Efficiency_of_a_Lithium-Ion_Battery_for_Electric_Vehicles_Influence_of_Manufacturing_Country_and_Commodity_Prices_on_GHG_Emissions_and_Costs. [Accessed January 24, 2023.]

[4] International Energy Agency, "Electricity Market Report December 2020." Available: https://www.iea.org/reports/electricity-market-report-december-2020. [Accessed January 24, 2023.]

[5] Ember, "European Union: The gas crisis interrupts a rapid coal exit." Available: https://ember-climate.org/countries-and-regions/regions/europe-an-union/. [Accessed January 24, 2023.]

[6] Moro A. et. al, "Electricity carbon intensity in European Member States: Impacts on GHG emissions of electric vehicles," Transportation Research Part D 64 (2018). Available: https://www.semanticscholar.org/paper/Electricity-carbon-intensity-in-European-Member-on-Moro-Lonza/f639b05f1e3cdf-40c7a89c-86c9b450677aae6245. [Accessed January 24, 2023.]

[7] Emilsson E., Dahllöf L., "Lithium Ion Vehicle Battery Production, Status 2019 on Energy Use, CO 2 Emissions, Use of Metals, Products Environmental Footprint, and Recycling," IVL Swedish Environmental Research Institute, (2019). Available: https://www.ivl.se/download/18.14d7b12e16e3c5c36271070/1574923989017/C444.pdf. [Accessed January 24, 2023.]

[8] Bieker G., "A Global Comparison of the Life cycle greenhouse Gas Emissions of Combustion Engines and Electric Passenger Cars," ICCT 2021 International Council on Clean Transportation Europe, White Paper 2021. Available: https://theicct.org/sites/default/files/publications/Global-LCA-passenger-cars-jul2021_0.pdf. [Accessed January 24, 2023.]

[9] Dai Q. et. al., "Life Cycle Analysis of Lithium Ion Batteries for Auto motive Applications," MDPI, Batteries, 2019, doi:10.3390/batteries5020048, Available: https://www.mdpi.com/2313-0105/5/2/48. [Accessed January 24, 2023.]

[10] Chen Q. et. al. "Investigating carbon footprint and carbon reduction potential using a cradle-to-cradle LCA approach on lithium-ion batteries for electric vehicles in China," Journal of Cleaner Production 369 (2022). Available: https://www.sciencedirect.com/science/article/pii/S0959652622029286?via%3Dihub. [Accessed January 24, 2023.]

01

WORLD'S FIRST FULLY AUTOMATED CHARGING SYSTEM FOR MINING TRUCKS

Plug-in mines

Automation and electrification have emerged as the major trends shaping the open-pit and underground mining industry. ABB's new eMine™ FastCharge solution →01, which is designed specifically for heavy duty battery electric vehicles (BEVs), provides fully automated high-power electric charging for haul trucks, thus contributing to safety, sustainability and productivity.

Nic Beutler
Process Industries
Baden-Daettwil,
Switzerland

nic.beutler@ch.abb.com

According to various industry sources, including McKinsey data from 2022, the mining industry is responsible for up to seven percent of global greenhouse gas emissions (GHG) [1]. Nevertheless, mining is critical if the world is to have sufficient quantities of materials such as copper, gold, iron and a host of other metals and minerals. In view of this, the drive is on to minimize the impact of extraction in the key areas of energy and water use. To meet this goal companies are increasingly investing in clean and green energy sources, electrification of mine transport systems for people and equipment, and timely maintenance and service programs.

ABB is involved in an ecosystem of partners to minimize the impact of extraction on energy and water use.

—
01ABB is working toward the deployment of eMine™ FastCharge for mining trucks in open and underground mines.

—
02 ABB offers solutions based on automation and digital systems that are tailored to mining industry needs.

Technology leaders, including ABB, are working with fellow innovators, original equipment manufacturers (OEMs), truck and mining machinery builders, organized industry consortiums and, of course, mining companies themselves. ABB has increasingly called for collaboration and action in this space, highlighted by many agreements and partnerships, including with Hitachi Construction Machinery, MEDATech, Liebherr Mining Equipment, Stäubli, FLSmidth and Perenti. The aim of these agreements is to build strong relationships and an ecosystem of technology partners where experts can come together to solve some of the mining industry's most pressing challenges.

One of the most obvious areas to focus on is the removal of fossil fuels. Reducing or eliminating diesel from heavy, fuel-consuming mining trucks and auxiliary vehicles will have a major impact. Some of the world's largest mines use more than 100 trucks, consuming millions of liters of diesel per year. For reference, a single truck with a 100 ton-payload consumes around 400,000 liters per year [2]. Converting or substituting these machines with systems that are environmentally neutral would be no mean feat and for years was considered impossible by many authorities in the industry. Today, existing technologies can reduce diesel consumption by up to 90 percent. In fact, based on ABB's own calculations (references available upon request), if every truck in every mine were entirely electrified, CO_2 emissions would be reduced by about 198,000 tons every day.

—
ABB's pilot solution is the world's fastest and only fully automated charging system for mining haul trucks.

Streamlining mine electrification
At ABB, a portfolio focused on electrification, automation and digitization known as ABB Ability™ eMine offers an approach that leverages over 130 years of mining industry experience to combine established methodologies with cutting-edge technologies →02. Here, a pivotal part of technology development is a pilot solution known as eMine™ FastCharge. Offering up to 600 kW of power, eMine™ FastCharge was introduced in 2021 and is today the world's fastest and only fully automated charging system for mining haul trucks. ABB is working closely with OEMs →03 to fast-track this new emissions-reducing system, which is designed to tie into and streamline a mine's entire electrification and automation operations →04 – a major improvement over the setup of traditional mines.

Over the course of the next five to fifteen years all-electric mines will become increasingly commonplace. As this trend develops, a key factor is ensuring that equipment performs exactly as expected and that trucks can charge exactly when required. With this in mind, ABB provides OEM-agnostic charging solutions designed to fit the needs of today's mining operations and interface with all vehicles and vehicle types. Behind this approach is a commitment to interoperable systems and proven open standards that can provide whatever solution is needed to charge battery electric vehicles (BEVs).

A GOLDMINE OF EXPERIENCE

ABB's mining technologies build on decades of project electrification experience and expertise, and over 10 years' experience in providing charging infrastructures for buses, trucks and cars. ABB offers solutions that are uniquely designed to handle the requirements of the mining industry based on the latest technologies. By integrating these solutions with advanced automation and digital systems, it is possible to plan, monitor and control processes, thus optimizing operations and energy usage from grid to wheel.

02

Nuts and bolts

eMine™ FastCharge, which has the potential to serve as a cornerstone of the transition to fully electrified mines across the industry, consists of two components: an electric charging module (ECM) and a connector terminal module (CTM). Both are fully ruggedized, modularized, and adaptable to a range of operational and infrastructure needs and are thus ready for the highest-altitude and most challenging mining environments in the world – locations where dust, moisture and dirt ingress can be a constant challenge.

eMine™ FastCharge has the potential to serve as a cornerstone of the transition to fully electrified mines.

Encased in a standard-footprint-size container and mounted on a removable skid, the ECM acts as the electric powerhouse of the solution. It is characterized by a mobile split-unit design that includes a powerful cooling system and heating, ventilation and air-conditioning (HVAC) protection cage, as well as a protective false floor for cabling and covered cable boxes for external connection points. Inside, it houses chargers,

03

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03 ABB's pilot eMine™ FastCharge demo with customers was organized at MEDATech's facility in Collingwood, Ontario, Canada.

main switchgear, a station control system, an auxiliary transformer, and distribution panels, all mounted on shock absorbers, such that the system is safe for transit even on rough surfaces.

From the ECM, DC power is transferred to the CTM, which is an innovative module outfitted with a protective bellow and lifting table that allows it to be raised or lowered depending on the vehicle type and the height of the charger connector socket on the vehicle. It is also equipped with a station indication system that displays its status (in use, charging or fully charged, and fault), and a vehicle recognition camera system that supports quick identification of, and connection to, the vehicle's charging outlet. Although positioning is completely automatic, it does have a human-machine interface (HMI) in case local control is needed. It also has a shock absorber and skid system similar to those of the ECM. The CTM's electrical pin connector from Stäubli, a leading manufacturer of connector solutions, is fully integrated with a special bellow and automated shutter system within the module such that it is protected prior to, and throughout the connection with the target vehicle.

Higher charging power on the horizon
In an industry where high productivity and efficiency are paramount, any viable charging solution must be fast and fully integrated. The eMine™ FastCharge pilot solution, which is designed specifically for heavy duty BEVs, provides high-power electric charging for haul trucks and is designed for the harshest environments. It can be installed anywhere and can charge any electric truck without human intervention at up to 600 kW in its first release – the highest power available in today's market – to minimize the downtime of mobile assets.

Naturally, the amount of time required for charging depends on a haul truck's onboard battery capacity and the vehicle's operational profile; however, in many instances a suitable state of charge can be reached within 15 minutes →05. Nevertheless, it is widely understood that the industry will need higher charging power. Work is therefore in progress to target higher power levels in the multi-MW range. In the meantime, considering that the system has a modular design, it offers a future-proof platform that adapts to higher powers and different grid connection voltages as technologies evolve.

—
ABB's modular platform design adapts to higher powers and different grid connection voltages as technologies evolve.

Further to this, eMine™ FastCharge is fully digitally enabled. By digitally connecting eMine™ FastCharge, the system can be monitored and managed to optimize charging processes and energy usage in real time, thus reducing a company's environmental footprint as well as improving its productivity at the same time.

Moving ahead, the charging operation will become an integral, additional step within mine processes. As this process takes shape, the system will need to be thoroughly managed, precisely planned, and correctly scheduled to prevent any impact on productivity, such as avoidable queuing of electric vehicles in front of the charge point. Planning will also have to ensure that sufficient electric energy is available to allow vehicles to perform their scheduled tasks in an efficient and cost-effective manner, and that charging activities are distributed across fleet and charge points in such a way as to mitigate high load peaks within a plant's electrical distribution system.

The System performs predictive production scheduling, automated execution, and reacts to interruptions in seconds.

The ABB Ability™ Operations Management System integrates mine operations in one platform and connects a facility's workforce and equipment in real time. It also performs predictive production scheduling, automated execution, and reacts to interruptions in seconds. Among other things, the system manages the constraints of charging operations and optimizes for maximum productivity, taking other system constraints, such as power availability, mine plan and operational targets, as well as asset availability, into account.

Like other companies along the value chain, mining enterprises want to play a role in the energy transition by maximizing sustainability as well as safety and productivity in everything they do. These are the core enablers to obtaining and retaining licenses to operate in key mining countries such as Australia, Canada, Chile, South Africa and Sweden, among others. eMine™ FastCharge helps in all three areas, whereby drivers and miners do not need to be involved in the charge connection process, which is fully automated, and are supported by electric vehicles that are less noisy and more comfortable to operate.

In a nutshell, eMine™ FastCharge is a versatile system solution and a game changer that enables mining operations to be conducted sustainably thanks to:

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04 ABB's new emissions-reducing vision is designed to streamline a mine's entire electrification and automation operations.

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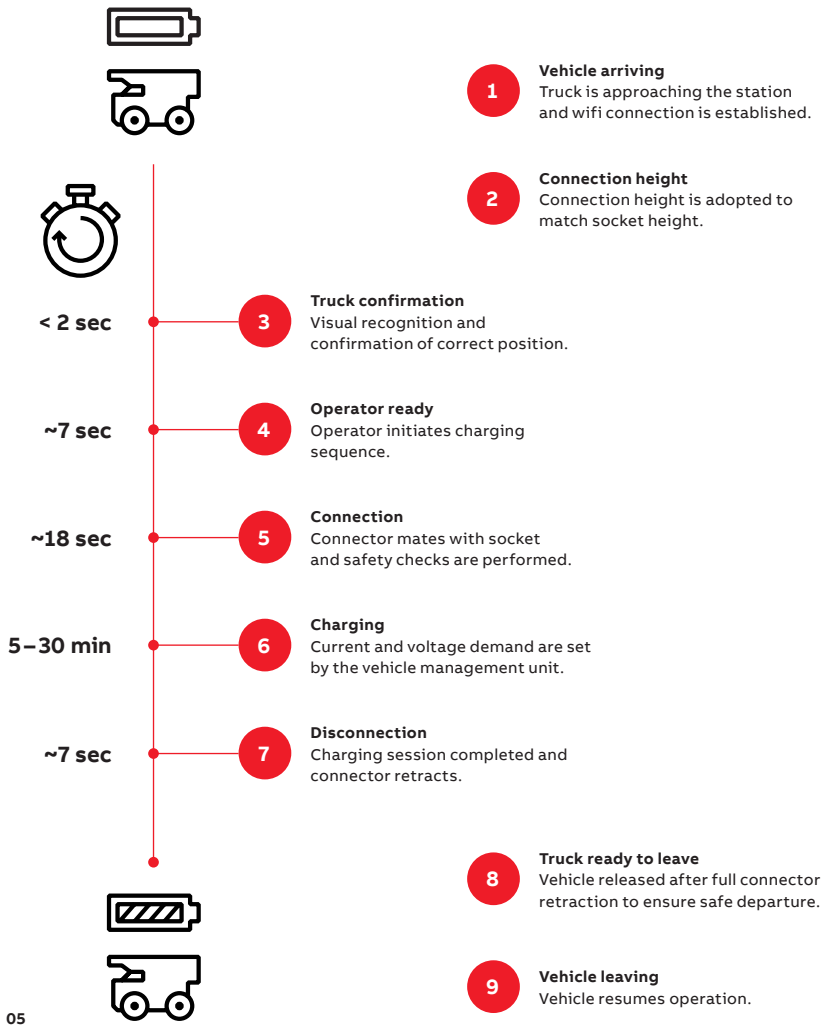
05 A suitable state of charge can often be reached within 15 minutes.



05

- a common interface that works on any haul truck.
- no manual operation.
- ultra-fast charging to minimize downtime.
- a mobile system that can easily be installed anywhere.
- modular design.
- rugged design for operation in harsh environments.
- future-proof digital design.

As the trend toward full mine electrification evolves, diesel fumes will give way to clean electricity, which will help to maximize energy efficiency and the movement of persons and machines. Trucks will run at higher speeds, mining operations and their employees will benefit from CO_2-free mines, and throughput will increase even as costs decline.

Mining leaders can truly imagine a connected workplace with their people and equipment assets in synergy, ideally powered by renewable energies, such as wind, solar or hydro power. ABB will continue to bring equipment, systems and people together to make mining operations more sustainable, safe and efficient for the benefit of the environment and future generations. •

—
The ABB Ability™ Operations Management System integrates mine operations in one platform in real time.

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References

[1] Climate risk and decarbonization: What every mining CEO needs to know | McKinsey. January 2020. Available: https://www.mckinsey.com/capabilities/sustainability/our-insights/climate-risk-and-decarbonization-what-every-mining-ceo-needs-to-know [Accessed: January 15, 2023.]

[2] Kecojevic, Vladislav & Komljenovic, Dragan. (2010). Haul truck fuel consumption and CO_2 emission under various engine load conditions. Mining Engineering. 62. 44-48.

MULTIPHYSICS-BASED REDUCED ORDER MODEL (ROM) FOR MINE POLLUTION CONTROL

Modeling flow

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

01

Successful development and verification of a constructed ROM allows realistic predictions of CO_2 concentrations in an underground mine setting. With the ability to be integrated with ventilation control systems, the ROM generated response surface could help improve pollution controls and therefore refine air quality.

—
01 An underground gold mine would benefit from ABB Ability™ Ventilation Optimizer for air flow control. ABB explores whether multiphysics-based modeling results could possibly be used for further improvements.

Mahesh J Vaze
ABB Corporate Research, Process Automation
Bangalore, India

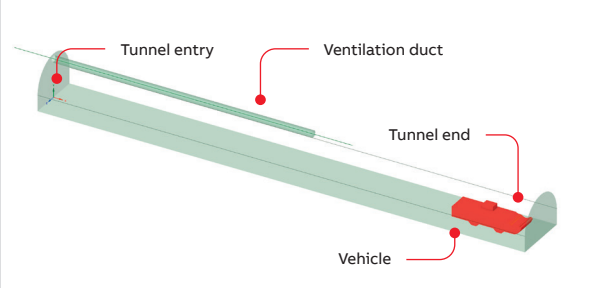
mahesh.vaze@in.abb.com

Subhashish Dasgupta
ABB Corporate Research, Process Automation
Bangalore, India

subhashish.dasgupta@in.abb.com

Multiphysics modeling is a globally sought-after methodology to simulate complex flow systems with high fidelity. This is possible due to the immense developmental strides that have been made in recent years with the ability of mathematical tools to capture complex flow patterns, heat transfer and gas dispersion. One important application that could benefit from multiphysics modeling is ventilation control of underground mines. With pollutant sources originating from diesel vehicle exhausts and blasting activity, mine ventilation control systems are hugely important for the health and safety of employees and for equipment safety →01. Air flow systems must deliver the quality and quantity of air when and where it is needed – a complex flow control process. Advanced strategies such as ventilation on demand (VOD) and optimization of ventilation, using algorithm control and digital twins, are already provided within ABB's state-of-the-art ventilation control for for the mining industry. However, ABB is ever ambitious to evaluate improvement potential and, if possible, take systems to the next level.

For this reason, ABB’s multiphysics experts investigated the possibility of leveraging multiphysics modeling, specifically computational fluid dynamics (CFD) modeling with species transport analysis to simulate gas dynamics within mines. The end goal is to improve ventilation control strategies so that customers will be able to reduce pollution levels better than ever, thereby ensuring the safety and health of



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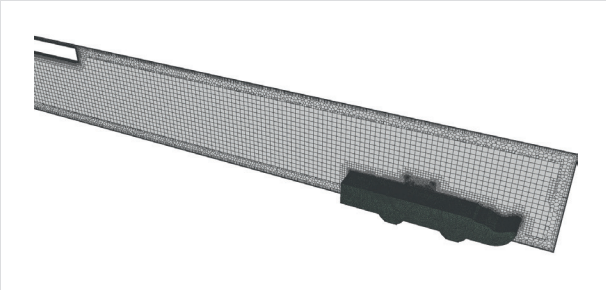

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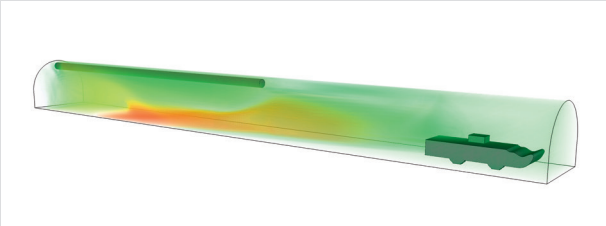

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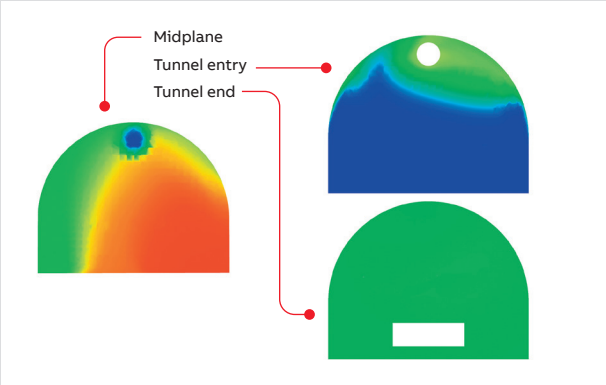

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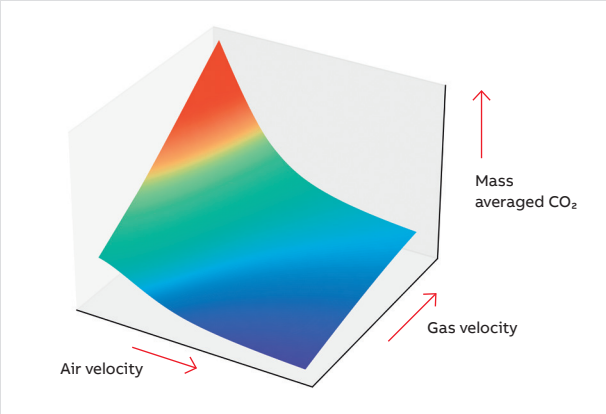


03

personnel. Furthermore, because mine ventilation is an energy intensive process, both energy and financial savings could be increased.

Introducing ROMs: An implementable version of CFD models

CFD modeling with species transport analysis is a proven methodology used to simulate gas dispersion, as evident from research publications worldwide [1-2]. With the capability of providing a holistic view of the distribution of gases, eg, carbon dioxide and methane, as they vary with time, CFD models are by far the best means to provide insights into complex gas flow systems. Nevertheless, CFD modeling is time-consuming and challenging when it comes to platform integration. Consequently, ABB evaluated the feasibility of developing ROMs, which is a more simplified modeling process approach than CFD, in order to facilitate integration with control system platforms.

ABB evaluated the use of a simplified modeling approach with ROMs to facilitate integration with control system platforms.

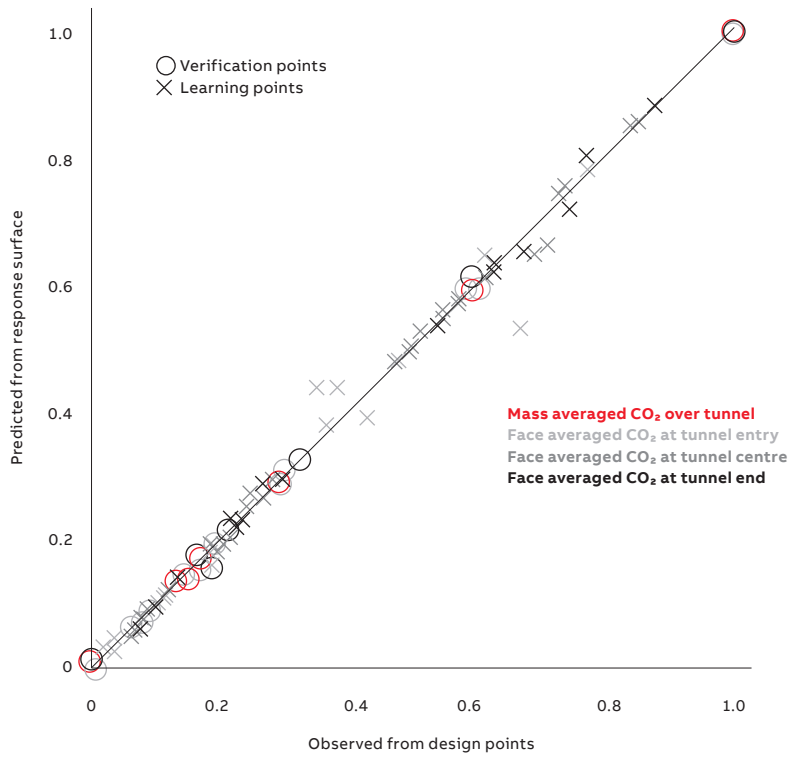
Not only does a ROM retain the essential features of a full-scale model and enable simulation of any given set of inputs to yield the output in an acceptable time, it offers further benefits:

- optimizes product design using several iterations in less time
- provides the opportunity to develop on-line physics-based digital twins
- allows low-or mid-level experts to use simulations.

And, because ROMs can be converted to front-end versions, in other words, to user-friendly and configurable versions, private and confidential data can be concealed from third party users. As a result of these advantages, ROMs can be used not only to lower computational resources and optimize design but can lower costs overall.

Building a ROM

As a first and essential procedural step to build a ROM, ABB developed an initial full-scale CFD model of the system. Numerous CFD simulations were performed on the same model setting, by varying input parameters and then recording the corresponding output results. Behind the scenes,



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02 The CFD modeling of vehicular pollution of an underground mine tunnel used for the simulations is shown.

02a Geometry of a tunnel.

02b Computational mesh.

02c CO_2 mass fraction over a tunnel.

02d CO_2 mass fraction over a plane.

—
03 The response surface generated by the ROM is depicted.

—
04 The results of the goodness-of-fit are shown.

a multi-dimensional curve fitting procedure, using machine-learning (ML) or neural-network (NN) algorithms, related the input parameters to the output results to yield the ROM. The ROM was then tested for accuracy and reliability, by using test cases, ie, comparing the model predictions for cases not simulated in the first step with predictions of the full-scale CFD model. These ROMs can be created and exported to other platforms in industry standard formats such as ".fmu" files.

Why develop a ROM for mine gas dynamics?
In this study, the primary source of mine pollution was considered to be vehicular exhaust. In this case, the ventilation duct forces fresh air through the mine tunnel in order to dilute the concentration of toxic gases such as CO_2, and to maintain the CO_2 level within the allowable legal limit. What if the CO_2 level could be realistically predicted under a given set of input parameters? Not only would such capability enable the efficacy of ventilation controls to be improved, it would, in turn, have a beneficial impact on the health and safety of employees as well as energy consumption.

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As an essential first step to building a ROM, ABB developed an initial full-scale CFD model of the system.

Testing the ROM: Does it work?
To investigate the possibility of using ROMs to make predictions, CFD modeling of vehicular pollution within underground mine tunnels was performed. The geometry and the computational mesh of an underground mine is as shown with the boundary conditions or model inputs given →02a-b. Here, the ventilation air velocity at the ventilation duct outlet and the exhaust gases emitted by the vehicle are considered to be the primary input parameters. The volume rendering of CO_2 mass fraction →02c shows the ventilation air ejects of the toxic gases away from the dead-end of the tunnel. The interesting results in this case are the mass averaged value of CO_2 over the entire underground mine volume, and the face-averaged value (entry, exit and mid-plane) of CO_2 for each of the three planes →02d. The ROM establishes the relationship between the output and input parameters for the given geometry and discretization scheme.

The design of experiments (DOE) for the ROM of gas dispersion within underground mine tunnel was established using the Optimal Space Filling Design (OSF) method. Initially, a few design points (DPs) or variations of input parameters are considered; these DPs are simulated using the CFD model. The input parameters are mapped to the output; this results in the generation of the

05

Photo fig. 05: ©Michael Evans/stock.adobe.com

ANSYS DesignXplorer Add-in for Excel

resSurfaceDXROM1.dxrom

✔ The evaluation operation was successfully performed.

What-If?

Caption	P9 - airVelocity	P10 - gasVelocity	P11 - mass-ave-co2-op	P12 - face-ave-co2-finger-entry-op	P13 - face-av-co2-mid-plane-op	P14 - face-ave-co2-dead-end-op	P11 - mass-ave-co2-op Predicted Error	P12 - face-ave-co2-finger-entry-op Predicted Error	P13 - face-av-co2-mid-plane-op Predicted Error	P14 - face-ave-co2-dead-end-op Predicted Error
Unit	m s^-1	m s^-1	None	None	None	None				
Type	Input	Input	Output	Output	Output	Output	Predicted error	Predicted error	Predicted error	Predicted error
Classification	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous	Continuous
Lower Bound	12,000	7,000								
Upper Bound	50,000	21,000								
Response Point 0	31,000	14,000	0,007	0,004	0,005	0,006	1,215E-04	3,200E-04	1,181E-04	1,241E-04
Response Point 1	49,000	8,000	0,004	0,002	0,002	0,003	5,059E-05	1,083E-04	2,655E-05	5,792E-05
Response Point 2	13,000	20,000	0,025	0,021	0,016	0,018	5,603E-05	1,468E-04	5,346E-05	3,990E-05
Response Point 3	20,000	18,000	0,014	0,010	0,010	0,011	2,303E-05	8,591E-05	2,602E-05	2,412E-05

06

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05 Improving the efficacy of air ventillation control is not only important for the health and safety of mine employees it would positively impact energy consumption.

—
06 Screenshot showing add-in for Excel; this provides the means to easily integrate the response surface.

ROM by means of the genetic algorithm method for solving constrained and unconstrained optimization problems. The output of the ROM is the response surface →03; this surface graphically depicts the relation of the primary output results; which in this case is the mass averaged carbon dioxide concentration within the tunnel volume and the input parameters, as well as the ventilation air and vehicle exhaust velocities. The accuracy and reliability of the ROM is verified using the goodness-of-fit procedure →04, which relates the predicted values from the response surface to the values from the design points obtained from the full-scale CFD model. With the ‘×’ symbols denoting the design points/learning points used to develop the ROM, and the circular symbols showing the additional verification or test points, it can be easily observed that all of the verification points follow the regression line, thereby ensuring the proper goodness-of-fit, required for validation →04. In this case, the Root Mean Square (RMS) error is only 1×10^{-3}, which is an acceptable error level.

—
ABB found that the response surface generated by the ROM can be an effective tool for the online control of mine pollution.

Platform integration is key

Based on these previously described experimental results, the response surface generated by the ROM, which relates exhaust gas concentration to the input parameters, can be an effective tool for the online control of mine pollution as long as the response surface can be integrated with ABB control platforms →05. This is the case since the ROM can be used to generate the “.dxrom” file, which can easily be accessed via Microsoft Excel →06 and in turn can be integrated into ABB’s currently available control platforms, such as VOD, and ABB Ability™ Ventilation Optimizer. Because three-dimensional high-end multiphysics calculations are the foundation of the ROM, leveraging the generated response surface would add a new dimension to the latest mine ventilation control technologies offered by ABB. Such a step would not only help customers to improve air quality, providing fresh air where and when it is needed, it would improve the health and safety of employees and coincidently save energy through optimization. This would translate to cost savings too. •

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References

[1] J.C. Kurnia, “CFD simulation of methane dispersion and innovative methane management in underground mining faces”, *Applied Mathematical Modeling*, 2014, pp. 3467–3484.

[2] Z. Lihong, “CFD modeling of methane distribution at a continuous miner face with various curtain setback distances”, *Journal of Mining Science and Technology*, 2015, pp. 635–640.

HOW CAN THE INDUSTRIAL METAVERSE HELP ABB AND ITS CUSTOMERS?

Industrial Metaverse

The Industrial Metaverse holds great promise for significant improvements across all aspects of industry.

Martin W. Hoffmann
ABB Corporate Research
Ladenburg, Germany

martin.w.hoffmann@de.abb.com

Yemao Man
ABB Corporate Research
Västerås, Sweden

yemao.man@se.abb.com

Although there is no generally accepted definition of the Industrial Metaverse, it can be pictured as an emerging user-centered space that connects and enhances the digital and physical worlds by integrating various recent technological trends such as digital twins, machine learning, the Internet of Things (IoT), mixed reality and 5G →01. Different types of metaverses may emerge for different purposes.

The constituents and potential of the industrial Metaverse

Adopting the Industrial Metaverse in particular brings opportunities to simulate, analyze and test industrial processes, products, data and equipment in a safe and controlled environment. For example, the Industrial Metaverse can help plant owners improve efficiency by using virtual engineering and co-simulation environments. It can also:

- Increase the agility and resilience of production facilities through continuous optimization.
- Shorten order delivery times through fully connected supply networks.
- Optimize energy consumption through integrated data analytics.
- Improve worker understanding of their role in the production process through visualizing work processes using extended reality (XR).

For example, nautical officers could immerse themselves in simulated real-world scenarios to practice remote supervision of an autonomous vessel [1,2] or check their own vessel's surrounding environment with an augmented view [3]. These are essential stepping stones to safe and efficient autonomous shipping operations.

With the rise of the Industrial Metaverse, a holistic digital twin of a production facility, its processes, workers and supply network, across all stages of its design and development life cycle, is on the horizon. In addition to XR, further enablers include omnipresent communication capabilities (based on 5G, for example), standardized information exchange – eg, via the Industrie 4.0 Asset Administration Shell – and industrial cloud platforms, such as Manufacturing-X.

ABB looks forward to exploring these exciting opportunities with its partners and customers.

Imagine, for example, a service engineer at a customer's plant who can use a lightweight XR headset to see the overlaid real-time, cloud-based simulations of the production process on the tangible assets, enabled by 5G and machine-learning technologies. Production experts and operators around the globe can join in this mixed-reality environment remotely using

—
01 Convergence of various technologies will enable the Industrial Metaverse.

similar headsets. Such a scenario will provide the participants with a broader understanding of the production process, minimize health risks and enable faster commissioning or re-engineering of a production line.

An evolving Industrial Metaverse
Many technologies of the Industrial Metaverse are already in use: On-site assistance from remote experts via video links – including XR applications, such as ABB's Collaborative Operations for Electrical Systems (CLOSER) or the ABB Ability™ AR Guided Support for measurement devices – are becoming industry standards. Furthermore, co-simulations with digital twins of plants and factories are nowadays feasible, by using, for example, ABB Ability System 800xA Simulator or virtual commissioning for drives.

The Industrial Metaverse will continuously benefit from advances in other metaverses, such as the Consumer Metaverse and Commercial Metaverse. One example of such a benefit is virtual collaboration. Further, AI delivers human-understandable insights that can help optimize industrial processes, leading to improved efficiency and productivity. Also foreseen is greater use of sensor technology and the IoT to gather data; more real-time analysis at the edge and in the cloud; and adoption of blockchain to secure and manage data and transactions. ABB looks forward to exploring these exciting opportunities with its partners and customers.

ABB Review will delve deeper into the Industrial Metaverse in a future edition. •

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References

[1] K. Tervo, "Navigating the future – a better operational team with ABB Ability™ Marine Pilot product family," *ABB Review*, 2/2022, pp. 10–17.

[2] ABB, "Autonomous Shipping." Available: https://new.abb.com/news/detail/84822/autonomous-shipping. [Accessed January 13, 2023.]

[3] ABB, "ABB Ability™ Marine Pilot Vision." https://new.abb.com/marine/systems-and-solutions/digital/abb-ability-marine-pilot/abb-ability-marine-pilot-vision. [Accessed January 13, 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 1/2023. From 1/2023 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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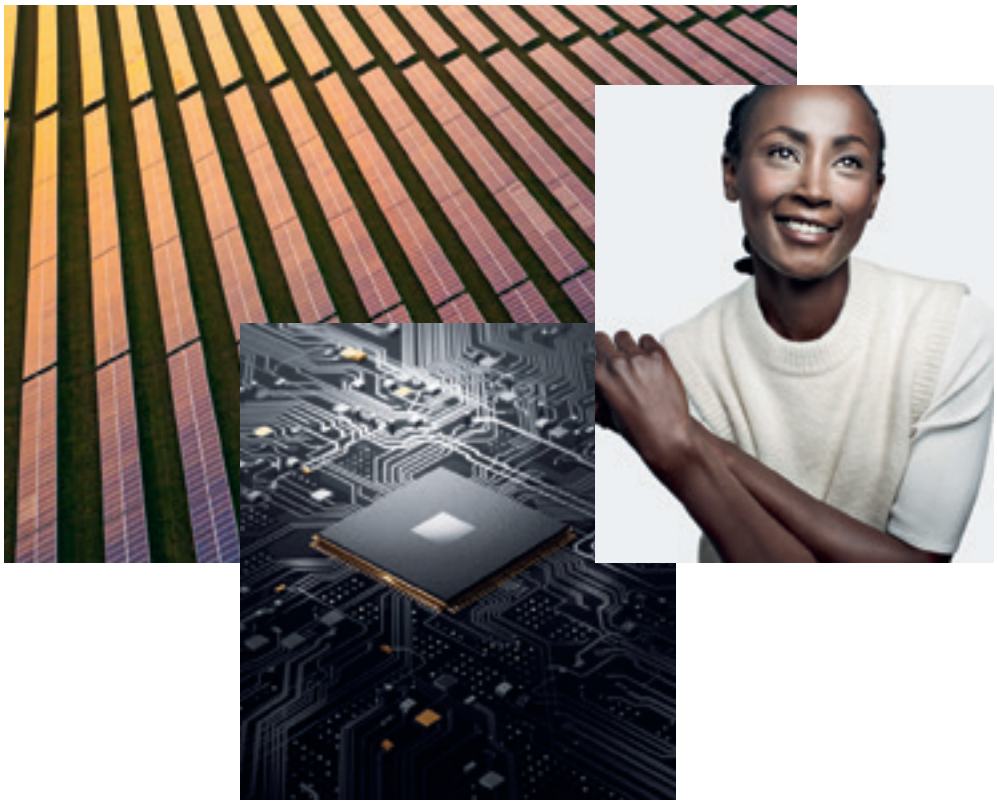

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