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The feature should make ABB Review simpler to navigate and give readers a preview on what to expect.

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Factory for the future

In 2018, ABB Review published an article looking at the future of autonomous systems. In the present issue, the authors of the original paper re-visit their predictions – and come to some remarkable conclusions. Progress and adoption in this area have been rapid. Much of what was speculative six years ago is now reality.

What will the next years bring, and what will industry be like in five, ten or twenty years from now?

Coming up in the next edition: **Navigating efficiency**

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EDITORIAL

Factory for the future

Dear Reader,

The operation of a large industrial plant requires a fine balance between numerous considerations. Whether during planning and construction, day-to-day operations, or in maintenance and upgrades; decisions must consolidate expertise from many disciplines.

Adding to this already formidable challenge, are ever-tightening standards and requirements on the one hand, and the increasing scarcity of skills on the other. ABB is supporting customers in numerous domains through the company's deep experience, supported in its delivery by cutting-edge technology and AI.

In this issue of ABB Review, we take you on a journey visiting, among others, a modular concept that take the pain out of plant engineering, an advanced Ethernet-based system that simplifies industrial communications, and a system that can detect machine anomalies simply by listening.

Enjoy your reading,

Björn Rosengren
Chief Executive Officer, ABB Group

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$ 125,000
average cost per hour due to unplanned downtime

300 million
operational motors in the world

ABB is using AI to predict anomalies and avoid unplanned downtime.

APPLYING AN UNSUPERVISED MODELING APPROACH TO DETECT EARLY-STAGE FAULTS IN ELECTRICAL MOTORS

Hunting for anomalies

ABB has developed a highly effective and scalable capacity for automated fault detection using unsupervised lightweight models that retrain themselves. By linking parallelizing, anomaly detection, and post-processing into a pipeline ABB makes sure this solution is reliable, reproducible as well as scalable.

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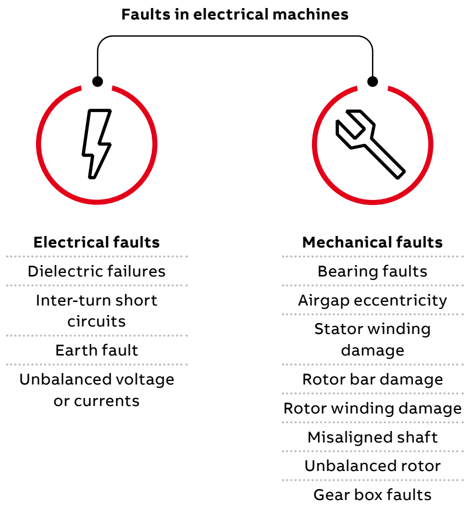
According to a survey conducted by ABB with 3,215 organizations [1], industrial businesses experience a typical cost of about $125,000 per hour due to unplanned downtime. It was also found that 69 percent of the surveyed plants experience unplanned downtimes at least once a month. Clearly, equipment such as electrical motors is essential for the smooth running of many industries, and reliability is key to minimizing failures and the negative financial impact of downtime.

Nevertheless, despite their prevalence – more than 300 million operational motors in the world [2] – ensuring this reliability is an ongoing challenge.

Condition monitoring that utilizes advanced algorithms on operational data from motors could mitigate unplanned downtime by detecting anomalies and alerting operators to issues before they escalate into more serious problems.

Challenges for motor anomaly detection
The fault types in electrical machines can be divided into two main categories: electrical and mechanical faults. The main electrical and mechanical faults are summarized in →01. The physics behind these faults differs. Thanks to advanced signal processing, the symptoms can be observed by analyzing the vibration, stray flux, acoustics and electrical current characteristics of the motors. [3]. For instance, considering mechanical faults, these can be observed in specific harmonics of the motor's vibration.

Utilizing advanced algorithms on operational data from motors could mitigate unplanned downtime by detecting anomalies.



01

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01 Main types of faults in electrical machines.

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02 Vibration patterns of identical motors used for different load types.

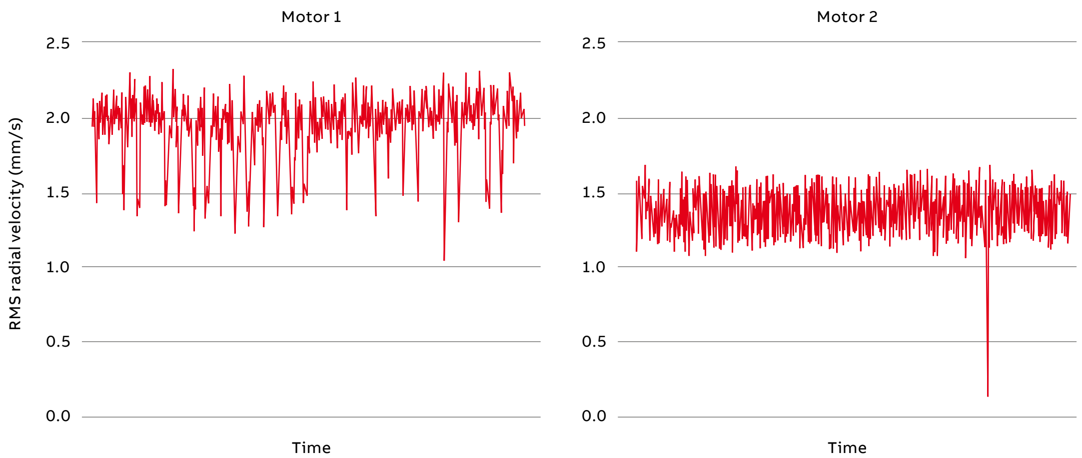
Such harmonics can be revealed by performing a FFT on the measured vibration signals. On the other hand, wavelet and envelope analysis of the vibrations can also be used to observe various faults in a low-intervention manner. [4]. In earlier days, the monitoring of these harmonics was done manually or by setting simple thresholds on the amplitudes. These methods are neither effective nor practical, considering the number of assets that need monitoring, lack of universal thresholds and the influence of factors like machine characteristics, operating speed and load.

These issues have been partly addressed in recent years, with advances in the AI domain. For instance, existing literature suggests that supervised ML methods could be effective in detecting and classifying faults in electrical machines [5]. Such methods however, require labeled data from the studied machines: models developed for one machine may not generalize to others of different sizes, applications, or operating conditions. Consider the measurement of radial vibration signals for two identical healthy motors that are connected to different load types →02. Even though the motors run at their rated power and speed, the vibration patterns are significantly different. Therefore, the models trained on vibration patterns of motor 1 will most likely produce incorrect predictions for motor 2.

—
Unsupervised modeling methods could be used to detect anomalies caused by deteriorating machine health conditions.

To address this challenge, one option is to collect more labels from various machines and explore additional fault cases to train larger or multiple models. However, this process is impractical, costly, and time-consuming. Alternatively, unsupervised methods could be used to detect anomalies caused by deteriorating machine health conditions, since labeled data is not required for training the model in these cases.

And yet, it is extremely difficult to train a single, generalizable unsupervised anomaly detector if a fleet of motors is being monitored, as is often the case. Hurdles exist, including factors such as motor design, size, mounting type, instantaneous torque, and speed, that impact the measured motor vibration and magnetic flux density



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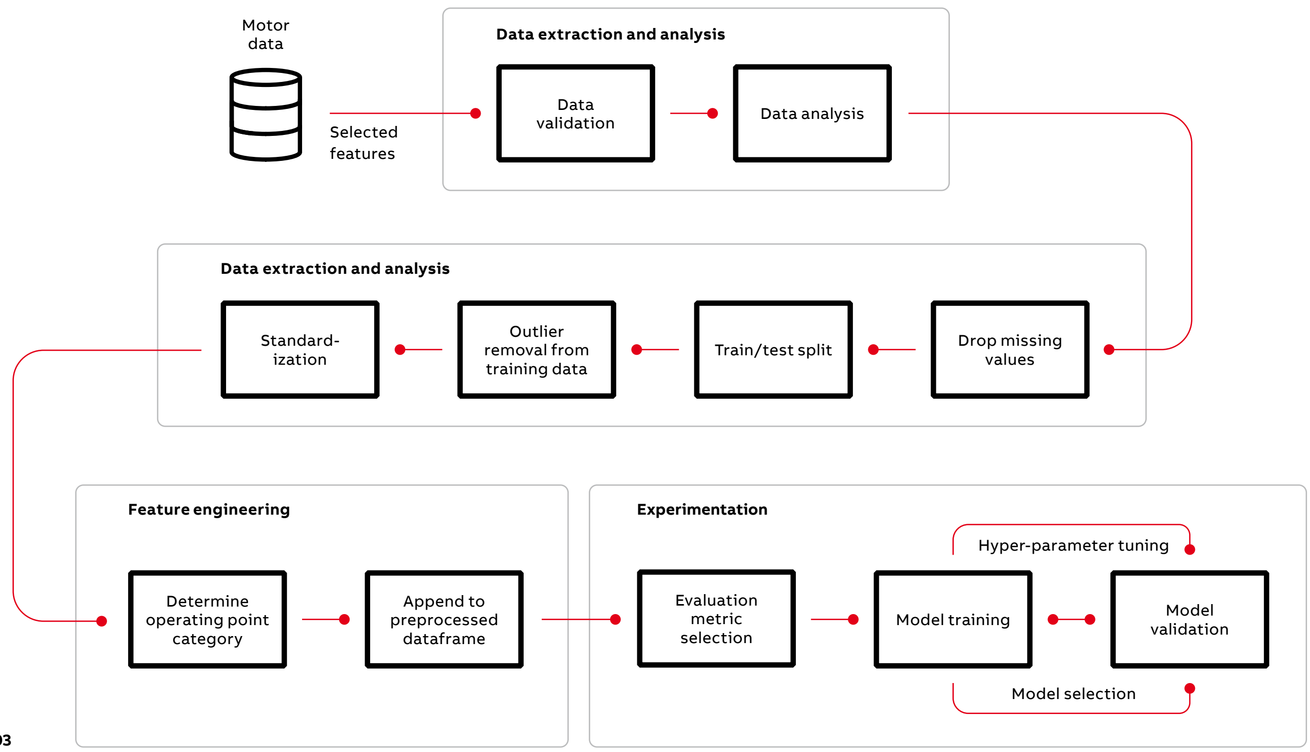

03

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03 Model development process.

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04 Evaluation of OCSVM that displays the summarized average results for the studied motors.

patterns. Such challenges can be circumvented by employing dedicated unsupervised models for each motor, which is precisely what ABB has done.

Having selected this approach, two relevant criteria had to be in focus. First, to monitor a wide array of motors, a traditional lightweight ML-based model that does not compromise performance should be chosen, rather than the computationally heavy deep neural network (DNN) method. Second, a consideration of the proper infrastructure was necessary in order to support the deployment and maintenance of models across a vast number of motors.

Considering these criteria, ABB's data scientists have developed a highly effective and scalable capacity for automated fault detection for motors. The detection feature incorporates both pattern-recognition-based detection of quickly developing serious faults and an unsupervised machine learning (ML) approach for identifying early-stage faults. This paper focuses on the ML-based approach.

Metric	Value
PR-AUC	0.92
F_β	0.92
Training time (for 4 weeks of data)	2.76 ms
Inference time (for 24 hours of data)	0.37 ms

04

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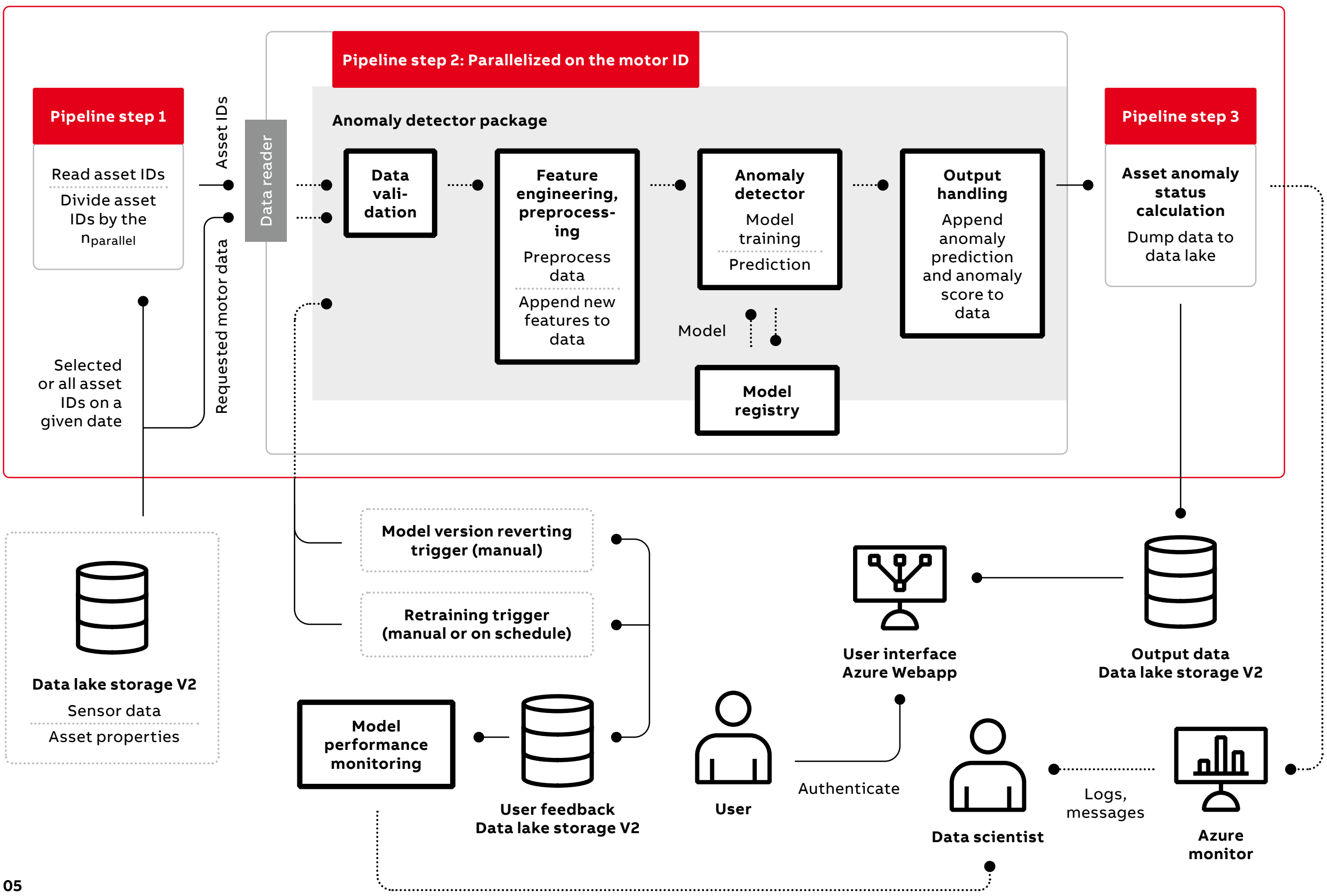
ABB has developed an effective and scalable capacity for automated fault detection for motors.

Developing unsupervised anomaly detection for electrical motors

The complexity of developing reliable, reproducible and scalable ML solutions is troubling for many organizations; this creates an obstacle for companies to take advantage of these solutions in real-life cases [6,7]. To tackle these challenges,

ML PIPELINE



05

05 Overview of the motor anomaly detector solution.

ABB benefitted from best practices in the discipl e of ML Operations (MLOps) in developing their anomaly detector solution →03.

Although the unsupervised model training does not require labeled data, ABB collected data from various motors with known healthy and faulty periods to assist with model validation,

ABB's detection feature incorporates an unsupervised ML approach for identifying early stage faults.

hyperparameter tuning and model selection. Once selected, the model only requires unlabeled data to be trained. Analysis of the labeled data showed that the data is highly imbalanced, with the faulty class in the minority. All faults in the studied cases can be detected effectively using vibration measurements.

First, the data has been preprocessed by removing the missing values, splitting the data into train and test sets, removing the outliers from the training data and standardizing the data. Afterward, during the feature engineering step, new features were created from existing data to enhance anomaly detection performance. Here, a categorical feature has been generated to group measured data points based on their deviation from the rated speed or slip. For variable speed drive motors, speed was used, while slip was used for direct online motors. This new feature helps to effectively consider the operating characteristics of the motor.

The final development step involved experimentation for model selection. The model has been trained using a predefined initial number of healthy data points. As evaluation metrics for such a binary classification problem with highly imbalanced data, precision-recall area under curve (PR-AUC) and Fβ-score with β=0.5 were selected to give more weight to precision and reduce false positives. PR-AUC and Fβ-score were used for model hyperparameter tuning and anomaly threshold optimization, respectively. In addition to these evaluation metrics, a constraint was employed to consider the computational burden of the calculations. One-Class Support Vector Machines (OCSVM), Isolation Forest, Minimum Covariance Determinant, Robust Random Cut Forest and Local Outlier Factor algorithms were studied; OCSVM was determined to be the best algorithm in terms of evaluation metrics and computational effort →04.

Model deployment

The deployment of the model was completed by connecting all the development steps into a pipeline. Considering the infrastructure design for deployment, one of the most difficult challenges is to design an infrastructure that can train and serve thousands of models in a reasonable amount of time. To this end, ABB utilized the parallel processing capabilities of Microsoft Azure Machine Learning Studio, where the job executions can be distributed to parallel compute clusters and nodes [8]. This can be scaled by increasing the number of compute-clusters or nodes, which comes with a cost. Thanks to the light computational burden of the OCSVM algorithm, only affordable CPU clusters were used.

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Model deployment is completed by connecting the parallelizing, anomaly detection and post-processing steps into a pipeline.

The pipeline consists of three key steps: parallelizing, anomaly detection, and post-processing. The parallelizing step checks the available data for a specific date, reads the corresponding connected asset IDs, and divides them for parallel processing. The anomaly detection step is the core of the solution, encompassing data extraction, validation, preprocessing, feature engineering, model training, and prediction. Model training is automatically performed using the first pre-determined amount of data from the motor, assumed to be from a healthy operation. The trained models are versioned and registered in the model registry for use in future predictions.

The post-processing step calculates the importance factor for anomalies, enabling appropriate user notifications. Finally, the results are presented in a user interface (UI) for further analysis.

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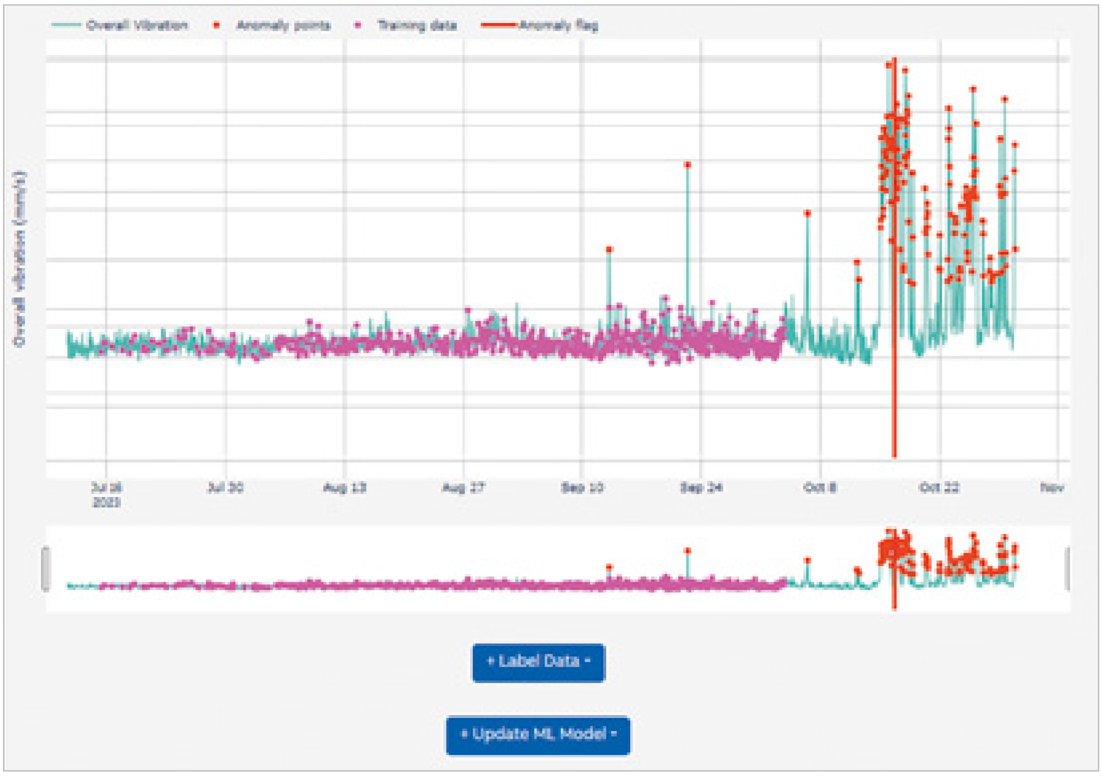

07

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06 Table with detected anomalies from the motor anomaly platform.

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07 The vibration plot from the motor anomaly platform is shown. Labeling and ML model updating options are also visible.

One of the important aspects of the pipeline is the automated model retraining that is done regularly on a schedule. The selection of the training data for updating a model for a particular motor is done by random sampling from the historical healthy data points determined by the model, with higher weight given to the newest data points. Such model retraining helps the models to consider the environmental influences that could appear due to, eg, variation in seasonal temperature, humidity fluctuations and the addition of newly installed equipment within the vicinity that might impact the vibration measurements.

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One of the important aspects of the pipeline is the automated model retraining that is completed regularly.

UI for the motor anomaly detection solution
The user interface (UI) for the motor anomaly detection pipeline offers a comprehensive set of features that include a table that provides a summary of information regarding motors with detected anomalies →06. Users, such as data analysts, can interactively apply filters to access the specific data they require. Additionally, the UI includes a line plot that displays the maximum RMS vibration along the 3-axis, highlighting any anomalies that might be present →07.

Furthermore, the UI is equipped with a data annotation feature, which allows users to provide feedback to the model by annotating the data. These annotations play a crucial role in monitoring the performance of the model. As more labels are collected, it becomes possible to explore the potential of supervised approaches. In addition, users have the option to request retraining of the model to obtain a new version. This control over model retraining is useful. For example, when a motor is repaired or replaced, the vibration characteristics might change completely compared to the past vibration features. Users can also revert the model to a previous version, if they observe better performance in one of the previous versions.

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The effectiveness of the anomaly detection functionality has been successfully demonstrated in an industrial case.

A case study

The effectiveness of ABB's anomaly detection function has been demonstrated in a specific industrial case. An early anomaly detection flag was raised for a motor driving a fan with a belt. Thanks to the notification, further analysis of the raw vibration data by an ABB expert using advanced signal processing tools was performed and revealed the occurrence of elevated harmonics related to the driven equipment →07. Upon physical inspection, it was confirmed that the bearing on the driven fan and the belt in between were damaged.

This case study demonstrated that the anomaly detector is even capable of successfully identifying a problem that originated from the application rather than from the motor itself, thereby preventing potential unplanned downtime. In this way, ABB shows that the anomaly detector, using the ML-based approach, is ready to help users in the future resolve fault issues early, thereby diminsihing downtime. •

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Acknowledgements

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PlantInsight is an ABB platform for machine-learning.

Algorithms predict system responses several steps into the future.

Control is more accurate.

01

PLANTINSIGHT: HOW AI IS TRANSFORMING INDUSTRIAL PROCESSES

Data-driven insights

—
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At the core of all industrial processes is the quest for ever more precise levels of control. Today, this quest is driven by increasing computer power and digitization in automation. However, although most of the underlying mathematics stems from the 1960s, only recently has it become feasible to apply some algorithms to real-time scenarios.

01 The ability to manage continuous processes with precision is essential in the chemical industry.

ABB's Ability™ PlantInsight platform →01 is a case in point. The platform makes it possible to run a variety of machine-learning (ML) algorithms for detection, segmentation, and prediction of specific patterns in vast amounts of process data. This, in turn, enables the implementation of AI-based optimization solutions that help reduce pollutants, extend equipment lifespans, and lower production costs.

Nowadays, artificial intelligence (AI) seems omnipresent. It is a common topic of conversation, bookstores are flooded with literature about it, and few applications seem to do without it. But considering the sheer amount of hype, one may wonder why AI is still so seldom used in process industries. Or could it perhaps be that it is already used, but just not recognized as such?

Generally, a system is considered to be AI-driven when it performs tasks typically done by humans, such as visual perception, decision-making, speech recognition, and translation. As a matter of fact, AI-driven systems can outperform humans in a range of activities such as solving numerical problems, pattern recognition, and retrieving information from a massive number of sources. Nevertheless, such systems are still in their infancy when it comes to abstract reasoning or creatively turning information into eloquent texts, to say nothing of social interactions, consciousness, or self-awareness, all of which are routine for humans but out of reach for machines – at least so far.

Vision, hearing, speaking and motion are tasks very similar to those encountered by process control systems.

In view of this, it is important to distinguish between different levels of AI. According to Kaplan and Haenlein [1], the evolution of AI can be divided into three stages:

1) artificial narrow intelligence – the application of AI to specified tasks.
2) artificial general intelligence – the application of AI to autonomously solve novel problems in multiple fields.
3) artificial super intelligence – the application of AI to any area that can benefit from scientific creativity, social skills, and general wisdom.

Most of today's AI solutions fall into the first category. In this sense, even James Watts' flyball governor, a speed regulator for his rotary steam engine of 1768, could be considered AI at stage one. However, it was never marketed as such – and the same can be said for the millions of control solutions operating in the power, refining, and chemical industries.

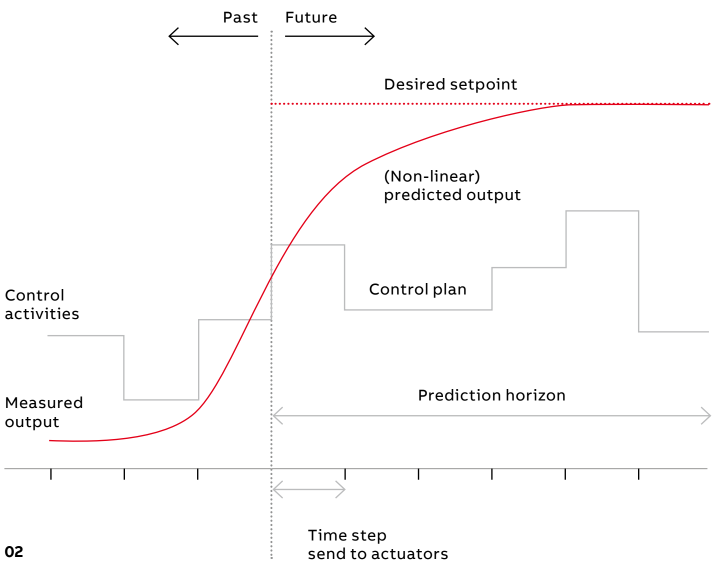
AI as a solution

Typically, AI systems not only consist of a brain, or in other words, a sophisticated algorithm; they also must be able to perceive and interact with the world. Vision, hearing, speaking and motion complement the brain and allow AI-based systems to solve real-world problems – tasks very similar to those encountered by process control systems. While sensors measure process values (dependent variables), such as pressure, flow, temperature, etc., the controller takes these inputs and calculates the best way to adjust actuators such as valves, dampers, etc. (independent variables) to meet certain control objectives. In this scenario the controller's role is that of a brain, running algebraic calculations and making logical decisions.

Why now?

One of the most obvious reasons why AI is gaining ground now is the exponential increase of available computing power. Some of the constraints data scientists had in the past, such as a limited number of neurons in an artificial neuronal network (ANN), basically vanished, thus opening the door to leveraging the full potential of deep learning networks. Furthermore, anybody with a laptop and access to a cloud solution can run a training algorithm. This opens the market for new business models such as self-service model training and software as a service (SaaS). This not only democratizes AI but reduces engineering requirements on control solutions.

In the process industry, digitization began in the late '70s with the widespread introduction of programmable logic controllers (PLC) and distributed control systems (DCS), which replaced analog controllers. Adding new data points and control features became a programming, rather than a hardware installation and configuration task. This significantly increased the flexibility of the control process while reducing costs. However, adding more control features led to more complex control structures, which were often difficult to understand and maintain. They also required significant engineering effort and process know-how. The need for a leaner and more transparent control approach arose.



02

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02 Principle of non-linear model predictive control (NMPC).

Advanced process steps

Advancements in mathematics and system theory, and the increasing availability of computer power, enabled the development of more advanced process controls. The mathematical fundaments behind this process can be traced back to the work of Rudolf Kalman et al. in the early 1960s [2]. While differential equations describe the dynamics of a physical system in a kind of 'cleanroom' scenario, Kalman added terms for state disturbance and measurement noise, something inevitable in any real-world application. Moreover, he directly formulated his equations using matrix representation, accounting for multiple differential equations with their respective inputs and outputs. This multi-inputs, multi-outputs (MIMO) approach made it possible to calculate an optimal control strategy not only for one actuator at a time, but for many simultaneously.

—
It turned out that Kalman's mathematical solution could be used to look into the future of a process.

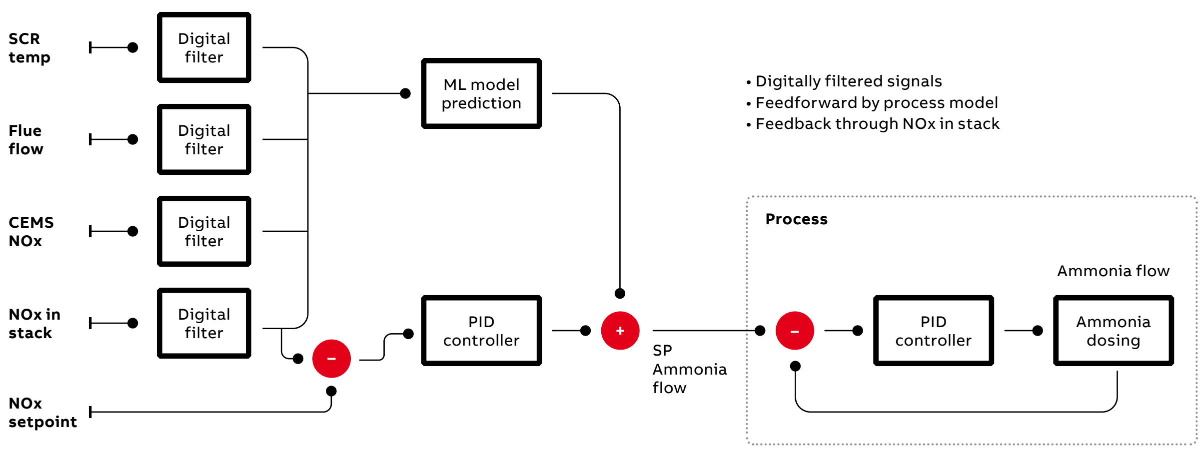
Moreover, it turned out that Kalman's mathematical solution could also be used to look into the future of a process. In contrast to a simple controller, which only calculates the next optimal step for one variable, it was now possible to look multiple steps ahead into the future for multiple variables. The goal remained the same: to minimize the control error, which is the difference between desired and actual process values. But whereas a simple control is 'driving by sight', a forward-looking regulator creates a longer-term plan to act upon.

However, as things often do not go according to plan, it became evident that controllers must be able to adjust to changing situations based on feedback from a process. This led to the development of Model Predictive Control (MPC), which generates an optimal control path but triggers

PLANTINSIGHT'S FIRST APPLICATION

Control solutions based on artificial intelligence not only keep a plant running at its economic optimum but can also help to better control and thus reduce its emissions. Indeed, as a first application, PlantInsight's AI capabilities were used in combination with conventional PID controls to reduce the emissions of a chemical residuals incineration facility. Compared to minimizing the emissions of a gas or coal-fired incineration plant, which is mainly a function of managing temperature, air and humidity, the emissions that chemical residuals emit during incineration are much harder to predict.

Based on one year of process data, PlantInsight analyzed the interdependency of multiple process variables that might contribute to emission levels. Deadtimes were considered by automatically shifting data and adding lagged process variables to the dataset. After feature selection of the most promising variable candidates, an artificial neuronal network was trained. The network was able to predict emission levels several minutes into the future with a high level of accuracy. This soft-sensor prediction was then used as feed-forward information for a conventional PID control system. As a result, cost savings due to reduced ammonia use were achieved. This in turn led to a reduced CO_2 footprint due to reduced ammonia consumption, while improving reliability and equipment lifetime due to reduced corrosive ammonia slip →03a.



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03 PlantInsight's first application.

03a Simplified representation of AI-supported control of an emission reduction system. PID: proportional integral derivative. CEMS: Continuous Emission Monitoring System

only the first step in each iteration. A moment later, once feedback is received, it repeats the process of calculating the optimal path until the desired operating point is reached →02.

Although these steps have significantly improved many processes, there are multiple areas where process control is still limited. The following section describes some of these areas and how AI can contribute to overcoming the remaining limitations.

Real-time feedback

As described above, controllers require feedback from the process they are controlling, otherwise their performance may suffer. This problem intensifies the longer the delay between action and feedback. Specifically, data with large time gaps compared to the actual process might pose issues. This is typically the case for laboratory data covering product properties that cannot be measured continuously or in real-time, such as viscosity or flashpoint. Adjustments to a process can be performed only after receiving results from the lab, which, because of the inherent delay, might compromise product quality.

One way to overcome this is to estimate the values of a product's qualities in real time using

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The accuracy of ML models, such as artificial neural networks, can be continuously improved with each new lab measurement.

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04 Machine learning models can help to overcome gaps in laboratory data.

ML models, such as artificial neural networks (ANN). Here, the accuracy of the models can be continuously improved with each new lab measurement. Predicted qualities can then be used without delay by the control algorithm to adjust the process. In this configuration, conventional and AI-based control algorithms work hand in hand to achieve and maintain desired production goals. This concept can also be applied to processes with long dead times or processes that use sensors that need to recalibrate regularly and are thus not continuously available. A practical use case pertaining to emission reductions illustrates the above concepts →03.

04

Adapting to non-linearities

Like most systems in the real world, industrial processes are often non-linear. This results in a systemic discrepancy between the real process and its linear process model. In the context of short time horizons and minor process alterations the resulting error may be neglectable. However, on a larger scale it may affect control performance. Although some non-linearities can be offset through transformation of their associated process data – for instance linearization of a control valve's characteristic curve – linearization is not always perfect and can be costly when dealing with many process variables.

AI techniques, on the other hand, can deal very well with non-linearities. ML models can basically adapt to any non-linear behavior. While most MPC implementations use a linear approach for modeling, the framework itself makes no assumption about the type of process model used or its linearity. Therefore, non-linear models trained with ML algorithms can also be used to reduce modeling errors. This leads to more accurate control and prevents the controller from getting trapped in minor optimizations.

Identifying the right process behavior

At the heart of any advanced process control system is a process model. However, the process of identifying the dynamics of a physical system is costly and requires domain know-how and experience.

Traditionally, there are two approaches to model design: a so-called first principles model, which is based on the design, mechanics, and fundamental physics of a system, and a so-called empirical model, which is based on observations of how a system reacts to stimuli, for example, by means of step-response experiments.

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Non-linear models trained with ML algorithms can be used to reduce modeling errors, thus leading to more accurate control.

Both approaches can be highly complex, costly, and in some cases, due to the nature of the process, impossible to implement. However, in many cases, this burden can be avoided if adequate historical process data is available. During normal plant operation, setpoints are regularly changed and disturbances are continuously happening, both triggering reactions in the process, and

05

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05 Example of automatically identified operating states that could be used for process identification. (gray = not-applicable, pink = applicable).

thus revealing its dynamic behavior. These footprints can be used by ML algorithms to easily create accurate models →04. To accomplish this, the data must be representative and thus cannot be randomly picked. For instance, abnormal process behavior, or periods with missing data must be removed. Doing this manually would be costly, but for an algorithm this is the perfect task. Selecting, segmenting and clustering vast amounts of data is a home run for machine learning →05.

Platform solution
Over the years, ABB has developed a suite of control and optimization solutions that have followed and often led technical developments in this area. From first principle modeling to proportional integral derivative (PID) loop monitoring, model predictive control, and dynamic optimization, ABB provides a wide range of solutions. Today, with the assistance of hardware and machine learning algorithms, it is now possible to complement this offering with the benefits and opportunities of artificial intelligence. With this in mind, ABB has developed ABB Ability™ PlantInsight, a platform that leverages the full potential of ML algorithms. This web-based application makes it possible to run a multitude of machine learning algorithms for prediction, segmentation, and detection of specific patterns in huge amounts of process data, while its modular concept makes it easy to embed proprietary python scripts and complement them with existing ones.

—
PlantInsight makes it possible to run a multitude of ML algorithms for prediction, segmentation and detection of specific patterns.

All in all, it can be said that joining the world of control to that of artificial intelligence can yield significantly improved results in terms of controlling industrial processes. Indeed, the more such hybrid control solutions spread, the more both worlds will converge – an apparently natural process since both share the same theoretical foundations. As this process evolves, continued progress is set to pave the way to the introduction of tomorrow's fully autonomous production facilities. •

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Share this article

ABB has defined a framework for autonomous systems.

Some industrial areas will reach full autonomy before self-driving cars.

Advantages include greater safety, lower energy use and higher productivity.

01

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In 2018, ABB Review published an opinion piece concerning the taxonomy of autonomy levels in autonomous systems, with particular reference to applications in the mining and marine sectors. Five years on, how have the concepts described in 2018 taken hold and what practical applications have emerged?

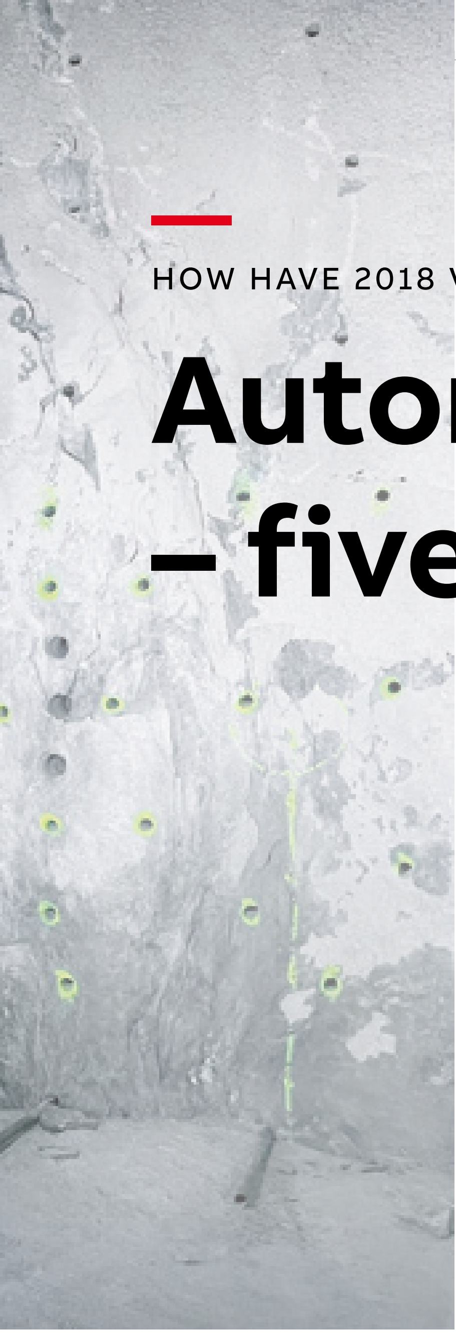
Traditionally, an autonomous system is defined as one that can – without manual intervention – change its behavior during operation in response to anticipated or unanticipated events. In 2018,

The 2018 article was intended to stimulate discussion around the topic of autonomous systems.

ABB Review published an opinion piece that introduced a more comprehensive definition of an autonomous system and sketched out some potential application areas [1] →01-02. The article was intended to stimulate discussion around the topic. An extended version of the material

HOW HAVE 2018 VISIONS OF AUTONOMOUS SYSTEMS TURNED OUT?

Autonomous systems – five years on



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01 Autonomous systems – like the charging robot shown here placing explosives in an underground mine – are already appearing in the field. How are such systems being exploited in the wider industrial world?

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02 The 2018 opinion piece on autonomous systems' taxonomy and trends. Read the original article here:

Photo fig. 02: ©Publik. Agentur für Kommunikation GmbH

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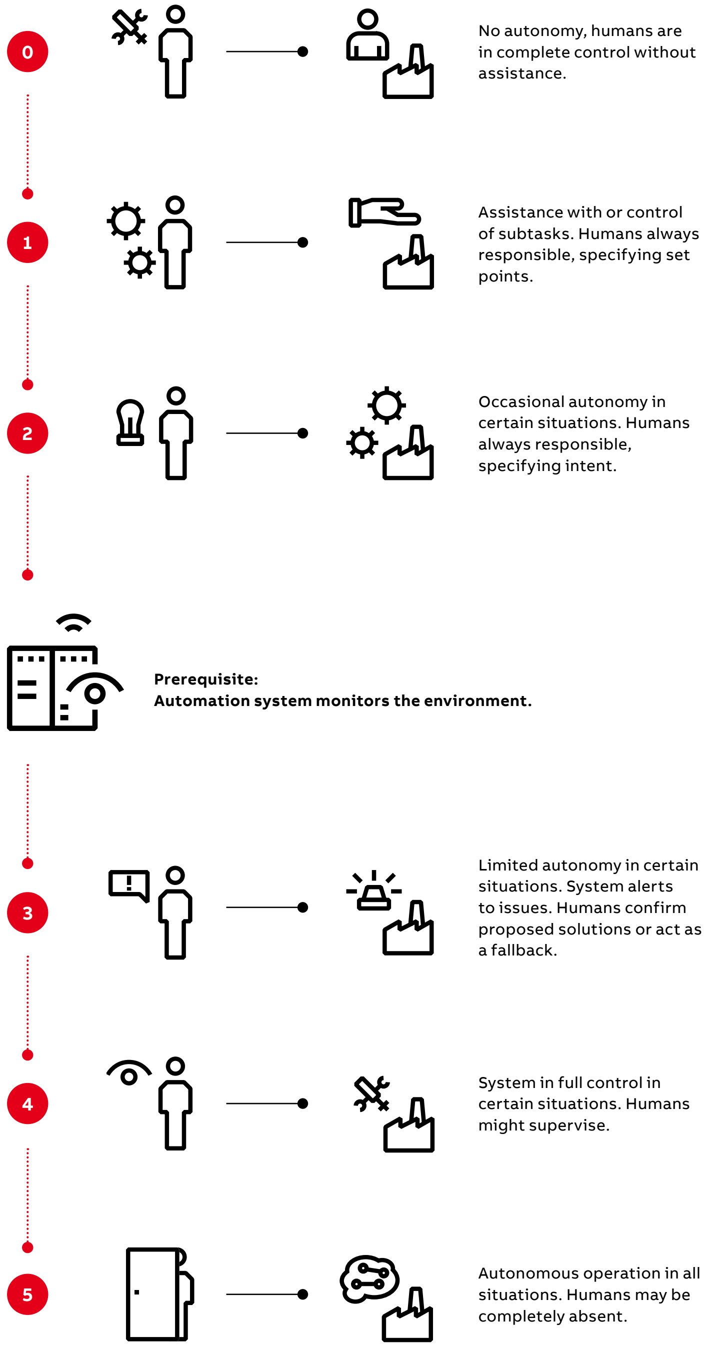
For the process automation described here, mining and marine are still the leading candidate application fields.

was presented at a conference on the dynamics of chemical processes (IFAC Dycops 2019) and subsequently published as a journal article in 2020 [2].

Additionally, the Industry 4.0 community has picked up on the idea and has published, for example, the autonomy levels proposed by ABB [3]. The work was inspired by the already ongoing development of self-driving automobiles and introduced a first taxonomy to describe industrial autonomy in a similar way – ie, with levels ranging from 0 to 5 →03. The ABB Review article observed that, for ABB, autonomy would first appear in applications similar to self-driving automobiles, such as mobile robotics, mining vehicles and machines, ships, cranes, etc. Potential implementations from the mining and marine sectors were described. The conference presentation and journal paper took the discussion further by reflecting on how autonomy might enter the process automation arena.

Now, five years after the first ABB Review publication, may be a good time to reflect on what has happened since in this technical area.

Autonomy in mining and marine
For the process automation discussed here, mining and marine are still the leading candidate application fields. For example, the 2018 ABB



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03 Proposed taxonomy of autonomy levels for industrial systems [2].

Review article mentioned the possibility of a robot autonomously placing explosives in predrilled holes in an underground mine. Such a charging robot has now been field-tested twice in a Swedish underground mine and a third test is underway →04.

Since much of the safety benefit lies in removing personnel from underground operations, ABB also produced a remote operator station. This station, which has been delivered to multiple customers, interfaces to both ABB and third-party applications. This universality eliminates the inconvenience of multiple operator interfaces from multiple vendors, each with their own look and feel.

Outside of ABB, suppliers of mining vehicles and machines are taking great strides towards equipment autonomy. For example, at the start of 2023, Epiroc (a Swedish manufacturer of mining and infrastructure equipment) announced the conversion of 96 haul trucks to driverless operation at the Roy Hill mine in Western Australia [4].

There has also been significant progress in shipping. Five years ago, ABB piloted ABB Ability™ Marine Pilot Vision, which provides a ship's captain and crew with situational awareness based on multiple sensor sources such

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04 The use of autonomous systems improves safety. Here, an autonomous ABB robot is preparing to insert charges into predrilled holes in a mine.

as radar, lidar and visual cameras. Since then, ABB has developed a collision avoidance system that utilizes image classification and tracking of other sea vessels (and other obstacles) to follow a new, collision-free path if a hazard is detected →05. The solution was implemented and successfully field-tested on a tugboat in the port of Singapore [5]. ABB has also developed algorithms for autonomous docking but these are yet to be tested live →06.

ABB had a strong influence on the autonomy levels published by the global One Sea Association (an influential non-profit global alliance of leading commercial manufacturers, integrators and operators of maritime technology) [6] →07. Bearing in mind the degree of manual attention needed for a ship's operation, the autonomy levels in the association's document are expressed pedagogically in terms of eyes-on or eyes-off, hands-on or hands-off, etc.

Progress in other fields
Even though ABB's initial publications drew attention to the relevance of autonomy levels for the process industry, it was still surprising how rapidly customer interest arose in that area. For example, even by 2020, the Norwegian company Equinor had announced plans to build an unmanned oil and gas platform in the Krafla field in the North Sea. Since then, ABB has completed a project on "one button start-up" for Equinor's gas field Aasta Hansteen in the Norwegian Sea, 300 km from land [7]. This installation saves about 5,000 operator clicks during start-up and reduces the start-up time by up to 10 hours. Note that the key here was to automate the knowledge acquired by the supplier and customer during many years of operating oil and gas platforms.

ABB's Augmented Operator
Recently, ABB conducted a research project called Augmented Operator aimed at raising the level of autonomy in industrial operations by training artificial intelligence (AI) on past operator actions. The workflow for supporting the operator with anomaly detection, for example, is depicted in →08 [8]. Project results have

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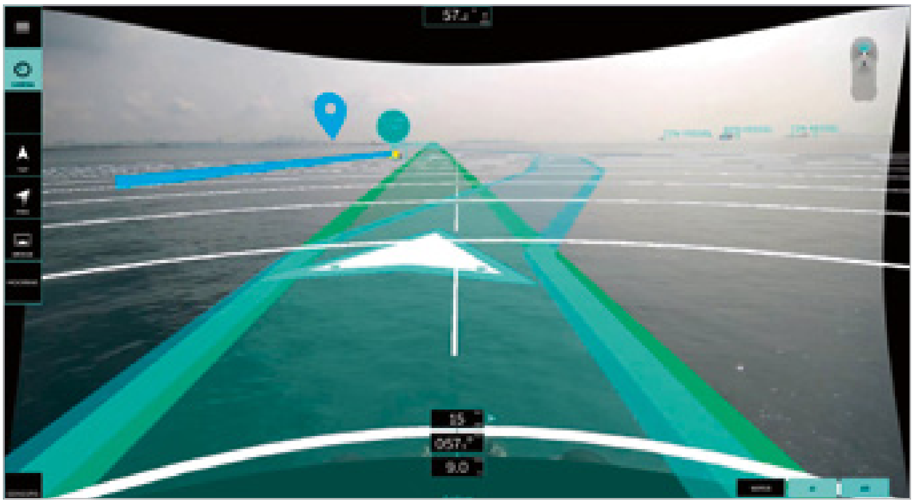
Augmented Operator raises the level of autonomy in industrial operations by training AI on past operator actions.

been taken over into product development and presented at the ARC Advisory Group Forum 2023 [9]. In that same year, ABB started a related research project with the goal to use AI to further reduce manual operator interventions. The ambition here is to handle different operating scenarios and, with multiple autonomous agents, control larger process sections or the entire plant autonomously.

Overtaking self-driving automobiles
ABB considers it feasible that certain industrial use cases may reach a wide application of autonomy levels 4 or 5 earlier than self-driving



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05 Clearing the way – ABB's collision avoidance system.

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06 ABB has also set course for an autonomous docking solution, which is not yet on the market.

automobiles, where progress appears to have slowed in recent years. Such an outcome is no surprise as autonomy in mining or process plants, for example, happens inside well-controlled, fenced-off areas and involves safety-trained personnel. Also, autonomous shipping takes place in an arguably more regulated environment than driving among the general public.

Progress since 2018?
It can be comfortably stated that there has been significant progress in industrial autonomous systems since 2018. There is a clear trend toward raising the level of autonomy in industrial situations by using a combination of AI and conventional control methods, based on different AI learning approaches, historical process data,

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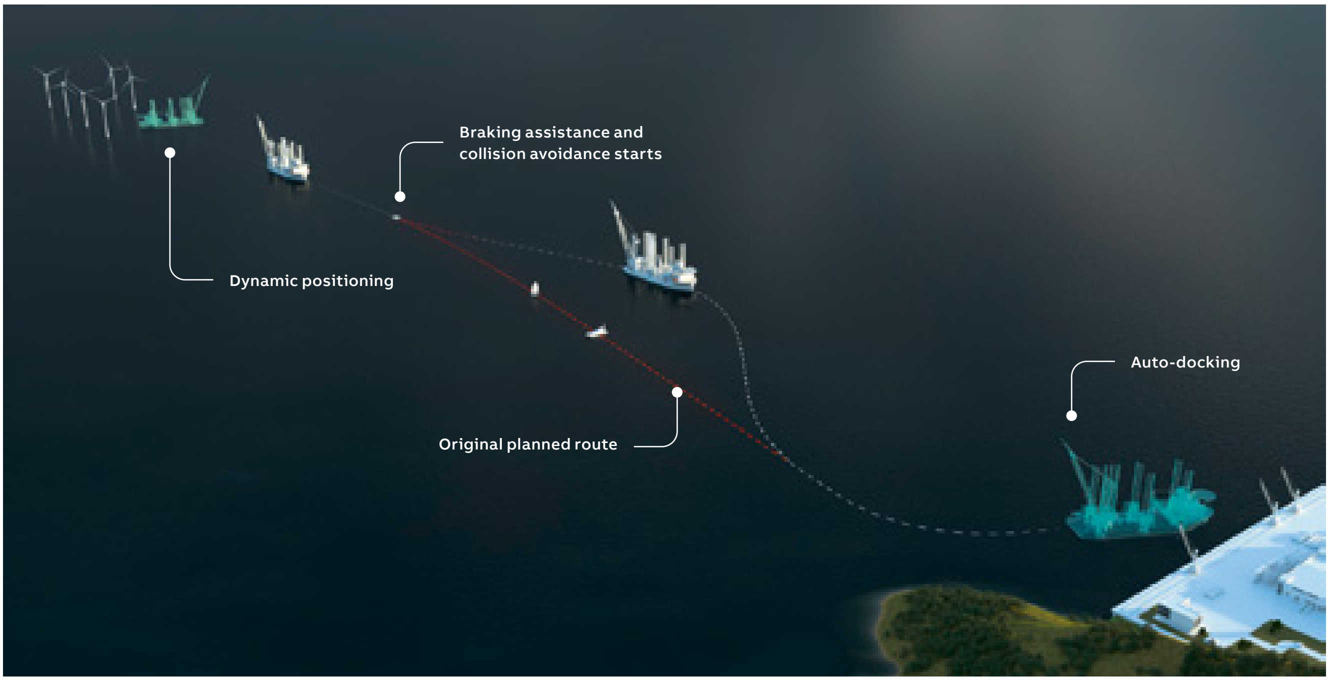
Skill shortages or remote servicing needs impel operators to embrace automation.

past operator actions and first-principle process models. The higher levels of autonomy achieved will lead to substantial customer benefits such as improved safety, reduced energy use and increased productivity.

Factors such as skill shortages or the necessity to service remote locations provide further impetus to operators to embrace automation



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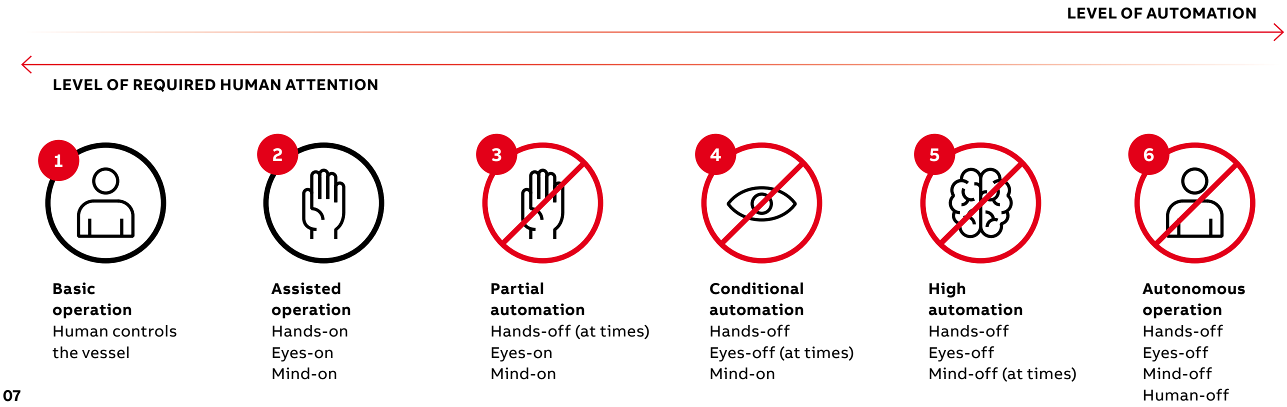

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07 Proposed autonomy levels of automation in shipping.

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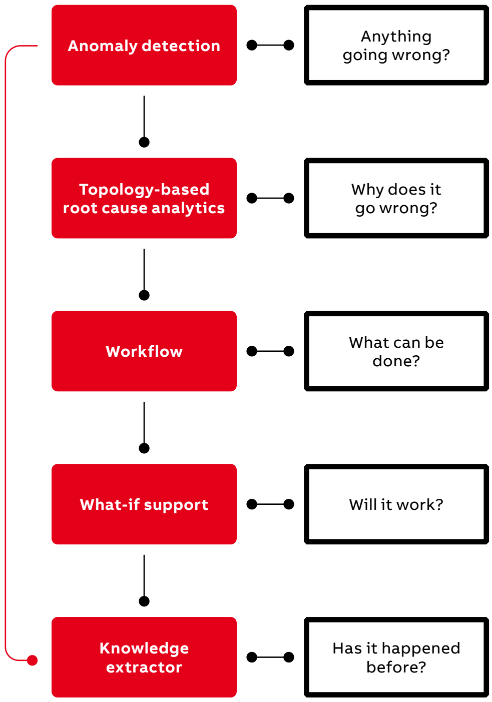
08 The Augmented Operator workflow [8].

technologies that optimize the utilization of their skilled personnel. After Covid, there is also an understanding that remote working for many professionals is not only desirable and efficient but is also well supported by technology. It is important for ABB to address these rapidly evolving customer needs via the support that further improved levels of automation can offer.

To underline its commitment to driving the future of autonomous systems, ABB is sponsoring, from 2021 to 2025, a position in the Chemical Engineering department at Imperial College London (ICL). Thanks to this initiative, former ABB colleague Mehmet Mercangöz now has the job title “ABB Reader in Autonomous Industrial Systems.” •



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Further information

Read more about the Augmented Operator in the article from Review 3/2022:

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REDUCE ENGINEERING EFFORTS AND COSTS WITH ETHERNET-APL

Unified communication

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By deploying Ethernet-APL together with widely-adopted PROFINET and field device integration (FDI) technologies, process industries can optimize their performance through enhanced process control in the field even in hazardous areas.

Ethernet-APL is a communication standard especially suitable for process industries.

Intrinsically safe because it eliminates sparking risk in hazardous environments.

Offers true interoperability between devices of different vendors.

Title photo: ©colnihko/stock.adobe.com (generated with AI)

Ratified in 2021, the Ethernet-APL standard provides an extended physical layer that carries high-speed process, configuration and diagnostic data plus power over long distances (1000 m) via a single twisted pair cable. Use of this new technology shows exciting promise for the process automation industries, particularly in hazardous environments eg, chemical and oil/gas facilities.

As process plant operators seek to gain new value from data through the convergence of information technology (IT) and operation technology (OT), one of their overarching objectives is an effective reduction in total cost per field measurement.

With field devices becoming more numerous, diverse and intelligent, operators not only benefit from greater availability of data, they are faced with the difficulty of handling vast amounts of process and maintenance data. This challenge is increased as projects grow in scale and complexity with various instruments that often combine a large number of different communication protocols and underlying physical layers.

Plant operators, therefore seek a uniform, intrinsically safe and cost-effective communication technology built around robust open industry standards, one that avoids vendor lock-in while bringing the ability to scale smoothly as their business needs evolve.

Resolving several of these challenges and introducing 'traditional' Ethernet as an extended physical layer in an industrial setting, Ethernet-APL offers particular appeal, especially when it is deployed in combination with widely-adopted PROFINET and field device integration (FDI) technologies.

What is Ethernet-APL?
A mainstay of the IT world for decades, Ethernet, standardized in IEEE 802.3, underpins other abstraction layers that collectively define interconnection and data flow between different devices and systems. Ethernet, the established standard for wired digital technologies in industry and business, is already used as the physical layer for the collection of data and control of remote I/O and electrical equipment that use protocols such as PROFINET and Modbus TCP. Until now, however, Ethernet's wider adoption to field devices in the process industries has been restricted due to its unsuitability for some

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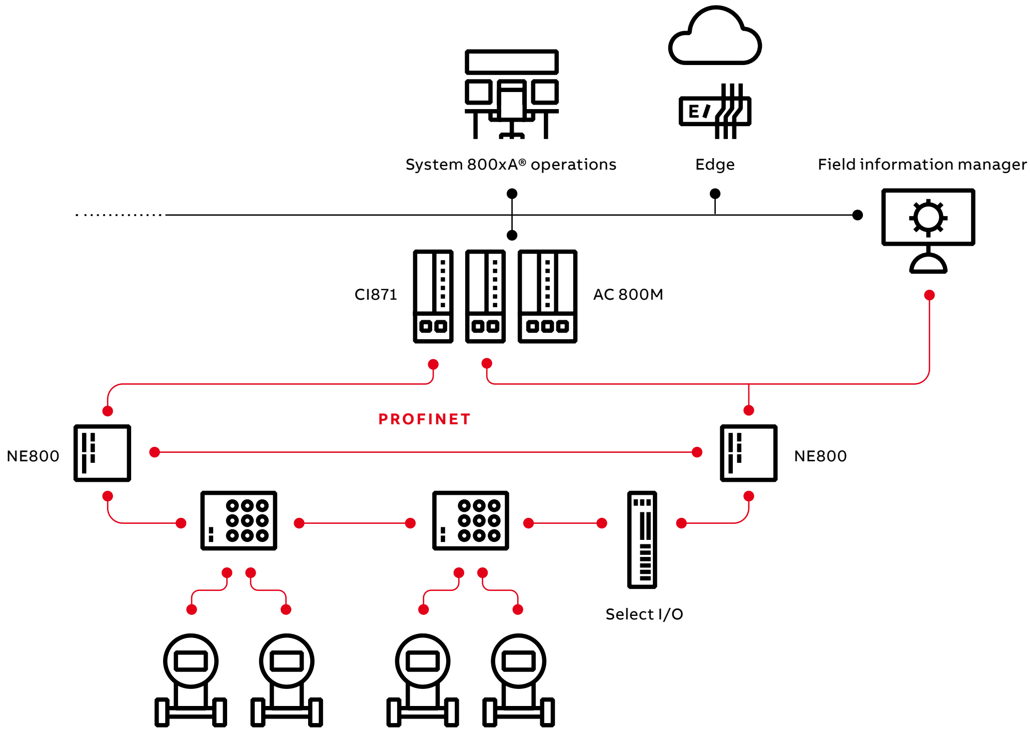
Operators face the difficulty of handling vast amounts of data, different communication protocols and physical layers.

process industry applications in hazardous areas eg, oil refineries. In addition to cost-effectiveness and simplicity, these facilities require Ethernet features such as the ability to transmit communication protocol and power supply to devices over long distances, enhanced safety, eg, explosion protection, and the ability to be repairable during inclement weather and at any time.

Working with other vendors and standard development organizations since 2015, ABB has been helping to develop technology, guidelines and best practices, thereby contributing to the enhancement of field-level Ethernet connectivity for its use in process automation industries.

01 Typical System 800xA® configuration with APL devices and remote I/O connected over PROFINET rings.



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Based on open IEC and IEEE standards, eg, IEEE 802.3cg-2019 standard, Ethernet-APL is an extended layer for single-pair Ethernet (SPE) based on 10BASET1L that brings the benefits and economies of scale of high-speed Ethernet communications out into the field →01. Moreover, Ethernet-APL simplifies the direct connection with enterprise systems, thanks to several specific features →02 that are beneficial for plant operation, including:

- 10 Mbit/s data communication rates, orders of magnitude greater (>300 times) than decades-old HART and Fieldbus protocols
- Single twisted pair of conductors within a shielded cable that simultaneously carry process data, device configuration and diagnostic data as well as power
- Accommodates trunk and spur network topologies familiar in the process industries, with a trunk length of up to 1,000 m – an order of magnitude greater than regular Ethernet's 100 m limit
- Intrinsic safety is fully integrated, including a profile that limits supply voltage and current to eliminate the risk of sparking in hazardous environments
- Works with most common industrial Ethernet protocols (including PROFINET, Modbus TCP and OPC UA)

Scalable, simple and cost-effective

Providing a high-speed channel for process data as well as configuration and diagnostic information, Ethernet-APL offers a readily scalable solution for connecting devices in the field to a distributed control system (DCS) via a single cable with power carried over the same physical link as well.

Moreover, Ethernet-APL significantly simplifies installation, eliminating the need for the traditional I/O modules of programmable logic controllers (PLC) or a distributed control system (DCS) because the controller can access the device data directly, instead of via an I/O module that converts analog standard signals and sends them to the central processing unit (CPU).

Ethernet-APL brings the benefits and economies of scale and high-speed Ethernet communications out into the field.

Ethernet-APL network equipment and field instruments are steadily becoming available to the market [1]. ABB has already deployed the technology in a number of large-scale automation projects. Ethernet-APL has been combined with ABB's Ability™ System 800xA® DCS and with CI871 PROFINET communication interface →03.

Parameter	Attribute
Power supply output (Ethernet-APL power switch)	Up to 92 W
Switched network	Yes
Reference cable type	IEC 61158-2, type A
Maximum trunk length	Up to 1000 m, into zone 1/div. 2
Maximum spur length	Up to 200 m, into zone 0/div. 1
Speed	10 Mbit/s, full-duplex
Hazardous area protection inspired by fieldbus	2-WISE for all zones and divisions, with optional intrinsic safety at the device
Standards	IEEE 802.3cg-2019 (10BASE-T1L), IEC TS 60079-47 ED1 (2-WISE)

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02 Technical attributes necessary for Ethernet-APL to be applied more broadly to the process industries, extending its use to the field.

Up to 252 field instruments can be directly connected through one APL network ring to a controller, while remote I/O can be connected over the same PROFINET ring to collect auxiliary signals that do not originate from APL-enabled devices. Such a combination of technologies helps to simplify engineering: less cabinet space is needed than for classical I/O device solutions and for earlier fieldbus solutions such as PROFIBUS PA or Foundation Fieldbus. The ease and speed of access to device diagnostic and configuration data also facilitates faster commissioning, together with quicker troubleshooting and reduced lifecycle cost by leveraging asset management solutions →04.

Ethernet-APL complements PROFINET
PROFINET, an advanced communication protocol, has become a dominant platform for industrial Ethernet as the market share of other fieldbus technologies has declined steadily over the last decade. Building on the proven foundations of Ethernet such as reliability, PROFINET has several features tailored specifically to its use in process automation environments; these include redundancy, the ability for online configuration, PA-Profile and functional safety (with PROFIsafe as an optional feature).

Already widely accepted and used in remote I/O and electrical integration applications, the appeal of PROFINET is further enhanced by the imminent arrival of a new generation of Ethernet-APL devices and current efforts by instrumentation vendors to implement PROFINET with PA-Profile 4.02.

The PA-Profile 4.02 offers greater freedom for users to achieve improved engineering efficiency through true interoperability between devices from different vendors. While the PROFINET protocol provides a reliable way of transmitting data over a network, no actual meaning or structure is applied to that data. Instead, this function is served by application profiles that act as an extra abstraction layer positioned between the device application and the PROFINET networking stack. This approach simplifies the interface for the application engineer and ensures genuine interoperability among devices from different vendors. When designing control application code, an application engineer can interact with the profile instead of the specific device, thereby enabling the reuse of knowledge, code, and troubleshooting methods irrespective of the device's vendor.

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Ethernet-APL network equipment and field instruments are steadily becoming available to the market.

Since the device is interfaced using the profile, the device as such can be replaced as long as the new device supports the same profile. It is expected that some 80 percent of devices will be able to use this generic profile while only 20 percent will require a specific profile. For example, a specific device driver is typically used for more complex devices such as valve positioners and analyzers.

A key requirement in the process industry is the ability to manage control system configuration changes online without causing any disturbance to the process that could result in downtime, and, or speed/quality losses. PROFINET provides this ability, with functionalities that provide for online configuration changes, including the ability to reconfigure, insert, remove, or replace devices or modules in the system. Additionally, plant modifications and expansions can be implemented in a running system. By combining the automatic device replacement with the device interoperability of PA Profile 4.02, system maintenance users can ensure non-stop operations because the powerful system functionality enables them to manage breakdowns or complex maintenance activities at any time of day.

> Use of PROFINET is further enhanced by the immenent arrival of a new generation of Ethernet-APL devices.

Of course another key feature of PROFINET is high availability. By providing different levels of redundancy, with the mandatory inclusion of S2 redundancy with PROFINET PA Profile 4.02 devices, the requirements of most real-world process automation applications are satisfied.

Going forward, by including safety applications using PROFIsafe, which ensures functional safety at the field level up to Performance Level (PL) e and Safety Integrity Level (SIL) 3, common uniform communication technology for process automation can be achieved that can be applied across the full spectrum of industrial environments, even those that are high risk.

Making device diagnostics available for control room operators

Diagnostic information from Ethernet-APL devices can be made readily available to plant operators, where NAMUR NE107 conditions and indications are natively supported from the Ethernet-APL device via the control application to the operator's screens in the ABB Ability™ System 800xA® Operator Workplace →05. This ready availability of diagnostic information allows operators to contribute proactively to maintenance activities in their daily operations.

Configuration using FDI over PROFINET for Ethernet-APL devices

ABB Field Information Manager (FIM) simplifies the configuration, commissioning, diagnostics, and maintenance of field devices. A typical FIM deployment with Ethernet-APL serves as a direct bridge to the PROFINET network. FIM can scan, auto-detect, and assign device packages to the connected Ethernet-APL devices. Direct connection to the PROFINET network also provides a separation from the mission-critical control system, in line with the NAMUR Open Architecture (NOA) philosophy.

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03 Ethernet-APL in combination with FIM (FDI device driver screenshot of Vortex flowmeter is shown) demonstrates that not only is device and system interoperability actually possible, but real-time data access is a snap.

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04 ABB Ability™ Field Information Manager, shown here in use, acts as a bridge between IT and OT for fied devices. This way, operators and others can more easily make data-driven decisions.

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05 Ethernet-APL devices, with control applications can supply data in real-time to ABB Ability™ 800xA Operator Workplace. This picture is taken from "How can ABB Ability™ System 800xA improve operator effectiveness?". Watch the full video here:

Reference

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Further information

ABB web story, BASF selects ABB for greenfield projects after a successful Ethernet-APL trial, Feb 22, 2024

FIM supports integration of field devices either via Electronic Device Description (EDD), Field Device Integration (FDI) packages or via the latest PA Profile 4.02 device package. The latter is used where ever customers want to benefit from field device interoperability. Ethernet-APL switches are also integrated in FIM, enabling configuration and diagnostic checking using the same workflow and tooling →03.

FIM also provides an OPC UA interface for applications such as asset performance management to leverage device diagnostic and performance data. The Process Automation Device Information Model (PA-DIM) can be applied on this OPC UA interface to further standardize the data stream to edge devices and the cloud.

Enhanced maintenance, health, and performance monitoring

The high data throughput provided by Ethernet-APL enables asset management applications for maintenance, health, and performance monitoring across a fleet of field instruments. This diagnostic data can be routed to the operators in the control room as well as outside the DCS system, where maintenance can perform detailed analysis of the diagnostic data →04. This enables better collaboration across different teams on maintenance activities.

Following the NAMUR NE107 standard, this diagnostic data helps operators and maintenance personnel to identify the possible cause of failure and suggested actions to resolve the problem. This provides clear guidance on how to resolve problems with field instrumentation.

High data throughput provided by Ethernet-APL enables asset management applications for maintenance, health, etc.

The use of ABB Ability™ Edgenius with Asset Performance Management (APM) applications opens new possibilities for early detection of issues, thus ensuring continuous operations while optimizing maintenance work and reducing costs across the fleet of field devices.

The ultimate solution

The promise of faster and easier access to data holds the key for organizations looking to optimize their performance through enhanced process control. By helping to address many of the hurdles that have traditionally hampered gathering, relaying, and accessing data in industrial applications, including suitability for deployment in hazardous areas, Ethernet APL presents the ultimate solution to meet the growing demands being placed on process control systems.

By resolving many of the challenges of using 'traditional' Ethernet as the physical layer in an industrial setting, Ethernet-APL offers an optimal fit for process plants, especially when it is deployed in combination with widely adopted PROFINET and FDI technologies. •

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INTRODUCING A MODULAR ENGINEERING CONCEPT FOR LARGE-SCALE PROCESS INDUSTRY PLANTS

Modularizing engineering

To extend modular plant production beyond those industries that already benefit from their use, an automation system-agnostic way of describing module types would make all the difference. ABB explores just how this can be accomplished.

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As some products' lifecycles shorten, the need to rapidly design and construct chemical and pharmaceutical production plants is growing. This rapid change is making a case for modular plant production. The value of such modular production, encompassing a modular automation system and engineering approach, has already been successfully demonstrated in pilot applications [1,2], where up to 50 percent of engineering and commissioning time can be saved.

Although 25 percent of future process plants in both of these industrial sectors are expected to be built utilizing modular fabrication and automation by 2030 [3], ABB pondered how modular automation could be leveraged to streamline engineering in the remaining 75 percent. Here, ABB presents a concept for modular engineering of conventional process plants, those plants that are not assembled based on modular production using Module Type Package (MTP), Process plants increasingly use modular designs.

ABB is further extending modularity to the automation system.

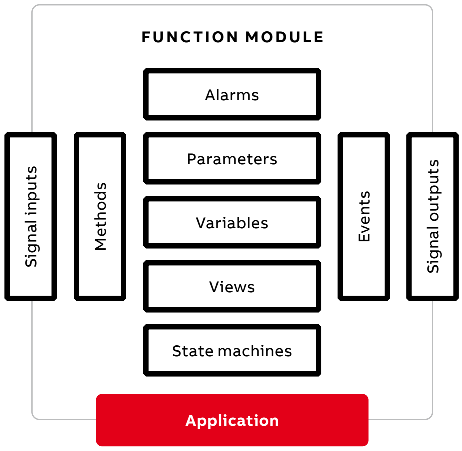
ABB's Function Modules provide a software description of functionality and interfaces.

Title photo: ©bannafarsai/stock.adobe.com

and introduces a new concept, Function Modules (FM). A use case from the oil and gas industry is also presented that validates the modular engineering approach and FM concept.

Modular production basics and the current situation

Pre-engineered, and pre-manufactured modules, defined as Process Equipment Assemblies (PEA), or skids, can fulfill a process function in modular production. For use in multiple applications, interoperability of PEAs is a must: The Module Type Package (MTP) makes this possible. MTPs are a standardized, manufacturer-neutral description of a PEA [2] that includes information necessary to seamlessly integrate a module into a modular plant, eg, descriptions of communication, services, HMI, etc. MTPs allow PEAs to be integrated into a supervisory control system, the Process Ochestration Layer



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modularized functional container for software, the smart standard controller and standard type-based engineering for the upstream oil and gas industry. Nowadays, these plants are not entirely built in a modular manner; they integrate PEAs and conventional structures in plant production and are known as hybrid plants [9].

For the application of modularization more broadly, to conventional plants yet to employ MTPs, a new modular engineering concept is required. Ideally, this concept would contain an automation system-agnostic way of describing reusable module types with the possibility of integrating ready-made modules that can then be instantiated[1] to create module instances that represent a physical module.

(POL) where functions are abstracted eg, into a service layer. Every PEA has, as a result, its own intelligence. The integration of MTPs and service-based process design make process function possible. In this way, engineering efforts and commissioning time can be reduced [4]. For conventional plants, those not using MTPs yet, off-site prefabrication of large modules in so-called module fabrication yards is gaining ground, eg, COOEC-Fluor Heavy Industries [5], EPC-M Group [6]. And yet such modules typically include only mechanical parts and instrumentation, not the all-important automation system. Why is this so? Simply explained, large-scale plants of global firms are usually constructed for a specific purpose. Process design is rarely altered after commissioning; including PEAs in the design phase would generate excessive costs because smart modules require a control system in every module. Nevertheless, for plants built in harsh environments eg, upstream gas facilities, it would be advantageous to fabricate larger parts off-site, assembling them on-site later, as partly done for the Hammerfest LNG plant in Norway [7].

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Demand for standarization and cost pressures lead plant operators to seek concepts that reuse solutions across different sites.

Demand for standardization and cost pressures is leading plant operators to seek concepts that foster reuse of molules across multiple sites. For example, ExxonMobil, introduced the “It Just Happens 2 (IJH2)” [8] initiative, to define the

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Footnote

1) Instantiate refers to the ability to represent an abstraction by a concrete instance.

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01 FM concept is shown. The FM functionality is comparable to the functionality of a PEA.

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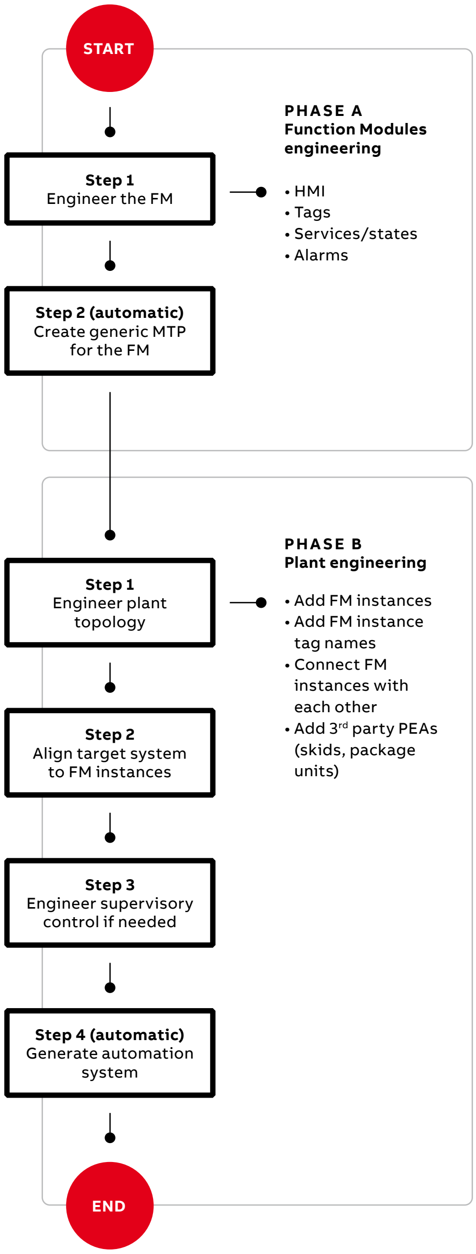
02 Engineering workflow using FMs which displays schematically Phase A with 2 steps and Phase B with 4 steps. In Phase B, plant engineering, all available generic MTPs can be used to create the needed instances, which are connected by means of the material flow (piping) and information flow (signal exchange). The instance information, eg, the instance name, is added, prior to the second step in which the automation system and the individual instrumentation are assigned to the FM instances.



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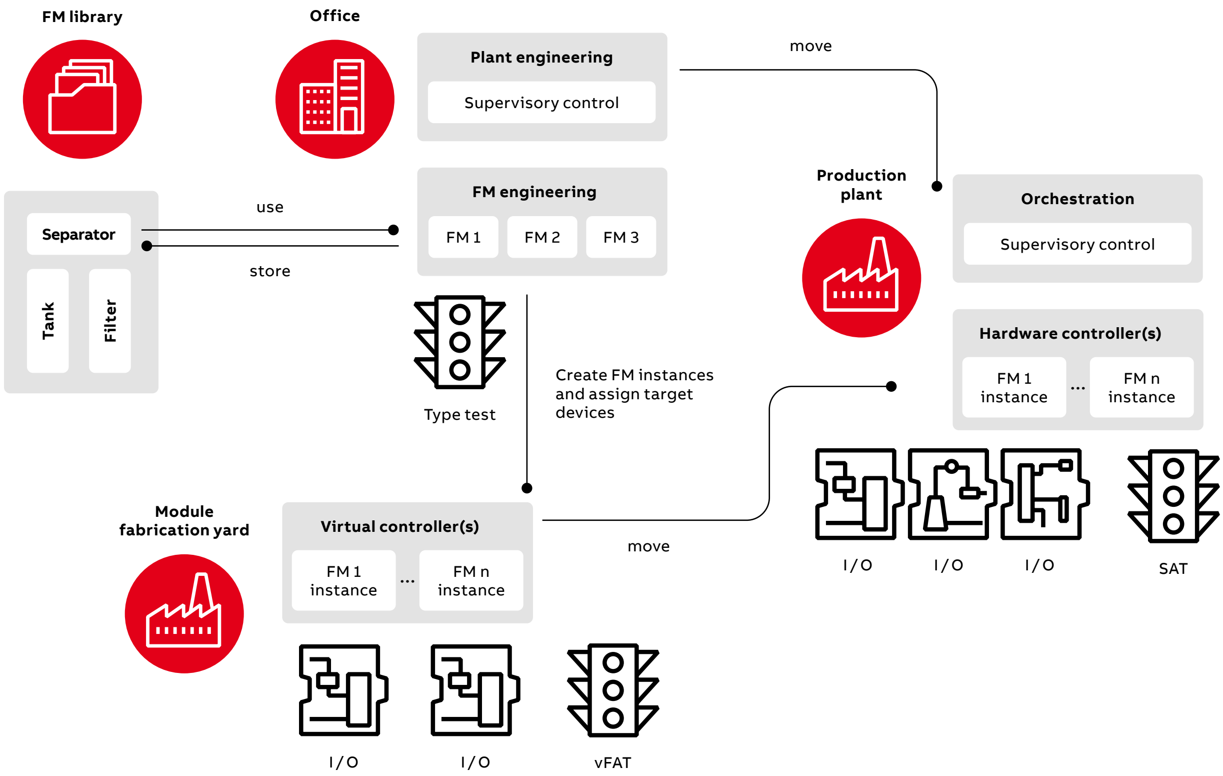

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03 A possible project execution workflow example using FMs is shown. Here the FMs and the corresponding instances are engineered in the office and the mechanical parts of the modules are constructed in a module fabrication yard. The FM instances are assigned to their counterpart, a virtual controller in the module fabrication yard and later – in the actual plant – a real (hardware) controller.

Function Module concept
To satisfy these aforementioned requirements, ABB developed the concept of FMs: a software description of a module type. In contrast to PEAs, FMs do not bind to a specific hardware type, they are a description of the functionality that

—
A new engineering concept would ideally yield an automation system-agnostic way of describing reusable module types.

the resulting automation system should contain, ie, parameters, views, variables and alarms that are executed by calling methods, setting signals and replying with events and signals →01. FM functionality, however, is comparable. During engineering of a module type, the automation software for the FM is described and the corresponding MTP is generated. Because the resulting MTP is embedded in the plant engineering process →02, the generated MTP can be used immediately. Thus, FMs are engineered in the same way as are PEAs, eg [10].

Type-based engineering
Following a type-based engineering approach, the FM is engineered before creating the actual instance of a process function. Because the automation software relevant parts are described generically, no automation system-specific information is required.

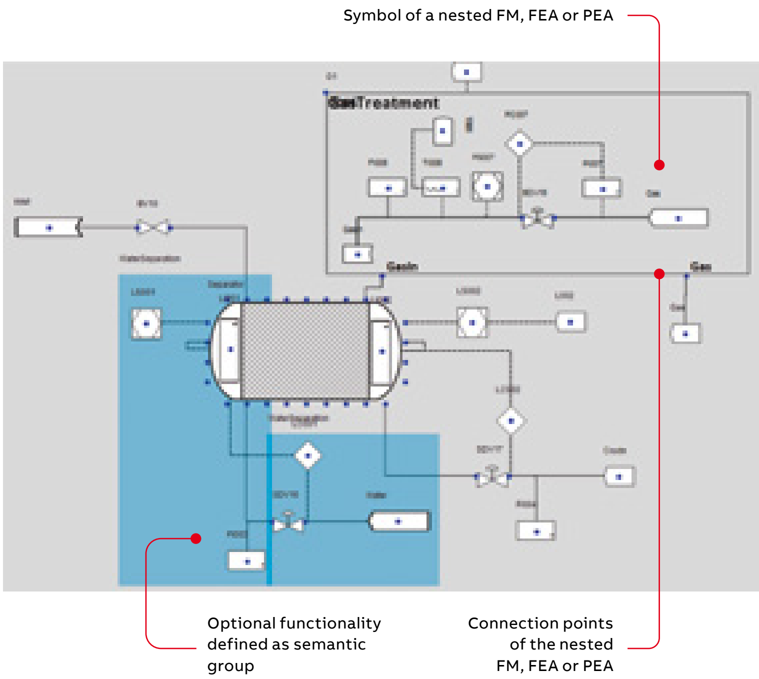
Once completed, the resultant type can be instantiated during the plant engineering phase. Every FM instance of a type has identical behavior and can be bound to an automation system in a later step with suitable controllers, eg, Freelance or System 800xA family, depending on the process and automation system requirements.

For every FM instance, instrumentation can be assigned to the FM's instrumentation connectors. For practicality, for the same measurement value of different FM instances that belong to the same FM, different sensor types can be used within the FM instance. If a different measurement principle is required, another instrument type can be used for a specific FM instance. Thus, FMs are neither bound to specific instrumentation nor equipment type.

While an automation system-specific MTP is needed to describe automation system-specific information, only a generic MTP is required for the description of the FM. Thus, the concept of MTP is generalized; this means that the target system-specific information is not contained in the MTP for the FM.

Engineering workflow of the automation system
The engineering workflow can be divided into two different, yet not necessarily sequential, conceptual phases: phase A; FM engineering,

NESTING AND OPTIONAL FUNCTIONALITY



Although FMs are engineered like PEAs, [10], an essential difference exists: It is possible to nest FMs and PEAs into other FMs, eg, a control loop developed as an FM can be reused in another FM as needed (except for recursive nesting usage). FMs are represented by a generalized MTP and a symbol generated from the HMI description of the FM. Because the symbol can be added into other FM HMIs, the FM is integrated in the other FM. The FM connection points are created from the generalized MTP. For every source and sink (termination object, [11]) of the nested FM, specified in the corresponding MTP's HMI aspect, a connection point is added to the symbol as illustrated in the diagram above where an FM with a nested FM and optional functionality is shown.

For identification in the FM instance, later, every nested FM receives a tag name. In the HMI, the nested FM behaves like a symbol, having connection points that can be connected in the HMI, just like a valve or pump.

Because PEAs are described using an MTP, as are FMs, PEAs can also similarly integrated in an FM. As the MTP is imported into the module, a symbol is generated, allowing the PEA to be used like a nested FM. Thus, the symbol can be used during the HMI engineering of an FM. During plant engineering, the engineer can decide whether the nested FM or PEA is required in the instance, and simply switch on/off the nested FM's functionality.

The engineering of optional functionality enables use of an FM within a better management of variants whenever the functionality cannot be implemented as an FM.

Here, the engineer can define semantic groups as in [11] (all elements contained in the same semantic group belong to it), every semantic group of an FM represents an optional functionality. As with nested FMs and nested PEAs, optional functionality can be enabled or disabled later.

04

—
04 The nesting concept and optional functionality are presented in detail.

—
05 Parameterization of FMs. Note the simplicity of deselecting functions illustrated in the lower right-hand part of the diagram: In the displayed FM instance ‘HP’, the optional functionality ‘WaterSeparation’ is disabled (compare this to the generic FM along with all optional functionalities that are enabled, →04.

and phase B: plant engineering; both can follow alternating or concurrent phases in the workflow.

FM engineering is initiated in step 1 with the description of the FM-type using HMIs, tags, services, etc. →02, while the generic MTP of the FM type is generated in step 2; thereby concluding phase A →02.

If a supervisory control is required, step 3 of phase B can be employed. In step 4, the automation system software for all instances and the specific automation system is created automatically. The MTPs for the instances are customized based on the automation system information →02.

Project execution workflow
ABB’s engineering concept, using FMs, makes distributed off-site engineering for conventional process plants possible. Module fabrication yards can continue constructing modules for the plants, including I/O, while the corresponding counterparts, on the automation side, are created off-site and later assigned to the I/O, as per →03.

Critically, testing is performed at every stage. A type test is performed for every FM. Once the FM instances are created and assigned to the modules in the module fabrication yard, a virtual factory acceptance test (FAT) can be performed using a virtual control environment already connected to the I/Os of the modules. The

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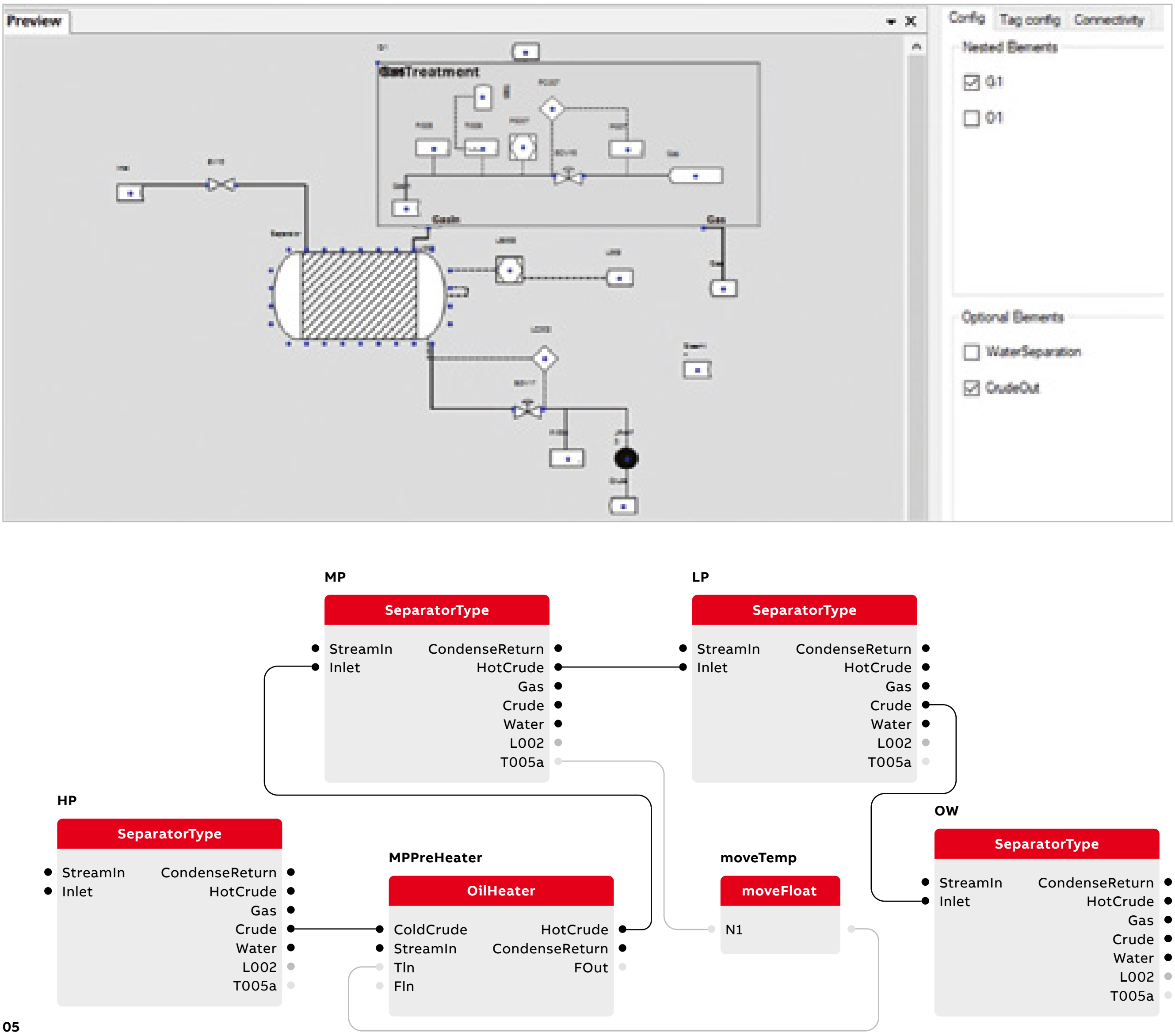
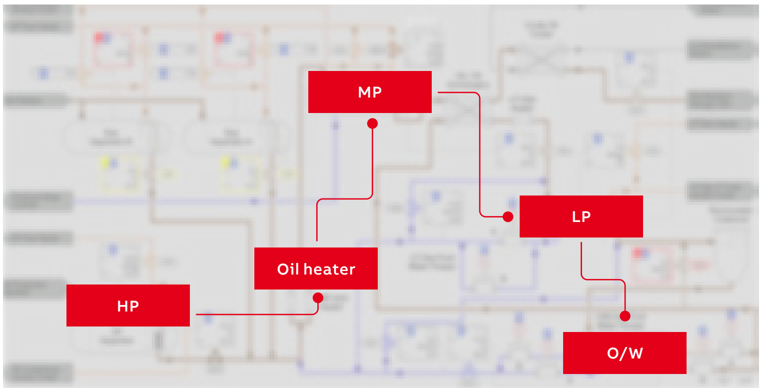
ABB developed the concept of FM, a software description of the functionality that an automation system should contain.



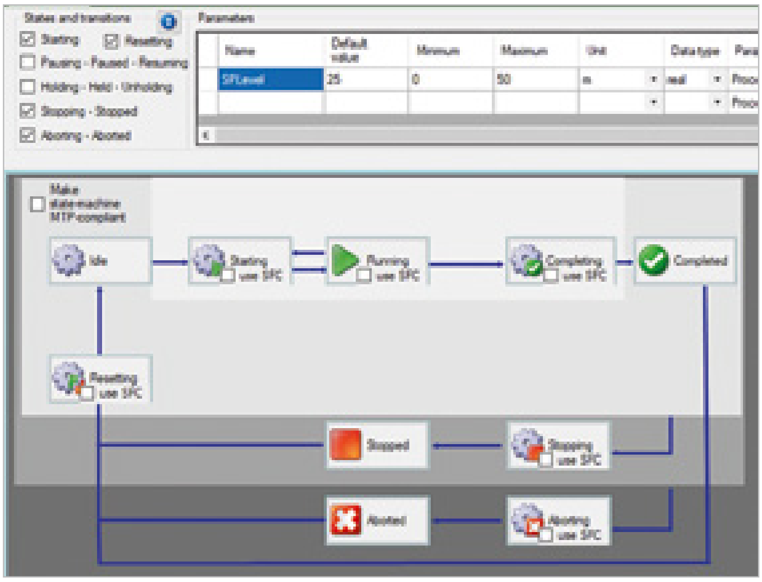
05

Sep-arator	No. phases	Gas blow-down	Gas flow	Gas temp	Gas press	Crude isola-tion	Crude level	Water isola-tion	Water level
HP	2	BDV	FI	TI	PC/PS	SDV	LC/LS		
MP	3	BDV	FI	TI	PC/PS	SDV	LC/LS	SDV	LC/LS
LP	3	BDV	FI	TI	PC/PS	SDV	LC/LS	SDV	LC/LS
O/W	2	°				SDV	LC/LS	SDV	LC/LS

06a



06b



07a

State	Mode of operation
Idle	Idle
Starting	Startup
Execute	Execute
Completing/completed	Shutdown
Stopping/stopped	Process shutdown (PSD)
Aborting/Aborted	Emergency shutdown (ESD)

07b

mechanical parts can then be transferred with the corresponding FM instances on-site. Here, a site acceptance test (SAT) can be executed with the installed real-world control system.

Thanks to the project workflow methodology, the plant engineering can be performed in the office, tested in the virtual environment with the FM instances and finally transferred on-site. To foster reuse, the FMs could then be stored in an FM library and be reused in other projects.

Variant management using FMs
To enable reuse of larger parts of a plant, management of variants by means of optional functionality and nesting (the nesting of other FMs

—

Importantly, the engineers can decide which FM functionality to disable by deselecting it.

and PEAs) might be useful, especially whenever it is desirable to develop a multi-functional type that can be parameterized for every instance separately, at a later time →04 [10,11].

Plant engineering using parameterizable FMs
Since FMs can be used to create instances and their parameters according to the needs of the process plant, whenever an instance of an FM is created during plant engineering, all nested FMs →04, PEAs, and optional functionality →04 are enabled by default, thereby streamlining the process. The instances are connected as for standard modular plants: by using material flow (pipes) and information flow (signal) connections, →05 [12].

Importantly, the engineer can decide which FM functionality to disable by deselecting it →05. Following parameterization, the code for the instance can be generated automatically, eg, [13], but only for the enabled functionality (and those for nested FMs); disabled parts are excluded from code generation.

Industrial case study
For proof of concept, ABB conducted an industrial use case for a 3-phase, 4-stage oil separation process, containing four oil-separators →06a.

A multi-functional FM was implemented, including optional functionality for water separation and a nested FM for gas treatment. Moreover, an oil heater function was implemented using a

—
06 Oil and gas use case separator definitions and process flow.

06a Separator types are defined.

06b The process flow of the separation process is shown in which the HP separator is upstream, then the oil flows through an oil heater, through the MP separator, then the LP separator, and lastly through the O/W separator. The background image is blurred because the use case process, clearly indicated, is derived from wthin the existing propietary process flow of the customer, which cannot be revealed.

—
07 The state machine.

07a Adapted state-machine of VDI/VDE/NAMUR 2658-4 [15].

07b States mapped to modes of operation of the service: produce.

third-party PEA, described as a MTP. In this use case, the high-pressure separation (HP) cannot separate water from the crude oil; the oil water separator (O/W) lacks a gas treatment functionality but can separate oil from water →06b. In contrast, the medium pressure (MP) and low pressure (LP) separators contain functionality for separation of all three phases →06b.

Engineering the separator FM
The separator is engineered as an FM starting with a piping and instrumentation diagram-like HMI as for a PEA, [10], which models the inner structure of the separator →04. The nested FM for gas treatment is added as a symbol, the water separation is marked as an optional functionality, indicated by the blue-marked area, which can be enabled or disabled in the FM instances later. Once HMIs are defined, tags are configured as per [10] using default values, which are adaptable for every instance later.

In contrast to the fixed state-machine of services defined in [10], ABB's new concept allows state-machines to be adapted according to needs. Here, three services are required: 'Produce', 'Commissioning', and 'Maintenance'. 'Produce' is the normal operation of the plant with the modes of operation: Idle, Startup, Execute, Shutdown, PSD and ESD. 'Commissioning', executed during plant commissioning, can only be started or completed, basically. 'Maintenance' is used by the engineer during plant maintenance.

For all services, the state-machine is adapted accordingly as for the service 'Produce' →07a. Thus, the different modes of operation can be mapped to the states of the standard state-machine →07b. Additionally, the services of the embedding module are configured to control the services of the embedded gas treatment FM.

—
The FM engineering concept makes distributed off-site engineering for process plants possible.

The states of the VDI/VDE/NAMUR 2658 state-machine [14] are mapped to the modes of operation from the service 'Produce' →07b.

Based on the services and tag configurations, an initial alarm set is generated. Here, all activated alarms from the tag list are included in the module's alarm configuration list, even those configured for the service transitions. For every alarm, depending on the type, a default message and a default severity is assigned. These can be altered as needed. By default, all alarms are enabled and must be acknowledged. To retrieve a service-based alarm for the separator, alarms are assigned to the services, where they can be activated.

When the service enters the startup state, the service-specific alarm configuration is set; when it enters the reset state, the alarm configuration is switched back to default. Hence, a service-based alarm capability is provided. Subsequently, the generic MTP is generated and can be used during plant engineering.

	Alarm	Tag	Raising Condition	Message	Severity	En	Ack	Commissioning	Maintenance	Produce
▸	HHH	FI003	FI003_VAHAct	FI003 has a HHH alarm	900	☑	☑	☐	☐	☑
	HH	FI003	FI003_VWHAct	FI003 has a HH alarm	600	☑	☑	☐	☐	☑
	LLL	FI003	FI003_VALAct	FI003 has a LLL alarm	900	☑	☑	☐	☐	☑
	HHH	FI004	FI004_VAHAct	FI004 has a HHH alarm	900	☑	☑	☐	☐	☑
	HH	FI004	FI004_VWHAct	FI004 has a HH alarm	600	☑	☑	☐	☐	☑
	LLL	FI004	FI004_VALAct	FI004 has a LLL alarm	900	☑	☑	☐	☐	☑
	HHH	FI005	FI005_VAHAct	FI005 has a HHH alarm	900	☑	☑	☐	☐	☑
	HH	FI005	FI005_VWHAct	FI005 has a HH alarm	600	☑	☑	☐	☐	☑
	LLL	FI005	FI005_VALAct	FI005 has a LLL alarm	900	☑	☑	☐	☐	☑
	HHH	LI001	LI001_VAHAct	LI001 has a HHH alarm	900	☑	☑	☐	☐	☑
	HH	LI001	LI001_VWHAct	LI001 has a HH alarm	600	☑	☑	☐	☐	☑
	LLL	LI001	LI001_VALAct	LI001 has a LLL alarm	900	☑	☑	☐	☐	☑
	HHH	LI002	LI002_VAHAct	LI002 has a HHH alarm	900	☑	☑	☐	☐	☑
	HH	LI002	LI002_VWHAct	LI002 has a HH alarm	600	☑	☑	☐	☐	☑
	LLL	LI002	LI002_VALAct	LI002 has a LLL alarm	900	☑	☑	☐	☑	☑

08

—
08 Alarm handling for the separator FM is shown. In ABB's case study, all alarms should be disabled during 'Commissioning', so all checkboxes are cleared. For 'Maintenance', only a few alarms are enabled. For 'Produce', all alarms are enabled. The alarms which can be raised when a specific service is executed is defined in the alarm configuration list.

—
09 Operator workplace for the separation process (automatically generated). One can observe that the instances in the POL are adapted according to the parameterization. The HP separator, for example, does not show the water level in the separator because water separation is disabled. The O/W separator does not include the gas treatment. Hence, the services of the gas treatment nested FM are not shown.

Engineering plant topology and supervisory control

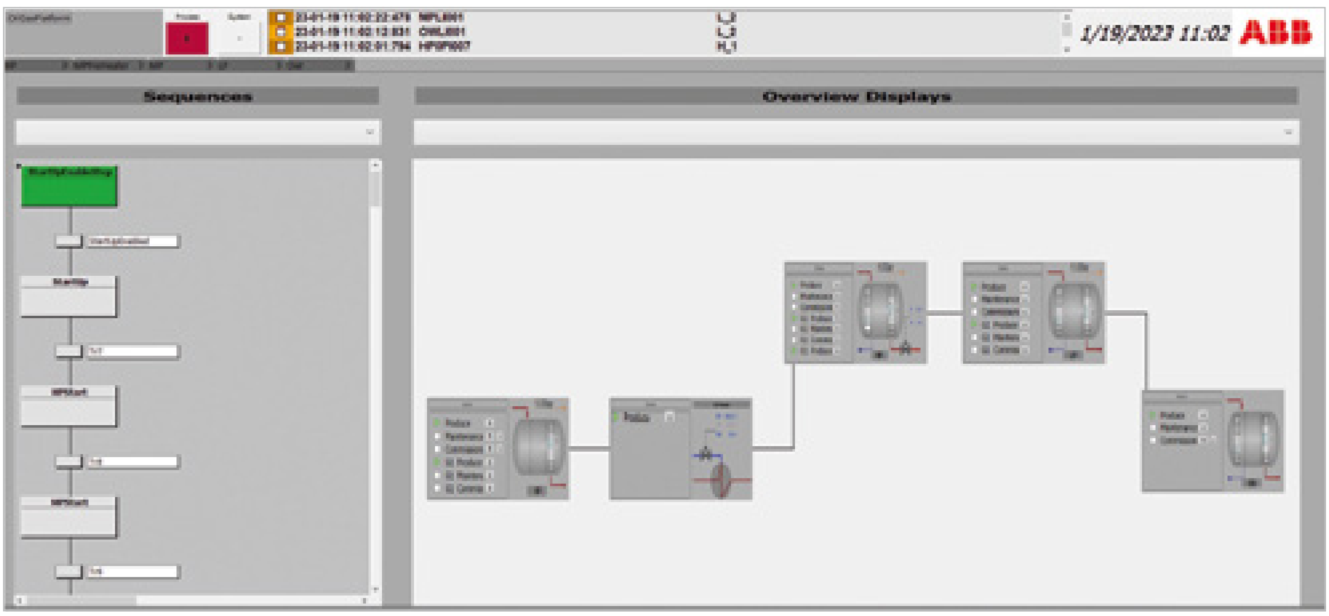
During plant engineering, four instances of the separator FM are created from the generic MTPs: HP separator, MP separator, LP separator, and oil/water separator. Additionally, a preheater (OilHeater) is included using a third-party PEA →05.

For supervisory control, a simple startup sequence, which starts the 'Produce' services of all instances, and a shutdown sequence, which completes and resets all 'Produce' services, is engineered. The separator instances are parameterized: for the O/W separator, the gas treatment nested FM is disabled; for the HP separator, the optional functionality water separation is disabled.

—
Plant engineering can be done in the office, tested in the virtual environment and finally transferred on-site.

The HP and O/W separator are executed on one controller, an ABB AC800M; the LP and the MP separator are assigned to another AC800M controller, and the preheater runs on a third-party MTP capable controller – a Freelance AC700 controller – the controller assignment and control code generation was not required.

Following separator assignment, the automation software is generated, automatically:



09

- The FM instance code is generated for AC800M controllers and automatically imported into a project, including the state-machines for the services, code for states, service parameters, FM instance internal interlocks; and the tags including parameters; the alarm configuration for the tags and the services; and the enabled nested modules.
- The supervisory control code is imported into an ABB System 800xA and the corresponding AC800M controller. This includes the sequences for controlling the FM instances, the FM instance to FM instance communication, the communication definition from System 800xA to the FM instances and the PEA, the tag definition from the FM instances and PEA, the HMIs for every FM instance and the PEA, a visualization for every state-machine from every FM instance or PEA adapted to the configuration of the service, and an overview HMI for the entire plant. This process successfully results in the automatically generated operator workplace →09.

This industrial use case validates ABB's FM engineering concept: generation of generic MTPs that can be utilized to describe FMs. Testing and validation of the plant engineering concept also demonstrate that ready-made modules can be instantiated to form FM instances that accurately represent physical modules. An automation system-agnostic way of describing reusable module types is feasible.

Outlook

ABB's presented FM concept creates the foundation for modular engineering methods to be used in conventional process plants. The feasibility of this concept has been tested in ABB's separation use case, which successfully demonstrated how the engineering approach and workflow can be applied to the oil and gas industry. The engineering efficiency benefits gained from the modular engineering of modular production facilities will apply to conventional, world-class large production plants, too. Ongoing research is addressing how early engineering phases could be formalized so that I/Os of the FMs can be automatically and semantically specified and matched [15,16]; such focus will help foster the early and accelerated development of this technology. •

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ABB's FM concept has been successfully tested in a use case, thereby supporting its application to the oil and gas industry.

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Share this article

COMPUTATIONAL FLUID DYNAMIC MODELING OF BLENDER JETS

In the mix

By developing high-fidelity models that can accurately predict the blending time required for fluids of a wide range of viscosities, ABB is helping process industries, eg, oil and gas industry, to minimize homogenization time and ensure quality mixing for better performance.

01

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01 The blending area of the Pelumas plant is shown. This fully automated, customizable lubrication oil blending plant located in the Tanjung Priok district of northern Jakarta was supplied by ABB with oil blending equipment for PT Pertamina.

To produce lubricants, paints, resins, pharmaceuticals, etc., process industries require innovative solutions for technologies that mix raw materials according to specific blending formulations to yield high-end products. The mixing technology needs to ensure a satisfactory level of homogeneity, and stability, within the produced fluid, while expending minimal energy during the mixing process. By optimizing blending time, and saving energy, the final product can reach the intended market faster, thereby reducing costs. The development of new blending technologies that take advantage of advances in modeling methods could help these process industries achieve customer-specific targets. Enter ABB to leverage advancements in physics-based computational modeling to simulate and predict the blending process for better performance.

Where it all happens
With more than 70 years of experience in process system implementation associated with formulation, blending and batch production, etc., ABB's researchers have joined forces with business experts to explore how they could leverage their knowledge and experience to help customers improve blending time for a range of viscous fluids to better achieve accuracy and cost targets for customers.

The mixing of fluid components needs a high level of homogeneity while minimizing energy and time.

ABB has implemented a mathematical model.

A digital twin was developed for accurate predictions.

To understand the entire blending process, ABB considered a generalized lubricant oil plant segregated into three different zones →01:

- Raw material storage farm: Typically, this zone is made of several storage tanks for base oils and additives.
- Blending units: These units are the core of the plant. They are used to mix base oils and additives in the required proportions to produce a portfolio of finished products with various specifications.
- Finished product area: Finished product storage tanks and filling lines are used to fill final products into small packs, drums, bulk trucks, or railcars.

The physical blending process

The performance of such process plants is significantly dependent on the efficacy of mixing to achieve the proper combination of petroleum derivatives and other components through blending technologies. The goal is to reach the desired level of homogenization swiftly and accurately.

Jet mixers are commonly used for blending in tanks because they are relatively easy to install, operate and maintain. Jet nozzle mixers →02 are based on the Jet-Venturi effect in which the transfer of the kinetic energy from a high velocity liquid is accompanied by a balancing drop in pressure as it passes as a jet into the surrounding tank.

Homogenization of the various precursor liquids within the tank is attained as some of the liquid is entrained through a pump that then returns the liquid to the tank as a high velocity jet

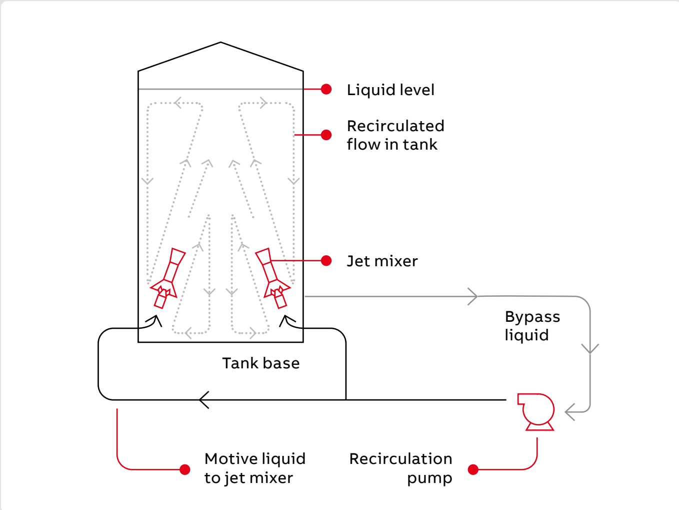
—

The goal of the blending process is to attain the desired level of homogenization swiftly and acccurately.

through a nozzle of a specific cross-sectional area. This action generates a circulation pattern within the tank that results in agitation and mixing of the contents.

Why change the process?

Given the jet mixing process described above, ABB's experts had questions: Is the recirculation process through the jet nozzle mixers, which is



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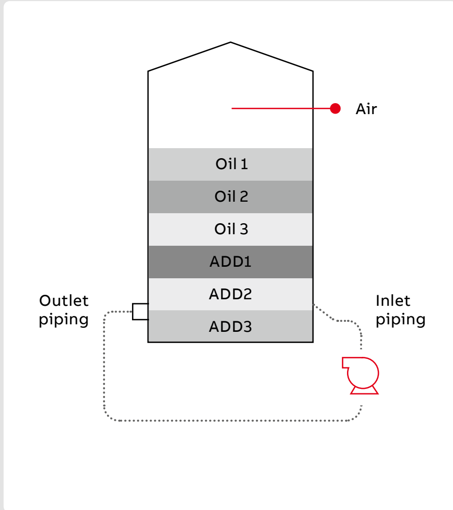

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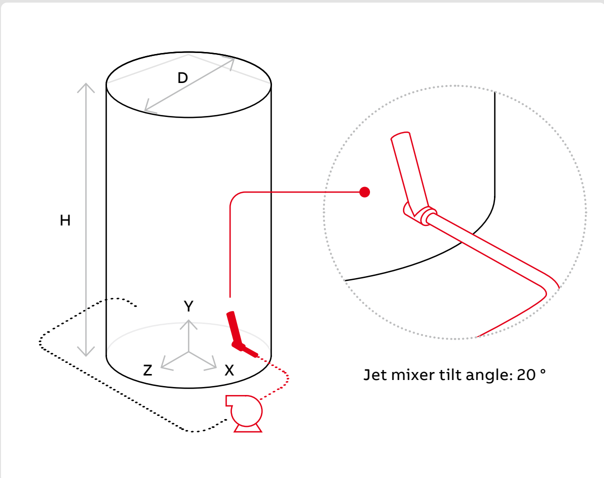

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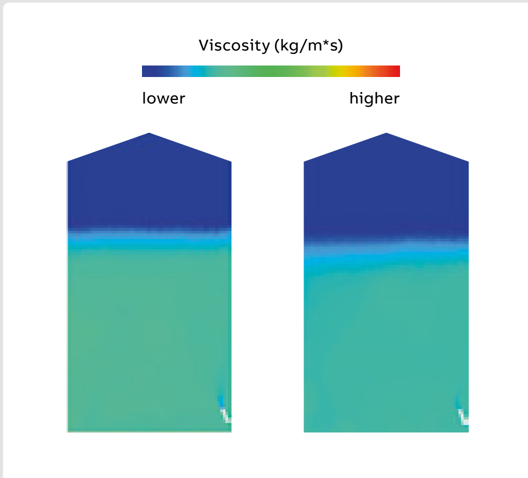

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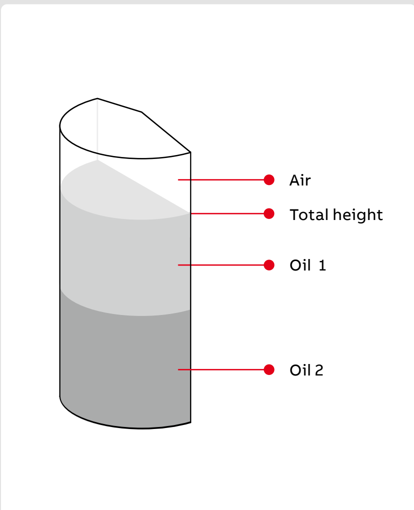

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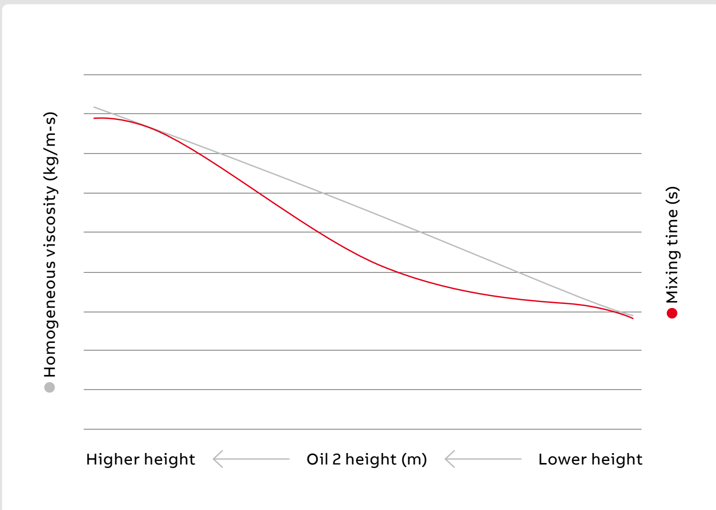

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02 Jet nozzle mixer process is illustrated for fluids in a tank that recirculates fluids.

—
03 Schematic of homogenization tank.

—
04 The modeling scheme illustrating the computational geometry.

—
05 Viscosity contour plots display viscosity variation over time.

05a Viscosity variation at t(arb) -Δt.

05b Viscosity variation at t(arb).

—
06 Geometry of two oil strata used for ROM development.

—
07 The theoretical response surface generated in this study is shown.

—
08 Blending of miscible liquids into a single homogenous phase is an important process for the chemical, and oil and gas industries whether in blending tanks or in storage tanks shown here.

08

utilized in the raw material storage tanks and final product storage tanks, adequate to assure the level of homogenization and mixing desired in terms of performance prediction? And, if not, how can it be improved? The designs are considered conservative.

Moreover, ABB pondered whether they could adequately predict mixing time by adjusting the various design parameters that are known to impact the efficiency of jet nozzle mixing technology.

By addressing these questions, ABB's aim was to help plant operators establish an optimized and shorter mixing time; this would enable the homogenized product to be ready for the next operational step more quickly. The more rapid

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ABB experts set out to create a model that could predict the blending time for miscible fluids with a large range of viscosities.

process would not only reduce energy consumption, it would also accelerate the freeing of storage tanks to accommodate another batch of base oils and additives sooner.

Analyzing the process
First, to address the fundamental question – whether the expected homogenization level matches the actual achieved level – ABB analyzed the mixing process challenges. Despite the seeming simplicity of the process, experience with suppliers on past projects shows that the high and variable viscosities of the fluids in the tanks complicate the blending process immensely. It becomes all but impossible for jet nozzle suppliers to estimate the impact of various fluid viscosities on the mixing process. Consequently, suppliers are unable to guarantee with certainty the expected performance associated with blending time – a conundrum for the process industries.

With this in mind, ABB's experts endeavored to create a numerical model that could accurately predict the blending time for miscible fluids with a large range of viscosities, eg, non-viscose fluids, and those with low, medium, high and very high degrees of viscosity. In addition, variable influencing parameters, eg, tank geometry, physical properties of the fluid, number and arrangement of jet nozzles inside the tank and the cross-sectional area of nozzle orifices, have been taken into account to develop a preliminary computational fluid dynamics (CFD) model.

CFD modeling – the basics
Once the physical process of mixing was understood, ABB set out to specify flow and determine a suitable mathematical model to employ. Because the efficacy of CFD models to predict complex fluid dynamics is well known, ABB chose to investigate CFD modeling of a jet mixer, an eductor-based mixer, that utilizes an external source of energy or pump to mix fluids.

By combining the literature survey results [1-5] with modeling expertise, ABB established best modeling practices in turbulent flow during jet mixing. The resultant CFD blender model, also known as the blender's digital twin, should enable mixing time to be predicted, ensure a satisfactory level of homogeneity, and potentially minimize the cost of testing. Ultimately, the model results would allow the minimum time required to reach the desired homogenization level in oil mixtures of various viscosities to be estimated, thereby improving blending performance.

Because complex flow patterns are encountered whenever multiple oil strata of differing properties, eg, viscosity, are mixed, ABB relied on best modeling practices in their study: incorporating assumptions that have minimal impact on prediction quality, developing the best discretization schemes, meshing; and selecting the best turbulent flow model to employ.

Assumptions and conditions
For this investigation, assumptions were made about the modeling system →03 and the computational geometry →04. Assuming a half-symmetric system, allowed a half-symmetric model →03 to be developed. The fluid space was assumed to comprise six horizontal layers; each layer was prescribed a unique viscosity and density. The absolute height of oil strata, oil densities and their viscosities ranged from 0.015 m to 4.651 m, from 828 to 1,000 kg/m³ and from 0.1059 to 7.788 kg/m-s, respectively. An exterior piping that recirculates the fluid mixture was added to the tank model →03.

Setting boundaries
To ensure an accurate solution to the Navier-Stokes equations (or equations for mass, momentum and conservation) used, boundary conditions were applied to the domain boundaries for CFD modeling. These included inlet, outlet and wall boundary conditions, among others. As mentioned previously, a recirculation piping system →03-04 was provided to the exterior of the mixing tank, connected to the base of the tank to simulate the recirculation effect that is driven by the real-world pump in the factory. This way, modeling of an actual pump and the associated complications could be avoided.

Simulations were performed using a multiphase CFD modeling approach to determine mixing time.

Exploring modeling methods
To determine the longest possible mixing time needed to reach homogenization, ABB considered an extreme case of oil stratification in this study: In this worst-case scenario, six completely segregated layers of oils with distinct viscosities (the lowest viscosity was 0.1059 kg/m-s and the highest was 7.788 kg/m-s) were simulated along the height of the tank.

09

To select the best modeling method, ABB explored species modeling and multiphase modeling. The first method models oil layers as different chemical species while the latter models the layers as physical phases. During this comparative study, the mixing and transport of species was simulated by solving fluid flow equations and species transport equations comprising convection and diffusion terms. Despite the suitability of the method for investigating the blending process, since oils are not diffusive, running the species transport model was found to consume a significant amount of computational time. The multiphase alternate approach was found to converge to a solution using less computational time than did the species transport model. Thus, the main simulations were performed using the mixture multiphase flow model. Computations were performed by solving the equations of fluid dynamics, high-end turbulent flow models simulated the mixing of the oil layers as a function of time.

Multiphase model predictions
For the simulation experiment, the eductor was inclined with respect to the vertical axis of the tank by 20 degrees. All necessary data related to geometry, flow and fluid were obtained from the business data sheet supplied →03-04.

To investigate mixing homogeneity using a qualitative approach, viscosity contour plots, across the symmetric plane, were observed at various time instances. ABB experts assumed that an adequate homogenization level would be reached when the contour plots' layers were indistinguishable →05. Prior to the experiment, the arbitrarily determined mixing time was

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09 An external storage area of the Pelumas plant is shown.

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10 The blending area of the Pelumas plant is shown.

set as t(arb). The viscosity contour plots →05 were monitored continuously until t(arb). The results show that only a negligible difference in the viscosity plots was observed at: t(arb) – Δt. Therefore, a mixing time of t(arb) – Δt, is considered an acceptable mixing time to achieve a satisfactory level of homogeneity within the tank. The positive results not only demonstrate that it is possible to achieve a reduction in the required mixing time, but imply a reduction in the mixing energy too.

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The ROM model can be used to investigate parameter impact and create a physics-based digital twin.

Advanced modeling with ROMs
While CFD models are globally accepted as high-fidelity tools to predict complex processes, using the models to perform multiple parametric studies is perceived to be challenging, due to the vast time and memory requirements. For these reasons, ABB evaluated the feasibility of using reduced order versions of CFD simulations also known as reduced-order-models (ROMs). While ROMs keep the indispensable features of CFD models, they utilize substantially less time and memory, thereby reducing the associated costs. Not surprisingly, this promising yet simpler modeling approach is gaining attention [6].

The process of ROM development involves running multiple simulations by changing a few important input parameters and computing the output. Advanced fitting techniques, eg, vector fitting, are then used to obtain a response surface; this surface provides the desired output that corresponds to any given set of input parameters.

To develop the model, ABB designed a simplified mixing tank with two oil layers of varying heights and properties →06. A ROM was constructed and the heights of the oil strata were varied in multiple simulations. The height of oil 1 was varied in proportion to the height of oil 2, while the total oil height was assumed to be fixed. The result is a relationship between homogeneous mixture viscosity, mixing time and oil height →07. By using this relationship, the mixing time needed to reach homogeneity for a given oil strata height can be deduced. These results support the the use of the ROM model to investigate parameter impact and develop a physics-based digital twin.

Providing the best results for customers
Aiming to offer world-class blending solutions to customers →08-10, ABB is pursuing the development of advanced analytics aided by high-fidelity models to minimize homogenization time and ensure quality mixing. The collaboration between business experts and research scientists has led to the development of multiphase CFD and ROM models capable of predicting the blending process. Blender digital twins are not only useful tools for predicting performance and estimating the minimum mixing time required, but can be used to study important mixing parameters to suit the needs of specific customers. •

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Field technicians must be able to troubleshoot equipment of myriad different types, designs and ages.

ABB provides a mobile application with virtual-reality support.

332 t CO_2/a

saved through reduced site visits by experts and faster problem resolution.

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01 Service Assist application testing using a Microsoft Hololens headset (planned release late 2024.)

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02 The app is specifically designed for field operators. They can access AR immersive guides.

SERVICE ASSIST: SITUATION-SPECIFIC SUPPORT

Augmented assistant

ABB has introduced Service Assist, a mobile application designed to provide in-depth, real-time, situation-specific information for engineers and technicians in the field. In addition to leveraging cognitive services such as speech-to-text, text-to-speech, and natural language understanding to find needed content, the app uses augmented reality (AR) to superimpose visual and audio information on existing systems, thus creating an interactive virtual assistant.

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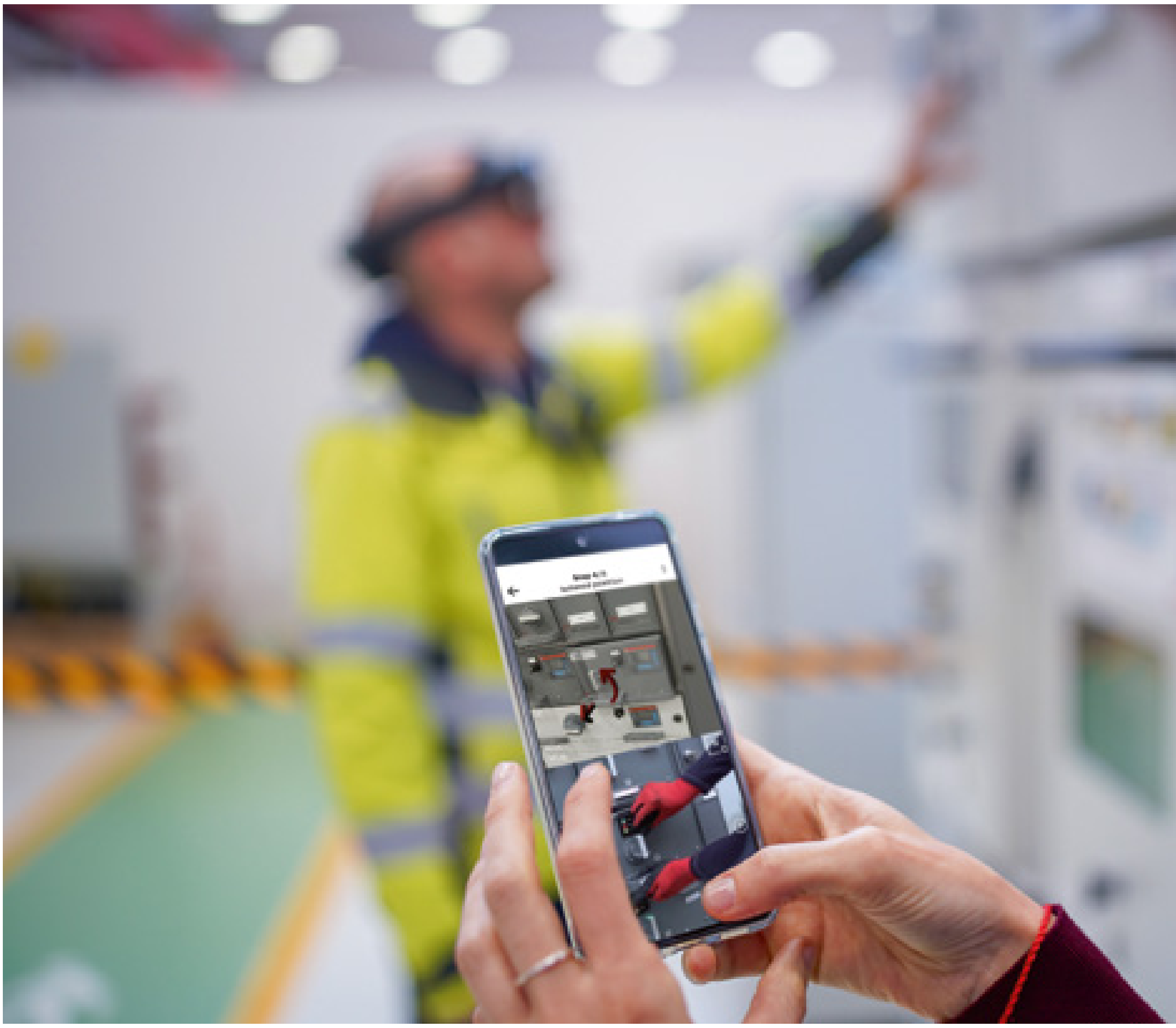

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03 Service Assist helps a technician troubleshoot an ABB medium voltage switchgear system.

03a Situation-specific data and images function as a virtual digital assistant.

03b Easy access to guides results in accelerated problem resolution.

—
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When it comes to technology, what was new yesterday can be history tomorrow. This is particularly true for energy distribution networks, which are becoming increasingly complex as renewable sources become a growing slice of the pie. This complexity poses a challenge for service technicians and engineers in the field who typically must diagnose and solve problems associated with a variety of elements in a customer's infrastructure, ranging from motors and valves to switchgear and transformers.

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

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Product names and local slang expressions can significantly slow a technician's ability to diagnose and repair a problem.

Furthermore, according to ABB's Energy Insights Survey [1] of 2,300 leaders from small and large businesses, 92 percent of respondents believe the continuing instability in energy prices is having a significant impact on the workforce in terms of decreased investment in

03b

employees – and therefore in training. So, as older workers retire, and training budgets are squeezed, the need for support grows.

A dedicated assistant for each operator
In view of these trends, in 2023 ABB introduced its Service Assist mobile application →01-02. Specifically designed for field operators who would benefit from an assistant in their day-to-day jobs, the app provides access to documents for electrical equipment, including augmented reality immersive guides. All content is tailored to the customer's installed base and presented with the customer nomenclature for the equipment. Service Assist can also be used for submitting training requests and booking appointments for either on-site or remote services.

One of the app's special features is ABB-e, a virtual assistant that helps users find guides and book appointments through voice control. This virtual assistant leverages cognitive services such as speech-to-text, text-to-speech, and intent recognition – to guide the user quickly and

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The app provides access to documents for electrical equipment, including augmented reality immersive guides.

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04 If the system's AR guidance is unclear, users can request real-time remote assistance.

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05 Proof of concept test showing the physical architecture of a monitoring and diagnostic system.

efficiently to the app's most useful content. It is also particularly versed in electrification network slang.

Technicians can request manuals, videos, and perhaps most important, augmented reality (AR) guides, which make it possible to troubleshoot problems even if the technician's experience level is not advanced. Furthermore, the system is not limited to ABB documentation or equipment; it can host other brands' documentation, as well as customer-specific information such as, for instance, a safety checklist to access a certain part of an electrical infrastructure.

Situation-specific data and images
Thanks to the app's AR technology, operational information is presented in a completely new way, such that the user's view of a real environment is augmented by situation-specific data and images that function as a digital assistant →03a, 03b. The result is fast support and easy-to-access operation and troubleshooting guides via an immersive augmented reality experience.

Crucially, this AR modality makes digital assistance interactive, more practical to absorb, as well as easier to understand and act upon. In other words, its core capabilities are visualization instruction and interaction.

In case the user is unclear about the information offered by the system's AR guidance, he or she can request remote assistance for electrical systems (RAISE) →04, which provides real-time guided remote support. Here, an ABB service specialist can place augmented reality instructions in the operator's field of view, allowing visual information to enhance voice instructions covering subjects such as repairs and troubleshooting, maintenance support, technical information on equipment operation, spare parts identification, monitoring and diagnostic analysis, or installation and commissioning. This reduces repair and maintenance time on electrical equipment, as ABB experts can remotely guide field operators on their Android or iOS smartphone, tablet, or via smart glasses or other supported wearables.

Accelerated problem resolution
All of this adds up to accelerated problem resolution, which is vital in minimizing potentially disruptive and costly downtime, especially when critical systems such as data centers or hospital power systems are involved. For instance, one of the world's largest marine shipping operators needed remote maintenance to support problem solving for its global fleet and reduce the impact of issues while at sea. Here, service support delivered through AR significantly extended the ability of onboard technicians to address failures they would have otherwise lacked the experience to diagnose and repair.

Furthermore, ABB's Service Assist remote support can significantly reduce service-related energy demand. According to company figures, the technology has cut ABB's CO_2 emissions by approximately 332 tons per year by reducing customer site visits by company service engineers by up to a third.

In addition to using live on-screen annotations and digital overlays in the technician's field of vision, remote assistance also makes it possible to take pictures and share audio and video in the context of a live text chat.

A new AR experience
Looking ahead, the introduction of large language models (LLM) such as ChatGPT has given impetus to the world of chatbots and assistants, and ABB's Service Assist is no exception. ABB is preparing a proof of concept →05 to include an LLM as an engine designed to prepare comprehensive answers to written or spoken questions rather than pre-designed responses. This new area of development may eventually be enhanced through the use of Apple's Vision Pro and Meta's Quest 3 headsets – systems that hold the potential of providing a new dimension to the handsfree AR experience. •

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Comprehensive answers based on a LLM may soon replace pre-designed responses to written or spoken questions.

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ABB-FLEXTRONICS® WIRELESS SMART HOME CONTROL PLATFORM OPENS THE DOOR TO ENERGY EFFICIENCY

Platform living

Demand for smart home technology is growing in response to increased consumer interest in energy efficiency. It is also being spurred by programs designed to incentivize the energy-related retrofitting of existing building stock, as well as by the acceptance of Matter and Thread, a new smart home connectivity standard and wireless protocol. ABB is addressing these trends through the introduction of a far-sighted smart home control platform, and the acquisition of Eve Systems, a leader in home connectivity.

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Considering the fact that buildings account for almost 40 percent of global carbon emissions [1], Busch-Jaeger, a brand of the ABB Group, has responded to the above-mentioned trends with the introduction of ABB-flexTronics® wireless, the starting point of a smart home control platform based on a 2.4 GHz wireless mesh-network. Capable of addressing the control needs of anything ranging from a single room to a complete smart home system, the platform benefits from ABB's state-of-the-art encryption and cyber security standards.

Given that the ABB-flexTronics® wireless system is based on wireless technology, it can be used flexibly anywhere and requires only a conventional 230-volt electrical installation. It is therefore attractive for upgrades and renovation projects and allows individual devices, rooms, or an entire system to be designed according to the occupants' personal requirements and later

ABB-flexTronics® wireless is the starting point of a smart home control platform based on a 2.4 GHz wireless mesh-network.

Share of global carbon emissions caused by buildings: **40 %**

ABB-flexTronics® is a wireless technology attr active for upgrades and renovation.

Energy savings through smart control

expanded or adapted. This gives electricians immense flexibility, even if the customer has last-minute requests →01.

Form follows function

One of the major advantages of ABB-flexTronics® wireless technology is the modular concept of its platform, which consists of a range of fitted flush-mounted inserts for controlling lighting and shading applications as well as different push buttons and sensors for standard switching operations or automatic light control via motion sensors →02. The sensors are compatible with almost the entire Busch-Jaeger range of switches and thus offer maximum flexibility in terms of design.

But the beauty of the platform's components is far more than skin deep. The newly introduced ABB art linear® switch series →03 is an example of a range of industrial products based on a uniquely sustainable design. The series consists of recycled and recyclable materials. That may sound unspectacular, but in point of fact, 98 percent of the series' black switches and 92 percent of its white switches are made of recyclate – resulting in an 82 percent reduction in the amount of CO_2 generated for their production.

In addition, the System Access Point, a powerful control center for the entire ABB-free@home® platform, can be easily extended to accommodate up to 150 wireless sensors or wired devices. Its premium and high-end functions include the integration of the ABB-Welcome® door communication system, as well as household and multimedia devices.

With its focus on saving energy, the smart home platform addresses a full range of electrical installation applications →04, including smart lighting control, automated deactivation of all unnecessary devices when no one is at home, day-night heating reduction, intelligent sun-heat protection through automatic blind control, door communication, and third party integration.

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The System Access Point can be easily extended to accomodate up to 150 wireless sensors or wired devices.

Furthermore, a home equipped with the ABB-free@home® platform can be remotely accessed via ABB's certified cyber security cloud service by means of an app on the user's mobile device. Transparency extends to the doorbell via the ABB-Welcome® door communication system, which allows the user to communicate via video with anyone who rings the bell.

How safe are ABB-flexTronics® wireless's connections? Very safe. If, for instance, the system's radio connection is interrupted, the user is not left in the dark. At worst, some functions such as scenes (combinations of lighting and blind positions for specific moods) or group controls could be affected, meaning that it might not be possible to manage several blinds at the same time. However, direct operation is always possible, and all devices can be activated manually.

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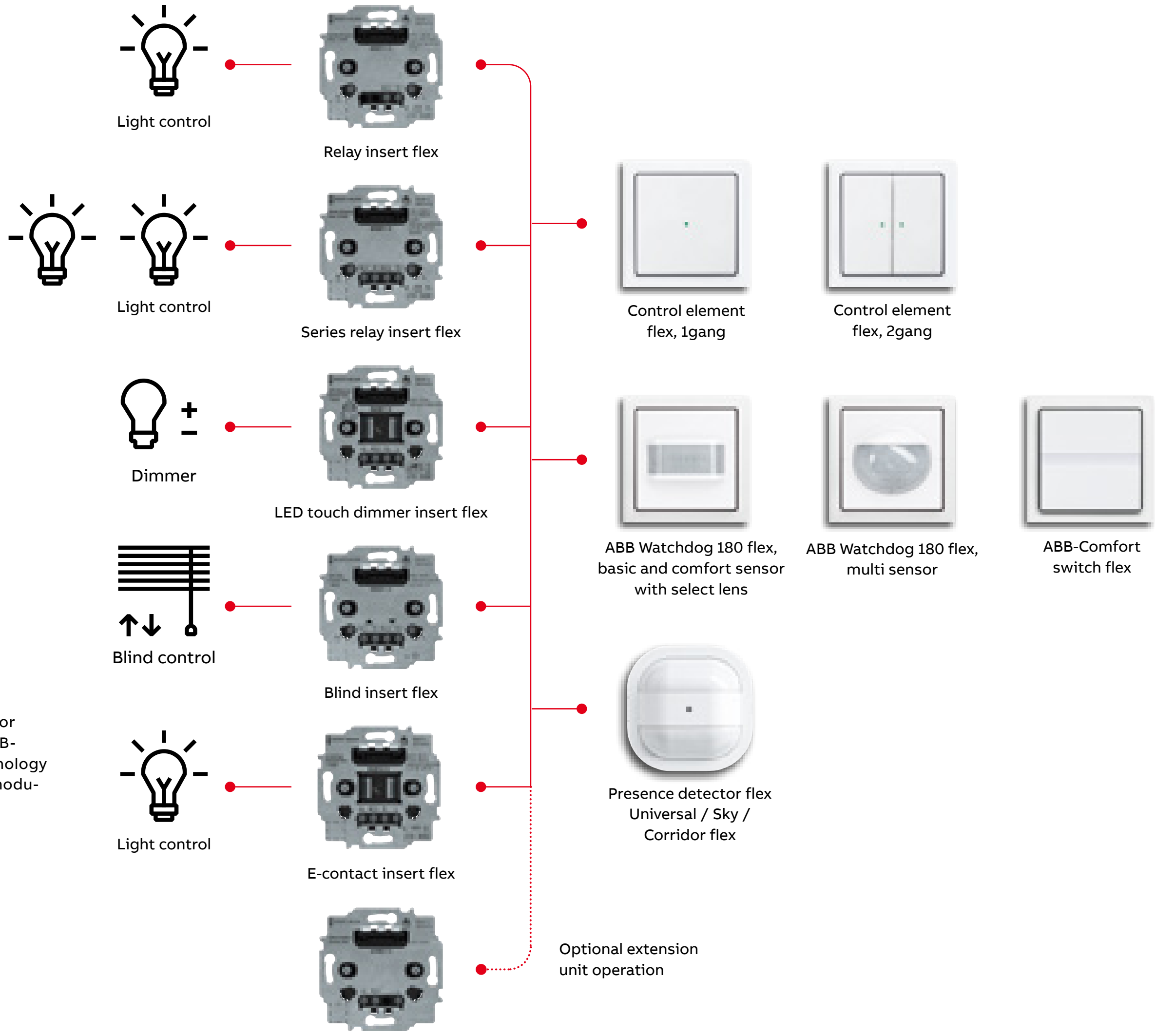
01 A single wire-less-mesh network can accommodate up to 32 networked devices, all of which can be managed by a cellphone-based Bluetooth connection.



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02 One of the major advantages of ABB-flexTronics® technology is its platform's modular concept.

Also, based on customer needs and a growing web of partnerships, the System Access Point itself is designed to evolve into an ecosystem of add-ons. Add-ons are software modules that customers can easily install or discard. Three levels of add-ons are planned:

- Those that are developed and maintained by ABB itself to help smart home customers respond to changing needs.
- Those that are not provided by Busch-Jaeger but are developed and maintained by partners and then tested by Busch-Jaeger.
- Those that are developed by third parties.

Customer and partner support is available through different channels such as phone, mail, social media, and new tools such as the Busch-Jaeger Community, an online exchange and support platform that uses artificial intelligence (AI) and machine learning (ML) to solve queries. These technologies are designed to streamline the resolution of customer requests and improve user satisfaction. The technologies leverage data sources from manuals, product documentation, and online communities to train AI engines and advanced ML to resolve recurring support requests.

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Eve's technology helps users manage energy use by allowing devices and services to integrate flawlessly, intuitively and securely.

In addition, with a view to this year's Light & Building fair, ABB is working on expanding its ABB-free@home® platform to integrate information from and visualization of energy use to actively manage residential energy demand. This

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03 The ABB art linear® switch.

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04 The ABB-flexTronics® wireless and ABB-free@home® system address a full range of home electrical control applications.

feature will provide information from wallboxes for electrical vehicle charging, solar panels and heat pumps – areas of particular interest for customers.

New standard

Parallel to the ABB-free@home® system's emphasis on energy savings is a wider trend that promises to consolidate the world market for smart home technologies. Major players such as Apple and Google have created a new wireless smart home connectivity standard and wireless protocol called Matter and Thread that is set to be a significant milestone in terms of the interoperability of smart home solutions. However, rather than merely playing follow the leader, ABB intends to play an active role in shaping this trend through its recent acquisition of Eve Systems →05, which will become the company's inhouse developer of Matter knowhow. Already considered to be a leader in Matter and Thread, Eve's technology allows different devices and services to integrate flawlessly, intuitively, and securely, making it possible for users to manage their energy use and surroundings conveniently and safely.

All in all, ABB's Smarter Home Solutions enable quick and flexible device configuration and digital remote control of a range of functions. Collectively, they contribute to making buildings smarter, safer, more comfortable, and increasingly energy efficient. •

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05 Eve Systems is a pioneer in the new Matter connectivity standard, which enables interoperability via Thread wireless technology.

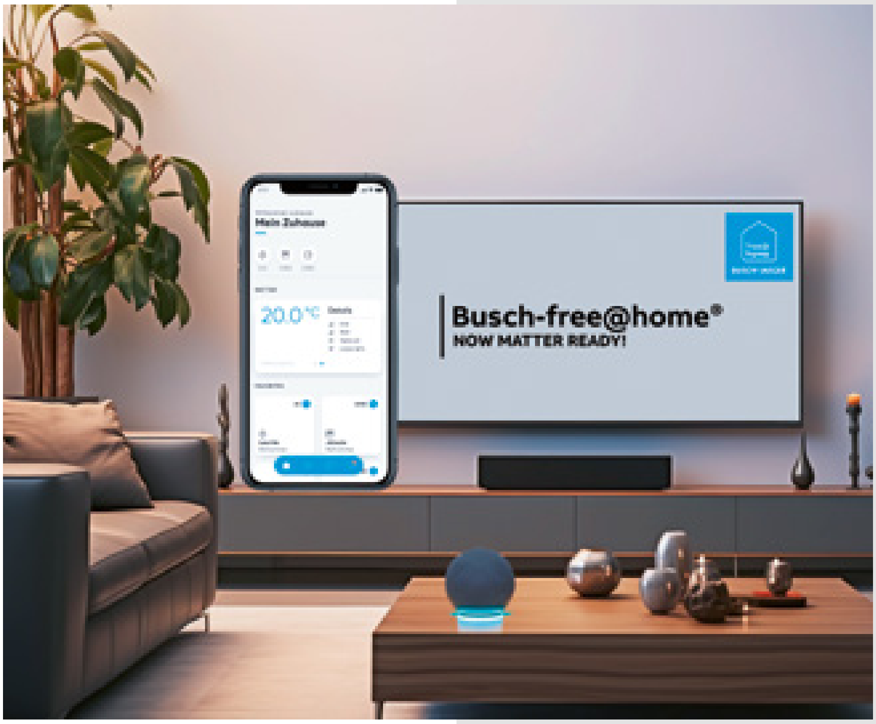
EVE SYSTEMS: STRENGTHENING ABB'S SMART HOME PORTFOLIO

In mid-2023 ABB announced the acquisition of Eve Systems GmbH, a Munich-based leader of smart home products with operations in Europe and the United States. The transaction is designed to make ABB a leader in smart home products based on Matter and Thread, the new standard for building system interoperability and wireless connectivity. The combined offer will accelerate ABB's delivery of safe, smart and energy efficient home and building technologies through Eve's extended complementary range of consumer-facing products tailored to the retrofit market.

Established in 1999, Eve Systems has developed a reputation as a company focused on the user experience and the quality of its smart home products, which include an extensive range of home automation, energy management, security, and appliance-monitoring devices.

Furthermore, Eve is a pioneer in the new Matter connectivity standard, which enables smart home products to be fully interoperable, irrespective of the manufacturer and user operating system, via Thread wireless technology.
With a view to meeting growing consumer demand for products that support energy efficiency, over half of Eve's consumer products help households with aspects of energy management.

Indeed, Eve's culture of innovation has resulted in a first mover advantage derived from its ability to develop and harness Matter and Thread protocols. Its acquisition by ABB is considered to be a significant advance into the fast-growing smart home technology market as demand increases for building stock retrofitting to address growing demand for greater comfort, convenience, and energy efficiency.



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MONITOR, CONTROL AND OPTIMIZE ENERGY CONSUMERS, GENERATORS AND STORAGE

Optimal energy management

01

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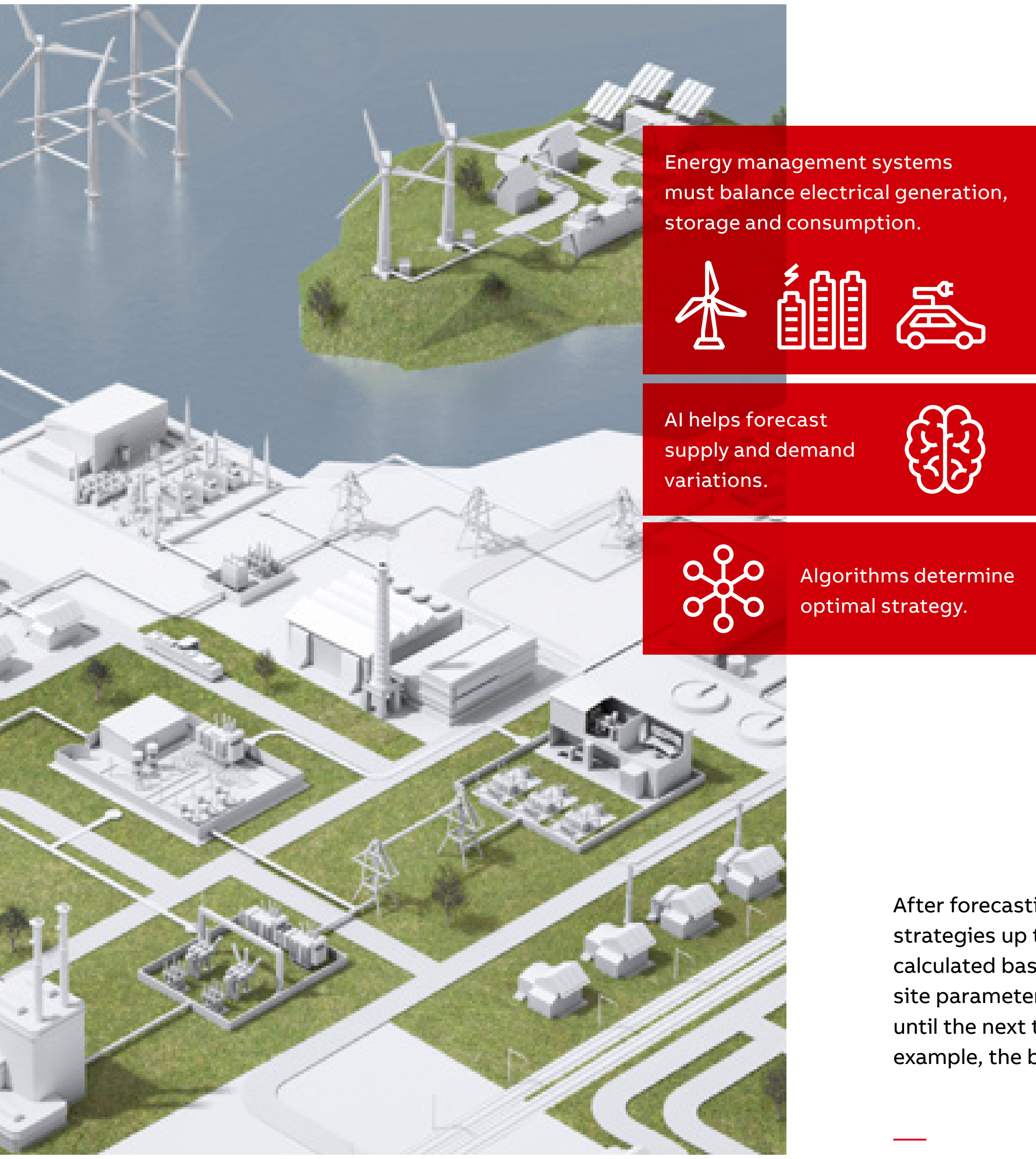
Energy management systems (EMSs) are key tools for addressing the challenges of a rapidly changing energy landscape. How does an EMS use techniques such as mathematical optimization and AI-based forecasting to satisfy all operating constraints while minimizing energy costs and CO_2 emissions?

Global energy consumption has increased rapidly over the last century and will continue to do so [1]. On top of that, energy prices have risen significantly in recent years and are expected to remain volatile. Additionally, power grids, which previously evolved gradually, are now changing rapidly, with local and decentralized generation and ever more dynamic renewable resources posing grid stability challenges →01. An EMS is a vital tool for addressing these issues.

An EMS is designed to monitor, control and optimize the performance of energy consumers, generators and storage – such as a battery energy storage system (BESS) – within an organization. An EMS can be considered to be a framework



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01 New paradigms in the world of power call for new tools.

consisting of various components, modules and processes. Two important functional ingredients for optimal energy management are forecasting and optimization, which ABB implemented as separate modules and are the subject of the discussion in this article →02. These two modules execute regularly (a typical execution frequency is every 15 minutes) with the forecasting module run first and its results input to the optimization module.

A forecast for the next 24 hours, for example, generates data, usually in the form of a time series, that could include expected photovoltaic (PV) generation or electricity demand of different loads.

After forecasting, the optimal asset operation strategies up to the forecasting horizon are calculated based on the forecast time series and site parameters. These strategies are applied until the next timestamp (eg, in 15 minutes). For example, the best vehicle battery charging strategy for the next 15 minutes would be applied, taking into account the renewable energy generation forecast, the energy needed to charge the vehicles and the current energy price profile. Both modules need a continuous data stream from the field as input for their algorithms.

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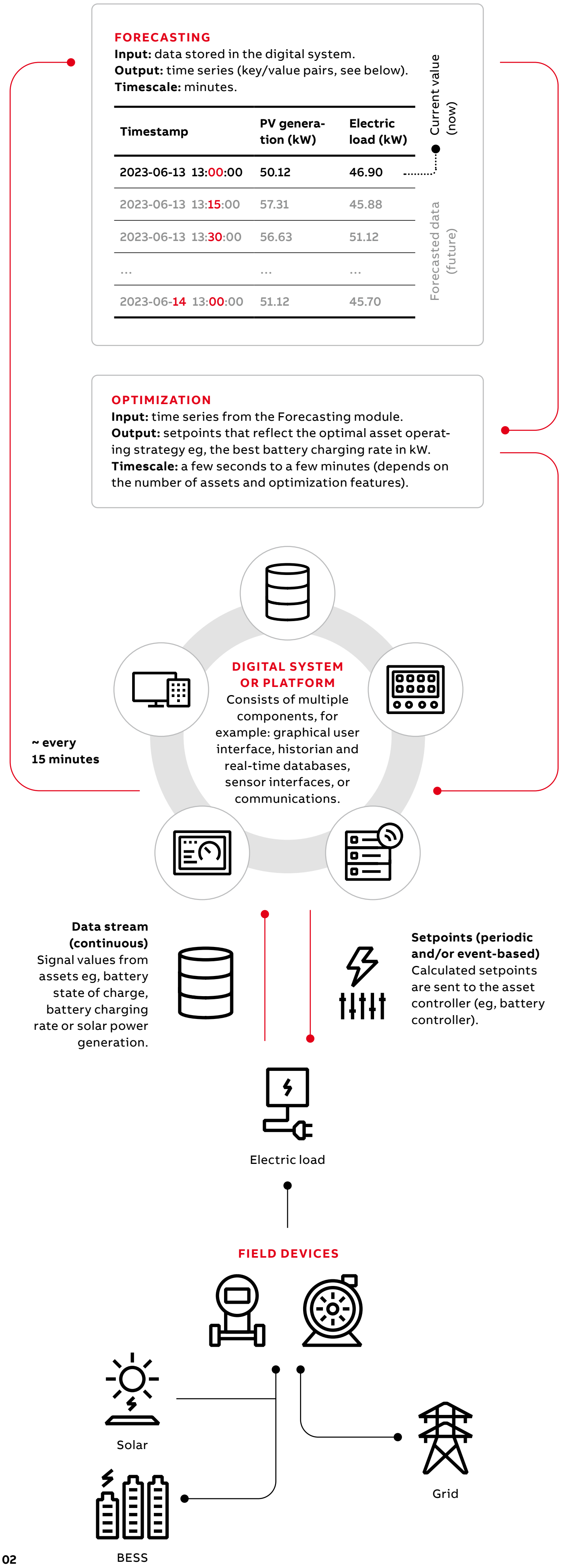
Two important functional ingredients for optimal energy management are forecasting and optimization.

The forecasting and optimization steps contribute the most toward minimizing energy costs. The approach ABB has chosen for these modules scales exceptionally well as it can optimize a very large number of assets simultaneously, covering all scalability requirements. Further, the optimization is performed in a global manner, ie, asset



Timestamp	PV generation (kW)	Electric load (kW)
2023-06-13 13:00:00	50.12	46.90
2023-06-13 13:15:00	57.31	45.88
2023-06-13 13:30:00	56.63	51.12
…	…	…
2023-06-14 13:00:00	51.12	45.70

02

groups are not considered in isolation from each other but simultaneously as a whole.

ABB's core EMS algorithm includes AI-based generation of forecasts for the production and consumption of power, as well as mathematical optimization of setpoints →03. The lightweight solution requires only a limited number of configuration parameters but guarantees a sufficient quality of physical asset modeling.

Forecasting – how it works

Forecasting is an essential component of an EMS because being able to forecast, for example, a peak in load demand for a few hours in a day enables the system to optimize energy use and storage accordingly, thus reducing costs.

ABB developed a generic forecasting module based on automated machine learning (AutoML). AutoML algorithms and techniques improve the efficiency and accuracy of finding the most appropriate machine learning (ML) model and its parameters by automating the search. This automation includes data preparation, feature engineering, hyperparameter tuning, model selection and evaluation steps →04.

The AutoML solution is tailored for sequential or time-series data. The module performs feature engineering relating to lags, seasonality, transformations, trends, etc. that enriches time-series data. Concerning energy management, an important requirement and attribute of ABB's forecasting solution is that it produces models

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ABB's core algorithm has AI-based generation of production and consumption forecasts and setpoint optimization.

that output sequence forecasts. For example, at the time of inference, the electrical load values of the past few hours (eg, 12 hours), when provided to the ML model, would generate a forecast of the electrical load over the next few hours (eg, 24 hours) at an even sample rate (eg, every 15 mins).

The forecasting module covers renewable energy generation and consumption and various electrical loads (eg, lighting or air conditioning), but the generic nature of the approach means it can, given sufficient training data, also be used to train models for other continuous quantities, such as the thermal load of a building or industrial process.

Handling forecast uncertainty

Forecasts of energy consumption and load are beneficial, but energy management can profit further from anticipating likely deviations from the forecast values. For this reason, ABB has incorporated automated training of a generic uncertainty quantification model into the forecasting module →05. Regardless of which ML technique is chosen as the best-performing by AutoML, an independent post-hoc uncertainty quantification model is created. Uncertainty quantification provides forecast intervals comprised of upper and lower bounds that should contain the true value of the load with a certain probability. Such uncertainty quantification conveys how reliable and trustworthy a forecast is. For example, narrower intervals can indicate that the machine learning algorithm is more confident in its forecasts.

Mathematical optimization

Once the forecasting module has decided what is likely to happen to energy generation and consumption over the given time horizon, it is up to the optimization module to determine the strategy that will best suit the energy targets

Besides static data, eg, the network topology or various asset parameters, there are also flexibilities that involve active decisions – eg, the battery charging/discharging strategy. This dynamic environment means that multiple – perhaps even infinitely many – possible strategies exist, all of which are physically valid. Because the strategy chosen can have a significant financial and/or environmental impact, the task is to find a physically feasible solution that satisfies all user requirements and minimizes costs. Mathematical optimization is an excellent way to determine such a solution strategy.

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The forecasting module incorporates automated training of a generic uncertainty quantification model.

Mathematical optimization requires multiple inputs, such as the technical properties of the assets (maximum battery charging rate, battery state of charge, etc.), their interconnections, asset-wise forecasted time series for consuming and generating assets over a given time horizon

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02 Framework for optimal energy management.

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03 Process flow: model training, forecasting and optimization.

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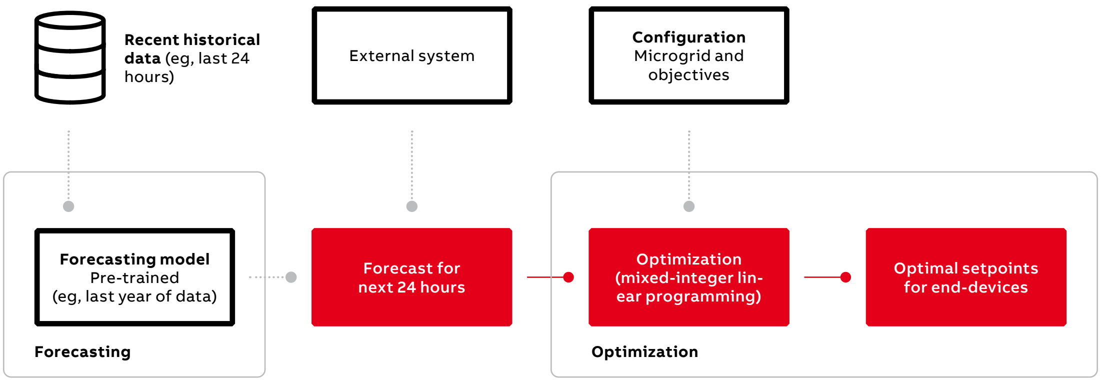
04 Forecasting process flow.



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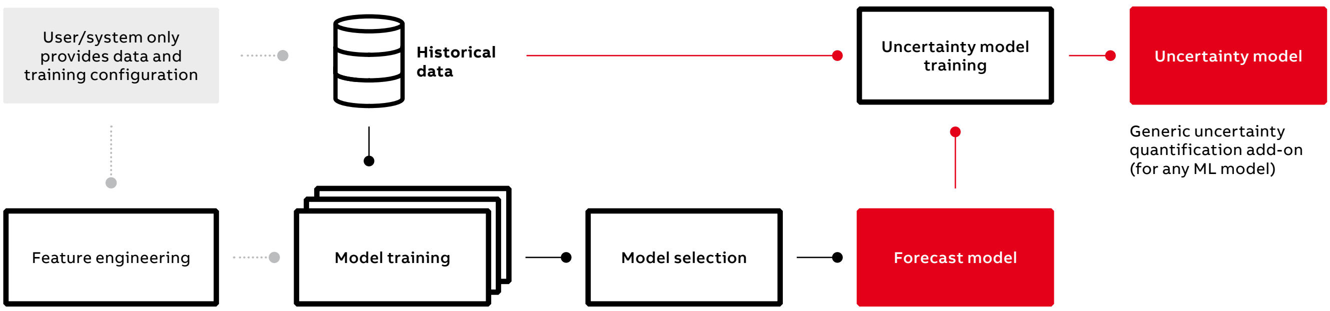

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(usually 24 hours) as well as grid prices for the same horizon and an optimization goal with respect to which the optimal solution shall be computed. It should be emphasized that all forecasts need not necessarily be provided by the forecasting module described above but can also originate from an external provider, thereby making the ABB solution very flexible.

Using the input information, a mathematical model is constructed that describes the evolution of the electrical network over a forecast horizon as a consequence of control decisions and the resultant costs, which one aims to minimize. The available control decisions may include a battery's charging or discharging behavior and the activation or deactivation of a flexible load. The underlying optimal control problem is modeled as a mixed-integer linear programming (MILP) problem.

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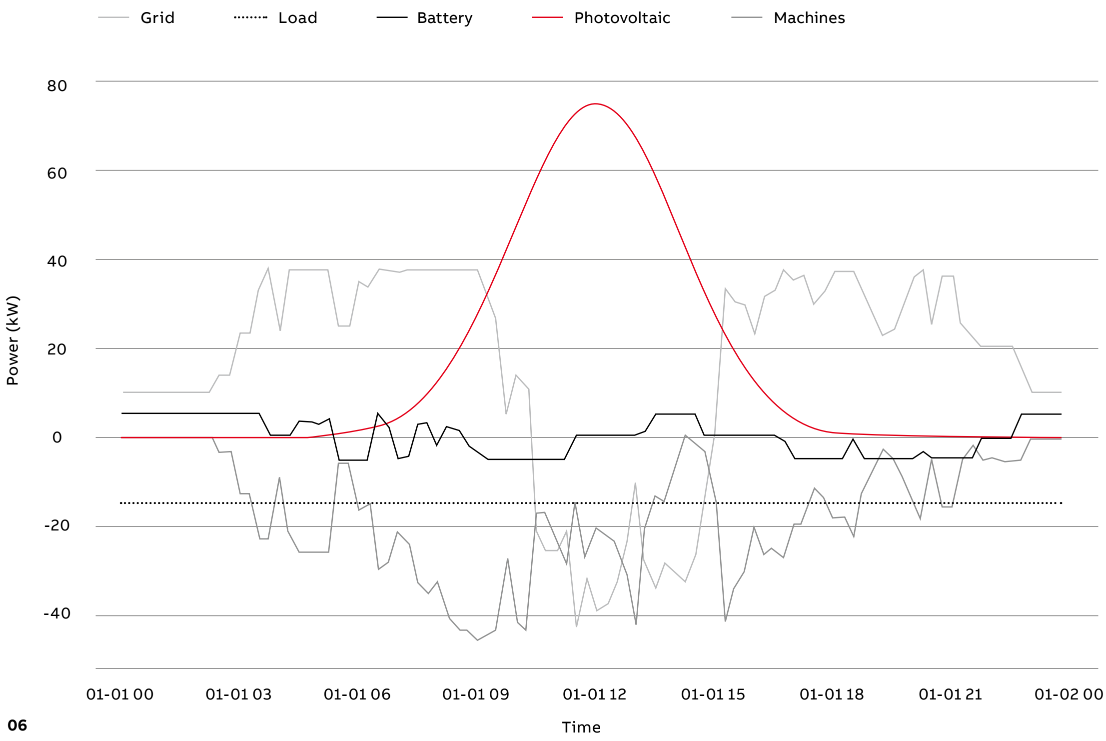
Forecasts can also originate from an external provider, thereby making the ABB solution very flexible.

Efficient solution
For MILP problems, exact solution algorithms exist that can efficiently find global solutions – ie, best-possible strategies among all possibilities. For the optimization discussed here, depending on the size of the network and the number of binary variables involved, solution times range from a few seconds to a minute.

The MILP model integrates a day-ahead operation of the energy network. Thus, all information available in the next, for instance, 24 hours impacts which setpoints are sent back to the field. For example, if there is a cloudy weather forecast for the next day, the optimization algorithm may decide to keep more energy in the battery overnight as it expects less PV generation. For a sunny forecast, battery energy may be used immediately →06.

General applicability
The ABB EMS solution is general and can be used in multiple applications, ranging from commercial and residential buildings through industrial buildings to battery charging depots. In fact, any network built from supported asset types is covered, including:



06

— 05 Especially renewable energy sources can introduce uncertainty. The forecasting module is designed to cope with deviations from forecast values.

— 06 Optimal setpoints calculated for the next 24 hours.

- Renewable energy sources
- Electrical loads with fixed demand (ie, an electrical load with a fixed consumption pattern)
- Electrical loads that offer certain flexibilities in their usage (eg, flexible starting time and duration with a fixed overall consumption)
- Stationary battery storage systems as well as electric vehicle charging

ABB's EMS is capable of executing various optimization strategies – depending on the particular customer's aim. These strategies include peak shaving, energy arbitrage, load shifting and load shedding (shut-off of single loads) but also

—

With this EMS, users can reduce costs and environmental impact, paving the way to a clean, electrified and sustainable future.

advanced objectives such as profile smoothing (minimization of fluctuations in grid or battery energy inflows or outflows) are covered. A combination of these strategies is also possible.

An easier path to a sustainable future

ABB's EMS is a lightweight framework for automatic and optimal energy management that leverages AI-based forecasting techniques along with sophisticated mathematical optimization. The solution requires only the most essential configuration parameters, making it easy to set up and operate. Additional parameters can also be set, depending on the degree of sophistication desired by the user. With this EMS, users can reduce costs and environmental impact, paving the way to a clean, electrified and sustainable future. •

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Reference

[1] Statista, "Energy consumption worldwide from 2000 to 2019, with a forecast until 2050, by energy source." Available: https://www.statista.com/statistics/222066/projected-global-energy-consumption-by-source/. [Accessed December 24, 2023.]

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Sound and vibrations from equipment contain information about its health and condition.

ABB is partnering with Cochl to leverage the possibilities.

Improved up-time and fewer equipment failures.

01

COLLABORATION ON AI-BASED MACHINE LISTENING

AI for sound

Vibration analysis is an essential tool for condition monitoring in industrial machinery. ABB is working with the US-based company Cochl to see how their AI-enabled machine listening technology can improve the vibration monitoring of machines.

—
01 A copper mine conveyor system in Chile.

—
02 Cochl Inc. company profile.

Machine listening is the technique of collecting sound or vibration data from machines, vehicles, animals, etc. and using signal processing and machine learning to extract useful information from it. In other words, just as computers can interpret images acquired by cameras to provide machine vision, machine listening is the ability of computers to analyze sounds obtained by microphones or other sonic transducers.

A straightforward example of machine listening is sound event detection, widely used in smart home devices for security and monitoring purposes. By setting home microphones to detect sound events such as glass breaking or footsteps, users can be notified of any potential break-in when they are away. However, the capability of machine listening goes far beyond simple sound event detection and can be used to analyze music, city noise, or even complicated underwater acoustics.

The US-based company Cochl has now significantly enhanced machine-listening technology by introducing artificial intelligence (AI) to dramatically boost the quality and accuracy of sound and vibration analysis. Cochl accomplishes this step forward by exploiting its proprietary deep-learning techniques and audio expertise →02. This way, the company can provide comprehensive machine-listening solutions for all enterprises. For example, Cochl has been working with the Korea Polar Research Institute (South Korea's lead agency for the country's national Arctic and Antarctic program) to classify different submarine or marine animal sounds. However, it is within the industrial domain that Cochl's technology for monitoring sound and vibration may present significant interest for ABB. Consequently, Cochl has been

—
Cochl has now significantly enhanced machine-listening technology by introducing AI-based analysis.

incorporated as a member of SynerLeap, ABB's innovation growth hub, which has a global mandate to catalyze and ignite innovation transfer across various industries [1]. SynerLeap is designed to enable technology companies

ABOUT COCHL

Cochl was founded in Seoul in 2017 by six researchers experienced in audio and machine learning. The company was named after the cochlea, a small bone in the ear that plays an important role in hearing. As the name implies, Cochl is specialized in AI for listening. Now with a headquarters in San Jose, California, Cochl is innovating in diverse industry verticals across the world, from manufacturing, through defense and smart cities to healthcare. Cochl has been leveraging proprietary deep-learning techniques and expertise in audio to provide an end-to-end machine listening solution for enterprise customers, including data collection, customization, application programming interface and software development kit for flexible integration, and intuitive dashboards.

02

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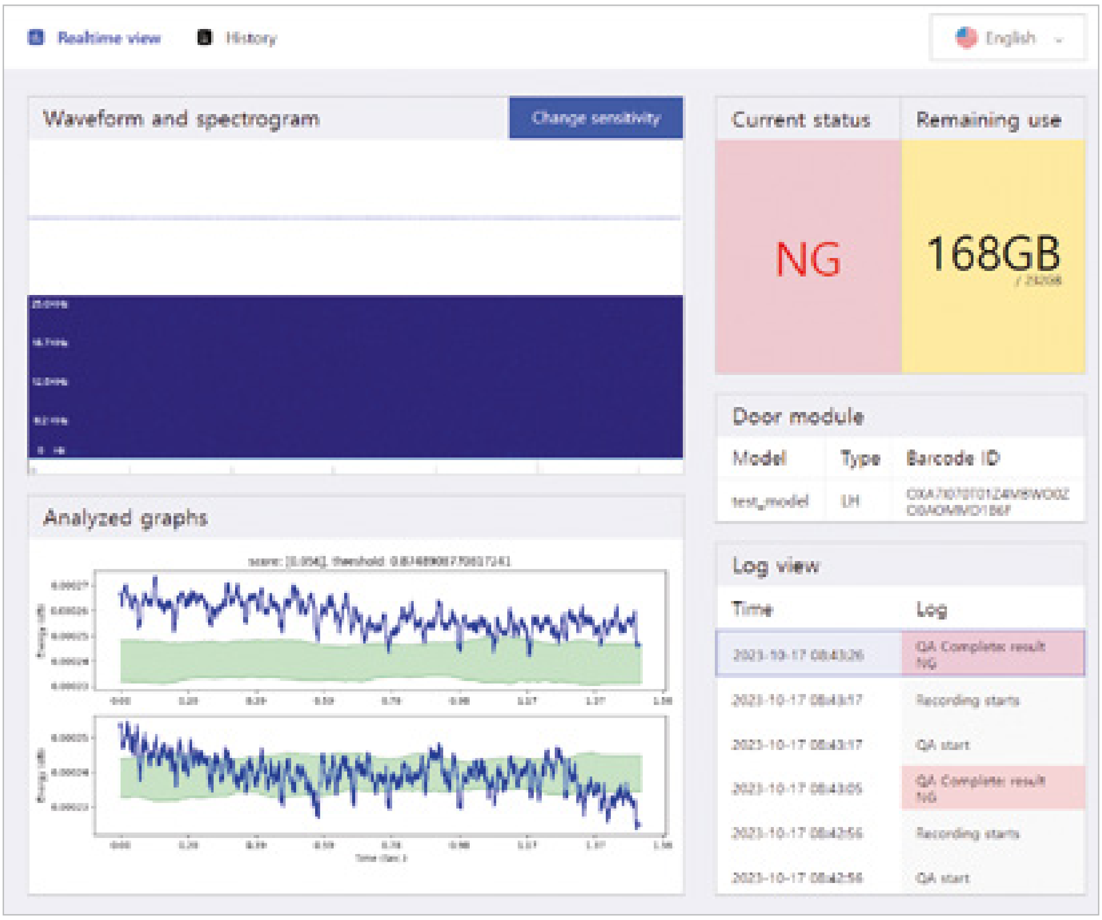


03a

—
03 Generic example functions of the highly customizable dashboard.

3a Dashboard for monitoring occurrence of anomalies in real time.

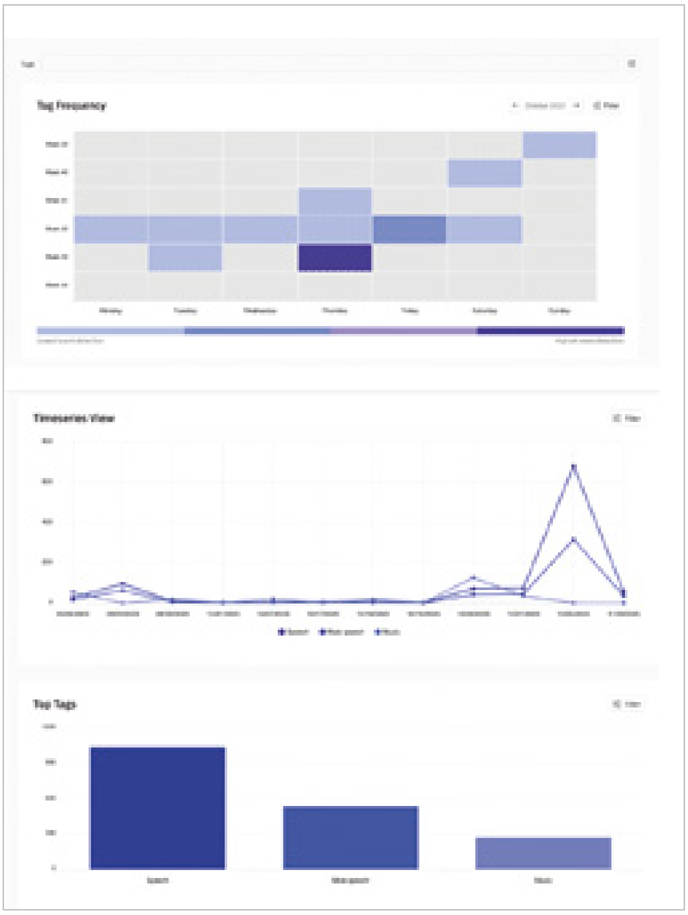
3b Heatmaps and graphs display analytics trends and insights.

to grow and expand in a global market within ABB's business areas, including industrial automation, robotics, grid technologies, smart cities, buildings, transportation technologies and energy [2]. So far SynerLeap has created more than 230 collaborations involving 190 startup members from 26 countries. SynerLeap brings in up to four new members monthly, with one new ABB collaboration starting every week. Sandvik, Hitachi Energy, Microsoft, Epiroc, IBM and Pedab are just a few examples of established partners.

—
Cochl usually attaches piezo sensors so only vibrations are detected and extraneous acoustic interference is excluded.

Sounds and vibration – are they different?
A production line full of clattering machines is an environment in which it is difficult to pick up slight anomalous equipment noise with a microphone. Because the primary transmission mechanism of sound and vibration is identical except for the medium that carries the signal, most existing machine inspection applications use vibration-based monitoring to identify anomalies. Accordingly, Cochl usually attaches piezo sensors to equipment so only vibrations are detected and extraneous acoustic interference is excluded. Whether to use microphones or a piezo sensor depends on each unique environment. Often, the use of microphones or directional microphones is sufficient, but in noisy environments or when attaching the sensor directly to the machine is not an issue, piezo sensors are preferred

This front end is somewhat similar to traditional approaches; it is in the back end that Cochl's approach differs. Here, advanced deep-learning techniques are employed to examine signals and extract much more information from them than traditional analysis can. The algorithms involved are capable of complex analyses that are far more sophisticated than those performed by conventional vibration-based solutions. The result is a rich and detailed picture of the vibration's cause and effect. In fact, many of Cochl's anomaly-detection customers have disclosed that the



03b

vibration-based avenues they initially followed proved ineffective in meeting their requirements, which is why they turned to Cochl for a better solution.

A customized acoustic inspection tool
Building an automated acoustic or vibration inspection system from scratch requires a team of dedicated experts experienced in handling complex audio data. Even with the appropriate expertise in place, many enterprises have spent years trying to realize an effective acoustic inspection system, only to fail. The field is technically challenging. Fortunately, Cochl now provides a shortcut for realizing a very effective inspection system.

The Cochl approach offers simplified steps for enterprises to build a customized acoustic or vibration inspection tool, from testing to production, all in a few months. Initially, the customer records audio samples on their smartphone and sends them to Cochl's researchers to determine the feasibility of the project. The next step would involve more data collecting to build the core of an optimized inspection tool that can be used in production. This step is followed by the construction of custom dashboards that deliver operational insights and enable the customer to make further optimization during operation →03. When ready for release, the model is deployed with a final monitoring system for the operator's use →04. Operators can control all features with a few clicks. The tool can also be integrated with an existing monitoring system.

Machine listening for remote monitoring and predictive maintenance
Because ABB focuses on advancing automation and digitalization in diverse industrial sectors, Cochl has been involved with the company to enhance operational efficiency through AI-powered automation, such as sensor data analytics and remote monitoring of industrial assets.

ABB solutions often operate in remote and challenging environments with scarce engineering or maintenance resources – in mining, for example. Mining sites can contain several kilometers of conveyor belts that carry the extracted raw material. The rollers ("idlers") bearing these belts are liable to break down in the harsh outdoor environments where mining activities are often

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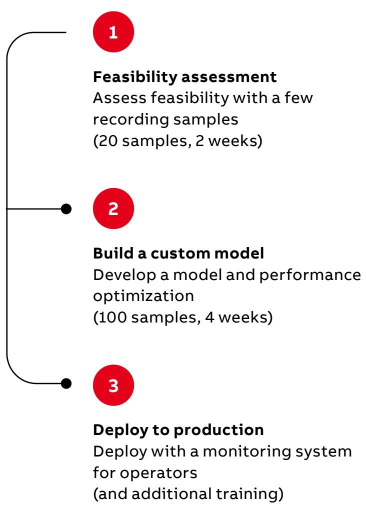
Deep-learning is used to extract much more information from signals than traditional analysis can.



04

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04 A simple, three-step workflow to build a custom model.

05

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05 Rock and rollers. Conveyor belts in open-cast mines typically have hundreds of idlers.

found, potentially interrupting the entire operation. However, it is difficult for a few operatives to closely monitor such an extensive array of moving parts.

Mining is an important area for ABB, so the company has been developing inspection robots that travel on rails along the conveyor belts in open-cast mines and provide automated monitoring of all idlers, finding those that need to be cleaned, greased or replaced during the next planned shutdown [3] →05. A fundamental problem of idler degradation detection is that degradation has various symptoms – such as ultrasound emissions and warm idler-bearing faces – that call for multiple sensing technologies. For this reason, the robots are equipped with a thermal camera, a visual camera with an LED light and an ultrasonic microphone. However, the analysis and classification of the many hundred audio samples acquired in one belt pass-through presents some challenges. ABB first encountered Cochl's technologies in the ABB AI Community's Webinar and has been working with Cochl ever since to build a classification tool to enhance remote monitoring of conveyor belts at mines further.

Machine listening for manufacturing quality control

In manufacturing, machine listening can be applied wherever acoustic cues indicate mechanical failure or abnormal conditions. For example, motors, compressors, rollers and fans generate a distinctive noise when running abnormally. Consumers purchasing vehicles or home appliances, such as washing machines, for instance, readily notice an unexpected noise. These noises and the mechanical issues creating them increase the number of customer complaints and a reduction in overall customer satisfaction. Accordingly, manufacturers treat noise compliance as a critical factor for high-quality production. Therefore, automobile makers and home appliance manufacturers have turned to Cochl for assistance in building automated quality control processes for products at the inspection stage →06. By relying less on human operators, who are prone to error in this area, fault rates in production lines have been reduced and end-customer satisfaction has improved.

—
Manufacturers have turned to Cochl for help in building automated quality control processes for product inspection.

Cochl's approach to acoustic monitoring and analysis is applicable to a wide range of manufacturing processes. ABB is working with the company to identify further areas in which their proprietary AI-enabled, deep-learning techniques and audio expertise can provide comprehensive machine-listening solutions for industry. •

06a

06b

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06 Signal detection.

06a An operator station for acoustic testing of automobile parts. Here, piezo transducers are directly attached to automotive modules to collect vibration information.

06b Directional or general microphones can also be used. Here, a tripod-mounted directional microphone is recording the acoustic signature of an air purifier's compressor and valve.

—
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[1] Cochl, "Cochl joins ABB's innovation growth hub SynerLeap." Available: cochl.ai/news21/. [Accessed January 3, 2024.]

[2] www.synerleap.com

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Buzzword
Demystifier

Generative AI

Today, the term “Generative AI” slips easily from the lips of many. But what is it exactly? And how can it benefit industry?

—
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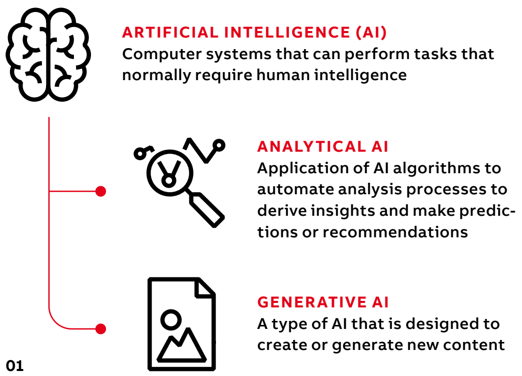
Generative AI refers to artificial intelligence (AI) systems that can generate new content – such as text, images, music, or computer code – based on training data and user inputs. These systems use machine-learning techniques, particularly neural networks, to analyze patterns and features in vast amounts of existing content (ie, training data) and produce original outputs similar in style. Generative AI – devoid of consciousness, emotions or subjective experiences – operates solely on probabilistic algorithms and data and generates content based on patterns identified in its training data, not personal creativity. The main difference to established AI methods lies in the generation of original content. For example, analytical AI, the traditional approach, is limited to deriving insights, creating classifications, or making predictions or recommendations →01.

—
Pre-training on vast datasets enables the model to understand patterns, context and nuances.

Originating in the mid-20th century, generative AI underwent a significant shift with the advent of deep neural networks in the 2010s, particularly with the introduction of the breakthrough Transformer architecture in 2017. By leveraging this neural network architecture, which processes information like the human brain, generative AI approaches, such as ChatGPT (Chat Generative Pre-trained Transformer), can create human-like outputs. Pre-training on vast datasets enables the model to understand patterns, context and nuances. Combining this pre-training “education” with the Transformer architecture produces a groundbreaking AI that is unleashed through advanced training that uses a huge amount of data. The “chat” part, ie, the interface to non-AI-scientist users, gives the technology a huge push, as it democratizes the accessibility of Generative AI to general audiences.



01

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01 Differentiation between analytical and generative AI.

Generative AI for and at ABB

While the media focuses on chatbots and image generators, Generative AI will also play a vital role in ABB industrial applications so:

- Employees can speed up their daily work.
- Internal business functions can be automated.
- Product performance can be improved.

ABB has already started using Generative AI, to the advantage of customers as well as internal applications. For example:

- Intuitive user interaction with ABB Ability™ Genix Industrial Analytics and AI Suite
- Efficient engineering of control systems and PLCs by control code generation

Risks, limitations and challenges

While offering transformative potential, Generative AI also presents risks, limitations and challenges:

- Due to its stochastic nature, Generative AI may "hallucinate" – namely, generate wholly or partially inaccurate information without indicating it is doing so.
- Copyright infringement: Generative AI can reproduce or closely mimic existing copyrighted materials, particularly when the model is pre-trained on a large body of data with incomplete copyright information.
- Generative AI's requirement for substantial computational resources may restrict the accessibility and business potential for certain customers and use cases.
- "Deepfakes" – highly realistic AI-generated images or videos – present serious concerns for misinformation and privacy violations.

Trends in Generative AI include multimodality for handling various data types (eg, language, visuals and sounds) and more easily customizable general GPT models so non-expert users can tailor them to their particular applications.

The reliable use of Generative AI in industrial applications requires a robust governance framework, ethical guidelines and technological safeguards. ABB is inviting its customers, partners and general public to collaborate on these topics to unleash the potential of Generative AI. •

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