ABB

# review

3|12

The corporate technical journal



## Software

Every operational technological device fulfills a role, not just in its direct system context, but in the broader economy and society. As the cooperation of these components and systems are optimized through software functionality, overall productivity, reliability and efficiency increases.

The robots on the front cover may be the most obvious software-driven components in the manufacture of the car body, but further software components are active in numerous aspects ranging from ERP (enterprise resource planning) systems to assuring the power supply. Representing a complex system of a different nature, the inside front page shows the Extrasol solar power plant in Spain.

Contents

Editorial

# ABB and software

**Prith Banerjee**

**Dear Reader,**

I would like to use the opportunity of this, my first editorial in my tenure as Chief Technology Officer of the ABB Group, to greet all readers and welcome you to this issue of the journal, dedicated to software in ABB.

I joined ABB in April 2012 after spending five years as Senior Vice President of Research at Hewlett Packard, 23 years in academia at the University of Illinois and at Northwestern University, and having founded two software startups. In the past several months, I have interacted with hundreds of technologists at ABB, and learned about the broad portfolio of products and solutions in power and automation. I have experienced ABB as a true engineering company with innovation at its core. Our researchers are working on both evolutionary innovation of our products and services, and disruptive innovation into brand new areas.

Software is among the youngest of the engineering disciplines, and one that has in its short history undergone remarkable developments. Software developers today can build upon a vast armory of tools and libraries as well as theories and frameworks, freeing them of many mundane and repetitive tasks and permitting them to apply their minds and creativity more fully to their core challenges. But it is not just the theory or the tools that have advanced. Breakthroughs in computing and communications are opening new opportunities for software. Who would have thought only some years ago that a power transformer would have a software component?

Rather than being a newcomer to the software scene, ABB's software activities go back many decades. The company now employs some 3,000 software engineers. Because much of the software was, until recently, embedded in other products, ABB was not recognized as being an obvious software company. This changed with the acquisition of enterprise software companies such as Ventyx and Mincom, rendering ABB much more visible on the software scene.

ABB's present offerings and activities are best thought of in three main categories. One of these is that of software embedded within devices. This can range from protection logic in breakers to advanced interactive functionality in analytical and measurement devices or robot controllers. The second type is that of system software, used to control and coordinate processes on a plant-wide scale (or beyond). Tens of thousands of individual devices can be connected to such systems and different levels of control activity can be integrated (for example the same operator workstation that monitors a plant-wide chemical process can also control power-management aspects). The third category of software consists of enterprise-level software, which, as stated above, has been significantly boosted by recent acquisitions.

ABB also pursues general software-related activities, acting horizontally across these three columns. One of these is its SDIP program to assure a uniform and high quality in all software development work. Another aspect that is of increasing importance as more and more devices are connected to public networks is that of cyber security.

The scope of software activities within ABB is wide indeed. This edition of *ABB Review* covers a representative selection of projects. I trust that this journal will kindle your interest in and further your understanding of the fascinating world of software within ABB.

Enjoy your reading.

Prith Banerjee
Chief Technology Officer and
Executive Vice President
ABB Group

# ABB's software is everywhere

## Why ABB is a software company

MARTIN NAEDELE – **ABB has been called "the biggest company that nobody knows". Its products – though essential for the quality of life of hundreds of millions of people – do not target the consumer market. In a similar way, ABB's software activities can be considered an aspect of the company "that nobody knows". The assumption that software is at best peripheral to ABB's business could not be further from the mark. With around 3,000 software developers in 40 countries worldwide and impacting about one quarter of ABB's revenue, there is no doubt that ABB is a major software company.**

**Title picture**
Software is one of the most overlooked ingredients of modern products and services, and one that the casual observer can easily fail to recognize. Similarly, it is not immediately obvious to what extent ABB has become a software company, and the role software now plays in its products and activities. The picture on this spread shows Dubai.

Through recent acquisitions, ABB has become more visible as a major vendor of “pure play” enterprise software The company is now one of the top three vendors globally in the area of enterprise asset management.

1 Much of ABB’s software is included in products such as these.

a) process instrument

b) robot

c) control system

d) comfort panel for the home

In the past, ABB’s software activities have often been overlooked as most of the company’s software was sold as part of hardware products. These included IEDs (intelligent electronic devices) for substation automation, process instruments, robots, or even transformers, or as part of a mixed hardware and software system, such as the company’s 800xA and Symphony+ automation and process control systems → 1, → 2.

However, following ABB’s recent acquisitions of the companies Ventyx and Mincom, ABB has become more visible as a major vendor of “pure play” enterprise software [1], for example in the area of enterprise asset management, where ABB is now one of the top three vendors globally [2]. These acquisitions and the expansion into the enterprise IT space that goes beyond ABB’s traditional CPM solutions [3] position ABB as a leader in the trend towards what some consultants like to call convergence of OT (operational technology, automation systems) and IT (information technology, enterprise information systems).

With this expansion of the company’s portfolio comes a change in business model. Many products, including software, were traditionally sold “by the meter” and for a one time charge. Attitudes, are evolving and customers are increasingly moving away from thinking of software as an “install once and forget” asset. They desire that their systems evolve and benefit from ongoing improvements. This is reflected in a shift from a “buy once” approach to a service-oriented model, granting customers access to the continuous stream of additional features, usability improvements, and adaptations being developed by ABB.

## Security

While on the topic of software updates, one area that cannot be ignored is security and the associated issue, painful to users and vendors alike, of security-related updates. While one might naively expect that a well-written piece of soft-

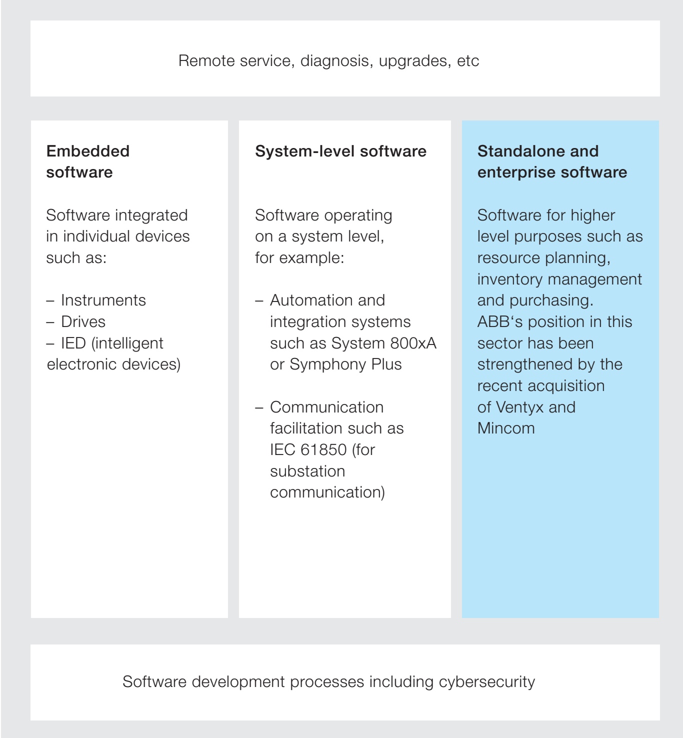
**Footnotes**

1 Enterprise software is software for use in organizations such as businesses or government. Possible features include online purchasing, inventory management and resource planning.

2 Source: ARC Advisory, EAM Solutions Worldwide Outlook 2011

3 CPM (collaborative production management) is a term used to collectively describe the tools and processes used to support collaboration between a company’s production activities and the areas with which it must closely interact (such as purchasing, inventory management and controlling structures).

2 ABB has strengthened its position in the enterprise software sector




3 Comparison of code sizes of various embedded software products.


ware is not vulnerable to any attack, experience has shown that in the real world it is not possible to write software that anticipates and prevents all kinds of future attacks. The key is to find the right balance between security requirements and what price users are willing to pay in terms of money and discomfort in operation. That said, security is not a new trend that ABB is joining. For example, security for automation systems has been a topic in ABB's labs for more than a decade. The company has driven security-related development of standards, for example in the standards commissions IEC and ISA, and today ABB is home to one of the leading research groups in control system security. Security teams from across the company are furthermore coordinated by the Group Head of Cyber Security, a new function created in 2011 to ensure that security of ABB products and systems is implemented at a consistent level across all parts of the company and in accordance with customer needs and emergent regulatory requirements (ABB's activities in cyber security are described more fully on pages 64–69 of this edition of *ABB Review*).

Security concerns for automation systems have arisen mostly due to the fact that today's control systems are increasingly also communication systems, often with global reach and connected to customer intranets and the Internet. Modern communication protocols in power and industrial automation – earlier more concerned with electrically representing bits on a wire – have evolved to complex software applications in their own right, representing in their sophisticated functional and information models the full complexity of the systems between which they transfer data. ABB has been at the forefront of this development, having been a key driver of both IEC 61850 in the power industry [4] and OPC-UA in the process industry.

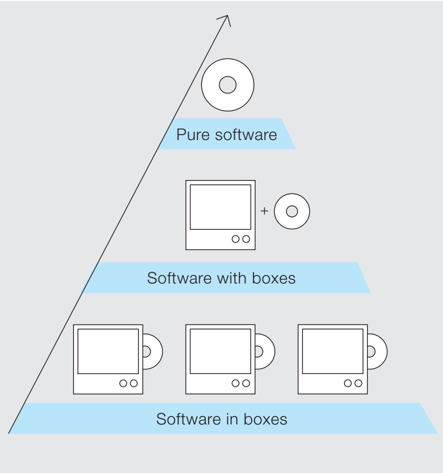
Modern communication protocols in power and industrial automation have evolved to complex software applications in their own right.

## Software development

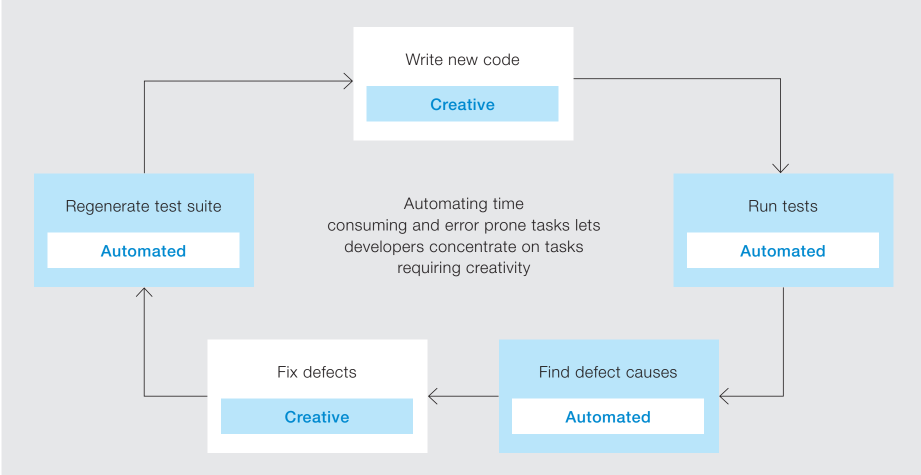
A modern process control or asset management system can easily extend to 10 to 20 million lines of code. This is comparable in magnitude to the code in a passenger airplane, a modern jet fighter, a computer operating system or a car → 3. The creation and maintenance of software systems of such size requires not only a highly qualified workforce of software developers, who are at home both in software and in the requirements of the various application domains, but also professional tools and mature devel-

Footnote
4 For more information on IEC 61850, see ABB Review Special Report IEC 61850.

4 Automation pyramid




5 Automated unit testing tool chain




While ABB is already collaborating with a number of universities on various software-related research projects, the company is seeking to extend its reach and invite further research groups from all over the world to participate.

opment processes. As ABB systems and solutions help customers to increase productivity and improve the quality of their production processes, ABB also strives internally to adopt state-of-the-art software development methods and tools and to improve the efficiency of its software development teams. One example of the achievements of the ABB Software Development Improvement Program (SDIP, see also pages 59–63) is the recent transition of all software development units across the globe to one common set of tools for requirement, code, and test management. This was not a trivial change for a traditionally decentralized organization such as ABB, which is furthermore both growing organically and integrating newly acquired companies. This common toolset is also the basis for making available to all of the company the advanced software-engineering tools that are coming out of ABB's Corporate Research centers – tools that are created in collaboration with leading academic software engineering researchers worldwide and that are automating those parts of software development that do not require human creativity and ingenuity → 4.

Examples for such tools are:
– Static analysis for certain coding errors (a kind of "spell checking" for code).
– Automated transformation of code (a very sophisticated, context sensitive search and replace function that can reduce person months of effort to hours).
– Automated creation of regression test suites → 5.
– Automated impact analysis.

While ABB is already collaborating with several universities on various software-related research projects, the company is seeking to extend its reach and invite further research groups from all over the world to participate. For this purpose the ABB Software Research Grant program was initiated in 2011, in which ABB invites submissions of research proposals for funding in a number of broadly defined areas of interest. [5]

## The user interface

Many of ABB's customers are facing a challenge. Experienced operators are approaching retiring age, and fresh hires drawn from the generation of so-called "digital natives", ie people who have grown up with computers and smartphones, are setting different usability requirements for industrial products. Whereas today's user interfaces typically emulate the displays and dials of the pre-computer age, today's users increasingly expect a user experience on par with their latest home consumer communication and entertainment devices. At the same time, the user interface must support the learning process for new operators through innovative tutorial and guidance functions, task oriented interaction schemes and safety features that prevent common errors and maloperations. ABB is meeting these challenges by integrating user-centered design principles in its product development process, conducting studies with end users both

**Footnote**

5 Detailed information about the company's research and about the grant program can be found at www.abb.com/softwareresearch

6 The Neptuno irrigation solution is an example of ABB's hosted automation system offerings.

at customer sites and in its state-of-the-art usability and user experience lab facilities. The company is also collaborating with universities such as MIT and participating in the Center for Operator Performance [6], the leading forum for advancing the state-of-the-art in industrial and control system usability.

## Software in the cloud

Another important aspect of ABB's growing software portfolio are the applications that are no longer installed at customer sites, but instead hosted and operated by ABB on behalf of the customer. This usage model, some years ago called Application Service Provisioning and more recently relaunched as "cloud computing" offers various advantages: For some applications, customers only have to pay for those functions and instances that they actually use (known as "pay per use" model), and do not need to worry about hardware or software maintenance or updates as this is all taken care of by ABB. Initially, such application hosting was used for business information systems such as payroll system, enterprise resource planning (ERP), customer relationship management (CRM), asset management etc., as well as for optimization and diagnosis applications. However, ABB realizes that in the classical automation space there are also applications where customers appreciate not having to deal with managing a full control or SCADA system. An example for ABB's hosted automation system offering is the Neptuno irrigation solution, which is successfully deployed in Spain serving more than 60'000 farmers who can fully monitor and control the irrigation of their fields using a web browser on a mobile device ➔ 6. Hosted solutions are also offered for enterprise asset management, where ABB combines the management of data for all installed ABB devices, including their updates and spare parts needs and service requirements. Such solutions use innovative diagnosis and service intelligence methods to permit a critical asset condition to be recognized and treated before it fails, so preventing costly unplanned downtime.

## Data centers

From social networks such as Facebook and Linkedin over search engines and media distributions sites to the growing "software in cloud" market mentioned earlier, the demand for data centers all over the world is soaring [7], and with it the associated thirst for electrical power. ABB has long been a supplier of the equipment that powers the computers inside data centers. More recently, the company recognized that managing not only the power supply, but the entire operation of hundreds of thousands of servers in a data center is a task for which no good integrated solutions are offered by classical IT companies, but for which ABB's products and experience could be adapted. ABB has long supplied the systems to manage and optimize operations in complex industrial plants such as oil drilling platforms or refineries, containing several hundred thousands of sensor and actors. These systems have also integrated different parts of the operation (power supplies and management, process data, diagnostics) into a single control system. In a way, the release of the ABB Decathlon data center enterprise management (DCEM) solution in 2011 marks ABB's step from industrial automation to post-industrial automation [8].

## The software company everybody ought to know

From being a company that traditionally created software purely for the internal needs of its own devices, ABB is rapidly becoming a company at the forefront of developing a far broader range of software products and services, touching the needs of everyday life and human activity in many ways and enabling many types of activities from smart grids and smart management of the information superhighway to greater comfort in the home.

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**Footnotes**

6 www.operatorperformance.org
7 http://investor.digitalrealty.com/file.aspx?IID=4094311&FID=12899535
8 Recent developments in ABB's offerings for data centers are to be discussed in an upcoming issue of *ABB Review*.

# A parallel future

## Continuing innovation for next-generation real-time controllers through software

MICHAEL WAHLER, SASCHA STOETER, MANUEL ORIOL, MARTIN NAEDELE, ATUL KUMAR – Programmable logic controllers (PLCs) started out as mere replacements for banks of hard-wired relays. Today's evolved digital controllers play an integral role in automation and power systems. Recent innovations in CPU and network technology have opened up new opportunities for parallelized future control systems, such as software-based fault tolerance and real-time data analysis. Before these benefits can be unlocked, however, many challenges must be overcome. ABB Corporate Research is actively pursuing the future of real-time controllers by tackling determinism, flexibility, scalability and sequential algorithms.

**1 Acronyms used throughout the article**

| Acronym | Description |
|---|---|
| COTS | Commercial off-the-shelf |
| CPU | Central processing unit |
| DCS | Distributed control system |
| HMI | Human-machine interface |
| ICS | Industrial control system |
| MPC | Model-predictive control |
| PAC | Programmable automation controller |
| PID | Proportional–integral–derivative |
| PLC | Programmable logic controller |
| RTU | Remote terminal unit |
| SCADA | Supervisory control and data acquisition |

The programmable logic controller (PLC) replaced hard-wired control relays ➔ 1. Today's PLCs have expanded well beyond their original design scope; they have to be much more than the relay logic replacement that they were initially designed to be. Born out of increased product diversity and innovation cycles, the PLC continues to evolve as new technologies are added to its capability. The result has been enhanced flexibility and reliability. By directly controlling equipment and processes, PLCs form the basis for supervisory control and data acquisition (SCADA), distributed control system (DCS) installations and programmable automation controllers (PACs). These industrial control systems have been around for decades. There are several flavors of control systems that each evolved due to very specific business needs and technological capabilities at the time of introduction.

Larger manufacturing processes with many sub-components are served by a DCS. The complete system benefits from the exchange of data that can be transmitted digitally among its nodes. This communication advantage allows, among other things, for a powerful human-machine interface (HMI). As commercial off-the-shelf (COTS) hardware is employed more and more, the focus of DCS shifts toward software differentiators including service. Rather than controlling processes like a DCS, SCADA takes a higher-level view. It is further removed from real-time constraints and coordinates processes. A PAC is a programmable microprocessor device that combines the functions of the PLC with greater flexibility in programming and tight integration with the other parts of the DCS. PACs are used for discrete manufacturing, process control and remote monitoring applications.

As technology evolves, especially the capabilities of hardware, networking, as well as the software systems, the boundaries become blurred. Moving forward, it is expected that the terminology will remain significant for historical reasons only, while the functionality will become unified. Many of these exciting developments will take place on the controllers themselves. They are the main and necessary interface between the process and the higher levels of the automation pyramid.

The current families of ABB controllers serve all automation areas well. For instance, some applications require fast cycle times, while others emphasize connectivity. ABB offers state-of-the-art products for each application.

## The future of controllers

Performance gains have, in the past, come naturally with each new controller generation. An increase in central processing unit (CPU) frequencies was directly and positively reflected in application speeds. Unfortunately, this "free lunch is over" [1] because clock frequencies no longer increase as before. One reason is that faster frequencies result in additional heat that needs to be moved off the device. Alas, most controllers disallow moving parts that are needed for active cooling (eg, fans). As a result, lower clock speeds must be set than are supported by the CPU. Another reason is that the maximum clock speeds for many modern CPUs are declining. Instead, new CPUs provide several options for executing code in parallel. They are able to work on multiple data items simultaneously (eg, as is done by the MMX instruction set for Pentium and its many subsequent extensions) or are capable of processing on multiple cores, including hyper-threading. Performance gains for future controllers will come from exploiting these parallel mechanisms, while hiding the complexity from control application engineers ➔ 2.

## Challenge: Scalability

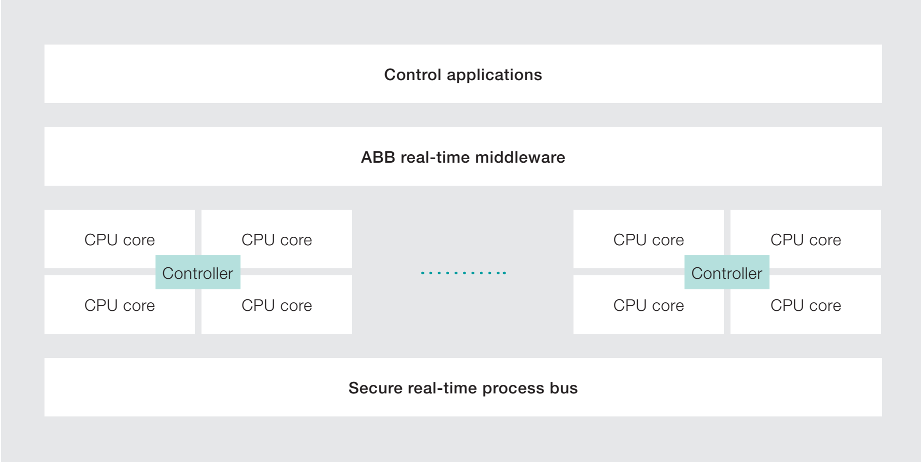
Distributed control applications are currently built in an ad hoc manner: with independent programs connected by a communication layer. Exploiting dual-core or quad-core CPUs is relatively easy; it can be achieved manually by either making small changes to the software or simply by letting operating systems distribute processes over the cores if they are ready to execute and can be executed in parallel. With the pervasiveness of multi-core chips, future generations of controllers will include a variable number of cores and hosts, making such a static allocation approach obsolete. The challenge is scaling software for an arbitrary number of computation resources, as a 128-core CPU or a 1024-CPU distributed system are an expected reality in a few years' time.

One solution to the scalability challenge is to break monolithic control applications into smaller components. The components are then scheduled to statically execute on the available computation resources (cores and hosts) [2]. Depending on the given deployment, a middleware chooses a suitable communication protocol for each pair of connected components.

This solution is not far-fetched, as it already corresponds to the control engineer's view of an application, where ladder logic or function block diagrams are commonly used to craft control applications. These

**Title picture**
Complex control systems benefit from parallel software

2 Envisioned system architecture for distributed real-time controllers




diagrams demonstrate that mutually independent components can be executed in parallel ➔ 3. Tragically, previous CPU generations are restricted to executing programs strictly one step at a time. Therefore, current technology must transform inherently parallel diagrams into sequential code, which is difficult and causes computational overhead. In contrast, parallel execution can exploit parallel branches in the control diagrams and make systems smarter.

### Challenge: Determinism

Determinism is the quality of a system to behave in a predictable manner. If a controller receives the same input, it is expected to react the same way each time. With multi-core processors this becomes hard to guarantee. The reasons are context switches, caching behavior, and task synchronization. State-of-the-art, real-time control systems execute multiple concurrent control applications using operating system mechanisms such as processes, mutexes, or message queues. Such mechanisms leave a high degree of freedom to developers but are often difficult to deal with: they incur runtime overhead (eg, context switches between threads) and often require tedious and costly fine-tuning (eg, of process and thread priorities). Reuse is often made more difficult by the tight coupling of software to a given hardware or other software.

By employing a software architecture and execution framework for cyclic control applications, the construction of real-time control systems can be simplified, while increasing predictability and reducing runtime overhead and coupling [3].

### Challenge: Flexibility

Speaking of determinism, with the limited computation power of single-core processors, reliably deterministic systems are often static – once configured and deployed they run until they reach the end of their lifetime. Changes can only be applied during maintenance windows, which may occur as rarely as once a year. This stands in strong contrast to real-world requirements as plants grow and evolve. Production becomes increasingly flexible up to mass customization approaches. At the same time, control algorithms will have to evolve during the lifetime of a controller.

Performance gains for future controllers will come from exploiting parallel mechanisms, while hiding the complexity from control application engineers.

Patches against newly discovered security threats will constantly be issued and need to be integrated quickly into the control system. The research question is thus: Can we build control systems that are both flexible and deterministic? Early research results show that we can [4]. Using novel software architectures it will be possible to reconfigure control systems at runtime and adapt them to changing environments. Think controller migration with zero downtime. Think up-to-date software every day. Think control systems that easily adapt to your changing needs.

### Challenge: Sequential algorithms

Control algorithms such as PID (proportional–integral–derivative) or MPC (model-predictive control) are described by mathematical formulas. In the past decades, researchers have devoted significant effort into developing and optimizing implementations for these algorithms. Thanks to these efforts, even computationally complex algorithms such as MPC can be executed at a microsecond time scale in today's systems.

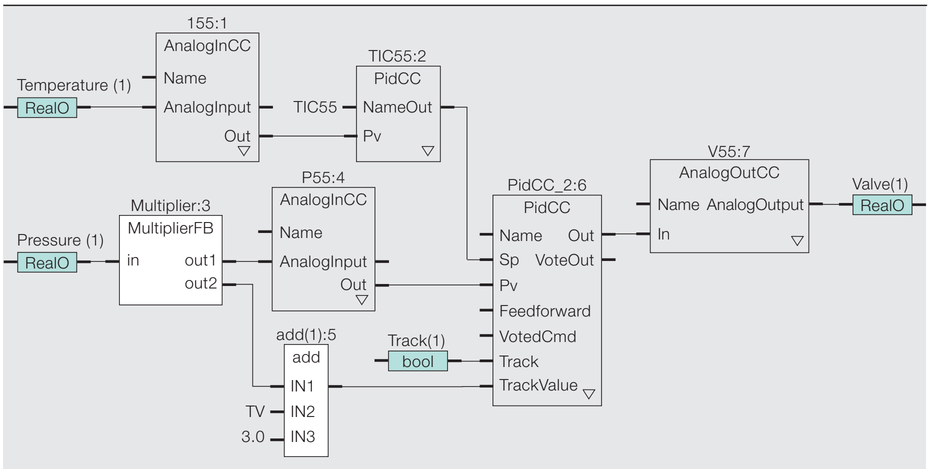
Further improvements to control algorithms will necessarily come through parallelization. The challenges are clear: what parts of the algorithms that have always been executed in a sequential way can be executed in parallel? How can we optimize data access for parallel branches of the code? ABB control theory scientists are collaborating intensively with ABB computer scientists to provide high-performance parallel implementations of control algorithms [5].

### Opportunities

The good news is that the solutions to these challenges give rise to new opportunities for future controllers:

– Hardware consolidation allows one to combine functionality on the same piece of hardware. Current practice is to use dedicated controllers for specific functional requirements.
 Using the increased flexibility offered by future controllers it will become possible

3 Example control application with parallel branches




By employing a software architecture and execution framework for cyclic control applications, the construction of real-time control systems can be simplified, while increasing predictability and reducing runtime overhead and coupling.

to place broad sets of functionality on the same physical device. This development will reduce the cost of control systems.

– Multi-core processors can provide more computation power than current single-core processors at significantly lower clock rates. They are easier to cool and thus, high-performance controllers will fit into small form factors.
– Integrated safety and software-based fault tolerance also contribute to hardware consolidation by using hypervisor and related isolation technologies offered by state-of-the-art CPUs. Using smart deployments, ABB scientists are working on achieving equal or even higher levels of safety and fault tolerance with the same or less amounts of hardware.
– High levels of cyber security can be supported by using some of the multi-core processing power for signing and/or encrypting network communication or other concurrent security checking activities. This is enabling technology for advanced features such as remote operations or DCSs. The importance of cyber security for industrial control systems is highlighted in another article in this issue of ABB Review [6].
– Additional functionality can be provided by the unlocked performance of parallel controllers. For instance, instead of time-consuming offline data analysis, data can be analyzed in real-time while control algorithms are executed. This will help optimize process efficiency as well as equipment longevity due to improved monitoring for predictive maintenance. Additional computation power offered by multi-core CPUs can also be used to increase the accuracy of control algorithms (eg, model-predictive control).

## Summary

Software is the key to unlocking the inherent performance promise of multi-core CPUs. By moving away from hardware-centric evolution, it is possible to overcome future bottlenecks and to build controllers that scale with the ever-increasing demands of our customer's applications.

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# Bridging customer needs

## A movable bridge application arises out of embedded control programs in ABB low-voltage drives

**MIKAEL HOLMBERG – Embedded control programs installed in ABB industrial drives provide a cost-efficient and application-specific solution for many of the most common drive applications. From ubiquitous pumps and fans, to more specialized applications like cranes and winches, the embedded control programs ensure that the drives not only speak the right language, but that they are delivered with the built-in functionality that is required to meet the most common customer requirements. These applications are designed and built using ABB's many years of experience of working with customers across a wide range of control applications. Sometimes, embedded control programs can themselves become the basis for new control solutions. This was the case when ABB was asked to provide a solution for a bridge control system.**

Movable bridges share many common control requirements with materials handling applications like cranes and winches. Therefore, ABB's existing crane control program offered the ideal starting point.

Developed for the ACS800 ➔ 1 industrial drives, the crane control program provides step-less speed and torque control for the hoist, trolley and long-travel movements. This is used on:
- Industrial cranes, mainly electrical overhead travelling (EOT) cranes ➔ 2
- Harbor cranes ➔ 3
- Construction/tower cranes
- Marine and deck cranes

The drives with the crane control program can work in either standalone or master-follower mode. In standalone mode, the drive is used simply for independent control of the crane movements. In a master-follower arrangement, several drives are interlinked, with one of the drives operating as the master to the other drives. This allows coordination and load sharing for different types of motors connected to the same system. This configuration can be used in speed-speed, speed-torque or speed-synchro mode.

**Title picture**
A typical movable bridge which benefits from AC drives used with the bridge control system.

Embedded control programs installed in ABB industrial drives provide a cost-efficient and application-specific solution for many of the most common drive applications.

1 ABB's ACS800 low voltage industrial drives

The functional programming provides the capability to switch between master, follower or standby mode. This ensures that the master and follower are not fixed, but can be changed at will simply by providing each drive with a selection switch. This provides a high level of redundancy for the crane application.

## Anti-sway control

Complementing the crane control program, the anti-sway control program for indoor cranes using ABB industrial drives provides a built-in solution to prevent load sway. This program estimates the time constant of the hoist by continually measuring its position and load properties, and factors in the swing velocity and angle to calculate the compensating speed reference for the long travel and trolley movements of the crane. Because the embedded anti-sway program calculates the sway, no external sensors are needed. Reducing the part count for an effective solution is an added customer benefit.

## Using crane control as the basis for winch control

Marine winches have many similarities to cranes when it comes to their drive control requirements. ACS800 industrial drives with marine certification provided the ideal hardware platform, and the crane control program was the perfect starting point, for the creation of a winch control program. These incorporate all the functions usually required for winch applications. The control program is commonly used on anchor winches, mooring winches (auto-mooring), roll-on, roll-off gate ramp winches, towing winches and research winches → 4.

The winch control program provides built-in features that replace traditional, costly hydraulic winch control systems. This eliminates high maintenance costs and performance inefficiencies, while improving operator safety and overall system reliability. The drive itself replaces contactors and other low voltage products used to bring winch motors direct-on-line, instead ramping the motor smoothly to the correct speed/torque. This reduces the impact on the ship's electrical network during winch operation.

The anchor control function provides a perfect example of the winch control program's built-in protection functions. These include slip detection, which detects any high load on the chain should it become snagged when raising the anchor. Such a high load creates a speed difference between the winch drum and the motor shaft and activates a load switch. The speed/torque of the winch motor is immediately reduced to a level set by the winch manufacturer. This prevents damage to the motor shaft, winch drum or clutch between the drum and motor.

## Torque control, the common requirement

All these embedded crane and winch control drive applications must fulfil one common requirement – very precise and powerful torque control. The key to the success of the control programs in ABB's

2 Waste handling crane

Built-in application software provides customers with solutions designed to the requirements of many different installations while speaking the language of their specific application.

industrial drives is the patented direct torque control (DTC) motor control platform → 5. This delivers the performance levels and protection functions demanded by materials handling applications.

In contrast to the way that conventional AC drives control input frequency and voltage, DTC uses motor flux and torque as primary control variables. This allows accurate control of speed and torque with or without pulse encoder feedback from the motor shaft. A key benefit of DTC is that it enables the drive to achieve full torque at zero speed without the need for a feedback encoder. Using a feedback encoder can be a problem on board a vessel as the harsh climate on deck can often damage the encoder itself or interfere with the feedback signal to the motors.

Furthermore, DTC offers an exceptionally fast response time of 25 microseconds in the control loop between the application (eg, crane or winch) and the motor control embedded in the drive. This is approximately 10 times faster than the typical response time possible through conventional flux vector control.

DTC's ability to work with a wide range of motors helps reduce retrofit costs when upgrading from older control methods. For example, when retrofitting a three-speed/three-winding marine winch with an ABB industrial drive, the existing motor can still be used, and the drive will use only one of the three motor windings. This significantly reduces upgrade costs and downtime.

Embedded software comes with the benefits of adaptive programming which enables the user to integrate external control logic, create new functions or to modify existing logic.

DTC, in combination with the embedded control programs, enables the customer to specify a single product with the control solution built-in. No other control components are required, saving on overall systems costs as well as increasing reliability by reducing the number of possible failure points.

### DTC: Heart of the movable bridge control system

Building on the extensive experience gained from the crane and winch control programs, ABB developed a movable bridge control application featuring ABB industrial drives. These drives feed power to the electric motors which drive the span or deck of the bridge and control the bridge's mechanical disk or drum brakes.

DTC, in combination with the embedded control programs, enables the customer to specify a single product with the control solution built-in, saving on overall systems costs as well as increasing reliability by reducing the number of possible failure points.

3 Harbor grab crane

They are increasingly being used on a variety of movable bridges, either as part of a new build or in a refurbishment or renovation program and tend to replace hydraulic drives or DC drives operating with DC motors.

The drives provide step-less, variable speed and torque control for the electric motors that are used to either lift or turn the deck around its axis, over a wide range of operating speeds and loading. They can positively control the speed of an AC motor when the motor is being driven, or back-driven or overhauled, such as when a span heavy bascule or vertical lift bridge is being lowered. The control program, along with DTC, ensures accurate control of speed and torque with or without pulse encoder feedback from the motor shaft. It provides the accurate slow speed control with high torque levels essential for bridge applications.

## Bridge control applications

In a movable bridge, when several drives are connected to the same system, the master-follower drive arrangement can be used. It enables coordination and load sharing for different kinds of motors operating within the system. However, other movable bridge applications require synchronized lifting. Within bridge applications there are two common master-follower control methods.

### Follower in torque control mode

If two motors are connected to each other via a mechanical shaft, for instance when two motors are lifting opposite sides of a bridge at the same time, then the master drive is speed controlled. This determines how fast the bridge raises or lowers. The follower is torque controlled which results in the load being shared exactly between the master and follower.

### Follower in synchro control mode

If two motors are not connected to each other, such as when the bridge is designed for each motor to work independently in raising or lowering the bridge, yet at the same time, then the master is speed controlled. This determines how fast the bridge raises or lowers. In this instance, the follower is operated in synchro mode to enable symmetrical lifting. This means that the two parts of the bridge are synchronized to lift at the same time and at the same angle.

### Symmetrical lifting with synchro control

Often the drives on either side of the bridge need to be perfectly synchronized when raising the bridge. To ensure the required level of accuracy, a standard incremental encoder can be used to feedback the deck position with respect to each variable speed drive. The encoder is essential in synchronizing the drive, based on the position of the master as measured by the encoder. The synchro control routine, built into the drive's bridge control program, works together

4 Winch – ropes from the dock

5 Direct torque control (DTC)

Direct torque control – or DTC – is the most advanced AC drive technology and has replaced traditional open- and closed loop type pulse-width modulation (PWM) drives. It is called direct torque control because it describes the way in which the control of torque and speed are directly based on the electromagnetic state of the motor but is contrary to the way in which traditional PWM drives use input frequency and voltage. DTC is the first technology to control the "real" motor control variables of torque and flux. Because these parameters are directly controlled, there is no need for a modulator – as used in PWM drives – to control the frequency and voltage. This in turn dramatically speeds up the response of the drive to changes in required torque. DTC also provides precise torque control without the need for a feedback device.

with DTC to provide the required level of synchronization. Synchro control can be used on a system with one master and up to four followers.

### Electric motor mechanical brake control and torque memory

The bridge control program also features an integrated brake control logic that, in turn, utilizes torque memory and pre-magnetizing to open and close the mechanical brake safely and reliably. The mechanical brake may be inside the motor (disk brake) or outside the brake (drum brake). Alternatively, both can be used at the same time for additional safety. The brake control logic within the drive includes a function that enables the drive to hold the shaft stationary until the mechanical brake takes over. The "slow down" safety control function limits the speed to a preset level in critical zones. High and low limit sensors stop the drive at the end positions. The "fast stop" safety control function is used in emergency situations.

### Speed monitor and speed matching

The speed monitor function ensures that the motor speed remains within safe limits to prevent overspeed. The speed matching function continuously compares the speed reference and the actual motor shaft speed to detect any possible difference. One of these functions will stop the motor immediately if a fault should occur in the operation of the motor.

### Dedicated, application specific software

Embedded software works together with the advanced DTC platform in ABB's industrial drives to offer significant performance advantages and precise control for a variety of materials handling applications. Not only does it enable many crane and winch control applications to be up and running virtually 'out of the box' it also comes with the benefits of adaptive programming (AP). This enables the user to integrate external control logic, to create new functions or to modify existing logic – for example to enable variable ramp timing during the bridge opening cycle.

Built-in application software provides customers with solutions designed to incorporate the requirements of many different installations while speaking the language of their specific application. The control program's extensive built-in functionality provides a cost effective solution for customers who are aiming to minimize their use of external discrete components. Through working in close cooperation with customers, listening to their needs and moving in anticipation of market trends, ABB will continue to lead the development of embedded control programs for industrial drives.

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# IT/OT convergence

## How their coming together increases distribution system performance

**TIM TAYLOR – Historically, information technology and operational technology have developed along separate paths, with separate goals, operating in separate arenas, living separate lives, so to speak. Now there is much to be gained by marrying, aligning and integrating the work that goes on in both. IT/OT integration is happening across numerous sectors and industries. With the increasing sophistication and application of smart grid technologies in the electrical distribution industry, IT applications can now work in tandem with OT applications to increase distribution system performance. Over the last several years ABB has established a leadership position in integrated IT/OT for distribution management. Distribution organizations are now applying integrated ABB solutions to increase organizational performance, enhance system efficiency and reliability, and improve customer satisfaction.**

**Title picture**
IT applications now work in tandem with OT applications to increase electrical distribution performance.

With practical examples at many distribution organizations, IT/OT convergence is not entirely new. But now there are strong technology and business reasons driving increased distribution IT/OT convergence.

### Defining IT and OT

While there are no industry-standard definitions of IT and OT in the electric power industry, it is possible to delineate the two ➔ 1 – 2. OT is typically associated with field-based devices connected to the distribution system, and the infrastructure for monitoring and controlling those devices. This includes control center based systems such as Supervisory Control and Data Acquisition (SCADA) and Distribution Management Systems (DMS). Most communications are performed device-to-device, or device-to-computer, with relatively little human interaction. IT is traditionally associated with back-office information systems used for conducting business-type transactions, such as cost and tax accounting, billing and revenue collection, asset tracking and depreciation, human resource records and time-keeping, and customer records. Manual data entry is often involved, and the computing resources have tended to be centered in offices, server rooms and corporate data centers.

### Technical development

Electric distribution systems have been set up with some degree of OT intelligence for a long time, in that local equipment controls have long been applied to voltage regulators, LTCs (load tap changers), capacitor bank switches, reclosers, sectionalizers, load-break switches and even electromechanical relays as local intelligence. Yet IT and OT systems are becoming increasingly more sophisticated, and the level of OT data for electrical distribution organizations continues to increase as more intelligent devices and communications are added to the grid ➔ 3.

> Electric distribution systems have been set up with some degree of OT intelligence for a long time.

## 1 IT and OT software applications

**Information Technologies** are mostly software applications for commercial decision making, planning, business processes management and resource allocation. Applications include, among others:

- Enterprise Resource Planning (ERP)
  For managing financial and human resources, materials and assets.
- Enterprise Asset Management (EAM)
  For supply chain, inventory management, work and asset management.
- Mobile Workforce Management (MWFM)
  For managing mobile field crews, mapping, work scheduling and optimization.
- Customer Information Systems (CIS)
  For managing customer data, metering data, settlements and invoicing.
- Energy Portfolio Management (EPM)
  For energy planning, portfolio optimization, scheduling, energy trading and risk management, market analysis, retail management, price and load forecasting, ISO bidding, settlements and post analysis.
- Demand Response Management System (DRMS)
  For managing demand response programs and virtual power plants.
- Advanced Metering Infrastructure (AMI)
  For gathering and managing metering data (interval and non interval). Includes remote reading, and possibly remote control.

**Operation Technologies** include software applications that provide operational control of assets in the electric network in real time (or near real time). Applications include, among others:

- Supervisory Control and Data Acquisition (SCADA)
  For real time data acquisition.
- Distribution Management Systems (DMS)
  For managing and control of distribution networks. Includes advanced applications such as Fault Location, Isolation and Restoration, Volt/Var Optimization, State Estimation, Outage Management Systems (OMS), etc.
- Energy Management Systems (EMS)
  For managing and control of transmission systems.
- Geographic Information Systems (GIS)
  For mapping and geographic information.

For example, the amount of OT equipment with sensing, data processing, control, and communications on feeders is increasing. The installation of separate SCADA systems for distribution, or the extension of transmission system SCADA to distribution, has become common. Advanced DMS network applications, which are often implemented in conjunction with new outage management systems (OMSs), are being performed. More organizations are using advanced metering infrastructure (AMI) data in their outage management and for providing loading information to operations. The evolution of IT for electric distribution includes IP-based LAN and WAN networks, integrated enterprise resource systems, continued adoption of geospatial technologies, server virtualization, some implementations of cloud-based systems, and mobile technologies. The complexity of these developments demands, and also allows for, the convergence of the two technologies.

> Potential benefits include the conversion of unplanned outages into planned outages.

This recent implementation of all these IT and OT systems in distribution organizations presents a large organizational improvement opportunity which is to date largely untapped. By eliminating silos which exist between IT and OT organizations can enable data sharing that will improve system performance, reduce costs and improve customer satisfaction.

### Total distribution management

Ventyx, a company recently acquired by ABB, has developed the total distribution management concept that is based on the recent developments in IT/OT convergence ➔ 4. Total distribution management combines real-time and near-real-time data, system modeling, visualization, simulation, and integration to all major systems used in distribution operations, to provide a new platform for managing and operating electric distribution systems.

The operational technologies include intelligent electronic devices (IEDs), remote terminal units (RTUs), meters, and other field equipment that communicates back to the control center. While revenue meters typically use AMI communications infrastructure, the other devices use the SCADA communications infrastructure. A single network model of the system, which explicitly represents the system connectivity and electrical characteristics, is shared across

**2 Differentiating information technology and operational technology**

| | Information Technology (IT) | Operational Technology (OT) |
|---|---|---|
| Purpose | Transaction processing | Asset monitoring and control |
| | Systems analysis and applications | Process control, metering, and protection |
| | Technical and business analytics | Device-to-device communications |
| | Human decision support | Server-to-device communications |
| Operating environment | Corporate data centers | Substations |
| | Officers and server rooms | Field equipment |
| | Control centers | Control centers |
| Input data | Manual data entry | Transducers and sensors via RTU's and PLC's |
| | Other IT systems | IED's, relays, and meters |
| | Data from OT systems | Operator inputs and other OT systems |
| Output | Data summaries | Device control actions |
| | Results of analysis and calculations | Displays of status and alarms |
| | Commands issued to other OT systems | Operating logs |
| Owners | CIO and IT departments | Operations and engineering managers |
| | Finance | Line of business managers |
| | Operations (OMS, DMS, EMS) | Maintenance departments |
| Connectivity | Corporate network | Process control protocols |
| | IP-based | IP-based, serial, hardwired analog and digital |

both the outage management system (OMS) and the advanced DMS applications. The integrated SCADA, OMS, and DMS are interfaced to the other IT systems. An advanced business intelligence system, developed specifically for electric distribution organizations, connects to all the systems and provides meaningful analytics and information, tailored for the different individuals internal and external to the organization → 5.

### Distribution system impacts

A model-based volt/var optimization (VVO) application has recently been introduced as an application in Ventyx's Network Manager DMS. The VVO application continuously monitors the distribution network and computes the optimal distribution control settings to minimize an objective function of MW demand, MW energy loss, or both MW demand and MW energy loss, subject to voltage/current violations in three-phase, unbalanced and meshed distribution systems. VVO computes the optimal control settings for switchable capacitors and tap changers of voltage regulating transformers. (ABB's activities in voltage/var are more fully described on page 44.) The optimized system condition is based on the current load flow solution that is performed on the system model. The VVO application then transmits the required control actions to the OT devices, such as capacitor switch status or voltage regulator tap position. For the distribution organization, the benefits can include a reduction in the amount of generation capacity that must be built or bought on the market, and a reduction in the real energy losses on the system.

Another example of how DMS OT applications are utilizing the GIS (geographic information system) network models, adapted for as-operated network conditions, is the FLISR (fault location, isolation, and service restoration) application. The FLISR application uses inputs such as fault current, faulted circuit indicator status, and breaker/switch status, along with the electrical network model, to determine the optimal switching plan to isolate a fault and restore service quickly to as many customers as possible. Unbalanced load flow calculations using the network model are performed to determine if any thermal or voltage violations will be produced for the possible switching plans. Once the optimal switching plan has been chosen, the appropriate control actions can be transmitted to the field devices through SCADA communications. Benefits for the distribution organization include improved reliability performance and higher customer satisfaction.

### Impacting workforce

There is an increasing trend to use data from OT systems, like automation and SCADA systems, in combination with IT systems for workforce process efficiency

By eliminating silos which exist between IT and OT organizations can enable data sharing that will enable system performance.

### 3 Technological developments enhancing IT/OT convergence

**A range of technology developments in the following areas are helping to advance the coming together of IT and OT systems in distribution organizations:**

**Remote data collection and communications**
The cost to collect and transmit operational data continues to lower. More cost-effective, wider bandwidth communications between the control center and remote field devices, such as gigabit backbones and wireless Ethernet radios, provides the data communications back to the organization's IT. Networks installed for AMI, which have not typically been broadband, are also being leveraged for operational monitoring, and even control, in some cases.

**Standard IT architectures**
Certain operational technologies, such as SCADA, DMS, and OMS, have been using standard IT platforms for some time, including Linux- and Windows-based software running in IP-enabled networks. This enables IT organizations to economically manage these resources, since such systems can be configured and monitored with standard network management resources. Chip capacity and higher disk and network capacity continue to lower costs throughout the OT and IT domains, providing the economic, high-scale computing capacity needed for increased distribution automation and advanced data analytics.

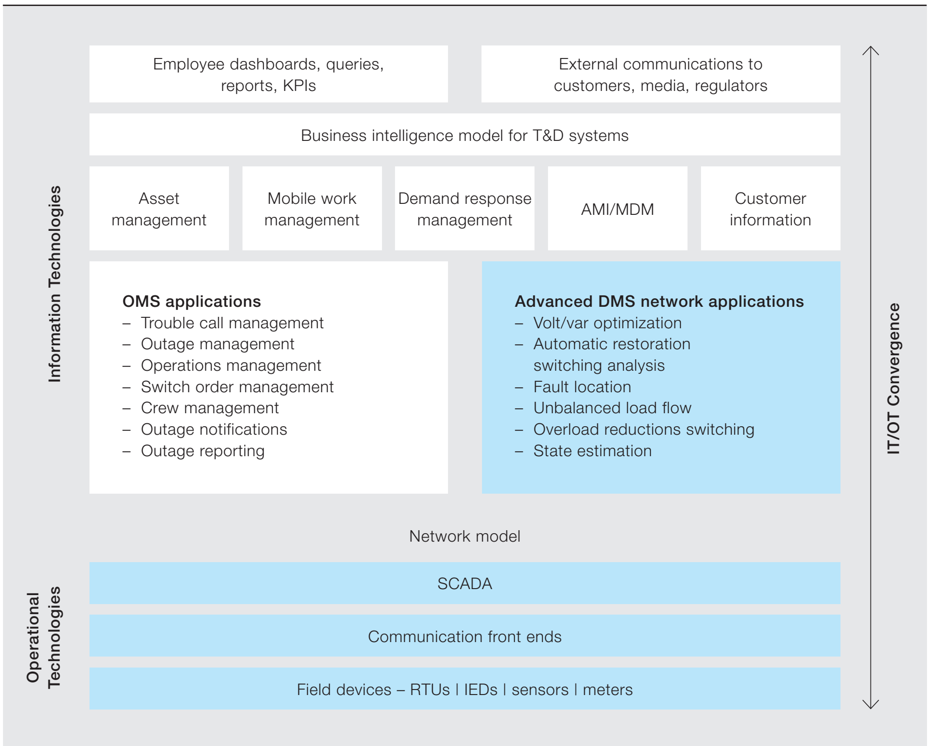
**Applications integration**
Technologies available for system integration have evolved substantially. Real-time publish/subscribe messaging middleware has made it possible to apply some of the principles of enterprise application integration (EAI) to distribution operations. Presently the trend for linking many IT and OT applications is the development of Web services in a service-oriented architecture, although a hybrid system architecture in which other interfaces, such as point-to-point, will be economic for particular applications. Application integration technologies continue to advance, further facilitating IT/OT convergence.

**Data modeling and integration**
Interoperability standards, which are developed by numerous bodies including IEC and IEEE, are starting to be employed. This includes IEC 61968, the Common Information Model (CIM) for distribution management. CIM will cover various aspects of distribution operations, AMI, distributed energy resources, and demand response. The maturation of such standards is crucial to facilitating further IT/OT convergence.

**Mobile computing and data access**
Extending, inspecting, operating, and maintaining a distributed asset infrastructure means that many distribution work processes are field-based. The escalation in mobile computing, data access, and even digital photography and video will result in substantial changes to distribution activities such as switching, inspections, design, situational awareness, equipment operating history, damage assessment, field resource optimization, and inventory tracking. Field crews will have much more access to operational data, some of which will be in near-real-time.

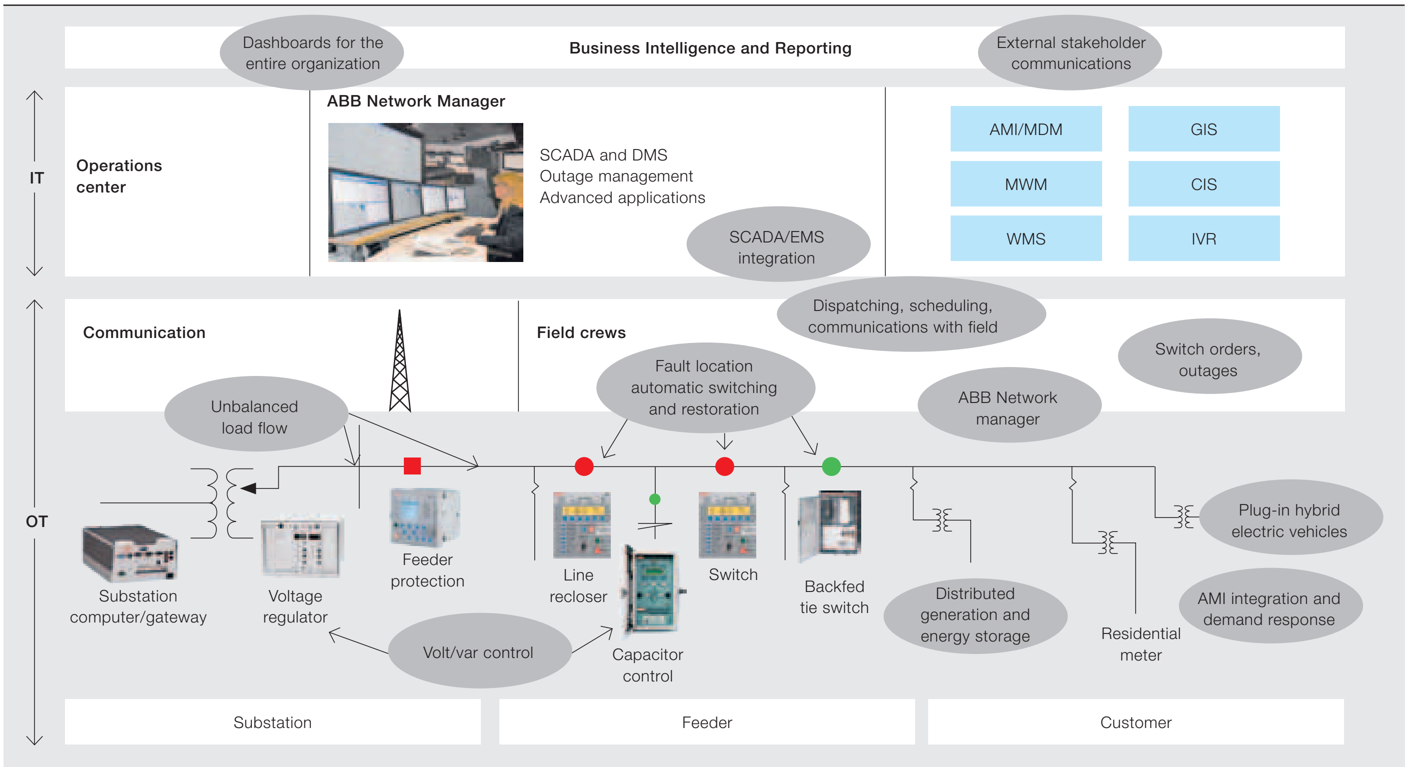
IT/OT convergence enables distribution organizations to keep external stakeholders better informed about their electric service.

### 4 How typical distribution processes cross over different IT and OT systems




improvements and better decision-making. One example is the process of using a DMS to locate faults that have caused protective devices, such as circuit breakers, to trip. Fault data, including magnitude, affected phases, and type of fault, is extracted from the relay or RTU and sent to the DMS. The DMS uses this data to estimate the location of the fault on the system, and provides this information to the control room operator or dispatcher within minutes. The dispatcher then informs the crew of the approximate fault location. The result is quicker restoration times and improved system reliability metrics. In this case, the data fed to the

5 IT and OT systems used in an electric distribution system




**The applications indicated in the bubbles are made possible by IT/OT integration.**

DMS system is then processed, enabling the operator and crew to perform their jobs more efficiently.

Data from various OT systems can also be sent to the back office IT systems, such as a business intelligence tool or enterprise asset management (EAM) system, to make better decisions related to longer-term asset management processes. Increasingly, OT data is being analyzed with data mining, pattern recognition, and statistical analysis. Data from sensors and online monitoring equipment, which can include temperature, pressure, historic equipment loading, duration and frequency of short-circuits and through-faults, number of operations, and other OT quantities, can all be used in the IT environment by asset managers to make better decisions about maintenance programs and asset replacement. Potential benefits include the conversion of unplanned outages into planned outages (if economically practical to do so), reduction in the number of catastrophic outages and better allocation of capital and maintenance budgets.

An increasing trend is also the application of business intelligence software (ie, IT) that can extract data from OMS, WMS, SCADA, and other OT systems to provide information dashboards and querying capabilities for the entire workforce. The dashboards, which are now available as cost-effective out-of-the-box solutions, can be customized to the specific job function in the organizations; ie, different dashboards can be created for operations, for customer service representatives, for senior management, etc. Users can drill down and drill across data to get more details. Improved situational awareness results, providing the workforce with the right information at the right time, in order to make the right decision.

## Smarter stakeholders

IT/OT convergence is enabling distribution organizations to keep their external stakeholders better informed about their electric service. External stakeholders include customers, government officials, regulators, and others with an interest in the electric distribution system performance. Such information can be related to service outages, power pricing as a function of time or usage, special offers and programs, as well as other information about its electric power service that a distribution organization wishes or needs to share.

A common example is outage maps placed on the utility website that show number of outages, number of customers out, and the general locations of outages. Based on forecasted network loading (of which past and present loads, collected from OT systems, are a key determinant), distribution organizations or power retailers can let customers know if a demand response event, in which power suppliers request customers to reduce demand, either directly through messaging or control signals, or indirectly through pricing, will be held that day. Information portals between utilities and other external stakeholders, such as public safety, regulators and local government officials, are becoming more common.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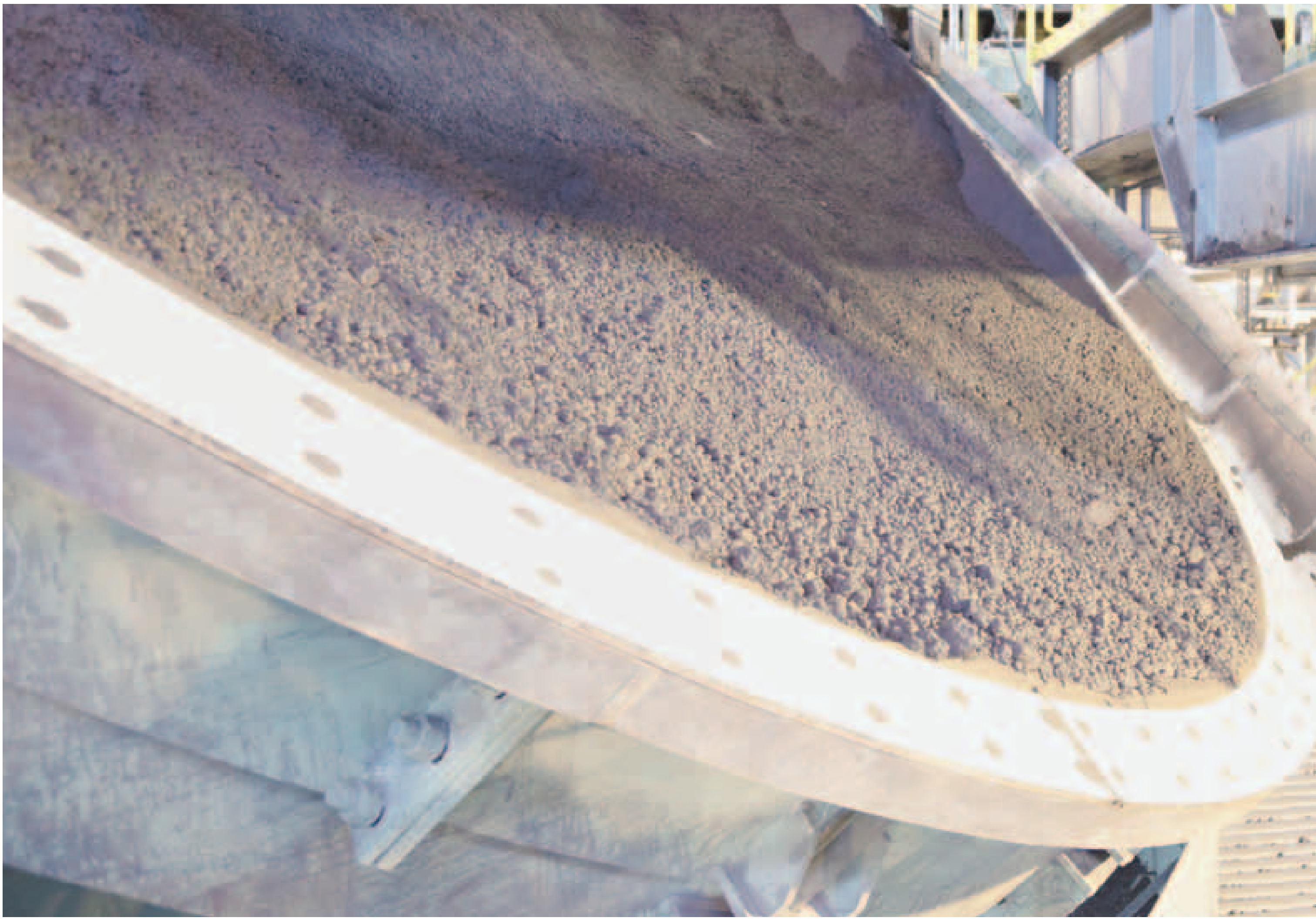


# A capital asset

## The PAS 55 specification and enterprise asset management

GORDON J MELVIN, JOHN BENDERS – Many of ABB's clients are involved in asset-intensive industries like mining, energy, public infrastructure and transportation. A holistic, efficient and whole-life approach to the management of physical assets is vital to be able to manage costs and risk and align operations with business strategy. In addition, asset and maintenance managers are increasingly required to report on performance against key indicators such as asset utilization, risk and return on assets. These metrics are critical in understanding the overall health of an asset-intensive organization and they rely on current and accurate asset information. Known as PAS 55, the publically available specification (PAS): 55-1:2008 asset management standard is rapidly being accepted worldwide as good-practice guidance for optimizing asset management systems and processes and reducing risks to people, the environment and the business. Ventyx Ellipse is a fully integrated enterprise asset management solution that is aligned with PAS 55.

The PAS 55 asset management specification is rapidly being accepted worldwide as good practice for optimizing asset management systems.

The consequences of an out-of-date or inaccurate asset register can be catastrophic. Consider the real-life example of an air breaker failure in a substation: If these failures are not recorded in the asset register, there is no way to track and maintain the breakers to prevent future occurrences. When a company that suffered a fatality due to a breaker failure addressed this issue, it discovered more than 10,000 unregistered air breakers. This unfortunate case involves just one asset type in one business area; across asset intensive industries almost every company has a significant register of assets that have to be tracked, evaluated, risk estimated, costed, audited and so on. Not surprisingly, in the past, each company had its own idea as to how best to manage their assets – there was no industry standard to drive harmonization. Now, with the advent of the PAS 55 specification, all that changes.

**Title picture**
The PAS 55 specification brings harmonization to enterprise asset management in a wide range of industries, including the mining operation shown here. How do the enterprise asset management products offered by Ventyx, an ABB company, align with the specification?

## PAS 55

Industry experts at the UK-based Institute of Asset Management, in collaboration with the British Standards Institute (BSI), developed PAS 55 as a guide to optimizing asset management efficiency. First published in 2004 and revised in 2008, PAS 55 provides clear definitions and a requirements specification for establishing and verifying a comprehensive, optimized management system for all types of physical assets throughout their life cycle → 1. Similar in approach to the ISO 9000 series specifications, PAS 55 is non-prescriptive and outcome-based; it describes what to do, not how to do it.

Now internationally recognized, PAS 55 is proving to be an essential, objective definition of what is required to demonstrate competence in asset management, establish improvement priorities and make clearer connections between strategic organizational plans and the day-to-day realities of asset and work management. PAS 55 is expected to develop into ISO standards (ISO 55000, ISO 55001 and ISO 55002) this year.

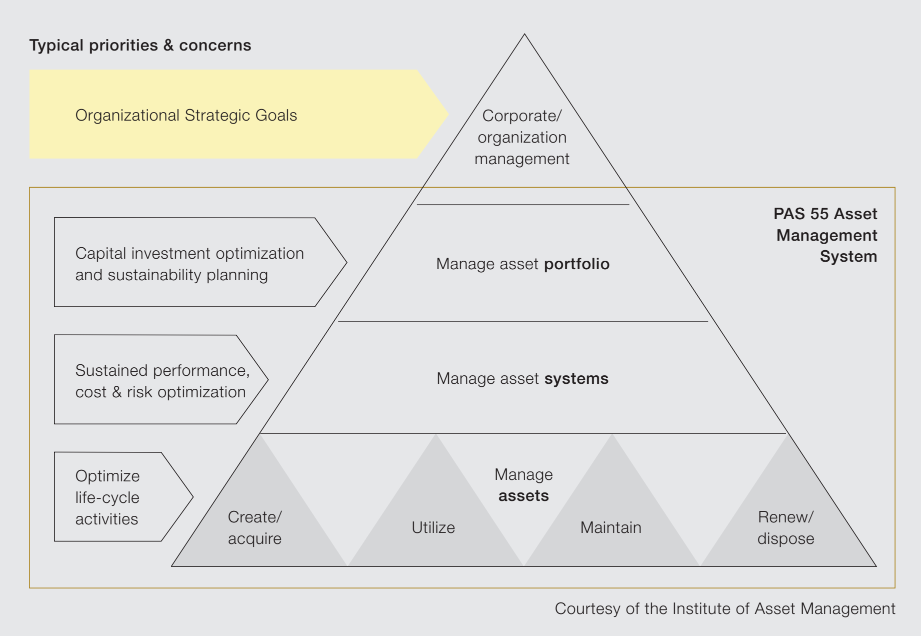
This introduction to PAS 55 and some key aspects of asset management also describes how the Ventyx Ellipse enterprise asset management (EAM) solution has been developed specifically to align with PAS 55 and to support a PAS-55-compliant asset management lifecycle approach for asset-intensive businesses.

## Challenges and opportunities

To manage cost and risk and align operations with business strategy, organizations must be able to answer fundamental questions about their assets, such as:
- What assets do we have and what condition are they in? What function do they perform and does this function contribute value?
- Do we have appropriate capacity?

Ellipse will become a PAS-55-compliant application as soon as compliance can be certified.

1 PAS 55 overview




A reliable and comprehensive asset register is central to all asset management activities.

Are some assets redundant, underutilized, unprofitable or burdensomely expensive?

- Are the risks of our assets causing harm to people or the environment sufficiently low
- Can we accurately evaluate the performance, risk reduction, compliance and sustainability benefits of proposed asset work or investments and, likewise, the impact of delaying or not performing the proposed actions?
- Can we confidently address these lines of inquiry and provide answers to stakeholders with a clear audit trail and reliable data?

PAS 55 can help address these questions.

**What assets does the company have?**

A reliable and comprehensive asset register is central to all asset management activities. It should provide information on asset location, condition, failure risk, depreciation and replacement → 2.

While this may seem basic, obstacles can emerge if the list is not comprehensive:

- Inadequate record-keeping. Many mining companies, for example, lack adequately detailed records of their electrical and ventilation systems, despite having thousands of meters of them in the field.
- Age. Organizations responsible for public infrastructure often have assets dating back as far as 70 years – long before computerized asset tracking. This can mean searching potentially out-of-date and inaccurate paper records, if they exist.
- Disconnected silos of information. Transportation companies may operate multiple networks – due to geography, type of operation, or through merger and acquisition. Often these employ different systems and processes, so getting a single view of assets, their condition, and how they are being maintained can be difficult.

The PAS 55 specification helps ensure assets are accurately and comprehensively recorded in the asset registry. Automating the underlying foundation of this process calls for an EAM system with built-in business processes that accommodate the PAS 55 framework.

**Risk of an asset-related disaster**

Determining the level of risk associated with an asset-related failure is of the ut-

2 A comprehensive asset register is essential especially when there are many spread-out assets.

Since the introduction of PAS 55, Ventyx has made alignment with this specification a core development priority.

Determining the level of risk associated with an asset-related failure is of the outmost importance.

most importance. Asset failure can mean substantial financial costs from lost revenue, personal injury, equipment damage and environmental harm. How should maintenance be prioritized and scheduled to mitigate risk?

Understanding the risk and criticality of assets is a central theme of PAS 55 that the EAM system must account for. By applying the PAS 55 framework, consistency of processes deployed across sites can be improved and global operations tailored to ensure risk of disaster is minimized.

**Current condition of critical assets**

When critical assets are not running, the company is not making money from them. And assets are often spread across a wide geographic area, making it difficult to get an overview of their condition. To combat this, PAS 55 delivers a comprehensive framework for evaluating asset condition – taking historical inspections, repairs and maintenance into consideration.

**Corrective versus preventive maintenance**

The financial implications of corrective versus preventive maintenance strategies can be substantial:

- Cost of maintenance. A general rule of thumb is that reactive work is two to three times more expensive than proactive work.
- Cost of part failure. The cost of replacing a failed part is often significantly higher than the cost of proactively maintaining it.
- Cost of an outage. Unplanned failure of an asset may lead to longer downtime and more lost production than a planned replacement shutdown would have done.

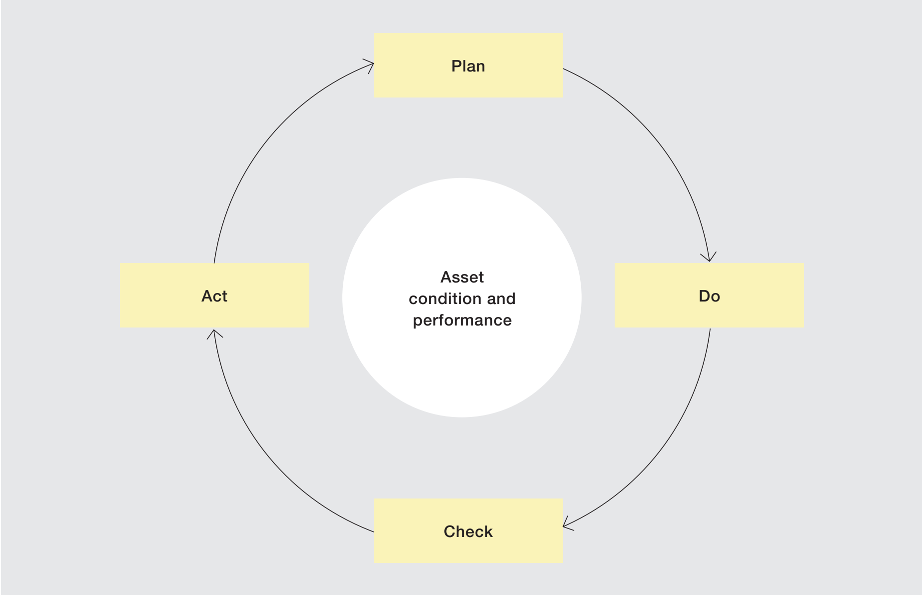
The correct application of asset maintenance strategies can ensure overall costs are minimized while operational effectiveness is maximized. Asset management based on a PAS 55 framework assists with this. The systematic collection of quality data enables corrective (or reactive) maintenance costs to be identified and compared with preventive (or proactive and predictive) maintenance costs. This informs decisions within maintenance programs and effectively balances the risk of asset failure against the overheads of preventive maintenance.

**Assets – repair or replace?**

Decisions on whether to maintain or replace equipment call for detailed asset records, including historical and compar-

When critical assets are not running, the company is not making money from them.

3 The plan-do-check-act cycle for continuous improvement




ative data – as well as an EAM solution designed to support the recommended best practices of PAS 55.

When it is properly maintained, an asset's life can be extended – significantly increasing the return on capital invested. The EAM system should include all the functionality required to manage replacement or refurbishment options over an extended time.

PAS 55 helps define the information that is required – and smart enterprise software simplifies maintenance of equipment using templates and processes specific to the precise operating conditions faced by the miner, steelmaker, railway operator, etc.

The financial implications of corrective versus preventative maintenance strategies can be substantial.

## PAS 55: business value

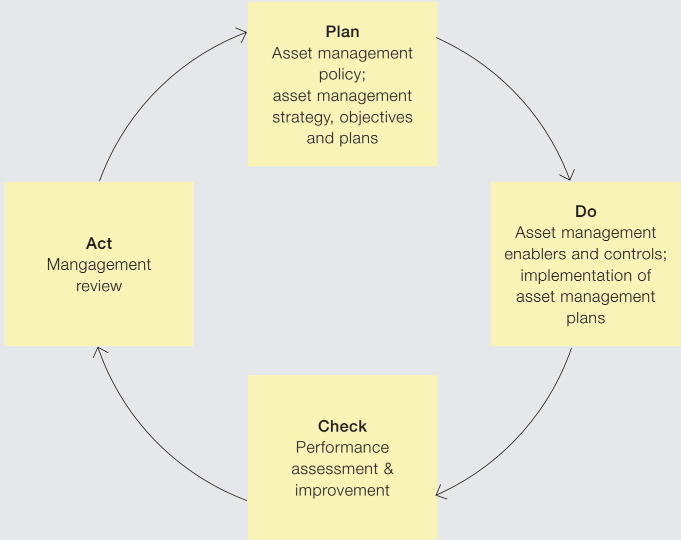
Asset-intensive businesses are well aware of the value of best-practice asset management for reducing costs and risks, and for facilitating regulatory compliance. Nearly every asset-intensive operation is under increasing pressure to control costs and maximize return on assets, while providing high service quality and continuing to protect the safety of employees and the public. Environmentally conscious initiatives are, likewise, growing in importance with regulators, stockholders and consumers.

In contrast to some other standards or specifications, which can sometimes be met simply by generating extensive paperwork, PAS 55 specifically requires evidence of alignment between good intentions and the actual day-to-day activities of capital project implementation, operations, and maintenance. Thus, PAS 55 is a valuable mechanism in ensuring confidence in results and in supporting good governance, long-term planning and sustainable performance.

The ability to demonstrate compliance with PAS 55 not only reduces operational and compliance costs and risks, it also drives competitive advantage through improved service and greater operational proficiency.

Embracing the PAS 55 specification helps asset-intensive businesses to:
- Align the asset management strategy and approach with the overall business strategy
- Improve the integration between asset management and financial management processes
- Maximize return on assets
- Maximize asset uptime
- Foster an organizational culture focused on quality, safety, and continuous improvement

4 The components of the PDCA cycle can be directly applied to asset management by PAS 55




**Plan.**
Establish the asset management strategy, objective and plans needed to deliver results in alignment with the organization's asset management policy and strategic plan.

**Do.**
Establish the enablers for implementing asset management (eg, EAM software) and other essential requirements, such as regulatory requirements. Implement the asset management plan(s).

**Check.**
Monitor and measure results against asset management policy, strategy objectives, regulatory and other requirements. Record and report the results.

**Act.**
Take actions to make sure that asset management objectives are achieved, and to continuously improve the asset management system and asset management performance.

## Applicability of PAS 55

PAS 55 is most relevant to asset-intensive businesses like mining, oil and gas, energy, utilities, and public infrastructure including roads, rail and ports. For these organizations, asset performance is central to the business objective.

Significant investment and ongoing expense and risk are associated with the acquisition, creation, utilization, maintenance, renewal and disposal of asset portfolios in such enterprises. Strong regulatory accountability for the safe management of assets and related services is a further driver for the adoption of PAS 55.

## The PAS 55 approach

Optimal management of assets and related costs, risks and performance requires a pragmatic, life-cycle approach. One needs to determine what assets to build or obtain, how best to maintain and use them, and how best to renew, recondition or dispose of them.

The PAS 55 approach to whole-life asset management is based on the widely used plan-do-check-act (PDCA) cycle for continuous improvement ➔ 3. The components of the PDCA cycle can be directly applied to asset management by PAS 55 ➔ 4.
Key elements that drive the asset management PDCA cycle include:

- An asset management policy to provide direction on how to manage physical assets in line with the organization's goals and objectives and to guide EAM system configuration.
- Asset management strategy, objectives and plans. This enables preemptive defect detection.
- Asset management enablers. This is the organizational structure of roles, responsibilities and authorities that aligns with the asset management policy, strategy, etc. This is essential because accountable people, not policies, bring about sound asset management.

## How Ventyx Ellipse supports PAS 55

Ventyx Ellipse is a fully integrated EAM solution that provides complete visibility and management of enterprise-wide assets to a wide range of industries.

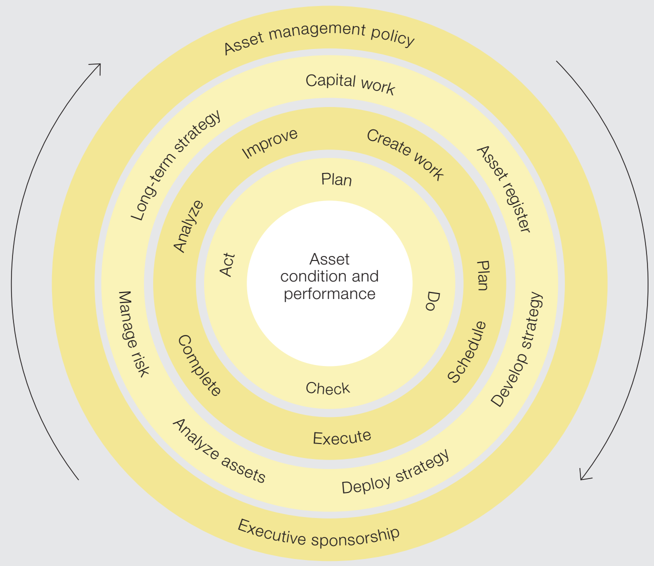
Ellipse has been designed from its inception to support good asset management practice. Since the introduction of PAS 55 in 2004, Ventyx has made alignment with this emerging standard a core development priority. Ongoing Ellipse product development since that time has focused on supplying a fully PAS-55-compliant offering, with all new or redesigned functionality being guided by PAS 55.

PAS-55-compliance starts in the DNA of Ellipse. It has not been achieved merely by mapping feature descriptions to the wording of the specification, but by thoughtfully engineering the product across two major releases with PAS 55 as basic design guidance.

Decisions on whether to maintain or replace call for detailed asset records and an EAM solution that supports PAS 55.

Nearly every asset-intensive operation is under increasing pressure to control costs and maximize return on assets.

5 The Ventyx Ellipse "manage physical assets" process parallels PAS 55.




Ellipse is aligned with PAS 55 most fundamentally in its inherent focus on proactive risk assessment and comprehensive support for corrective and preventive actions, versus the identification and remediation of after-the-fact performance failures. In particular, the Ellipse "manage physical assets" process follows and embodies the PDCA process that is the guiding principle of PAS 55 → 5.

The core functional capabilities of Ellipse align with PAS 55 guidance by enabling asset-intensive businesses to achieve these key PAS 55 mandates:
- Manage risk before it becomes a problem
- Know the condition of every asset
- Standardize the asset registry business process

## Asset futures

PAS 55 provides a clear, internationally recognized definition of what good practice asset management means for any organization. It provides detailed guidance and examples for demonstrating competent governance of critical assets, along with a checklist of good practices in asset life-cycle planning and cost/risk optimization, and an extensive glossary of terms that provides a common language for all stakeholders.

Developed over more than six years with help from over 50 public and private organizations in 10 countries and 15 business sectors, PAS 55 has earned broad, enthusiastic acceptance and is in widespread use. It represents a huge stride forward in the consistent application of asset management techniques. Perhaps most importantly, PAS 55 is driving more realistic and risk-sensitive asset management decisions at boardroom levels.

Since it was first published in 2004, Ventyx has been at the forefront of supporting its customers to align with PAS 55. Ventyx has also applied PAS 55 at the foundation of its EAM software design and development methodology, such that Ventyx Ellipse delivers comprehensive compliance with and support for PAS 55 guidelines today. Ellipse makes it straightforward for asset-intensive businesses to adopt PAS 55 and achieve commensurate benefits in cost and risk reduction.

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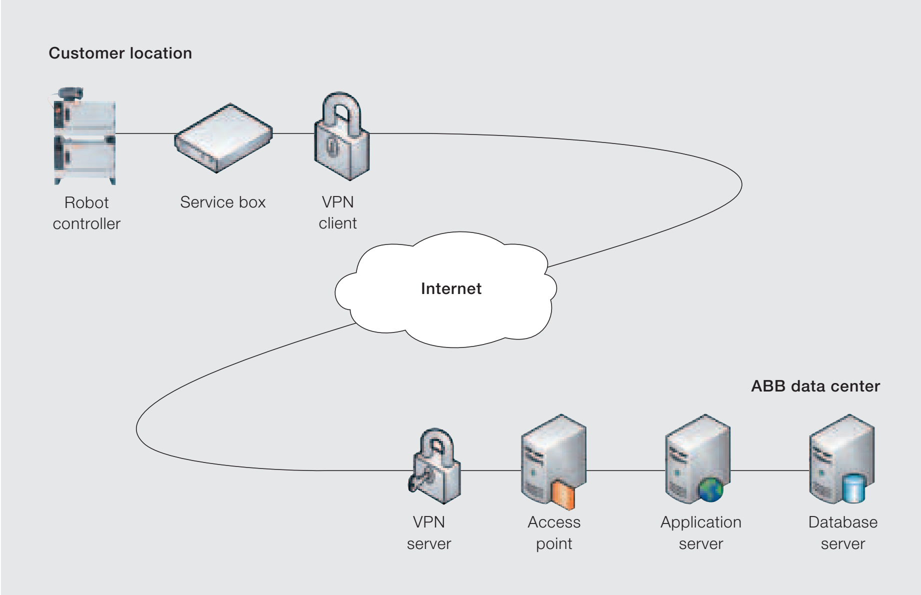
# Scaling factors

## Software scalability for ABB's future IT

THIJMEN DE GOOIJER, ANTON JANSEN, HEIKO KOZIOLEK, STEVE MURPHY – Robots are hard-working and valuable members of any production line and any time they are out "sick" can have a significant negative effect on productivity. For this reason, ABB offers robot service agreements that provide assistance to customers in case of failure as well as preventive maintenance to reduce the frequency of failures. This service has been enhanced by letting the robots communicate with the customer and to ABB so that timely interventions can be made. Since 2007, when this feature was introduced, more and more robots have started communicating. Not only that, but the number of related services offered has increased, too. These factors have increased the load on the infrastructure, so ways to optimize the back-end scalability and performance requirements have been studied.

1 High-level software architecture of the current remote service platform




It would be very troublesome if one were to build a pyramid and, upon completion, discover it should now be made 10 percent larger – unless the construction plan had been designed with scalability in mind. Similar scalability challenges are faced in industry and a good case in point is the ABB back-end system that handles remote diagnostic communication with robots under service agreement.

This back-end system, known as the robotics remote diagnostic platform, consists for four tiers, the first of which is the service box connected to the robot controller itself → 1. This box communicates with the other tiers, the so-called back-end, which are situated at ABB. This back-end consists of an access point, an application server and a database. The access point secures the data flow between the robot service box at the customer site, and the application server and database on ABB's internal network. The application server, the heart of the remote service system, performs the necessary diagnostics. All data is stored in the database.

**Title picture**
IT infrastructure has to be scalable to efficiently accommodate the rising number of robots "reporting in."

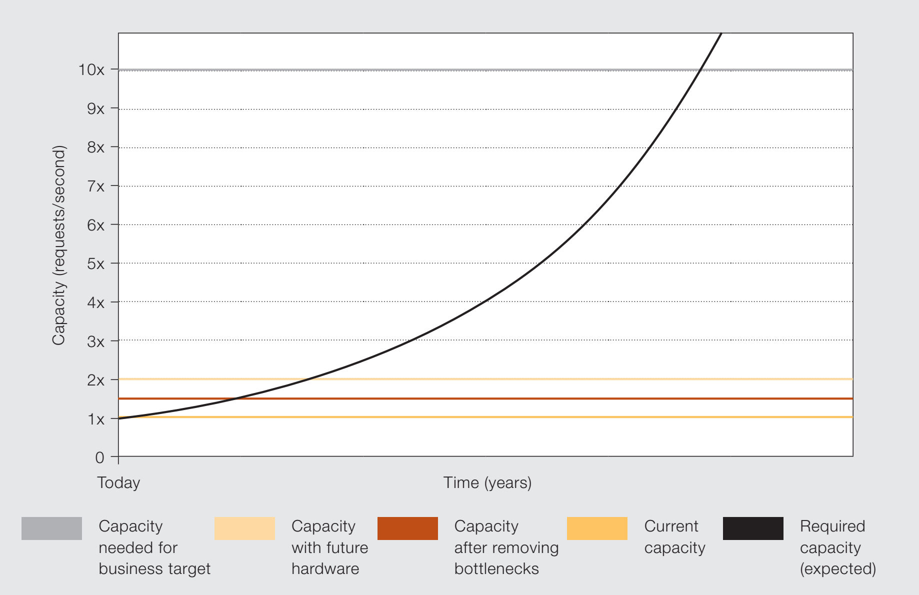
Increasing demand from robots in the field, coupled with elevated levels of service and performance, means that ever more service boxes interact with these three back-end elements. This continually increasing traffic makes it all the more important that a defined methodology for scaling up the back-end capacity is in place. A capacity increase in the back-end requires careful redesign of the three tiers, taking into account the interaction between them. Ideally, the capacity of all three back-end tiers would be identical; if the capacity of one tier is too low, a bottleneck will arise, slowing the other tiers and resulting in generally slower response times and delays.

Increasing demand from robots in the field, coupled with elevated levels of service and performance, means ever more interaction.

When work to examine scalability methodology began, the remote diagnostic platform was already heavily loaded, with capacity just slightly higher than demand. Initial investigations quickly identified and eliminated bottlenecks, increasing capacity by 56 percent → 2. Hardware upgrades were planned to further boost capacity, but any gains from these would be eroded in one to three years by increased demand and further extensions to the services offered. Actually, to support the long-term business target, a tenfold capacity increase is needed. This calls for careful engineering of the software architecture and a roadmap to guide the system's transformation.

Three steps were taken to establish a roadmap for system scalability. First, the performance of the current version was measured to identify bottlenecks. Software bottlenecks occur when one software routine, for example, a Web service, is stopped or slowed down because it has to wait on another, slower routine. Software bottlenecks inhibit efficient hardware use. Second, a performance model of the system architecture and a cost model for the system resources were created. Third, a performance simulation was used to evaluate how different design alternatives perform under the predicted number of remotely connected robots. Based on this model-based stress testing, a roadmap comprising multiple cost-efficient steps toward improved capacity and scalability was produced.

**2 Capacity requirements of the robotics remote service platform**




To support the long-term business target, a tenfold capacity increase is needed.

### Bottlenecks

Before an accurate performance model can be created, the system performance itself must be understood and any bottlenecks have to be identified. This was done using a dynaTrace[1] application that features integrated application performance management (APM) and performance profiling. This tool was selected from a list of 58 tools for its good .NET platform support, automatic source code instrumentation and its distributed transaction tracing technology → 3. Server log analysis was used to discover which transactions are performance-critical and occur most. This information was input into a load generator application to simulate a realistic workload on the system in the experimental environment. During these experiments various performance measurements (eg, CPU load, network delays) were obtained.

### Performance model

To model performance, data were fed into a software architecture simulation tool called Palladio[2]. Palladio's modeling language uses a notation similar to the unified modeling language (UML), a de facto industry standard, which makes it easy to create, use and communicate model and simulation results[3]. Models can be reused and rearranged to investigate alternative software architectures. While constructing the performance model, trade-offs between abstraction, detail, and prediction accuracy were continuously made. The first model recreated the current system and this was calibrated so that the model predictions matched the measured performance. In later stages, the robustness of the model was increased to ensure accuracy of the predictions for varying workloads and different system designs.

Planning for future capacity needs is not just a matter of performance – there are hardware, software, and hosting costs too.

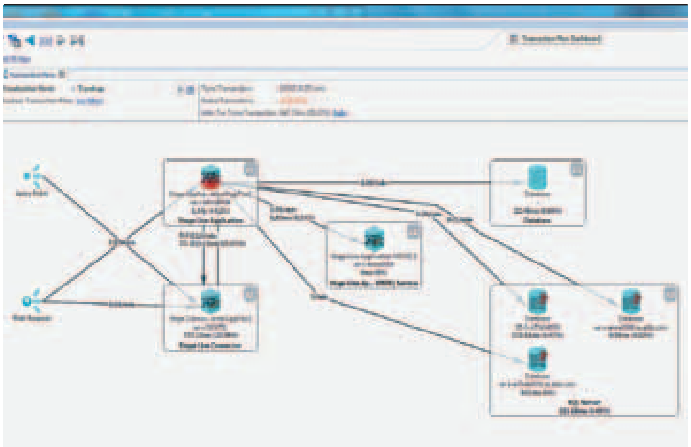
### Cost model

One obvious way to avoid the risk of resource under-provision, and consequent customer dissatisfaction, is to massively over-provide. However, planning for future capacity needs is not just a matter of performance as hardware, software and hosting costs also need to be taken into account; idle resources cost money. To capture this second dimension, a cost model, based on several price lists, was created. This model specifies the cost of the resources in the performance model.

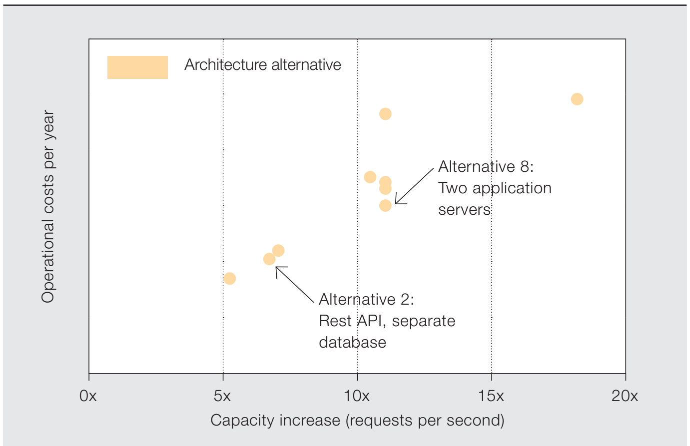
**Footnotes**

1 http://www.dynatrace.com/
2 http://www.palladio-simulator.com/inventory
3 http://en.wikipedia.org/wiki/Unified_Modeling_Language

3 A dynaTrace screenshot showing response time monitoring and request flows between servers



4 Costs of overcapacity per evaluated architecture candidates




If the performance model alone were used to construct the roadmap, it could advise only on actions to increase capacity. By combining it with the cost model, the costs can also be taken into account, creating a cost-efficient transition schedule that guarantees timely action to satisfy capacity demands.

## Architecture alternatives and migration roadmap

Over a dozen architectures that accommodated the desired tenfold capacity increase were considered. Approaches included, for example, cloning specific services; splitting the responsibilities of existing services so that they can be better distributed between multiple servers; and separating incoming requests into different classes that can be processed by dedicated servers. Actually implementing and deploying the alternatives suggested by the modeling in order to measure their actual performance would be too expensive. However, it was possible to model each of them by altering the performance model. Each alternative was simulated and its capacity in terms of supported requests per second determined. Similarly, the cost model delivered the expected annual operational costs for each alternative → 4.

Alternatives 2 and 8 are highlighted in the figure as they are the most cost-effective solutions for providing a fivefold and tenfold capacity increase, respectively. Alternative 2 suggests implementing a REST API (a type of distributed Web service) for the system and deploying the database onto a dedicated server. Alternative 8 suggests replicating the application server, which hosts several services, and using a load balancing mechanism to distribute the incoming requests evenly.

Directly migrating to alternative 8 would be wasteful because the capacity it supports is not needed for several years. In addition, alternatives 2 and 8 are compatible with each other, ie, they may be combined to reach a higher capacity. Thus, the current plan is to migrate the system to alternative 2 and then, later, to alternative 8. This provides the most cost-effective way to fulfill the target requirement of a tenfold capacity increase.

## Increasing need for IT capacity planning

The approach to scalability presented here is very suitable for the growing demands arising from both the increased levels of service being offered and the increasing number of robots talking to the ABB back-end system. It can also cater to the demand arising from the ease of retrofitting remote diagnostics to an installed base. The scalable software architecture discussed can serve as a blueprint for other ABB remote diagnostics offerings where more powerful hardware is simply not sufficient to reach the target capacity, as well as for future remote service solutions.

With the advent of the Internet of things (IoT) [4], the relevance of highly-scalable back-end systems is increasing for ABB. Scalable systems will have to be created at multiple levels in the IoT to keep performance for end-users at the expected level and to make sure that customers with smart homes and factories will not experience delays in remote communications. The experience gained in this engineering approach to scalability will help ABB build scalable systems cost-effectively and to tackle performance problems as they arise.

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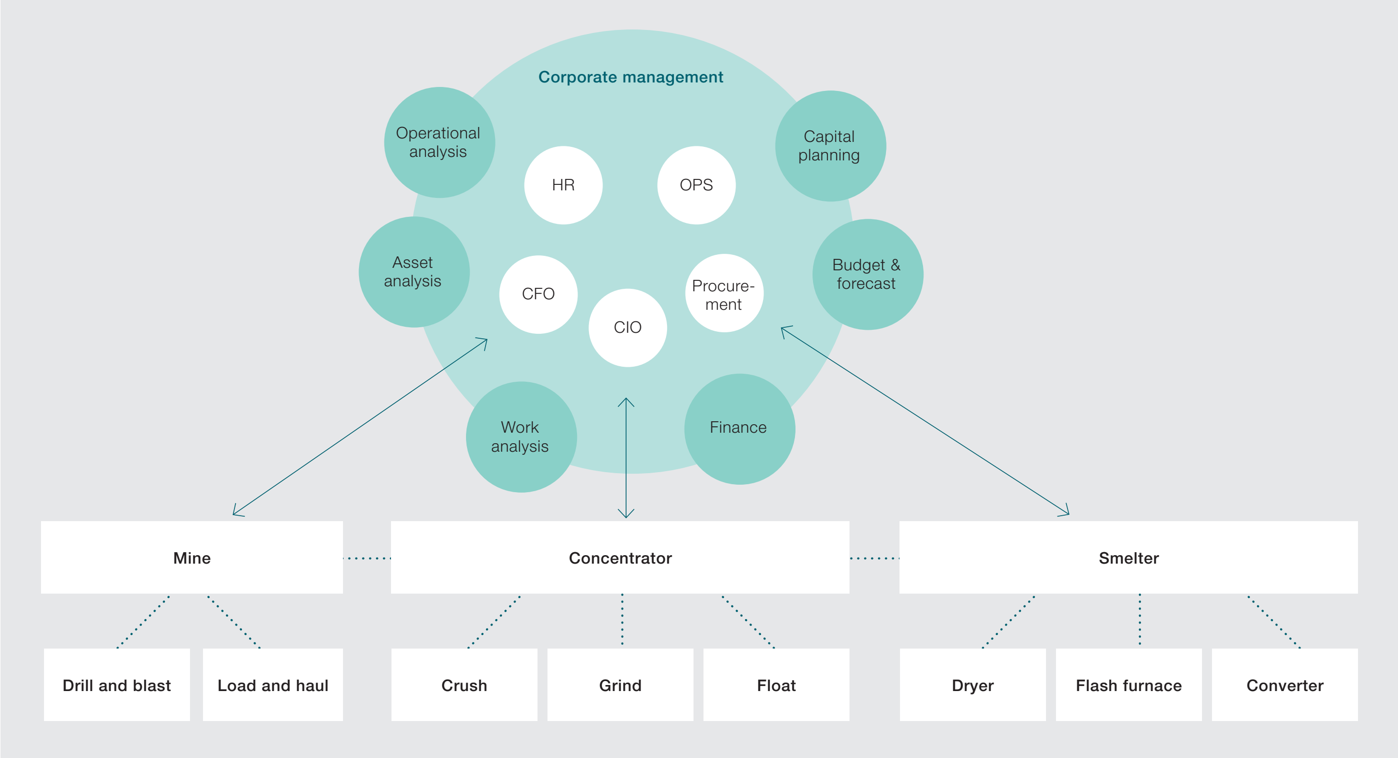
**Footnote**
4 http://en.wikipedia.org/wiki/Internet_of_Things

# Optimizing mining operations

## Integration across the mining enterprise is key to increased productivity

JOHN JESSOP – As the resources sector continues to gain momentum, mining companies around the world are seeking to maximize production, enhance productivity, streamline processes and improve profitability to maximize returns from their operations. However, mining's complex value chain typically creates organizations that are structured into divisions based on their functional or expertise area. In most cases, each division stands alone with little or no interaction. The reality of multi-site operations further increases this complexity. The formation of these "functional silos" makes it difficult for mining companies to reach peak performance. This issue is further exacerbated by the lack of information systems crossing these functional divides. Ventyx, an ABB Company, provides a full suite of integrated mining solutions software that bridges the functional and information silos that populate most mining organizations. This incorporates enterprise support systems for managing the entire mining support mechanism, including equipment, maintenance, logistics, production and personnel, as well as enterprise mission systems that cover the extraction, processing and delivery of raw material. This results in improvement in key performance metrics all along the value chain.

1 Functional silos in copper mining




Breaking down silos is challenging as there are a number of historical and structural reasons that support the status quo, including geographic distribution of the operations, complexity of the planning process, the fractured software marketplace servicing the industry and the misalignment of performance metrics → 1. For example, in a hard rock mining situation (eg, copper or gold), mining engineers often control costs by reducing blasting → 2. This ends up increasing overall cost of the operations because poorly fragmented material is delivered to the plant, dramatically increasing milling costs and, more importantly, decreasing throughput.

## The tyranny of distance

Mining operations are often distributed over a large geographical area. For example, an iron ore supply chain may consist of several mines, multiple plants, a rail network and one or more ports that are all spread over several hundred kilometers. In turn, the chain of professionals responsible for running different aspects of the operations, such as geologists, mining engineers, metallurgists, supply chain planners and the sales team, are also geographically dispersed. This makes the daily, informal collaboration required to optimize the business almost impossible.

Many mining companies are responding to this tyranny of distance by creating remote operations centers (ROCs) that accommodate and centralize key operational processes in a single, conveniently located facility. Although there are many benefits, such as improved safety, reduced travel and better living conditions for key staff, the most important outcome for many miners is getting all the key decision makers in a single room each and every day to ensure the entire operation runs optimally.

ABB has a long history of helping other industries, such as pulp and paper and oil and gas, to dramatically increase efficiencies through ROCs and has more recently brought this experience to bear in the mining sector. Ventyx, with a broad suite of mining industry specific applications covering geological modeling, mine design, product inventory management, asset management and sales and marketing, provides a key differentiator for ABB's traditional ROC offering by expanding the software platform to cover all key operational processes, not just those typically covered in process automation.

## The complexity of coordination

Planning complexity is also a major contributor to suboptimal organizational performance, particularly over the long term.

> To bridge functional and informational silos and improve business performance, mining companies need to take a wider view of the entire value chain and adopt solutions that encompass the whole of mining operations from exploration to market.

There are many components of a mining operation that need to be coordinated for the operation to function.

**Title picture**
Software solutions can improve the complex logistics involved in the mining industry

2 Quarry blast at a gold mine

For example, the mining sequence has to take into account the geometry and quality of the orebody to achieve a consistent feed of ore to the downstream processes. This has to interact with the maintenance plan – equipment capacity needs to match the mine plan. Similarly, capital spending and financial planning have to tie in with these production and maintenance plans. For many commodities, the sales plan, which results in contracted commitments, has to connect with all these plans and work with infrastructure (eg, rail and port) capacity constraints.

It is hard enough to get a single feasible plan together, never mind working through multiple iterations to achieve an optimal plan. The agility of the organization is also compromised if external factors, such as commodity prices or infrastructure capacity, change and force a re-plan. This fragmented approach to planning results in many months of sub-optimal performance within the changed world.

The path to integrated operational planning has many stages. Because of the technical complexity and site specificity of mining industry information system requirements, a typical mining operation's software environment requires a broad range of specialist operational technology platforms, such as plant process automation and mining fleet management systems, as well as planning and management software including mine planning, optimization of short and long term plans, plant reporting, stockpile management, site worker management, logistics optimization, asset management and the list goes on.

By continuing to rely on separate solutions, however individually robust, mining operations will continue to be hampered by informal, spreadsheet-based integration points between those solutions, which thwart cross-functional communication, impede process optimization and introduce uncertainty into decision-making. To enable business process improvement, formal and integrated IT solutions must replace informal, spreadsheet-driven processes.

However, solution modules must be configurable to adapt to both department and enterprise-level needs. Each functional area can then "add value" to the overall operations process by providing its critical piece from which the complete "information picture" is created. Data management can then be largely automated and rules-based, freeing technical experts to focus on optimizing the value chain end-to-end through improved collaboration.

Mining operations are geographically dispersed, making the daily, informal collaboration required to optimize business almost impossible.

3 Gearless mill drive at Aitik copper mine Sweden

Once the underlying information architecture is sound, integrated operational planning can become a reality – this is a key area of research and development within Ventyx.

For example, mining, processing and logistics areas all have requirements for planning, scheduling and optimizing operations at the departmental level. However, there is a growing recognition of the business need to optimize these tasks across the operation, commodity or region. Cross-functional integration is essential to taking an enterprise-level approach, but this has repeatedly proven to be prohibitively costly, slow and failure-prone across multi-vendor IT environments.

As IT and OT converge, more real-time data on asset condition will be available to streamline maintenance effectiveness, enabling condition-based monitoring. When business analytics are applied to this wealth of real-time data, miners can get high-value insights into the real condition of these critical assets. Furthermore, material tracking sensors can update the supply chain model, which can then be used for better short-term planning and scheduling, helping the company eliminate unneeded costs.

Again, Ventyx provides solutions covering the entire value chain and is uniquely placed to understand what this integrated "information picture" should look like and has the capability to bring it

Ventyx has a broad solution footprint unique in mining and provides multiple system components within a single suite, allowing mining companies to derive the system-wide KPIs required to support optimal organizational performance.

together. Once the underlying information architecture is sound, integrated operational planning can become a reality – this is a key area of research and development within Ventyx.

As a very simple example of what can be achieved with integrated planning, supply managers look to drive supply costs down, while maintenance managers need to keep inventory available to maximize equipment uptime. Information on inventory usage and criticality of equipment, such as through a graphical electronic parts catalog (Ventyx LinkOne) and inventory optimization (Ventyx Critical Inventory Optimization), can be aligned to detailed maintenance activities in the enterprise asset management system (Ventyx Ellipse EAM) to enable these teams to work together to eliminate obsolete inventory without incurring undue outage risk. The result can be millions of dollars (perhaps 20 percent of inventory value) in capital saved.

### The peril of performance measures

Traditional key performance indicators (KPIs) are heavily geared towards the performance of individual functions rather than the system or operation as a whole. Revisiting the blast optimization example, the effect of poorly constructed KPIs is clearly illustrated. Various studies, both academic and in the field, show overall throughput improvements in a mill of 10 to 15 percent through more careful control of blasting → 3. Given that the mill is often the single most capital-intensive component of an operation, this is an enormous overall gain. However, the improvements from a blast optimization program often dissipate over time. This can often be attributed to poorly constructed KPIs. Careful control of blasting increases costs and this directly affects the key cost KPI of the mining engineer responsible for blasting. However, if the the mining engineer works to their KPI this reduces throughput at the mill as crushers are blocked by large rocks or grinding power costs increase due to particle size distributions.

To construct KPIs that support overall operational performance in this example, the following systems need to be considered:
– Geological modeling
– Drill & Blast design
– Drill & Blast costing
– “As mined” measurement (survey, fleet management)
– Ore tracking & stockpile management
– Plant performance
– Plant costing

To construct relevant KPIs over all these systems is complex. However, Ventyx has a broad solution footprint unique in mining and as a provider of all of these system components within a single suite, the company is able to derive the KPIs required to support optimal organizational performance. Once the right KPIs are determined Ventyx has business analytics solutions that can be applied to provide executive visibility into the performance against these metrics.

### Taking a wider view

To bridge functional and informational silos and improve business performance, mining companies need to take a wider view of the entire value chain and adopt solutions that encompass the whole of mining operations from exploration to market. There are significant benefits when technical professionals, whether they are maintenance engineers, mining engineers, or mining geologists, are able to communicate with each other and share a clearer picture of the operation as a whole and what needs to happen to optimize business processes. As the above examples illustrate, when mining divisions are able to work collaboratively the result is often increased production output at significantly lower expense.

ABB together with Ventyx is well positioned to help miners align plans and goals across divisions in order enhance operational and financial performance, and execute the right strategies for the future.

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Because of the technical complexity and site specificity of mining industry information system requirements, a typical mining operation’s software environment requires a broad range of specialist operational technology platforms.

# Model behavior

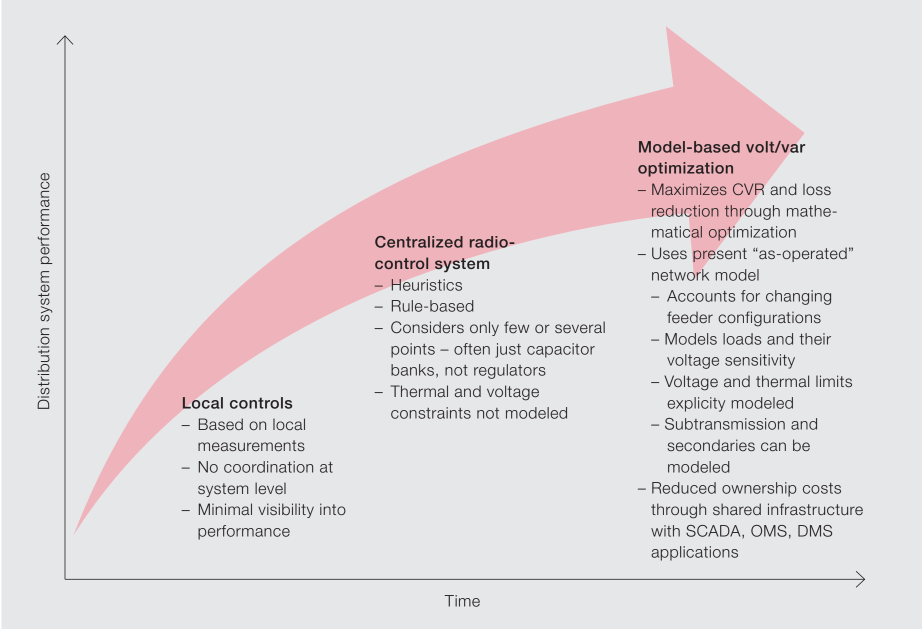
## Using distribution models to deliver smart grid volt/var control

**TIM TAYLOR – Power distribution organizations are under pressure to become more efficient and manage increasing peak demand. As the cost of adding incremental capacity to networks has risen, organizations have had to evaluate new operational strategies to reach these goals. Distribution volt/var control, while not a new topic, is experiencing a resurgence in the industry, due to technology advances that have increased its effectiveness. Volt/var control includes conservation voltage reduction, where the system demand is reduced by controlled voltage reduction at customer load points. This can typically reduce demand by 2 to 4 percent. System loss reduction can also be minimized by the optimal operation of reactive compensation equipment. Operational strategies can be optimized by using a dynamic operating model in the distribution management system (DMS) that reflects the current state of the network. In this way, model-based volt/var optimization always takes into account, for instance, outages and system reconfigurations. With the commercialization of model-based volt/var optimization, distribution organizations are now able to achieve significant performance benefits such as reductions in demand, real power losses and operating costs.**

**Title picture**
How does dynamic modeling of a distribution system contribute to the smart grid concept and deliver significant savings?

The benefit of utilizing a dynamic model is that the volt/var optimization is always dealing with the “as-operated” network state.

1 The major developments in volt/var control




Today’s emphasis on implementing energy-efficiency programs and limiting peak demand growth is driving renewed interest in an effective method of implementing volt/var control on distribution systems: conservation voltage reduction (CVR). In CVR, the system demand is reduced through controlled reduction in operating voltage at customer load points.

Model-based volt/var optimization (VVO) utilizes a dynamic operating model of the distribution system, in conjunction with a rigorous mathematical optimization algorithm, to achieve a given operating objective. It is typically based on a distribution connectivity model, as found in an organization’s geographic information system (GIS). The operating status of the components in the system model is usually changed by direct operator action in the control room or via a SCADA interface. The SCADA delivers changes in the status of system components, such as distribution breakers, switches, reclosers, fuses, jumpers and line cuts.

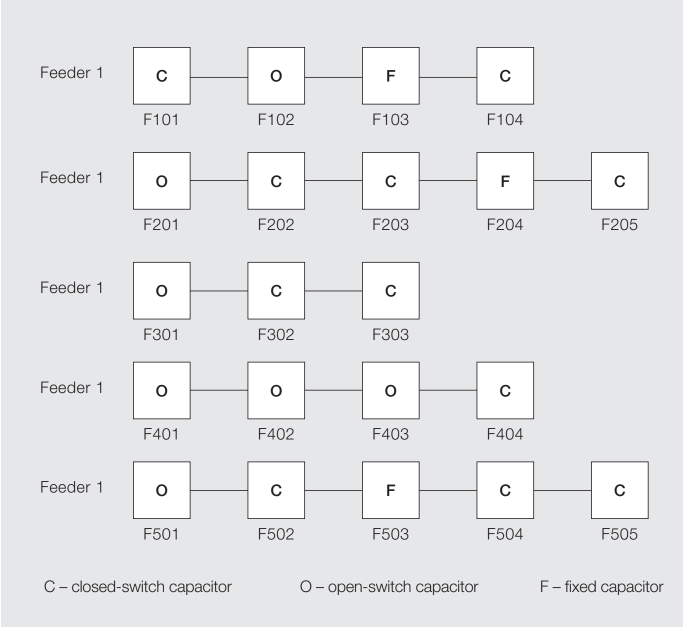
The benefit of utilizing a dynamic model is that the volt/var optimization is always dealing with the “as-operated” network state. This ensures that the determination of the voltage regulator taps, load tap changer (LTC) taps and switched capacitor states always reflects the present operating configuration of the system.

The savings made by deferred generation expansion, reduced capacity procurement, lowered system losses, decreased customer energy consumption and reduced operating and maintenance costs provide a very strong business case for model-based VVO in smart grids.

Due to their inherent technology limitations, previous volt/var control methods – namely local-based controls and one-way centralized radio-controlled systems – did not permit systematic optimization of voltage and var controls for maximum effectiveness in terms of loss reduction and CVR demand. Legacy systems also required additional

Once implemented, the infrastructure and resources that are needed for model-based VVO can be leveraged to provide additional functionality.

**2 Heuristic radio-controlled model versus model-based volt/var optimization**




**2a Heuristic radio-controlled model**

- Electrical model of distribution system – impedances and capacities. Three phase unbalanced model.
- Customer loads modeled: % impedance vs. % constant power and voltage limits.
- Optimization of capacitor states and tap settings via load flow iterations.
- Considers the "as-operated" state of the distribution system.

**2b Model-based volt/var optimization**

servers and communications infrastructure unsuitable for additional smart grid functionality such as fault location, self-healing restoration, and comprehensive distribution system monitoring and control.

With the commercialization of model-based volt/var optimization, and the extension of SCADA and intelligent electronic devices on the distribution system, distribution organizations are now able to achieve maximum performance benefits with reductions in demand and energy, real power losses and operating costs.

## History

Since distribution systems were first developed in the late 1800s, a great deal of effort has been spent countering the impact of reactive power and voltage drop. Distribution line voltage regulators, load-tap changing transformers and switched and fixed capacitor banks were developed to help keep customer voltages within regulatory bandwidths, free up capacity in the generation, transmission and distribution systems, and reduce real power losses.

Local controls were the first control measures introduced. Applied to LTCs, line voltage regulators and switched shunt capacitor banks, they utilize measurements local to the device. These measurements include current and voltage, and, in the case of switched capacitor banks, sometimes indirect inputs such as time and temperature. These inputs are often used as a proxy for the actual reactive current flow ➔ 1.

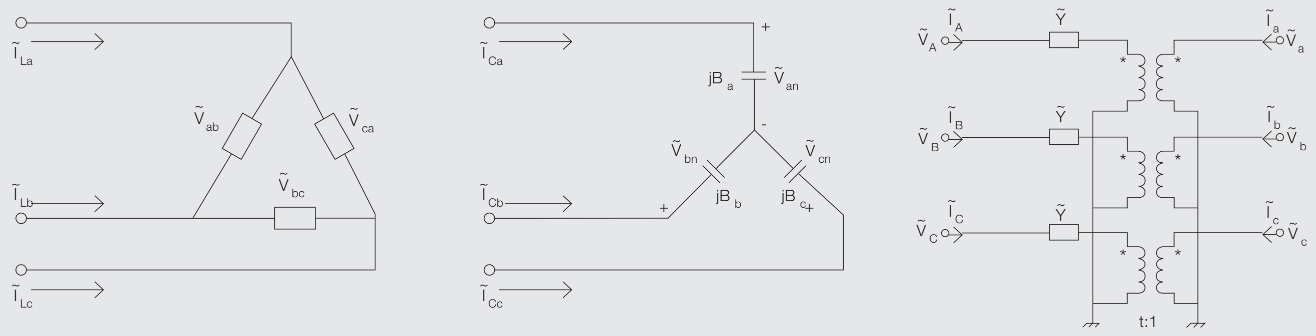
With local control, there is no explicit centralized coordination of volt/var devices at the system level, and implementation of CVR is far from optimal. In addition, there are costs for field personnel to travel to a site to check for things such as blown fuses, to verify controls are operational, or to change control settings to match the seasonal load.

If banks are not operational, or even if they are operational but with the wrong settings, the voltage may be unacceptable and the power factor will be less than ideal most of time. This also occurs when time or temperature settings are not well correlated with the actual reactive current on the feeder during given days or seasons. This creates additional real power losses caused by excessive reactive current flow.

Centralized radio control was introduced about 30 years ago. This utilizes a central monitoring system, often based on heuristics, utilizing only the var measurement at the distribution feeder breaker. Simple one-way communication with switched capacitor banks, for example, is typically employed. Often the only quantity that is monitored is the var flow at the feeder breaker. If the distribution feeders are reconfigured due to normal switching, load balancing or fault isolation, the

Model-based volt/var optimization has many advantages over local-control based methods and centralized radio-controlled schemes.

3 Loads, capacitor banks or transformers can be connected in various configurations in model-based VVO.



rules-based logic is not able to automatically track the capacitor banks on the presently connected feeders. The lack of visibility, predictability and optimization across the system made CVR implementation impractical. Therefore, distribution companies have advanced to model-based VVO methods.

## The Increase of distribution models in system operations

Computerized distribution system models have been used in distribution planning for decades. They have been used to facilitate distribution system planning and design, and study system modifications such as line extensions, reconductoring, substation and feeder additions, voltage uprates, sectionalizing devices, shunt capacitors and voltage regulators.

Back in the early 1990s, the distribution models started to be used more often in the operations environment. Namely, model-based outage management systems were developed for use in distribution control rooms. System connectivity, the location of protective and switching devices, and the location of customers permitted more accurate outage prediction engines. Shorter customer outage times and more efficient use of field crews were the result.

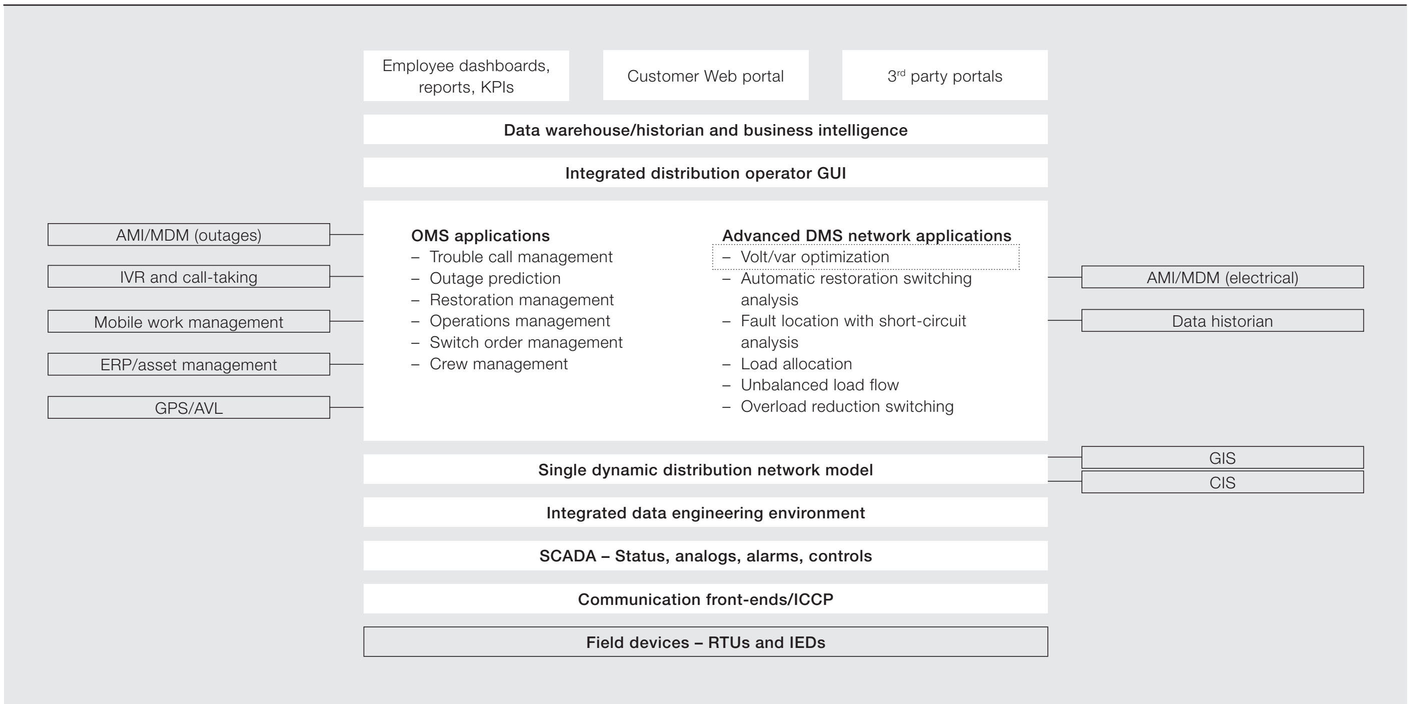
Initially, the electrical characteristics, such as equipment impedances, ratings, and loads, were not used in the distribution operations system model. This was for several reasons: First, the effort required to maintain and use such data in an operations environment was judged to be greater than the operational benefits gained. A distribution system model is different from the transmission model that most operations used in SCADA and/or Energy Management Systems (EMSs). The distribution system is much larger, 10 to 20 times, typically, and the system model must be a per-phase, unbalanced model to accurately calculate distribution conditions. Second, distribution system applications, such as fault location, volt/var optimization and self-healing had not been developed to leverage the distribution models in the operations environment.

Today, there are a number of factors driving the use of electrical models in the operations environment. Business drivers include demand reduction, energy efficiency, improved asset utilization and improved distribution situational awareness. Technical drivers include improved availability of computational power for handling large distribution models, more companies with a complete GIS model of their distribution system, the addition of cost-effective sensoring, intelligent devices and communications that can be used with the distribution system model and the development of advanced distribution applications such as volt/var optimization.

## Model-based volt/var optimization

Model-based volt/var optimization has many advantages over local-control-based methods and centralized radio-controlled schemes ➔ 2. Foremost among these is that the as-operated state of the system, including near real-time updates from

4 VVO in an integrated distribution operations platform




SCADA and outage management systems (OMSs), is used. This enables distribution companies to maintain the precise voltage control needed to implement CVR without violating customer voltage limits. Model-based systems are able to consider changes to the network as they occur, including load and capacitor bank transfers between feeders, and changing load conditions.

Past heuristic methods, such as monitoring power factor at the feeder breaker, are not optimal solutions. There can be tens of km (or miles) of conductors on a feeder. It is the voltage and var flow throughout the entire feeder, and not just at the feeder breaker or several other points, that impact the losses and demand on the feeder. A three-phase, unbalanced load-flow model-based solution results in a more accurate volt/var strategy than heuristics.

The technology required to support VVO, including GIS-based network models, two-way communications to distribution substations and line equipment, and IT resources, is now commonplace.

Model-based VVO will also enable distribution organizations to accommodate new complexities: increased renewable generation located at distribution voltage levels; more automated fault location and restoration switching schemes; increased system monitoring and asset management processes; and expansions in electric vehicle charging infrastructure.

## How it works

Simply put, the model-based VVO application is used to optimize an objective function subject to a set of nonlinear equality and inequality constraints, including thousands of equations for unbalanced load flow with several thousand state variables. The nonlinear, non-convex combinatorial properties of the model-based VVO problem, coupled with high dimensionality (a large number of state variables) explain why model-based VVO has been a longstanding challenge in the industry.

> Integration of the DMS applications with other utility enterprise systems can deliver additional value.

The model-based VVO algorithm can be summarized as follows: Minimize real power losses and/or real power load, subject to the following engineering constraints:

Model-based VVO helps organizations deal with growing numbers of renewable energy generators.

- Power flow equations (multiphase, multiscore, unbalanced, meshed system)
- Voltage constraints (phase-to-neutral or phase-to-phase)
- Current constraints (cables, overhead lines, transformers, neutral, grounding resistance)
- Tap-change constraints (operation range)
- Shunt capacitor change constraints (operation frequency)

Using the optimization control variables:
- Switchable shunts (ganged or unganged)
- Controllable taps of transformer/voltage regulators (ganged or unganged)

Model-based VVO uses unbalanced load flow (UBLF) and load allocation (LA) applications to obtain the starting network state. It also invokes UBLF to provide sensitivity (gradient) factors, obtain intermediate solutions in the voltage control iterations and check the feasibility of candidate solutions. The UBLF application is required, as opposed to a balanced load flow application, due to the numerous single-phase loads typically found on a distribution system, as well as single-phase laterals that can have controllable regulators and capacitors.

The common three-phase, unbalanced distribution model used by model-based VVO can accommodate all common transformer connection configurations, ungrounded or weakly grounded networks and any degree of meshing.

For accuracy, a detailed network model is used. Phase-based models are used to represent every network component. Loads or capacitor banks can be delta or wye-connected. Transformers can be connected in various delta/wye and secondary leading/lagging configurations with or without ground resistance and with primary or secondary regulation capability ➔ 3.

Both voltage and var controls can be ganged or unganged. The method works on radial as well as meshed networks, and with single or multiple power sources. Voltage controls are enforced for each individual phase, using phase-to-ground or phase-to-phase voltage, depending on the connection type of the load. Any regulators or capacitor banks that are temporarily disabled due to maintenance or operational issues can be temporarily excluded from the analysis.

Model-based VVO considers the voltage-dependent component of loads in order to model the reduction in demand versus the reduction in voltage. The optimum settings for each regulator or LTC depend on the mix of constant power and constant impedance loads on the distribution circuit.

### Integration with other smart grid functionality

Once implemented, the infrastructure and resources that are needed for model-based VVO – including the network model, SCADA, communications and the server/hardware infrastructure – can be leveraged to provide additional distribution management system (DMS) functionality, such as self-healing (automated restoration switching analysis), unbalanced load flow, fault location and overload reduction switching. Furthermore, integration of the DMS applications with other utility enterprise systems (eg, demand response management systems, business intelligence applications and OMSs) can deliver additional value ➔ 4.

In addition, operators and utility enterprise systems can benefit from better situational and operational intelligence. Knowing, through the graphical maps and tabular displays in the DMS, the status of volt/var equipment along an as-operated feeder improves operator awareness. Model-based volt/var applications can also leverage SCADA/DMS alarms for failed Field-based controllers, blown capacitor fuses and failed regulators or capacitor banks. This and other information can be fed to asset management and mobile workforce management systems. The loss and demand reduction data can be supplied to systems that evaluate savings arising from reduced fuel costs for a generating utility and reduced power purchase costs for nongenerating utilities.

### Advantages

Model-based VVO now allows distribution companies to implement voltage and var optimization under real-world conditions and with numerous advantages over previous methods:
- The mathematical optimum is computed, instead of a rule-based heuristic solution.

– Maximum reduction in power and energy losses, customer demand reduction and freed-up capacity is determined using a mixed-integer, nonlinear programming method.
– Operating objectives can be changed to meet business requirements.
– The optimization can be set to execute on a defined schedule, or when there are significant system changes.
– Offline simulations can be performed, allowing different system configurations and contingencies to be studied.

The as-operated state of the network is utilized by the optimization.
– As outages and system reconfigurations occur, the network maintains proper connectivity of loads, capacitor banks, regulators and other feeder components.
– The network model is kept up to date incrementally as part of the outage and distribution updating process.
– With one common as-operated network model for all smart grid applications to draw from, consistency is guaranteed.

Infrastructure and maintenance costs for implementing multiple DMS applications are reduced.
– Model-based VVO utilizes the same resources as SCADA, OMS and other DMS applications.
– With integrated DMS, there is no duplication of computing infrastructure and communications environments for implementing other smart grid applications.
– Having a single DMS distribution network model eliminates synchronization issues between different models maintained in different applications.

A three-phase unbalanced network model is utilized.
– A detailed, unbalanced three-phase system model improves accuracy.
– Multiple voltage levels can be modeled, including subtransmission and secondary voltage levels.
– Networked and looped systems can be included, not just radial.
– The impact on the entire network model is calculated.
– Voltage imbalance is included, as are ganged and unganged controls.

Customer loads are modeled explicitly.
– A voltage-dependent representation of customer loads is used since they differ with how load varies as a function of voltage and differ in reactive power requirements.
– The location, size and type of loads on the system determine the optimal LTC and regulator settings for CVR.
– Voltage at load points is calculated and compared with operating limits.
– Customer loads can be represented as a function of time.

## Model-based VVO: the future

Model-based VVO is perfectly attuned to other advances in distribution systems. For example, the increased use of automatic fault location and automated switching and restoration schemes uses the same model. These applications reconfigure the distribution system, changing the location of loads as well as the location of voltage regulators and capacitor banks. Older-generation, rule-based volt/var methods were not able to account for such system changes, whereas model-based VVO can. Indeed, it can do so explicitly and automatically.

Further, model-based VVO helps organizations deal with growing numbers of renewable energy generators. Distribution organizations are already experiencing the voltage fluctuations caused by distribution-connected renewable generation, especially from single-phase residential photovoltaic systems. Model-based VVO already models multiple generation sources and it can be adapted to model and control reactive power from renewable sources.

As advanced meters and cost-effective remote voltage-sensing devices continue to be deployed at load points in ever greater numbers, additional end-point voltage readings will become available to the optimization routines. This additional information will further enhance the performance of the model.

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# Better together

## The value of transforming data into actionable intelligence

SIMO SÄYNEVIRTA, MARC LEROUX – Since the early 1990s, manufacturers and vendors of automation or manufacturing software have been talking about the value of moving from “islands of information” to a collaborative model in which the right information is available to the right person, at the right time. Latterly, it was recognized that data, out of context, was just data, so an additional axiom was added: with the right context. What is needed is actionable intelligence – data with the proper context applied to it and data that includes operational experience. While progress has been made to help manufacturers move in this direction, the reality is that many are still in a position similar to that of three decades ago. What is the situation in manufacturing today? How will things develop? And what products are available that can be used by a manufacturer as building blocks in a true collaborative environment?

The systems should collaborate and determine the solution that is best for the business – this changes the focus from production-based to profitability-based manufacturing.

Today, the typical manufacturer has between 20 and 40 information systems in any given facility. Despite good intentions, these largely exist as "data islands" and, because of historical difficulty in integrating these islands, decisions are often based on only the most immediately relevant system, with scant regard for the overall business picture. Enterprise resource planning (ERP) systems have long held out the promise of improving this situation, but the reality is that there is a significant difference between making a business decision and implementing it in real-time manufacturing operations. Also, while ERP systems are very good at ensuring business rules are followed, they typically work on data that is periodically consolidated, which, by definition, is not current.

**Title picture**
How do ABB solutions help customers turn production data into value for the enterprise?

Another favorite focus area is process improvement. But improvements are often too narrowly targeted and fail to take account of impact on the entire supply chain. Broadening scrutiny to cover topics like product consistency improvement can reduce both raw material and finished goods inventories, lower transportation costs and improve cash flow. This can have a tremendous impact on the net profitability of a company, but this impact can only be properly assessed if all the relevant subsystems collaborate.

What is needed, then, is a true collaborative model. The good news is that technology has now caught up with the requirements: Collaboration between systems is no longer prohibitively expensive, or limited in functionality. And such collaboration is already having a big impact on major companies today.

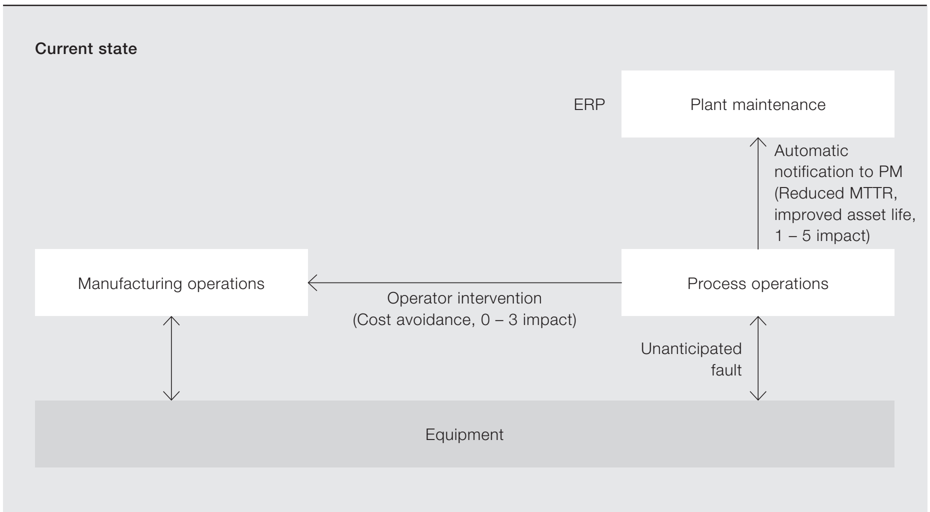
## Together, but apart

Often, production equipment will fail. Usually, the operator will call maintenance, who will then assess the situation, order parts, schedule the work, inform the supervisor, and so on. This is a very time-intensive process, with actions recorded electronically, typically after the fact → 1.

Alternatively, the equipment could detect the fault automatically and notify the operator and others. All pertinent information would be acquired by the computer maintenance management system (CMMS), which would then automatically check resources and parts inventories and notify the operations and production planning systems. Many companies have this today → 2. (Asset Optimization for Extended Automation System 800xA, for example, is an ABB offering, that provides this functionality.)

The next step is to have the systems collaborate and determine the solution that minimizes the cost to the business. This changes the focus from production-based to profitability-based manufacturing. At this point, the decision that is best for the whole business, rather than for a subset of it, can be made.

1 Processes can be very time-intensive when systems are not integrated into a collaborative structure.




Many executives would believe that this is where they are today, or where they have been since they invested in an ERP system. A common belief is that all aspects of the organization are integrated by the ERP system. Unfortunately, this is far from the truth. While tremendous cost reductions can be realized through the installation of an ERP system, much savings potential remains. The good news is that the infrastructure is in place. The current vision just needs to be extended.

## Integrated, but not

Each entity inside an ERP implementation may have access to the same data, but each tends to focus on its own interests, to the detriment of the whole: Maintenance will focus on work orders and spare parts inventory, production planning will focus on optimizing the planned manufacturing process, and the customer-facing part will focus on customer orders and receivables.

One of the primary reasons for this is the still very limited communication between the corporate/ERP level and the manufacturing systems. This is perpetuated by the belief of manufacturers, and IT personnel, in the segmentation of manufacturing layers. This attitude is even enshrined in the de facto standard for integration of manufacturing and business systems (ISA-95/EC 62264 Enterprise to Control System Integration) → 3.

Such boundaries need to be eliminated and manufacturing has to be treated as a component within an overall enterprise system.

## Interfacing vs. integration

For a collaborative manufacturing system, it is essential to differentiate between interfacing and integration:

- Interfacing: Replication of data between one system and another. The result is data that exists in multiple systems. The transferred data may, or may not, have context, or meaning, applied to it.
- Integration: Data is referenced between systems through a model that automatically applies context, ensuring that the system referencing the data knows that it is up to date and that it is being referenced in the proper context.

> Manufacturing and engineering staff can be located where they are the most effective – if there is real-time access to data, monitoring and control.

Integration addresses two fundamental principles of computer systems:

- Data without context is data. Data with context is information.
- If the same representation of data in multiple systems is different, then both are wrong.

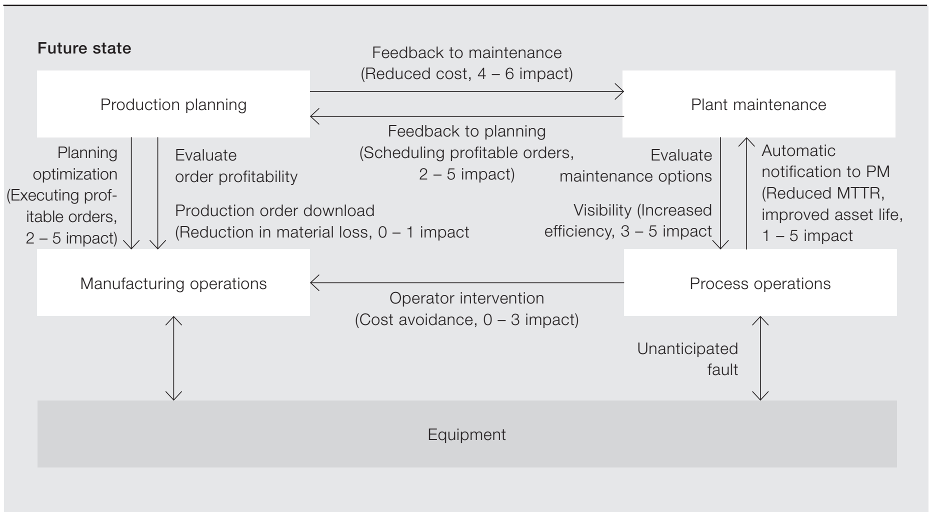
Data originates at the device level and is used at the automation level. This data is captured and stored in high resolution and is visible at the manufacturing level in the collaborative production management (CPM) system, where models can be applied and an integration framework exists for seamlessly integrating information between systems.

## Collaboration – business benefits

Many trends are driving the need for an improved collaborative approach. For instance, the increasing number of aging workers who are retiring and taking their long years of experience with them. There is also recent economic uncertainty and the drive to meet shareholder expectations. These have caused some organizations to switch to off-shore production in a bid to cut costs. This may lead to decreased operational efficiencies due to organizational knowledge being lost, company culture not being understood or much higher employee turnover rates. A further, and very relevant, trend is company growth through acquisition. Major challenges here are the alignment of diverse computer systems, product line rationalization and the shutting down of production lines or facilities deemed to be underperforming.

The key to overcoming these challenges is a re-evaluation of the overall manufacturing process structure, taking each facility not as a standalone entity, but as a part of the whole. This leads to an

2 Collaborative organizations function much more smoothly (relative impact).




Collaboration becomes much more important as geographically disparate sites become part of a virtual organization.

integrated manufacturing environment that facilitates a collaborative manufacturing process. For example, with fewer technical resources on-site, manufacturing problems can be addressed by a team of experts located in geographically different locations.

As in IT outsourcing, manufacturing and engineering staff can be located where they are the most effective. For this to work, there must be real-time access to manufacturing information and events and the ability to monitor and control the operations remotely, as well as collaboration between systems. This becomes much more important as geographically disparate sites become part of a virtual organization.

## Collaboration – becoming a necessity

In some fields, a collaborative mode of working is inescapable. New oil and gas finds are now usually in geographically remote, harsh environments. This presents a dual challenge: Putting experts on-site is logistically difficult and expensive, and, at the same time, the harsh conditions make operational problems difficult to resolve. To solve this, real-time sensor data and related analytics must be made available remotely, in a secure way, so they can be accessed by the key experts, wherever they are in the world.

For example, in the oil and gas industry, this approach is supported by ABB's integrated operations (IO). Their solutions include secure, high-speed data collection and storage, remote asset diagnostics, remote control rooms providing collaborative automation, and advanced process control solutions. For example, the optimization of production on an oil platform in the North Sea can be managed from a control room in India.

Similarly, in the mining industry, ABB's MineMarket and Ellipse collaborative production management solutions, together with System 800xA automation platform, manage all the aspects of integrated mining operations, from the mine face to the port. The functions include operations planning, execution of the production processes, tracking material flows and product quality through the entire supply chain, and asset management. Information is coordinated through the collaborative production management infrastructure.

Each facility is not considered to be a standalone entity, but a part of the whole.

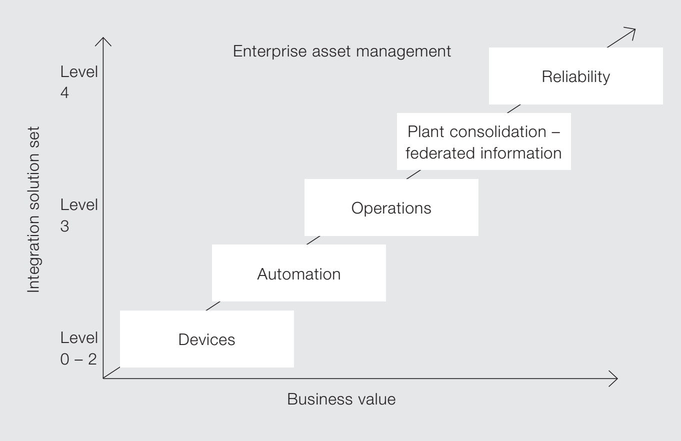
## Changing business paradigms

A collaborative manufacturing environment can completely change the rules of the game. Take, for instance, the cost of energy in energy-intensive manufacturing processes. This has traditionally been treated as a fixed cost that cannot be influenced. This is rapidly changing. In many countries, the electricity markets

3 Even standard models of enterprises have a boundary between level 3 (manufacturing) and level 4 (enterprise).

| | | |
|---|---|---|
| Level 4 | **Business planning and logistics** Production scheduling, business management, etc. | Establishing the basic plant schedule – production, material use, delivery, and shipping. Determining inventory levels. |
| Level 3 | **Manufacturing operations** Dispatching production, detailed production scheduling, reliability etc. | Workflow / recipe control to produce the desired end products. Maintaining records and optimizing the production process. |
| Level 2 | **Manufacturing control** Basic control, supervisory control, process sensing, process manipulation | Monitoring, supervisory control and automated control of the production process |
| Level 1 | | Sensing and manipulating the production process |
| Level 0 | | The physical production process |

4 ABB has a comprehensive service strategy.




A key aspect of manufacturing that will see a dramatic change with the advent of collab-orative systems is service.

have been deregulated, allowing manufacturers to become active market participants, buying and selling electricity at the hourly market price. Even if the supply of electricity is secured by long-term contracts, the actual opportunity cost of manufacturing operations is now no longer a static variable.

This complexity can be turned into a business opportunity. As one example, ABB's cpmPlus Energy Manager allows manufacturers to plan, monitor and optimize their energy operations together with their manufacturing dynamics, in real time. In addition to obtaining optimal energy rates, and avoiding penalty conditions, the product can inform manufacturers when it makes more sense for the overall business to shift production to off-peak energy periods or to slow down or stop it altogether and sell the saved electricity to the grid for a profit.

## The future of service

A key aspect of manufacturing that will see a dramatic change with the advent of collaborative systems is service → 4. Traditional service roles will become blurred as assets now have the ability to monitor their own health, and to automatically report any exceptions before failure. This increases profitability by reducing production downtime and increasing asset life. In a complex operation, small inefficiencies – a sticky valve for example – can have a huge ripple effect throughout the entire operation, and as process instability sets in, the root-cause becomes obscure.

Over the past decade many established manufacturers have recognized that maintenance is not a core competency. This has driven companies like ABB to increase their service portfolios to include:

- Maintenance services: keeping assets operating at peak levels
- Reliability services: understanding the projected reliability, risk and cost of failures.
- Performance services: understanding the impact of changes on an asset's performance and providing the expert services to retune the process.

All three of the above must operate in a controlled and collaborative fashion to optimize overall performance and profitability. ABB has recognized this, and has developed a comprehensive service strategy that extends from device status through to a complete asset health, reliability and maintenance solution. Central to this is a collaborative environment that facilitates the interaction between systems.

## Barriers to adoption

Fundamentally, most of the topics mentioned so far are not new, yet they are still central themes in manufacturing conferences and industry analyst reports. Some reasons why they have not yet become reality are:

- The "we already have it" attitude. Manufacturing executives have heard the claims that their multimillion dollar ERP investment includes this integration and they question the need for further investment.
- Organizational silos: Planning, operations, customer service, maintenance and IT, as examples, are all independent silos with their own objectives and metrics. Often the

5 The right information available to the right person, at the right time, with the right context

metrics are contradictory: Maintenance will always take the lowest cost approach if they are being measured on maintenance cost only, not on the complete organizational performance.
- Security: One of the chief roles of IT today is to maintain the integrity of data. The easiest way to do this is to limit the interactions between systems, rather than promote the collaborative integrated scenario.
- Sunk costs: Often, investments do not yield all the expected benefits. There can be reluctance to commit more funds for incremental improvements to realize these missing benefits as they are regarded as having already been paid for. This is particularly true with software projects as they often have intangible benefits, or have already experienced unrealized expectations and cost overruns.

These issues can all be effectively addressed, but the key is that organizations must first understand that they exist.

## How to get there?

Technology is just an enabler; investments in technology will not, by themselves, translate into value. Further, having a multiyear improvement plan can become a liability. It is often better to have a five-year plan where one is always at year one and, as new factors are incorporated, opportunities and results are re-evaluated. This means that companies can stop focusing on sunk costs and look at the incremental value that change brings.

A key action of this strategy is to drive business value to all levels of an organization. Every decision, from the operator level to the senior management, should be based on its value to the business. This brings one back to the collaborative environment: Seamless access to information allows operational decisions that factor in customer requirements, quality, asset condition and cost to provide an optimal recommendation. Data from multiple systems must be consolidated to provide a picture that focuses on business objectives and drives business value.

> The good news is that the infrastructure is in place. The current vision just needs to be extended.

A prerequisite for this is quality industrial software that has been developed with integration in mind. An architecture that is designed to seamlessly integrate with other systems, collect information at high resolution from underlying decisions and store it so it can be quickly retrieved and visualized is key. ABB has this today with Collaborative Production Management platform cpmPlus, and the industrial software applications built on it.

The underlying automation also needs to be designed to take advantage of this integration. This is the case with ABB's flagship automation systems, Symphony Plus and System 800xA, as well as with the underlying sensors and devices. And the solutions must extend up to the enterprise level to include operations, reliability and enterprise asset management (EAM) products. ABB has this today in its vertical industry offerings and Ventyx enterprise solutions.

Finally, all of this needs to be tied together by services carried out by people who understand the domain and who know how to utilize the technology and solutions to drive operational excellence and business value. ABB has service and consulting resources that do this every day.

ABB has the technology, the products, and the services to implement a collaborative manufacturing system. All the components are in place. The last action is to work toward this goal together, manufacturer and supplier, in a collaborative fashion → 5.

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ABB
Für Unbefugte
Aufenthalt
verboten

# Taking the initiative

## ABB's software development improvement initiative bears fruit

BRIAN P. ROBINSON, JOHN HUDEPOHL – **in the past, software was sometimes considered a sideshow to the main event, the hardware. Now, the software content of a product is often seen as a crucial differentiator. The amount of software in many products has increased dramatically over the years, too. ABB's recognition of these trends can be seen in its strategic acquisition of strong software companies such as Ventyx and Mincom, for example. Software development takes place in all parts of the ABB group and in order to maintain the leading market position of existing software solutions, and to create new ones that are best-in-class, ABB is exploiting modern software engineering methods. A recent group-level initiative brought about significant improvements in software development by focusing on three important aspects: processes, technology and people.**

**Title picture**
With a product's software content now often being the differentiating factor, software development must follow best-in-class practices.

The software content of ABB products is increasing. Indeed, some products are nothing but software. Whereas, in the past, software often merely lent a helping hand to the hardware, it is now frequently seen as a differentiating technology in its own right. Software can be mission-critical, too: Consider the power-stations, industrial plants and infrastructure that rely on well-written and fault-tolerant software for their operation.

### Self-scrutiny: Benchmarking ABB's capabilities

To assess ABB's own software capabilities, ABB approached experts in companies that make long-lived, critical infrastructure products. Some of these individuals, along with managers and technical experts from ABB, were formed into a benchmarking team. This team interviewed developers and testers at various ABB software development sites. As a result of these interviews, the team was able to compare ABB's software development capabilities with those of related industries.

### Improvement initiative

Since ABB is a large company with very diverse products, developed in different parts of the world, an initiative was launched at the group level to act on the results of the benchmarking. While the initiative was planned and coordinated at the group level, the people involved were embedded in all five of ABB's divisions. The initiative focused on three main aspects of software development: processes, technology and people.

On the process side, the initiative was tasked with bringing best practice into ABB's development teams.

Under the newly-created software development improvement program (SDIP), these teams created a set of processes that would lead to improvements in their particular area → 1. The work also touched upon the software development life cycle and the ABB gate model.

The software development improvement initiative focused on processes, technology and people.

SDIP creates and defines the best software development practices for the group and the methodology for implementing these.

1 SDIP brings consistency and harmonization to software developed for products like the paper machine drive shown here.

## SDIP

SDIP strives towards continuous improvement by assessing progress and regularly validating achievements using the industry-standard capability maturity model integrated (CMMI), a process model provided by the Software Engineering Institute at Carnegie Mellon University, as a reference. SDIP creates and defines the best software development practices for the group and the methodology for implementing these. It specifies, and arranges, global license agreements for the best software tools.

The ABB tool suite seeks to establish a cost-effective and professionally-managed software engineering toolset.

## Software development framework

An important result of SDIP is the software development framework. This framework ensures that the latest and best processes are used and it provides tools that embody and automate processes wherever possible. Human factors, such as training and motivation, are also covered by the framework.

Because shorter, more responsive development cycles are demanded, agile or iterative development life cycle models are often used in ABB. Every stage of these includes requirements, design, implementation and some testing.

Software development projects are performed in three phases: concept, development and deployment. The development life cycle used for software projects focuses on requirements, architecture, design, coding, testing, tracking and fixing. It defines the way the software community operates on a day-to-day basis and links to the ABB gate model at key points.

## The ABB gate model

The gate model provides a conceptual and operational roadmap for moving a product project from idea to launch, and beyond. It provides a framework for better management of product development projects and it ensures that the line organization is actively involved in the project. At each gate, a decision is made whether to continue or stop. The projects software development life cycle is aligned

2 SDIP brought significant improvement.

> "ABB has progressed a lot in software development practices since 2008, and there seems to be an excellent spirit in the organization to keep the improvements going. Software development is now generally taking place at a very professional level. Remember though, that agile programming or CMMI levels are means, but not goals by themselves."
>
> Professor Claes Wohlin, Blekinge Institute of Technology, Sweden

with the gate model process so that inputs required for gate decisions are available at the appropriate time.

## Software development technology

While there are many technology areas to consider, so far the initiative has concentrated on selecting and deploying best-in-class development tools across ABB's teams.

The ABB tool suite seeks to establish a professionally managed software engineering toolset. It realizes the vision of a common and integrated software engineering tool chain that simplifies the work flow for users, and increases the visibility of progress via metrics and reports throughout the software development cycle.

Standardization and transparency are important watchwords of this global platform. Software engineering tools are employed to provide strong support for deployment of repeatable processes and tool-generated metrics, and reports increase transparency across all stages of a development project.

In other words, the ABB tool suite provides important infrastructure to enable speed, consistency, reliability, and measurement. The backbone of the system includes industry-leading tool packages. These tools streamline development so that products are delivered to the market faster and they support all the basic aspects of software development:

– Requirements, design, test cases, defects, configurations and build management.
– Early defect eradication.
– Effective validation (employing test automation and coverage tools to ensure products are built according to customer requirements).
– Measuring achievement of objectives and targets with data, using key metrics to make gate and milestone decisions.

This common approach also makes it easier to move people around inside the group and leads to a motivated and productive team.

## A motivated and productive team

The group initiative also concentrated on training and career development. Software practices advance very quickly, so it is important to keep the practitioners up-to-date. A quality work force of global teams made up of skilled and motivated individuals will undoubtedly be successful in product development. In addition, performance improves when teams are given working processes that are appropriate, mature, and delivered with tools that reduce the effort needed. A competence development framework and software engineering curriculum are used to ensure that software development team members are equipped with the current and future skills needed to fulfill their project roles.

> A software development life cycle is aligned with the gate model so that inputs for gate decisions are available at the right time.

## Benchmarking the improvements

After a certain time, the original benchmarking team was reassembled to assess progress. This time, a larger number of development groups were visited. For all of the focus areas in the benchmark, ABB showed significant improvement → 2.

## Significant improvements

In accordance with current best practice guidance, ABB had improved software productivity in manageable stages by

### 3 Process improvement steps

| Step | Actions |
|---|---|
| 1 | Begin with an assessment and baseline. |
| 2 | Initiate an upgrade to management skills in planning and estimating. |
| 3 | Start a measurement program to track progress. |
| 4 | Improve software defect removal via peer-to-peer reviews and static analysis. |
| 5 | Improve defect prevention via better requirements and design. |
| 6 | Improve the maintenance process via complexity analysis and restructuring. |
| 7 | Improve the conventional development process. |

### 4 Improvement benefits

| Software aspect | Percentage improvement |
|---|---|
| Development productivity | 5 – 20% |
| Maintenance productivity | 10 – 40% |
| Schedule shortening | 5 – 15% |
| Reuse volumes (over 5 years) | From <20% to >75% |

**Global vendor license arrangements, group-wide implementation of the common toolset and a global tools infrastructure.**

focusing on the top-ranked cost and schedule aspects and then carrying out a sequence of process improvement steps on these → 3. According to the latest research, based on information from many organizations, typical software process improvements have the potential to bring tangible benefits → 4.

An SDIP activity is now established in each ABB organization and individuals dedicated to software process improvement have been designated.

A process improvement example common to all was code review, which is an important technique for early defect detection in software development. Code reviews are labor-intensive events performed by developers, so it is important to have a lean, time-efficient process. For example, in the code base for one particular ABB product, significant productivity gains were made by supplementing manual code reviews with the Klocwork [1] static code analysis tool.

As some components in the code have over 100,000 lines of code, tracking code change dependencies during manual reviews was difficult. Klocwork massively reduced rework effort. After this success, extensive training on the tool was organized and its use is now widespread.

Another product that was improved is one that has an annual software release involving millions of lines of code. To address the problems experienced in past product launches, a number of process improvements, based on the CMMI, were put in place for the most recent release.

Information from reviews, for instance, helped balance project requirements against available resources, while code reviews not only helped catch code defects, but facilitated cross-training, mentoring and improved attention to detail.

**Footnote**

1 http://www.klocwork.com

5 Global license arrangements, a common toolset and a global tools infrastructure are essential for best-in-class software development. Source: Hewlett Packard.

Standardization and transparency are important watchwords of this common global platform.

These relatively small changes had a dramatic impact. The release was superior in terms of timeliness, functionality and perceived quality, and early indications from the validation are that big steps forward in terms of product quality have been made.

## The way forward

While ABB has improved its ability to develop high-quality software, there are other best-practice improvements that will help ABB further differentiate its software products from those of its competitors.

Only by continually revisiting software development practices and implementing the best techniques available can ABB thrive in an industrial world where software is becoming ever-more widespread, differentiating and critical. As the life cycles of product development, and indeed of products themselves, shorten, only those with best-in-class development practices will succeed ➔ 5.

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# Cyber security

## Protecting critical infrastructure in a changing world

SEBASTIAN OBERMEIER, SASCHA STOETER, RAGNAR SCHIERHOLZ, MARKUS BRAENDLE – Twenty years ago, the cyber security of systems and devices used in critical infrastructure such as energy transmission and power production was not an issue. Networks were truly isolated, and engineers expected devices to receive exactly the kind of data for which the devices were designed. No one imagined that it would be possible for an attacker to inject arbitrary data packets into isolated networks or to directly influence the underlying production process. As industrial control systems gradually changed from being isolated or from using proprietary networks, to being highly interconnected using commercial off-the-shelf technologies and open standards, these concerns and the demand for cyber security slowly but steadily grew. By the beginning of the new millennium the importance of cyber security in industrial control systems had become self-evident. But cyber security has long been an important initiative for ABB, having evolved from a research topic to being fully embedded in the company's global organization and in all levels of the product and system life cycle.

**Title picture**
Cyber security protects all aspects of critical infrastructure.

1 Cyber security safeguards against unauthorized local as well as remote malicious access to control rooms.

Cyber security is an integral part of ABB's products and systems. It is addressed at every phase, from design and development to maintenance and support of the product. Threat modeling and security design reviews, security training of software developers, as well as in-house and external security testing as part of quality assurance processes, are examples of the numerous steps ABB is taking to increase the reliability and security of its solutions.

## Cyber security embedded in the product life cycle

ABB was, for instance, the first SCADA (Supervisory Control and Data Acquisition) vendor to partner with the US Department of Energy's Office of Electricity Delivery and Energy Reliability through its National SCADA Test Bed program at Idaho National Labs. Work began in 2003 to perform cyber security assessments for ABB's Network Manager SCADA/energy management system (EMS) product. Results from that initiative led to many security upgrades and improvements.

One very important initiative within ABB is the Device Security Assurance Center (DSAC). The objective of the DSAC is to provide independent and continuous protocol-stack robustness and vulnerability assessments of embedded devices as part of the development process. The test center utilizes a suite of state-of-the-art open-source, commercial and proprietary solutions, and the testing scope includes device profiling, known vulnerability scanning, and protocol fuzzing. The DSAC currently performs more than 100 tests per year, helping ABB to continuously improve the robustness and resilience of embedded devices.

> ABB has identified cyber security as a strategic initiative and therefore established a formal cyber security organization.

Examples of the improvement of cyber security capabilities include the recent releases of ABB's Extended Automation System 800xA, which has a substantial set of security capabilities to support the secure operation of process automation solutions. These capabilities include support for third-party malware (ie, malicious software) protection solutions (antivirus as well as application whitelisting), granular access control (flexible account management as well as granular access permissions and role-based access control), and secure communication using IPsec (ie, Internet Protocol security) → 1. However, the security considerations are not limited to system capabilities, as they also include support during the product life cycle; eg, providing validation of third-party security updates and a firm process for vulnerability handling.

Another example of the company's efforts to improve cyber security is the RTU560, widely used as a classical, substation-automation, smart-grid and feeder RTU (remote terminal unit), or as a gateway. Its security capabilities address the market needs induced by NERC CIP (North American Electric Reliability Corporation Critical Infrastructure Protection [1]) compliance and address industry standards such as IEC 62351 and IEEE 1686. The capabilities include granular access control (including role-based access control), logging and reporting of security events (locally or to an available Security Information and Event Manager, or SIEM) and support for secure tunneling of communications through an integrated IPsec VPN client.

The product life cycle is of course not limited to product capabilities and the support of products, but it also encompasses the secure delivery of projects. An excellent example in which cyber security was

One of the big challenges in oil and gas production is that remaining reservoirs are increasingly difficult to exploit. Thus more advanced technology and expertise are required for production. However, it is prohibitively expensive to maintain all the necessary expertise on-site at remote locations such as offshore production facilities. At the Ormen Lange gas field and the Draugen offshore rig, ABB and Norske Shell have collaborated to establish a Service Environment™ that enables remote access to the sites, thereby taking advantage of expert knowledge while saving on travel costs. Cyber security concerns are of course paramount in all remote access scenarios and thus a solid security architecture was developed. One key success factor in this endeavor was the integration of Shell's own Process Control Domain security concept with ABB's security technology and services. Another was the early implementation of cyber security, ie, during the plant design and construction.

ABB performs and assists in the system operations to match Shell information security policy. Remote system monitoring is integrated with the site inventory so historical data can also be considered. Secure client server management, loop tuning, process optimization and preventive maintenance are all part of ABB's remote capabilities and responsibilities. The Service Desk, which is both manned and automated, is the heart of information collection. Here the cases are recorded and dispatched to the correct team within a defined timeframe. The team leader assigns each case to a specialist, who could be any one of a variety of ABB experts all over the world. Important aspects of Service Desk functionality include configuration, field alert and overall change management – all facilitated remotely.

The scope of these services is not limited to new projects. While the Ormen Lange project provided the opportunity to embed cyber security at the project design phase, the Draugen platform already existed before remote access and ABB's cyber security services were added.

integrated throughout the project life cycle is the development of Norske Shell's Ormen Lange gas field and Draugen offshore platform ➔ 2.

### Cyber security embedded in the organization

ABB has identified cyber security as a strategic initiative and therefore established a formal cyber security organization led by the ABB Group Cyber Security Council. The council ensures a continuous strengthening of ABB's operational readiness and actively works to maintain the internal cyber security awareness and expertise throughout the company. The ABB cyber security organization comprises experts from various backgrounds including R&D, IS infrastructure, legal and communications in order to properly address the multifaceted challenges of cyber security. In addition, ABB complements and enhances its internal expertise and scope not only through collaborations with customers and government organizations but also through a strategic partnership with Industrial Defender, a company dedicated to ensuring the availability, reliability and security of critical infrastructure.

The future of industrial-control-system cyber security is comparable to the enterprise IT domain, where security has become a part of daily life with automated software updates, security patches and antivirus updates in order to thwart a growing number of threats. ABB is prepared to constantly enhance the security features of its offerings through technological advances and organizational readiness so it can continue to provide products and services that meet the security needs of its customers' critical infrastructure.

### Collaboration across industry

To establish a high industry-wide cyber security level, standards are required. Standardization initiatives by IEEE, IEC and ISA were established with ABB playing an active role in defining and implementing cyber security standards for power and industrial control systems ➔ 3. The main objective of these initiatives is to establish and maintain the necessary levels of cyber security, while preserving the availability and functional interoperability of systems. In addition, ABB has participated in EU projects, eg, ESCoRTS and VIKING , and continues to invest in initiatives that bring together all stakeholders, including private companies, governments, academia and other research organizations.

#### ESCoRTS

ESCoRTS[2] was a joint endeavor among EU process industries, utilities, leading manufacturers of control equipment, and research institutes to foster progress toward the cyber security of control and communication equipment in Europe. It

Extended Automation System 800xA has a substantial set of security capabilities to support the secure operation of process automation solutions.

**Footnotes**

1 See www.nerc.com

2 See www.escortsproject.eu

3 ISA99 / IEC 62443

ISA99 is the Industrial Automation and Control System (IACS) Security Committee of the International Society for Automation (ISA), which is developing a multipart series of standards and technical reports*. Work products from the ISA99 committee are also submitted to the International Electrotechnical Commission (IEC) as standards and specifications in the IEC 62443 series. In order to avoid confusion and to demonstrate the alignment, the ISA will relabel the standard series from ISA99 to ISA 62443.

The standards and technical reports are organized into four general categories that identify the primary target audience for each group:
– General: includes general information such as concepts, models and terminology.
– Asset Owner: addresses various aspects of creating and maintaining an effective IACS security program for asset owners and operators as well as the necessary organizational support from suppliers of products and services.
– System Integrator: provides technical system design guidance and imposes security requirements on the integration of control systems by using a zone and conduit design model.
– Component Provider: describes the specific product development and technical requirements of control system products.

ABB has verified the applicability of IEC 62443 in the ESCoRTS EU project and supports the work of the committee by active participation and contribution.

* ISA99, Industrial Automation and Control Systems Security, www.isa.org/isa99

4 Cyber security is an essential component in today's power grids, enabling a reliable supply of power by protecting against attacks.

Collaboration with reputable universities is also a key element of ABB's research strategy.

addressed the need for standardization and developed a dedicated roadmap for standardization and research directions.

ESCoRTS has been a leading force for:
– Disseminating best practice on security of SCADA systems
– Hastening and ensuring convergence of SCADA standardization processes worldwide
– Paving the way to establishing cyber security testing facilities in Europe

The ESCoRTS project included a field evaluation of the available cyber security standards. ABB and the Italian energy utility ENEL jointly performed a cyber security assessment of an ENEL power generation plant that was redesigned in 2003. The assessment was based on the current status of the IEC 62443 standard at the time. The results included a positive assessment of the standard's applicability and utility in securing an industrial control system and also demonstrated that, with the commitment of and collaboration among the vendor, system integrator and asset owner/operator, an industrial control system's security posture can be improved within cost and resource constraints typically applicable to existing plants.

**VIKING**

VIKING[3] was a cyber security project that investigated vulnerabilities in state-of-the-art SCADA systems used for the supervision and control of electrical grids → 4. The VIKING consortium was led by ABB and consisted of members from utilities, industry and academia. The objectives of VIKING were to:
– Develop calculation models for SCADA system security
– Estimate the societal costs and consequences of blackouts generated by failing SCADA systems
– Propose mitigation strategies for the vulnerabilities identified

These objectives were fulfilled by developing a security analysis language and a virtual society model, and by investigating vulnerabilities in power applications and proposing countermeasures for these vul-

**Footnote**

3 See www.vikingproject.eu

5 Research case study: Advanced Anomaly Detection and Security Configuration (ANADS)

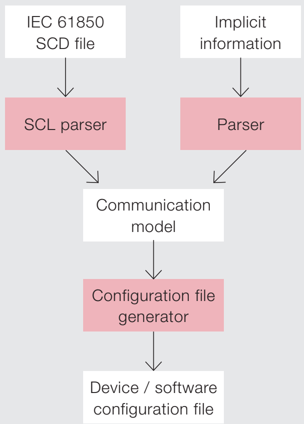


ABB is actively researching new ways of identifying intruders. The following example from its research labs shows what the future of cyber security in industrial control systems may look like.

In an IEC 61850 based substation automation system, intelligent electronic devices (IEDs) are sending out GOOSE (generic object-oriented substation events) messages at a certain frequency (eg, 200 Hz) to other IEDs. These GOOSE messages are meant to inform the receiving IEDs that the sender is active and ready to take part in providing particular logical functionality (eg, an interlocking function or a protection function). In this setup the substation automation system should ensure that the GOOSE messages reach the correct recipient within a given timeframe. Failure to deliver the GOOSE message to the correct recipient at the correct time may result in the failure of the particular function(s). Although these types of anomalies (missing or delayed sampling messages) will be passed on to the control center, the system lacks information about the primary cause of the anomaly, which may be a security incident.

ABB has developed a new approach for anomaly detection that takes the expected traffic into account and can issue an alert if traffic is not sent. For this, the substation configuration is enriched with implicit information that allows the generation of a detailed communication model as illustrated above. This model is then analyzed, and appropriate rules for configuring a firewall or an intrusion detection system are automatically generated. This allows for comprehensive monitoring of the complete data traffic in order to detect intruders at an early stage.

nerabilities. The results have been summarized in a number of story boards where possible cyber attacks on SCADA systems are described, and they include the likelihood of success for these attacks as well as their social and economic impact. Also included are possible mitigation methods and their potential to improve security.

## An ongoing research topic

Collaboration with reputable universities is also a key element of ABB's research strategy. In 2006, eg, ABB began a three-year

> ABB played an active role in defining and implementing cyber security standards for power and industrial control systems.

research project, "Threat Modelling," in cooperation with the University of St. Gallen and the Swiss Commission for Technology and Innovation (CTI). In this project, a methodology for threat modeling of embedded devices was successfully developed. The methodology allows for assessment and documentation of the actual security of the developed system throughout product development [1, 2]. On several occasions this methodology has been used within ABB to conduct security assessments as part of the development process.

ABB is committed to technology leadership and significantly invests in internal research as well – looking at, for instance, new innovative ways to protect industrial control systems [3,4]. ABB has and continues to address current and future needs by developing new approaches for cyber security in industrial control system. Examples include novel approaches for anomaly detection → 5 and the design of authentication architectures that allow the use of a single password per user throughout a complete plant.

For more information about cyber security at ABB, please visit www.abb.com/cybersecurity or email cybersecurity@ch.abb.com.


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# ABB drives training home

## ABB helps set up and equip drives training center in Austria

GERALD LIPPITSCH, PAUL DWORSCHAK – Over the past few decades, industrial electrical products have become much more complex and specialized. Not only that, but ever more regulatory and safety aspects, as well as government mandated courses, have come into play in the modern industrial electrical setting. This has pushed the level of expertise required by engineers who deal with this type of equipment to new heights. The foundation of such expertise is a thorough practical and theoretical training experience, carried out in an environment that utilizes the technology currently in use in the field. With this in mind, it was to ABB that the long-established vocational training institute (Berufsförderungsinstitut) in Vienna turned when the institute sought an industry leader to equip its training center with a new state-of-the-art learning facility for electrical drives and power technology.

1 Working with a large selection of modern products means the trainees become familiar with what they will encounter in the field.

For over 50 years, the vocational training institute in Vienna has, in various forms, been providing training to engineers. Over 25 years ago, the institute established a training center, which now provides intensive courses in the areas of building, timber, IT, metals and electrotechnology. It is for this latter area, specifically for drives and power technology that a brand-new facility has been constructed.

## Education and technology

A basic prerequisite in the realization of the drives and power technology facility was that it should be open, flexible and constructed in such a way as to perfectly complement the educational content of the courses available. At the same time, a top priority for the institute is, of course, safety, so the design had to be "rock solid" in this respect, while not impeding the learning experience or the flexibility of the facility.

Educationally speaking, a key aim of the enterprise is to bridge the gap between the world of theory and the real world in which the trainees will find themselves when they leave. To this end, ABB and the teaching staff have cooperated to construct the course content. Although emphasis in the electrical drives area has been laid on frequency-converter-fed three-phase machines, a more general, classic DC and AC basic education is also taught. Having completed all of the training units, the trainees should be capable of dealing with both low-voltage switchgear and low-voltage AC and DC drives in a skillful and safe way.

## Facility layout

The complete training center was built using the ABB Striebel & John TriLine® modular switchgear cabinet system for rated currents between 100 A and 4,000 A. There are 10 fixed workplaces, one drive assembly workplace and three units comprising mobile, wheeled, 125 A switch cabinets for practical work.

All of these are fed by a 630 A TriLine low-voltage main distribution board. This unit consists of seven panels, the first three of which are used to connect and disconnect the individual workplaces via a control system using ABB SACE circuit breakers and contactors.

The remaining four panels are used to integrate three existing 20 kVA three-phase regulating transformers with two switchable rectifier sets for the generation of adjustable three-phase AC or DC voltages for the workstations and two 125 A test panels. These latter panels, together with an ABB ACS880 industrial drive, will be used in a second extension phase to build a 55 kW drive and switchgear test bay → 1. This allows virtually all relevant drive systems to be tested using the remaining 125 A test panel. With such an infrastructure, the training laboratory may justifiably be regarded as a truly professional drive laboratory.

> The complete training center was built using the ABB Striebel & John TriLine modular switchgear cabinet system.

A free side wall of the facility provides the location for one more tool for the trainees: A testbed upon which the assembly and commissioning of low-voltage main distribution boards can be practiced. The testbed comprises a TriLine training-level low-voltage main distribution board with a 1,250 A incoming feeder panel, an outgoing circuit breaker panel and a phase-compensation panel. This comprehensive constellation of equipment satisfies one of the main wishes of the institute – to provide an environment that mirrors the real industrial world as closely as possible.

**Title picture**
ABB played a major role in setting up a drives training facility in Austria. How does this educational establishment cater for such a fast-moving technological sector?

As safety plays a very important role in a facility of this nature, ABB implemented an appropriate monitoring and safety management scheme based on the ABB Freelance hybrid process control system and the AC 800F controller.

### Cabinet appointments

The unusual nature of the mission, and space limitations, dictated the design to a great extent. The modular nature of the ABB TriLine switchgear cabinet system that was used provides the perfect solution. Not only that, but TriLine products are employed in the courses themselves; their use throughout lends consistency and harmony to the training environment.

### Safety first

Safety plays a very important role in a facility of this nature. Because it was expected to be used by trainees and teaching staff with very different levels of qualifications and experience, ABB developed an appropriate monitoring and safety management scheme based on the ABB Freelance hybrid process control system and the AC 800F controller.

The AC 800F Freelance controller is capable of handling process and diagnostic data from up to four Fieldbus gateways. The non-mobile workplaces and the low-voltage distribution board were connected via PROFIBUS to an ABB S500 I/O and then on to the AC 800F. This occupies one Fieldbus input; the remaining three are free for future use ➔ 2.

The binary interconnects of the Freelance engineering tool Control Builder F are used to perform all the classic PLC-type tasks performed by trainees and teachers alike: switching off and on, voltage interlocking, ramping voltage up to operational levels and so on.

Monitoring, controlling and logging are well-known aspects of the process control world to which close attention is paid in the facility. Without exception, all protection switches, emergency off switches, etc., are monitored. If, for example, a trip occurs in one of the workplaces, the entire facility will go into fault mode. The workplace concerned will immediately be completely electrically isolated. If one of the dual-circuit-monitored emergency off switches is triggered, the entire facility will immediately be disconnected from the mains by an ABB breaker on the main board and the facility will go into alarm mode.

The exact time and location of the fault will be indicated on the facility schematic shown on the ABB DigiVis PLC supervisory control software station, allowing teaching staff to quickly identify which area is involved and react incisively.

As the system architecture of Freelance provides a process level and a control level via the DigiVis tool, all switching actions can be controlled, monitored, followed, checked and logged, thus ensuring safety and transparency. In addition, all switching operations can be viewed by the teaching staff and the departmental management, which ensures legal compliance regarding traceability of operations.

### Start it up

The first training modules get the trainees acquainted with switches, drives and other devices. To simplify this part of the instruction, ABB, together with institute staff members, conceived a breadboarding system that allows demonstration circuits to be assembled in the facility itself. These are tested and certified by ABB before use. In this way, the hardware used can be perfectly matched to course content. Since ABB products are exclusively used, the trainees quickly become familiar with the characteristic of the devices, especially the connector schemes, and the supervisory duties of the staff are made easier.

As the training modules become more advanced and move into the realm of three-phase drive technology, yet another ABB product is utilized to assist the students in their education: The AC500-eCo starter kit, including the ACS355 machinery drive for simple motor control. This provides a very flexible and comprehensive multidisciplinary training tool.

The starter kit links learning modules devoted to PLC, drive technology and bus communication. These are often taught separately and combining them into one unit provides the student with a more interesting learning experience.

### Practically perfect

Once the trainees have reached an appropriate standard, they can graduate to practical training on one of the three mobile units.

As the largest establishment for adult education in Austria, the institute in Vienna offers a complete intensive vocational training course for technicians.

2 The ABB Freelance controller

3 The mobile motor center

This predicates that the courses have a very strong practical element. To help accomplish this, ABB, together with the institute, developed the mobile motor center → 3.

The AC motor center consists of several ABB TriLine modular switchgear cabinets, into which typical industrial applications have been built. The AC motor center is effectively an outgoing feeder panel to a process-critical heavy-duty pump drive. The three-phase induction motor pump drive system can be operated in three ways: variable-speed control, soft start or direct online start. The required load is provided by an appropriately rated, separately excited DC machine, which is, in turn, connected to a DC motor center.

With this configuration, the DC motor center can be used to demonstrate modern DC applications, such as those used in ski lifts, and to simulate loads such as pumps and calendar stacks.

The AC motor center uses an ABB ACS800 industrial drive and an ABB PST37 soft starter. The mode of operation is selected via the ABB AC500-eCo PLC.

TriLine products are employed in the courses themselves; their use throughout lends consistency and harmony to the training environment.

Both motor centers use state-of-the-art ABB industrial drive technology.

The entire apparatus, with the corresponding circuit diagrams and work instructions, is handed over to the trainees so that they can practice a full commissioning procedure – under strict supervision, of course. The tasks embrace both the programming and loading of the PLC program into the AC500 using the ABB PS501 Control Builder and the parameterization of the ACS800 drive with the ABB Drive Window software tool. They also include an identification run, the manual configuration of the PST37 soft starter, using the local input panel, and measurements and adjustments involving the motor center and the machines during operation.

Similar exercises are performed with the DC motor center on the thyristor-based ABB DCS800 and DCS400 DC converters.

Intensive training on the servo motor center with three ABB ACSM1 machinery drives for motion control applications with permanent magnet motors rounds off the intensive drive technology training.

## Looking forward

The vocational training center in Vienna is now well equipped to meet the changes in training requirements thrown up by the rapid advances in electrical drive technology. The center's design has been conceived so as to be flexible enough to accommodate new technology as it appears without having to engage in major, costly rebuilds. For example, the new ABB ACS880 industrial drive series can immediately be integrated into the motor center systems by simply changing a mounting plate.

In Vienna, a new type of universally adaptable training center for electrical drive and power technology has been created with the help of ABB. The wish of the client, the vocational training institute, to establish a modern and forward-looking educational facility for drives and power engineers has been completely fulfilled.

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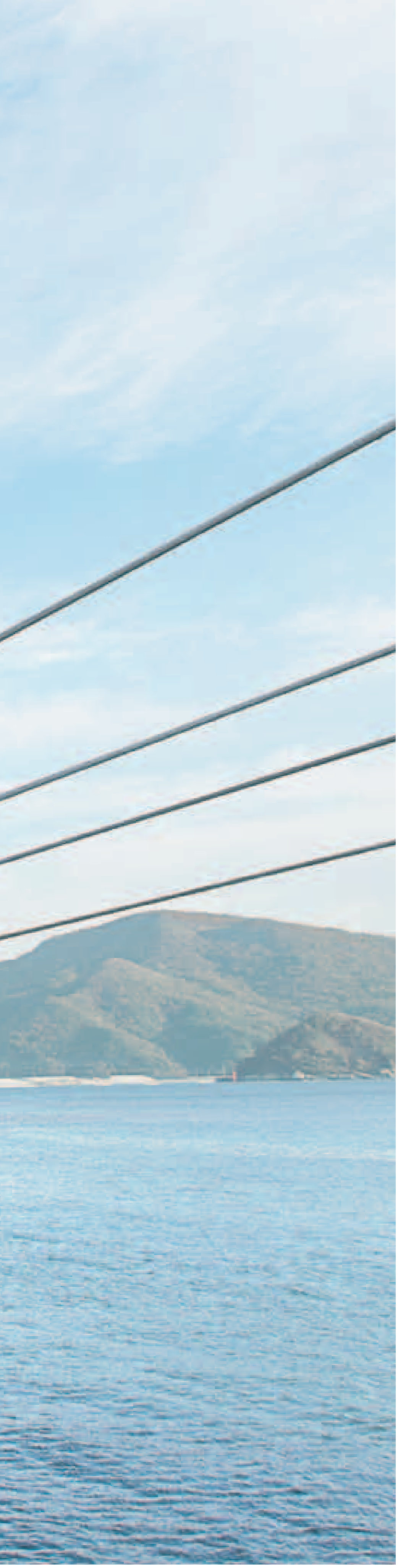


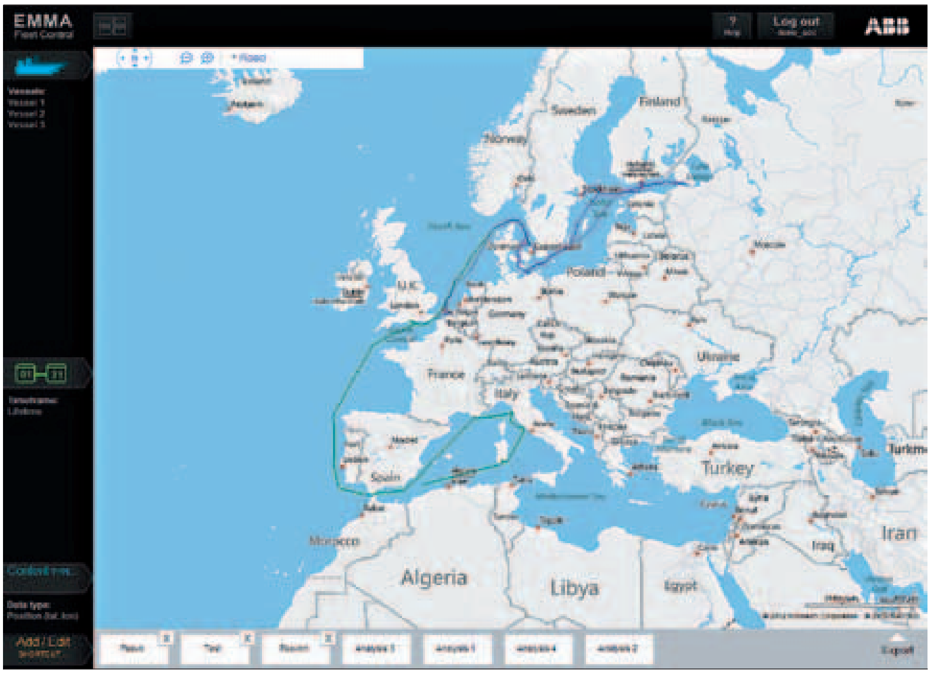
# Sea change

## ABB will set the standard for software on ships

KAI T. HANSEN – In the thousands of years that humans have sailed the oceans, marine technology has gone through a number of astonishing changes. This decade will see a significant evolution with a new wave of technology that features software that utilizes all the available data from intelligent ship equipment. This technology opportunity, together with environmental concerns and high fuel prices, are some of the drivers for VICO – Vessel Information and Control – ABB's new center of excellence that provides software solutions to the marine business segment. VICO is strengthening ABB's position as a solution provider by complementing existing marine electrical solutions and propulsion products with advanced IT.

**Title picture**
Automation and software will radically change ships over the next decade. ABB is in a unique position to provide the smart integration required for this.

1 Fleet control map




Around 90 percent of world trade is carried by the 70,000 or so vessels that make up the international shipping industry. In addition to these, there are a number of ships performing specialized duties, such as drill ships, research vessels and offshore supply and construction vessels. ABB's Azipod makes it a leader in the high-end electrical propulsion market, but ABB also delivers electrical systems for both diesel-electric vessels and ships with traditional propulsion. This means that a large part of the ocean-going fleet already carries mission-critical ABB equipment. In addition to these systems, ABB also delivers different control and software products that optimize propulsion and electrical system operation and facilitate maintenance and troubleshooting.

On many of the newer ships, modern drives, protection relays, motors, etc. offer rich sources of data that can be integrated with other information like speed, wind, waves and the weather forecast to optimize a vessel's operation and save energy. If the ship's computer system is not one delivered by ABB, as is often the case, this valuable resource can go unexploited.

Further, online communication via satellite is now common and vessels are able to report their technical and operational status to headquarters. This gives the ship owner the ability to elevate planning, monitoring and vessel comparison to a new level. Satellite communication can allow ABB to log on to the ship, inspect the status of equipment and help the crew when expert advice is needed. This saves traveling time and expense and increases equipment reliability → 1 – 2.

VICO will build a complete product and solution portfolio for these application areas, based on a smart integration of the existing products and development of new software products. These will seamlessly connect solutions from the ship's sensors all the way up to the owner's boardroom.

Satellite communication is now common and vessels are able to report their technical and operational status to headquarters.

## The green sea

A primary benefit arising from these new products, and smart integration, is a reduction in energy usage. Fuel accounts for between 30 and 40 percent of the cost of running a cruise ship. This increases to between 50 and 60 percent for most merchant vessels. Reducing fuel consumption by just 1 percent can mean an annual saving of $50,000 for a midsized bulk carrier and $300,000 a year for a large container ship.

A ship uses energy in many ways: for propulsion, lighting, heating and air conditioning. The amount of energy used for propulsion is influenced by the wind, waves, sea currents, trim and degree of hull fouling. ABB's new EMMA™ software is now able to take these effects into account and inform a vessel's owners and operators where every last drop of ship fuel is consumed, and how efficiently it is consumed → 3 – 5. Most importantly, this knowledge creates an awareness of a ship's energy consumption processes and enables benchmarks to be set and best practices to be targeted.

One current EMMA feature is the trim optimizer → 6. This measures the ship's trim angle and gives advice to the captain as to how he should move ballast water in order to raise or lower the bow in the

2 Fleet control line graph


3 EMMA onboard tracker – main layer – dashboard


4 EMMA's power overview


5 EMMA display – power with forecasting


water. Obtaining optimal trim is far from trivial as trim depends not only on the shape of the ship but also on the speed, waves, wind, etc. It requires a good understanding of ship dynamics as well as measurements and observations of the actual vessel in real-life situations; large waves created behind the ship, for instance, could be due to suboptimal trim. Fuel, in that case, is being used to make waves instead of progress – hardly the best use of fuel.

Other products will, for example, allow the air conditioning to take into account the outside temperature, humidity, weather forecast, etc., and thus save energy.

## Reliability at sea

Marine equipment integrity is not only a cost issue – it is also one of life or death. Redundancy and quality have always been answers to this and will remain important, but we can now also exploit asset supervision to further increase vessel uptime.

Power blackouts on a ship are very serious as most systems, including steering, rely on a working electrical power distribution. ABB, as a vendor of both the electrical and the automation systems is in a unique position to couple these two worlds together and provide information about the electrical system directly to the chief engineer's console in an integrated way. Having immediate access to a detailed plot of the voltage as a function of time while sitting in front of the power management system user interface can simplify post-incident analysis and speed root cause identification.

Further, new ABB protection relays with IEC 61850 Internet technology enable a standardized engineering process, provide very fast communication between

A large part of the ocean-going fleet already carries mission-critical ABB equipment.

6 EMMA advanced optimizer trim


6a Suboptimal trim

6b Optimal trim

Asset management, combined with remote access, improves the way a ship is maintained and problems are solved.

electrical protection equipment and the control system, and deliver much more diagnostic information. ABB has successfully delivered IEC 61850 in other industries and this solution will be equally useful for marine automation solutions based on ABB's Extended Automation System 800xA platform.

## Keeping it ship-shape

Asset management, combined with remote access, improves the way a ship is maintained and how problems are solved.

An early warning of incipient faults can be obtained by acquiring and analyzing status information from equipment. This enables equipment to be replaced or maintained in a more intelligent manner than would be the case with a rigid repair/replace schedule.

Today, ABB's new remote diagnostic system is deployed on a number of vessels and ABB service personnel can now give the ship's crew much better assistance and detailed instructions on exactly what to check, wherever the ship is located on the oceans. ABB provides periodic reports for each ship detailing the status and any incidents. This is highly valued by the customer.

Extending this further and giving access to accurate status information anywhere in a smart integrated system will give even more customer benefits in the future.

## Full steam ahead

ABB expects the full suite of smart marine integration products to be ready by 2015. Several are already available and they are making a big impact on marine operations. Finland-based Viking Line, for instance, has selected ABB's EMMA for a new ultra-energy-efficient passenger vessel that will have almost zero greenhouse gas emissions.

"One of the top priorities at Viking Line is to lower the emissions and fuel consumption of our fleet," said Kari Granberg, project manager at Viking Line. "We were looking for a good monitoring tool that automatically regulates power consumption and is as easy to operate as a traffic light. As a result ABB's EMMA became our first choice."

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**Publisher**
*ABB Review* is published by ABB Group R&D and Technology.

ABB Technology Ltd.
*ABB Review*
Affolternstrasse 44
CH-8050 Zurich
Switzerland
abb.review@ch.abb.com

*ABB Review* is published four times a year in English, French, German, Spanish, Chinese and Russian. *ABB Review* is free of charge to those with an interest in ABB's technology and objectives. For a subscription, please contact your nearest ABB representative or subscribe online at www.abb.com/abbreview



**Printer**
Vorarlberger Verlagsanstalt GmbH
AT-6850 Dornbirn/Austria

**Layout**
DAVILLA AG
Zurich/Switzerland



ISSN: 1013-3119

**www.abb.com/abbreview**

Preview 4|12

# Service

ABB serves an extremely broad spectrum of industries and utilities, with each sector requiring its own technologies and facing its own specific challenges. Looking across the range, however, there are also many common developments and tendencies. One example lies in the field of service. Traditionally, plant and equipment operators employed in-house service teams. The role of manufacturers was often restricted to supplying spare parts or offering specific advice. Many customers, however, are rethinking this strategy. Contributing factors include the increasing complexity of equipment, pressure to further raise levels of productivity in a globalized and competitive market, and the prospect of losing vital knowledge as personnel retire.

ABB is responding by broadening its service capabilities. With ABB on board, customers can benefit from the company's extensive knowledge and tool base in maintaining and upgrading equipment.

For example, the best way to avoid unplanned downtime is through the timely recognition of the causes of failure. In many cases, many of the signals containing clues are already measured, but often remain marooned in the field. The collection and analysis of this data opens hitherto untapped capabilities in diagnosis and prevention, enabling the transition from a reactive to a proactive approach to maintenance.

*ABB Review* 4/2012 will be dedicated to service and visit different angles and aspects of the service offerings and activities of the company.