

ABB

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The corporate
technical journal

review

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Trends in technology



ABB is continuously developing its products and services to face new challenges, both extending the scope of previous solutions and innovating into wholly new areas. This issue of *ABB Review* looks at some of the more unusual applications of its technologies.

An increasing number of ships use ABB's electrical systems. This issue dedicates an article to such installations. The front cover depicts the port of Houston, the fourth largest in the United States. This page shows the Soweto Soccer City Stadium. With a seating capacity of close to 100,000, it hosted key matches of South Africa's 2010 World Cup. ABB's scope of delivery includes transformers, switchgear and a SCADA management system.



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Technology



Claes Ryttoft
Chief Technology Officer
ABB Ltd.

Dear Reader,

Technological progress enables us to achieve things that were previously not possible, or to do what was previously possible more efficiently. The bounds of technology are continuously being rolled back in terms of speed, accuracy, efficiency and power. As the Information Age advances, we can add to this list such terms as controllability, smartness and interconnectedness.

Several articles in this issue of *ABB Review* are dedicated to the sharing of information. A central aspect is that such sharing cannot be a goal in itself, but that the data needs to be presented in a timely, intuitive and contextual manner. Modern day control room displays, for example, make extensive use of graphic and contextual elements. However, operators are not the only people requiring access to actionable plant data. From shift meetings to management discussions, up-to-date information is vital for planning. Jointly with the Interactive Institute of Umeå, Sweden, ABB has developed its Collaboration Board. The display's intuitive tablet-style multitouch interface provides instant access to trends and data from across the plant and beyond, and enables the rapid "drilling down" from key performance indicators to root causes.

For service personnel, process data may be of less interest but equipment data is of immense value. ABB's ServicePort is a configurable gateway providing controlled access to this information. Taking accessibility one step further, not only industries and

utilities benefit from instant data: It can be of value in the home too. A family of products from Busch-Jaeger (a member of the ABB Group) provides individual monitoring and trending of domestic energy consumption. Robots are sometimes referred to as "the extended arm of man." ABB not only encourages its customers to make use of these helpers, but is employing them in its own factories too. A case study looks at an example of this, while a customer story presents their work in a brewery.

A series of articles also looks at different approaches to increasing energy efficiency. From ships through irrigation to power transformers, ABB is advancing a broad range of approaches to saving energy and reducing emissions.

On a personal note, this is the last issue of *ABB Review* being produced in my tenure as Chief Technology Officer. I am being succeeded in this position by Prith Banerjee. I would like to thank all customers, readers and authors for their continued interest and support of ABB in general and *ABB Review* in particular.

Enjoy your reading.

A handwritten signature in blue ink that reads "Claes Ryttoft". The signature is fluid and cursive, with the first letters of the first and last names being capitalized and prominent.

Claes Ryttoft
Chief Technology Officer
ABB Ltd.





Collaborating in a new dimension

An interactive display helps make the right decisions



The tool makes it easy to intuitively follow the chain of effects from the problematic KPI down to the root cause, which could be in a completely different part of the process.

MARTIN OLAUSSON, MAGNUS LARSSON, FREDRIK ALFREDSSON – A picture, it is said, is worth more than a thousand words. Visual representation renders data instantly accessible and helps pinpoint trends and correlations. When the managers or operators of a plant meet to discuss the challenges and tasks ahead, the graphic portrayal of trends, requirements and bottlenecks is essential to the identification of priorities and actions. How will the presentation tool of tomorrow support this? ABB believes this tool will automatically collect data from different sources in the field, represent key performance indicators (KPIs) in an intuitive manner in conjunction with live process data and support zooming in and “drilling down” to details. The tool will also allow annotations to be added and freehand notes and sketches to be made, supporting the thought process of the decision team. Rather than a clunky keyboard and mouse, the tool will have a smart-phone style multitouch screen with intuitive 3-D navigation. For SCA’s pulp and paper plant in Obbola, Sweden, this tool is reality today. The proof of concept was jointly developed by ABB and the Interactive Institute, Umeå (Sweden), and is hailed a success by SCA.

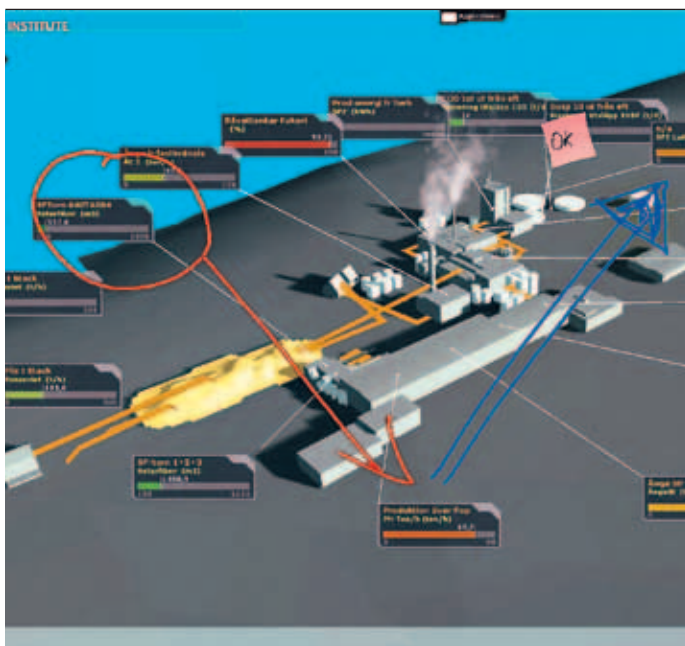
Title picture

The latest version of the collaboration tool runs on the Apple iPad.

3 Zoom down to an extended level of granularity. Decisions can be based on historical data.



4 The whiteboard function allows annotation, sticky notes and drawings.



plant in three dimensions with its key performance indicators (KPIs) → 1. The plant is shown as a 3-D model of the actual buildings and equipment. Using intuitive touch and multitouch functions known from smart phones and tablets, the displayed model can be rotated to bring different elements to the foreground, and can be zoomed into to enlarge details, permitting additional data to be displayed → 2. The viewer can seamlessly move from the plant-level KPIs to lower-level KPIs and further down to individual process variables.

KPIs and variables can be displayed in different formats, ranging from simple figures to historic trends → 3. Color cod-

It is only by looking at the same data that a group can reach a common interpretation and conclusion.

ing permits the instant highlighting of values that require attention. A KPI that falls below a defined threshold draws attention to itself by changing from a green to a yellow color coding. A further negative development makes it red. An example

of such a trend might be an increase in the volume of waste/rejects, which in turn might be caused by maladjustments in the underlying process. The tool makes it easy to intuitively follow the chain of effects from the problematic KPI down to the root cause, which could be in a completely different part of the process. Trending tools help differentiate between random fluctuations and genuinely slipping performance and so help meeting participants decide which issues need to be tackled with the greatest urgency. Besides variables extracted directly from the process, values from other inputs can be displayed in a similar manner. One metric that is important to SCA is staff motivation (which the company monitors on a periodic basis), and which is handled as a KPI and represented on the display.

Further to the live data, meeting participants can add observations to elements in the form of (virtual) sticky notes. These remain attached to the represented elements rather than to a position on the screen and can thus be used for individual annotation. When no longer needed, they can be discarded with a simple and intuitive flick of the finger. Similarly, the screen can be used for handwritten notes and sketches in the style of a whiteboard or flipchart, supporting the decision-making process of the meeting → 4.



The current installation at Obbola was built with recent development technologies from the game industry, a sector with vast expertise in 3-D technologies.

User experience has been the guiding light during the development of the proof of concept. The implementation of every feature has been strictly balanced to

Staff motivation is important to SCA and is monitored on a periodic basis.

ensure that functionality does not forego ease-of-use or the satisfaction of using the application.

Hence, by means of user-study methods that are in line with user-centered design methodology, the researchers have shown that the concept is intuitive and provides an appealing user interface.

The implementation

The current installation at Obbola was built with recent development technologies from the game industry, a sector with vast expertise in 3-D technologies. It is the task of the development team to explore efficient technologies from other domains for future use in product development. In the ABB research lab, the researchers are currently working on the next version, which will run on the Apple iPad (→ [title picture](#)).

The 3-D production status and collaboration platform is currently not productized. It is intended only as a proof of concept at this stage. An important benefit of such development is that it permits the exploration of both the strengths and weaknesses of the concept. This creates a better understanding that will be of value in the future product development phase.

The tool is a useful addition to System 800xA, bringing the integration functionality already available at the operator workplace level to the collaboration and management levels and permitting other data sources such as SAP to be similarly integrated. There is, however, no reason why it should not also be made available for other control systems or also integrate further sources of information.

Empowered by accurate and timely data and the ability to expose correlations and causations, this tool is bringing meeting participants closer to the process and is helping them make the right decisions → 5.

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Magnus Larsson

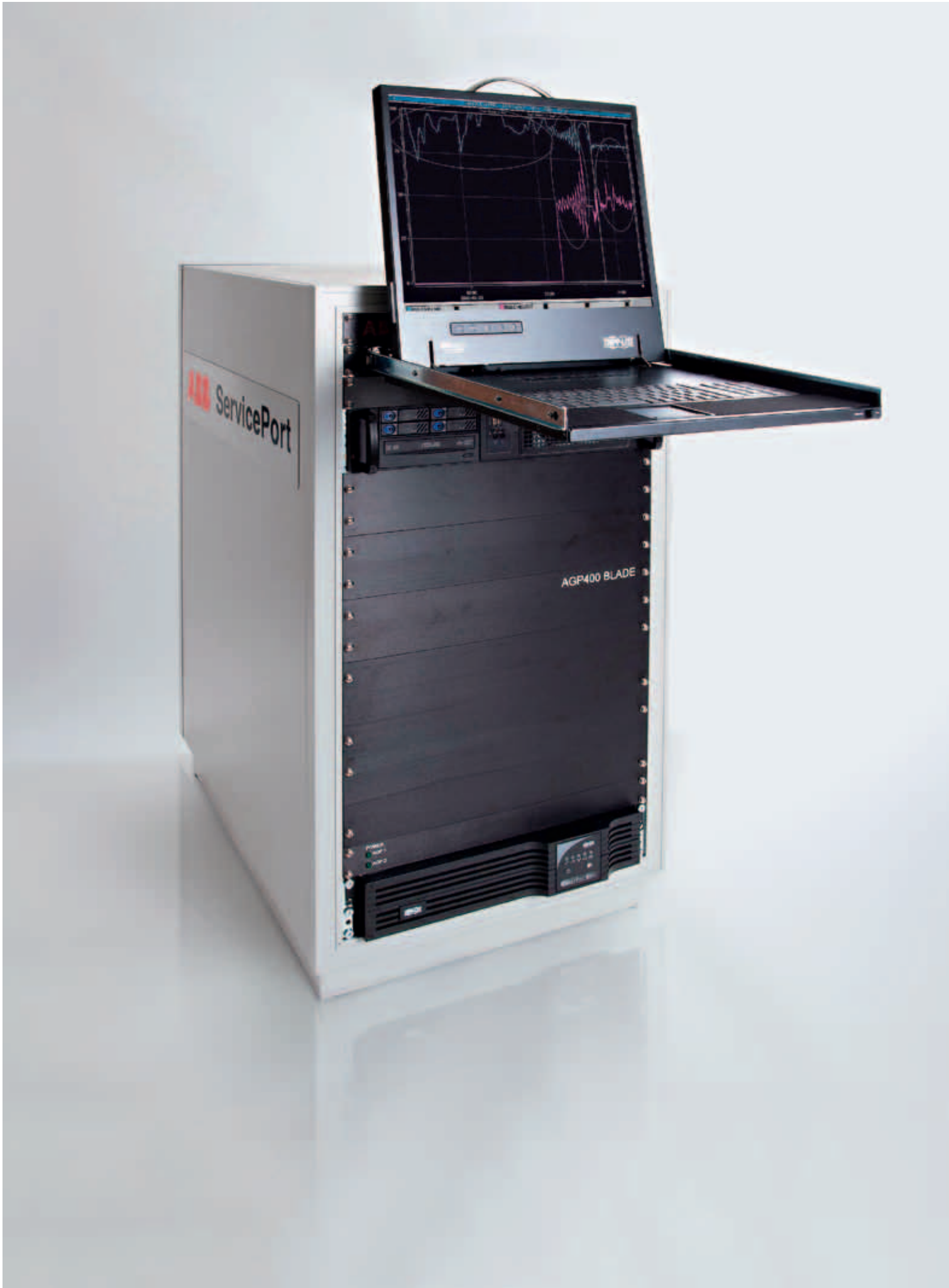
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Expert access – anytime, anywhere

ServicePort delivers top process expertise to anywhere in the world

KEVIN STARR – In business, repeatability is often the key to success. Whether one is manufacturing widgets, distributing foodstuffs or engaging in any one of a multitude of other business activities, the ability to find the optimal path, and repeat it consistently, is critical. But when it comes to service, things get difficult. Service is delivered by individuals, each of whom is, well, individual. Training can be consistent, but it takes time to become an expert and, even then, absence of variability is not guaranteed. Expert service, then, cannot be engineered for repeatability. Or can it? Add to this challenge the fact that demand for experts to perform system and process optimization is soaring, and it is easy to see why ABB, the world's largest provider of process automation systems and services, is putting a lot of engineering into its services. This engineering spans the gamut from automating analysis, through packaging repeatable processes, to designing secure, remote-enabled interaction between the tools, the processes and the experts that the customers want.

Although advanced services have long been among ABB's offerings, they have often been viewed as reactive tasks that are a "necessary evil" required to support sophisticated products. Service delivery was often only as good as the individual performing the task. Less successful service provisions could lead to unhappy customers and even lost business. A common goal for many ABB product groups is to create designs that are robust and that require less service.

The paradox is that the better ABB products become in automating customer processes, the higher the demand for value-added ABB services. This is because customers are now operating with fewer staff of their own, in some instances reducing or even eliminating process engineers. When something goes wrong, customers still need process experts to troubleshoot the problem, and ABB is often called because of its expertise in the process automation area.

The demand for expert ABB service is also fueled by the rapid growth of emerging economies such as Brazil, China and India. While ABB can respond to increased equipment demand reasonably well, in some instances by transferring entire factories to high-growth countries, it is difficult to transfer whole teams of process experts to emerging

Title picture

ABB's ServicePort allows remote access to customer systems and brings repeatability to top-level expert service in a wide range of processes.

The growing demand for expert ABB service is also fuelled by the rapid growth of emerging economies.

1 ABB's automated service tools can bring huge benefits to a wide variety of processes, such as the papermaking process shown here.



economies, or to replicate its many years of experience in new, local teams.

Whereas ABB strives to send their most experienced process engineers to the

dition. So, instead of a method that is effective only in the hands of a limited number of experts, or for a limited number of customer processes, these automated service tools capture and analyze

data so effectively that they can be used by less experienced engineers and for multiple customer processes. This reduces the effort needed to capture and analyze data at customer sites and

The better ABB products become in automating customer processes, the higher the demand for value-added ABB services.

parts of the world where they are most needed, or to where they can make the biggest impact, there are simply too few such experts to meet the rising demand. Even if enough experts could be found to canvass the globe meaningfully, they still would struggle to operate consistently as their experience, insight and approaches would vary.

Automating services

Service experts have long had methods for collecting and analyzing customer diagnostic information. These methods are very effective in the right expert's hands. Some are documented and engineers are trained on them. But if they are only used every few months, then engineers often have to relearn the method for each new job. To provide consistency, ABB began, some years ago, to write software tools that automate some of these methods to make them simpler, repeatable and expe-

dition. So, instead of a method that is effective only in the hands of a limited number of experts, or for a limited number of customer processes, these automated service tools capture and analyze

When these tools were originally developed, ABB's background as a products company meant that it did not focus on service as a high-growth business opportunity. It was a desire to protect the ABB installed base, rather than grow service, that motivated the initial investments in these automated service tools. The results from the first automated service tool were so startling that this attitude was very soon revised.

The service tools were engineered as a direct response to customer needs for process troubleshooting, even though the customers did not necessarily anticipate exactly how these tools would help. Many customers tend to feel only the immediate pain points of their process, and they focus solely on fixing that pain.

2 ServicePort brings repeatability to expert service.



A better approach is to determine and fix the source of the pain, so as to provide a long-term solution. The high-level automated service tools uncover this source so ABB experts can permanently remediate the process problems → 1.

Service toolkit

ABB's current achievements in system and process optimization owe much to the success of the first automated service tool and its many successors.

The main function of these tools is to quickly and consistently capture data from process control systems and analyze that data to produce key perfor-

cess issues for multiple industries and geographies. These tools include:

- MD Analyzer: Provides automated analysis of process controls that control linear (or “machine-direction”) parameters in a production process.
- CD Analyzer: Provides automated analysis of process controls that control cross-linear (or “cross-direction”) parameters in a production process.
- AGP500 (“Acquisition of Gauging Process Data”): Provides automated analysis of data collected by in-line instruments or sensors, which measure process parameters that can be automatically controlled.
- DL300 (“Data Logger”): Used during transitions (such as grade changes) to expose discrete events. It captures data constantly in a buffer so that when a discrete event occurs, the tool has significant data before and after the event to more meaningfully analyze the source of trouble.

These tools monitor process parameters and automatically and expeditiously identify events and situations that require attention. Previously, highly experienced process experts would have had to collect, sift through and analyze very large quantities of data to achieve similar results.

Somewhat contrarily, while these automated service tools eased the pressure for experienced experts to be at customer sites for lengthy periods, the awakening demand for the new, improved process analysis created, in turn, a necessity for more experts to be on-site to conduct it. As emerging economies grew, this necessity increased even

further. In addition, after successful problem resolution, the customer very often requested more of these services. To continue to meet customer demand, more ideas were needed.

Remote delivery

ABB process experts were traveling from site to site with the automated service tools and the unique connectivity hardware required to expedite customer data collection. However, if this unique hardware were to remain at the customer site, it would be possible for the expert

The tools quickly and consistently capture data from process control systems and analyze it to produce KPIs.

There are simply too few service experts to meet the rising demand.

mance indicators (KPIs), from which conclusions can be drawn. The tools standardize and automate less structured methodologies and enable engineers with varying levels of experience to collect and analyze data meaningfully. This is an important breakthrough in ensuring repeatability.

The initial automated services tool development, which addressed customer process issues in one industry and geography, led to the development of several such tools that address customer pro-

3 ServicePort provides a range of tools for expert service.



to access and analyze data remotely and fix the customer problem, even when off-site. In fact, the problem could be fixed faster and at lower cost since travel time and expenses would be eliminated. The analysis could also be carried out more often and on a regularly scheduled basis, in accordance with customer needs.

At first, customers were cautious. Remote connection to their systems was perceived as a data security risk. But the unique hardware was already connected to the customer process on-site. The remote interface was designed to connect only to this hardware, drawing data from it without directly connecting to the customer process. The customer's data is protected. Furthermore, customers were given discretion over the level of security implemented.

This approach was used to perform even more process analysis and troubleshooting for customers, at a lower cost, thereby increasing value for customers and for

ABB. Customers spent less to get more of what they wanted and ABB was able to provide high-level analysis to more customers without overtaxing their service experts.

Thus was born the ABB ServicePort service delivery device → 2. The unique hardware that expedited process connection and data collection already ex-

The main advantage of ServicePort is the provision of easy and fast optimization from high-quality ABB experts at any time, from anywhere in the world.

isted as part of an ABB process expert's "took kit." The device was not designed to be left at the customer site. However,

when it was realized that the best way to meet customers' needs was to leave this hardware on-site and collect and analyze data remotely, the first field test of what was to become the ServicePort can be said to have taken place.

After initial customer testing of this concept indicated a strong market reception, engineering of remote optimization services for repeatability began. The eventual deliverable needed to include the unique connection/collection hardware, engineered for easy access and connection by customers. Because a desirable aspect of this unique hardware is its portability (ie, ease of connection to various processes in different parts of a customer plant), the customer version features a docking station in the ServicePort. While the automated service tools were something that could reside remotely, it was decided that this portability tool would reside in the ServicePort to offer maximum flexibility in collecting and analyzing data remotely and on-site → 3.

Cost-effective solution wins paper-maker's business

U.S. Corrugated's 100 percent recycled containerboard mill is one of the world's greenest paper operations. The mill, located in Cowpens, South Carolina, recycles and reuses all of its water, keeping its process water out of local streams, rivers and sewers. A winner of multiple environmental awards, the mill also prevents the unpleasant paper production odors from spreading through the surrounding area by using natural gas and electricity to generate steam for its paper-drying process.

While the mill uses ABB's distributed control system (DCS) to automate its production processes, U.S. Corrugated recently added advanced ABB quality control systems (QCSs) to ensure product quality. After the installation, the mill consulted with ABB about how they could cut service

delivery costs but still optimize process performance.

Because of ABB's modular and flexible optimization service delivery approach, U.S. Corrugated chose ABB's ServicePort to provide secure, on-demand diagnostic and troubleshooting support remotely.

Using a beta version of ServicePort, ABB specialists were able to effectively monitor and troubleshoot as needed by connecting remotely, resulting in considerable savings in time and money.

Additionally, ABB has helped the Cowpens mill increase product quality, reducing the product variability substantially (the average paper basis weight 2-Sigma is below 0.5 and the average paper moisture level 2-Sigma is below 2). By keeping quality high, customer complaints have been all but eliminated while production has increased, giving the Cowpens mill the financial benefits sought by U.S. Corrugated.

Remote service performs even more process analysis and troubleshooting for customers, at a lower cost.

Expanding applications

As is the case with many successful products, other applications and opportunities for ServicePort come up constantly. For instance, every control system ABB has sold has a PC with system configuration tools on it. For a small additional cost, the system configuration tools could be delivered in ServicePort, thus providing important installation and commissioning tools for startup in the same device that can later be used to deliver remote system and process optimization once the plant is in normal operation.

Other applications are currently part of the design. The ServicePort is sometimes referred to as the "cable box" due to its similarities to cable TV hardware: One data stream enters the device and is split into multiple "channels." ABB is creating new channels of content, including:

- System configuration
- Preventive and corrective maintenance
- Service scheduling
- Work order tracking
- Spare parts management and ordering
- System optimization
- Process optimization
- Condition monitoring
- Event notification
- Support services

A package of initial content is being decided upon for formal launch (beta versions are in operation at various customer sites; formal launch is awaiting patent approvals).

Remote service benefits customers and ABB

For customers, the main advantage of ServicePort is the provision of easy and fast system and process optimization from ABB experts at any time, from anywhere in the world. For ABB, ServicePort helps meet the growing customer demand for such services.

Culturally, ServicePort changes the service interaction between customers and ABB. ServicePort acts as a "cable TV box," presenting easy access to a wide variety of services that customers may never have used before, making it easy for them to evaluate and acquire the services. Its ability to collect and evaluate system and process data from competitive systems increases the customers' range of service options as well as ABB's attractiveness as a service provider. This level and range of service availability and access maximizes ABB process automation life cycles, which is good for the long-term success of customers and ABB alike.

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The tools make it easier and faster for less experienced process engineers to detect process issues.



Energy control at your fingertips

Award-winning technology delivers an unprecedented insight into energy usage

MICHAEL WASILETSCHKO – Few would disagree that an individual who takes responsibility for, and is fully aware of, his own energy consumption consequently improves his usage behavior. And even small improvements, when aggregated over many such individuals, can have a significant, positive impact on resource conservation and greenhouse gas reduction. Yet how many can state with any degree of accuracy how much water, gas, oil or electricity they used yesterday? Very few, and that is because the relevant data is difficult for the individual to get at and meaningfully collate. A new range of products from Busch-Jaeger now changes all that. The Busch-EnergyControl®, Busch-EnergyDisplay® and Busch-ComfortPanel®, in combination with the energy data gateway, present individual consumers with an unprecedented insight into their usage behavior and allow them to personally optimize their energy budget.



In recent years, there has been a massive increase in the power generated by renewable sources, and all the signs indicate that this trend will continue unabated. The infrastructural and attitudinal changes accompanying this shift almost demand a corresponding modification of consumer behavior. The energy user should no longer be blind to how much energy he consumes, when it is consumed and at what price. Currently, very few people can say how much water, gas, oil or electricity they are using, or if it is being consumed at on- or off-peak rates. The reason for this is that the relevant data are not easy for the individual to access.

This all changes with the new Busch-EnergyControl, Busch-EnergyDisplay and Busch-ComfortPanel, in combination with the energy data gateway (MUC-C).

Thoroughly modern metering

The days of traditional water and electricity meters are coming to an end. Smart metering is now the preferred means of capturing energy consumption data in a building. Smart meters compile consumption values and forward them directly to the supplier, for billing purposes, and to displays in the building, for informational and control purposes.

The energy data gateway MUC-C (multi-utility-communication controller), with its classic modular MDRC (modular DIN rail components) design, can compile all consumption data such as electricity, gas, water and heating and is available in four versions, each adapted to a different method of communication with the energy supplier → 1. Power and mobile networks, as well as radio, can be used as communication media. The gateway is set up on-site to individual circumstances, for example the number of oil, gas, water and electricity meters, and is optimally configured to suit the customer's requirements.

The MUC-C works with each of the new displays: the Busch-EnergyControl; the Busch-EnergyDisplay; or the multiple prize-winning Busch-ComfortPanel. In this way, four configurations may be realized, each of which ensures energy transparency and opens up all the possibilities of modern energy management.

Busch-EnergyDisplay – everything accounted for

The compact Busch-EnergyDisplay fits in every standard flush-mount box and is available for almost all ranges of Busch-Jaeger switches. On the back-lit 3.81 cm (1.5 inch) display, information about all the primary forms of energy relevant to the household, as well as the latest costs and rate estimations, insofar as the energy supplier provides this service, can be displayed → 2. The cur-

Currently, few can say how much energy they are using, how much it is costing, or if it is on- or off-peak.

rent rate and on- or off-peak can be indicated by the red and green background colors, respectively. Furthermore, the Busch-EnergyDisplay can also be used as a light switch or dimmer.

Due to its harmonic integration into the Busch-Jaeger switch range design concept, the Busch-EnergyDisplay can be optimally adapted to particular equipment and configurations. The floating rocker switch feature, similar to that used in the Busch-DigitalRadio, room thermostat and Busch-Timer®, ensures intuitive control.

Title picture

Fingertip control: The high-resolution, 22.86 cm (9 inch) wide TFT touch screen of the Busch-ComfortPanel controls and displays building system data. It also hosts Internet and home entertainment applications.



The current rate and on- or off-peak can be indicated by the red/green background colors, respectively.

Busch-EnergyControl – trend spotter

The 8.89 cm (3.5 inch) screen of the Busch-EnergyControl provides a clear display of consumption information in the form of graphs and diagrams → 3. One glance is enough to see, for example, in which direction the current electricity consumption in the building is trending. The consumption values, costs and rate estimations – if supplied by the energy provider – can be displayed for all the relevant basic types of energy. The current trends can be marked in color.

High consumption rates can be responded to straight away, by switching off some of the consumers, for example. This can also be set up to happen automatically. In addition, the functions on the touch screen offer the option of switching off several consumers at the same time by pressing one button – for example, when leaving the building.

A normal flush-mount box is sufficient for installing the Busch-EnergyControl. This facilitates quick and simple retrofitting.

Busch-ComfortPanel – the complete solution

The Busch-ComfortPanel does away with the barriers between building system technology, home-entertainment and IP-based communication: Users now experience completely new perspectives in living comfort and quality, as the device is not only a convenient facility for building control but is, at the same time, an information and entertainment center. And all this on top of comprehensive functions that provide complete energy usage transparency.

The high-resolution, 22.86 cm (9 inch) wide, color screen of the Busch-Comfort-Panel enables the clear, large-format presentation of consumption information in the form of graphs and diagrams. One glance is sufficient to see the building's current electricity consumption trend. As before, the consumption values, costs and – in the case of electricity, and if the utility provides it – the rate estimations and current trends, can be displayed for all the main basic types of energy. As in the Busch-EnergyControl, Busch-ComfortPanel users can respond straight away to high consumption values.

The Busch-ComfortPanel's color-oriented operating system was awarded the prestigious "Red Dot: Best of the Best 2008" prize.

The Busch-ComfortPanel also hosts home entertainment and IP-based communication applications. Users will, thus, not only have a control center for the entire building system, but, at the same time, a communication center with intuitive controls for calling up the current weather forecast or stock market data on the Internet, receiving emails, playing favorite music on the integrated MP3

3 The Busch-EnergyControl has a large-format 8.89 cm (3.5 inch) screen and displays information on all relevant primary energy types.



The energy user should no longer be blind to how much energy he consumes, when it is consumed and at what price.

player, listening to Web radio via the integrated loudspeaker or external active speakers, or watching video clips. The Internet connection can be implemented via a LAN cable connection, or by wireless via WLAN. The device can also be used for VoIP Internet communication. Internal communication with other Busch-ComfortPanels is possible via video telephone using the integrated video camera. The camera facilitates room monitoring and can even be used as a baby monitor.

Remote control

Mobile communication with the Busch-ComfortPanel is possible by using a VNC (Virtual Network Computing) server. A mobile telephone, laptop or webpad can be employed for remote control. All the functions that are on the panel can now be conveniently controlled via the usual user interface. All VNC-compatible smartphones and PCs with an Ethernet port are suitable for this.

Selection box

The range of functions supported by the Busch-ComfortPanel can be individually customized. In the area of building con-

trol, this range includes all the “smart home” features, from heating and air-conditioning, through lighting regulation and sun-shading, to fault and alarm messaging. The room plan of a house, with mimic displays of rooms, incorporating integrated operating switches, can be displayed on the touch screen, as can video signals from external monitoring systems (eg, external cameras).

Noble prize winner

It is not only in the technical sense that the Busch-ComfortPanel distinguishes itself: Its color-oriented operating system was awarded the prestigious “Red Dot: Best of the Best 2008” prize. All the control elements are part of an intuitive color operating concept. It is based on a consistent color-orienting concept where a color is assigned to a functional area – eg, lighting, blinds, heating, or the lighting scenarios. All functions in the area of lighting are assigned the color yellow (representing the sun and brightness); heating is orange (for warmth and well-being); and blind control is blue (for coolness and the color of the sky). Violet or magenta (the colors of extravagance and

the theater) are associated with lighting scenarios. It is a labeling code that is understood internationally and that does not rely on language.

In harmony with the growing movement toward more conscientious energy use, this range of products enfranchise the modern energy user and allow him to monitor and take control of his energy usage. Armed with this new insight, he will be able to optimize his energy costs, lessen his resource consumption and decrease his carbon footprint.

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Red robots in the red house

ABB robots help a traditional Black Forest brewery

ANDREAS SCHWADERER – Germany’s Black Forest has long been famous for its natural beauty, clean water and clean air. It also has a tradition of precision workmanship going back many centuries, with products such as its clocks being famous the world over. These high standards in mechanical deftness and accuracy are a strength that is shared by ABB’s robots. Finding these robots at work in a traditional Black Forest brewery may be unusual, but is, nevertheless, consistent with the tradition of precision. The Rothaus brewery, maker of the famous “Tannenzäpfle” beer, uses four ABB robots in handling and packaging.

High up in the Black Forest in southwest Germany sits the 221-year-old Rothaus (“red house”) brewery → 1. The beer brewed here has long since achieved a cult status among German beer drinkers and the brewery’s distinctive beer bottles, with their foil cladding and label showing a German Fräulein,

are known throughout Germany, and beyond. Despite being over two centuries old, the brewery is equipped with the latest in modern technology, including four ABB robots that handle the beer kegs and cases.

On the production floor, the scene is like one from a delicate and very precise ballet of technology: An ABB robot bends gracefully forward and grips a stainless steel beer keg gently but firmly around its “waist,” then smoothly rotates 90 degrees and carefully places it,

Title picture

One of the brewery’s two IRB 6640 robots at work as a keg handler.

1 From monks to ministers



The Rothaus State Brewery was founded in 1791 by monks from the nearby St. Blasien monastery. Enough spring water and wood was available near “the red house”, above the picturesque village of Grafenhausen, to adequately supply the water- and energy-intensive beer operation. After the monastery was dissolved, ownership passed to the Grand Duchy of Baden in 1806. Later, it was taken over by the state, in whose ownership it remains. The famous stylized Fräulein figure, essentially unchanged since the 1960s, has been dubbed “Birgit Kraft,” from the local pronunciation of “Bier gibt Kraft” (beer gives you strength).

With an annual production of 840,000 hectoliters, the Badische Staatsbrauerei Rothaus AG is one of the biggest in the Baden-Württemberg region.

2 The IRB 6640



A strong robot for a range of applications

The IRB 6640 comes in different arm lengths and handling capacities. The robot can bend backwards fully, providing a large working range while permitting it to fit into space-restricted production lines. Typical application areas are material handling, machine tending and spot welding. The robot is also available with different options for different working environments, such as Foundry Plus 2, Foundry Prime 2 and Clean Room.

Payload

The maximum payload is 235 kg, which makes the robot suitable for many heavy material-handling applications. The robot also follows the ABB tradition of having outstanding inertia capabilities, so it can handle not only heavy, but also wide parts. Collision resistance is another feature for which ABB robots are valued.

Easy maintenance

Simplified forklift pockets and more space in the robot foot allow for easy maintenance.

Increased path performance

IRB 6640 runs the second generation of TrueMove™ and QuickMove™. This gives the robot highly accurate motion, which translates into less time for programming as well as a better process result. This software also supervises internal robot loads, meaning reduced risk of overload and longer robot lifetime.

Passive safety features

Passive safety features include load identification, movable mechanical stops, EPS (electronic position switches) and a stiff steel structure.

inverted, in the packing area. For many years, keg handling was done by hand; then, later, by an elaborate gantry unit. Now two identical ABB IRB 6640 → 2 robots perform the task, like clockwork and with much less fuss. The special Foundry Plus 2 robot variant is ideally suited for conditions in the brewery. One jockeys the empty, not-yet-cleaned, stainless steel kegs from a wooden pallette onto a conveyor belt. A good 10 minutes later, its partner neatly stacks the now thoroughly cleaned and filled kegs → title picture. The two comrades-in-arms are painted the fiery Rothaus RAL 3000 red, like all other moving equipment in the brewery. “They couldn’t

be more reliable and low-maintenance,” reports Robert Jäger, who is in charge of the beer-filling operation, “and in

Packing a six-pack

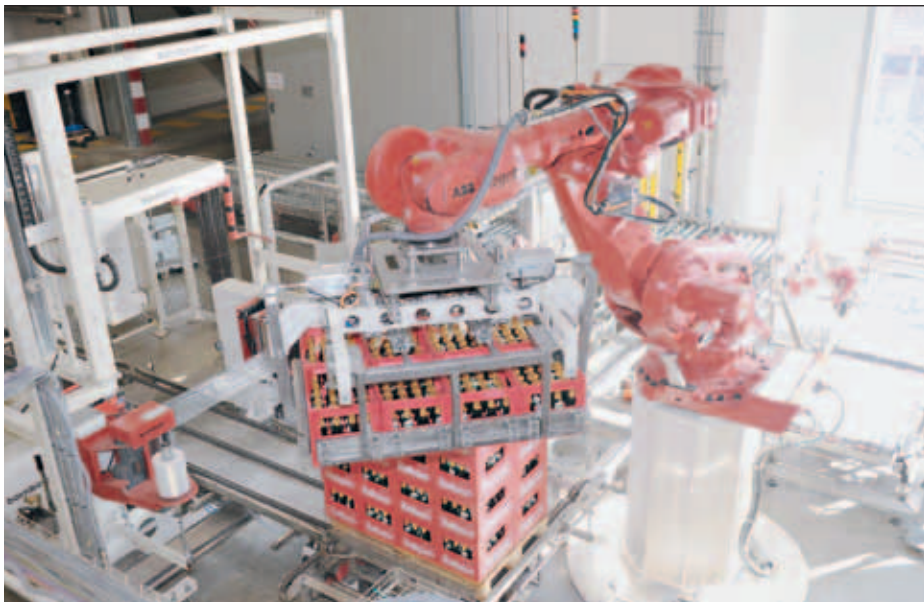
Only 10 percent of the Rothaus beer ends up in kegs; the rest goes into the attractive bottles so loved by beer drinkers up and down the country. Of the bottled beer, one in every eight is sold in a six-pack – and here, again, an ABB robot has a hand in hand in

An IRB 6640 robot “assists” the automated packing machine in which a 24-bottle crate is repacked into four six-packs.

comparison to the earlier gantry unit they take up a lot less room, too.”

passing around the beer. Since 2005, an IRB 6640 robot has been “assisting” the automated packing machine in which a

3 An IRB 6640 robot assists the packing machine



One ABB IRB 6640 robot jockeys empty kegs onto the conveyor belt; an identical unit at the other end of the belt stacks the cleaned and filled units.

4 The smaller IRB 140 working alongside the larger IRB 6640 in the world-famous Rothaus brewery

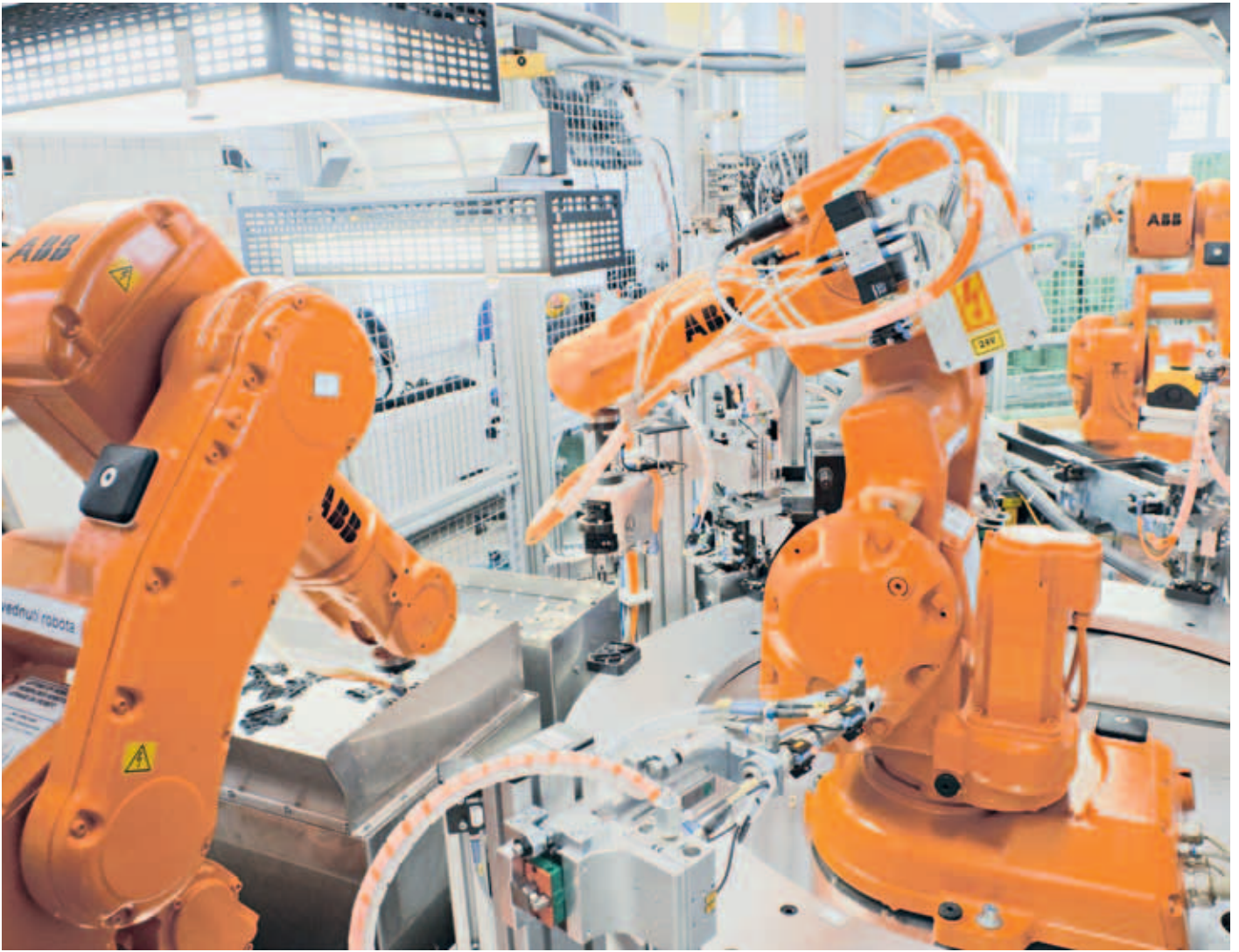


24-bottle crate is repacked into four six-packs. The IRB 6640's strong beer-lifting arm can effortlessly whisk its 142 kg load onto a conveyor belt → 3.

The beer crates come tied together, for safety during transport, in a four crate wide, two crate deep configuration. Removing the safety band is the job of the fourth member of the ABB robot team: the small IRB 140 → 4. With its rather diminutive size compared with its colleagues, it may be like a "Bonsai" of industrial robots, but it is very capable nonetheless.

Project leader Ralf Krieger, is also pleased with the ABB products, saying "Like the two robots in the filling area, these two were also brought into service really quickly." These are words that the ABB team members like to hear – maybe they will celebrate them by clinking together some of those attractive foil-topped bottles.

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Looking within

ABB is making use of its own IRB 140 robots to step up productivity, improve quality and reduce costs in its own factories

DAVID MARSHALL – Today’s automated industrial processes for manufacturing industries are a far cry from Charlie Chaplin’s iconic depiction of a factory worker frantically struggling to keep up with an assembly line production in the 1936 film classic “Modern Times.” ABB was the first company to introduce a fully electrical, microprocessor-controlled robot in 1974. Since then, there has been a steady increase in the role of industrial robots in manufacturing, impacting the productivity and safety of these industries. ABB is a leading supplier of industrial robots, with more than 200,000 installations worldwide. In keeping with the notion of “practicing what we preach,” ABB not only manufactures robots for use in industry, but also uses robots to manufacture its own products. One such example is Czech-based ABB Elektro-Praga, which employs ABB’s IRB 140 robots in the manufacturing of its dual-plug sockets.

1 IRB 140 at a glance

- Payload of 6 kg, spherical reach of 810 mm that is 360 degrees rotational, fast acceleration, and a large working envelope
- Can be suspended at any angle, permitting flexible, easy and cost-effective integration
- Runs on the latest IRC5 robot controller
- Two Ethernet interfaces enable PCs to be integrated for process monitoring, production information and program adjustments
- Open software language and system configurability allow for adding new functionality
- Arms are IP67 protected
- Collision detection option with full-path retraction makes the robot reliable and safe
- TrueMove and QuickMove second-generation technology ensures accuracy for path, position and speed

2 The IRB 140 Foundry Plus



Acquired by the ABB Group in 1993, Elektro-Praga – now ABB Elektro-Praga – specializes in wiring accessories such as low-voltage circuit breakers, switches, sockets and control products. To enhance the quality of its products, boost productivity and reduce costs, ABB installed a new production line at its factory in Jablonec nad Nisou in the Czech Republic for the manufacturing of the company's Tango line of dual-plug sockets. The production system features three 6 kg capacity industrial robots from ABB.

Small wonder

The IRB 140 robot → 1-2 is compact and powered by a high-performance motion control unit. Each six-axis machine boasts quick acceleration and a high payload. The compact robot is exceptionally fast, accurate and powerful. It has one of the fastest cycle times (as fast as 0.77 s) of any articulated robot.

In the future, the factory plans to use the same production unit for at least four other product lines. Adjusting the production line takes 10 minutes or less, and the product variant can be changed up to 30 times per week, resulting in flexible “production to order.”

The production unit incorporates three digital cameras – an ideal solution for handling imaging applications such as high-speed assembly or semiconductor inspection. The cameras run on Cognex Vision Pro software, which supports the coordination of the robots and enables the arms to “pick and place” components at each point in the assembly process.

Higher productivity

Requiring only one operator, three robots work two eight-hour shifts per day. Cycle time is only 2.3 s per electrical socket, and the robots process 8,500 dual-plug sockets per shift. Prior to automation, each shift required up to nine people to process 950 pieces per person.

The IRB 140 robots have sophisticated control systems that allow variable task programming. Any number and virtually any type of visual inspection can be included within the cycle by simply changing the parameters of the robot and PLC programs.

Stoppages or errors are shown on the operator's monitor, indicating exactly where and what the problem is, and enabling downtime to be kept to an absolute minimum.

Adaptable technology

The IRB 140's flexibility has been seen elsewhere in the production plant. When difficulties with the material feed on another assembly line for light switches occurred, the problem was solved by installing another IRB 140 linked to a

vision system. This solution had been implemented previously to solve a manufacturing problem in another material feeding station at the plant. Now, the small metallic frames are being fed reliably. The use of a single robot increased the line's output by 15 percent.

Adaptability is one reason for the IRB 140's success. Another is its ease of use: Once the software has been configured, operators need only a few hours' training.

All mechanical arms are completely IP67 protected, enabling easy integration of the IRB 140 for a variety of applications.

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Title picture

The IRB 140 in action: Three of these six-axis robots can process 8,500 pieces in an eight-hour shift and require only one operator.





Onboard DC grid

The newest design for marine power and propulsion systems

JAN-FREDRIK HANSEN, JOHN OLAV LINDTJØRN, TOR ARNE MYKLEBUST, KLAUS VANSKA – Think of a Mac from Apple, a Le Corbusier chair, a Frank Lloyd Wright house. All are designs that are clean, elegant, streamlined. All are designs that took an existing element and created something innovative. ABB has done just that with its onboard DC grid for electric power distribution, creating the most flexible marine power and propulsion system to date. The system merges the various DC links throughout the vessel and distributes power through a single 1,000V DC circuit, thereby eliminating the need for main AC switchboards, distributed rectifiers and converter transformers. The onboard DC grid combines the best of both AC and DC components and systems, is fully compliant with rules and regulations for selectivity and equipment protection, can be used for any electrical marine application up to 20MW, and operates at a nominal voltage of 1,000VDC. The best part: ABB's onboard DC grid increases a vessel's energy efficiency by up to 20 percent and reduces the electrical equipment footprint and weight by up to 30 percent.

In designing the new system, ABB looked at the entire power delivery chain of energy conversions on marine vessels and identified a case for using DC distribution rather than the traditional AC system.

Two longstanding and crucial principles have been carried over from the traditional AC distribution system to form the framework of the onboard DC grid philosophy: Personnel and equipment must be protected in case of failures and proper selectivity¹ shall be ensured in such a way that safe operation is maintained after any single failure.

Advantages of DC distribution in certain cases include lower overall losses and fewer problems with harmonic distortion. Yet historically there have been challenges with DC distribution, primarily being how to achieve full selectivity and equip-

Footnote

- 1 In the event of a fault on a component or subsystem, selectivity means (on a functional level) that only the faulty component or subsystem is affected and taken out of operation.

Title picture

Offshore support vessels, like the MT 6022 design shown here, are prime candidates for the onboard DC grid system.



1a Onboard DC grid



1b Traditional AC grid

The new system merges the various DC links around the vessel and distributes power through a single 1,000 V DC circuit.

ment protection in ways similar for AC distribution. AC currents are by nature simpler to interrupt because of their natural zero crossing every half cycle. DC circuit breakers exist but are more complex, larger and more expensive than comparable AC circuit breakers.

ABB overcame these challenges by breaking with the classic protection philosophy where selectivity is achieved through an arrangement of coordinated circuit breakers and instead capitalizing on the opportunities afforded by power electronic components in the onboard DC grid system.

Power distribution and configurations

In traditional electrical propulsion systems, variable-frequency drives typically account for more than 80 percent of the installed power. At its simplest level, the onboard DC grid concept is a reworked and distributed multidrive system where distributed rectifiers are eliminated → 1.

The new system merges the various DC links around the vessel and distributes power through a single 1,000V DC circuit, thereby eliminating the need for main AC switchboards, distributed rectifiers and converter transformers → 2. All generated electric power is fed either directly or via a rectifier into a common DC bus that distributes the electrical energy to the onboard consumers. Each main consumer is then fed by a separate inverter unit. When an AC distribution network is still needed, for example with a 230 V hotel load,² it is fed using island converters, developed by ABB to feed clean power to these more sensitive circuits. Additional converters for energy storage in the form of batteries or super capacitors for leveling out power variations can be added to the DC grid.

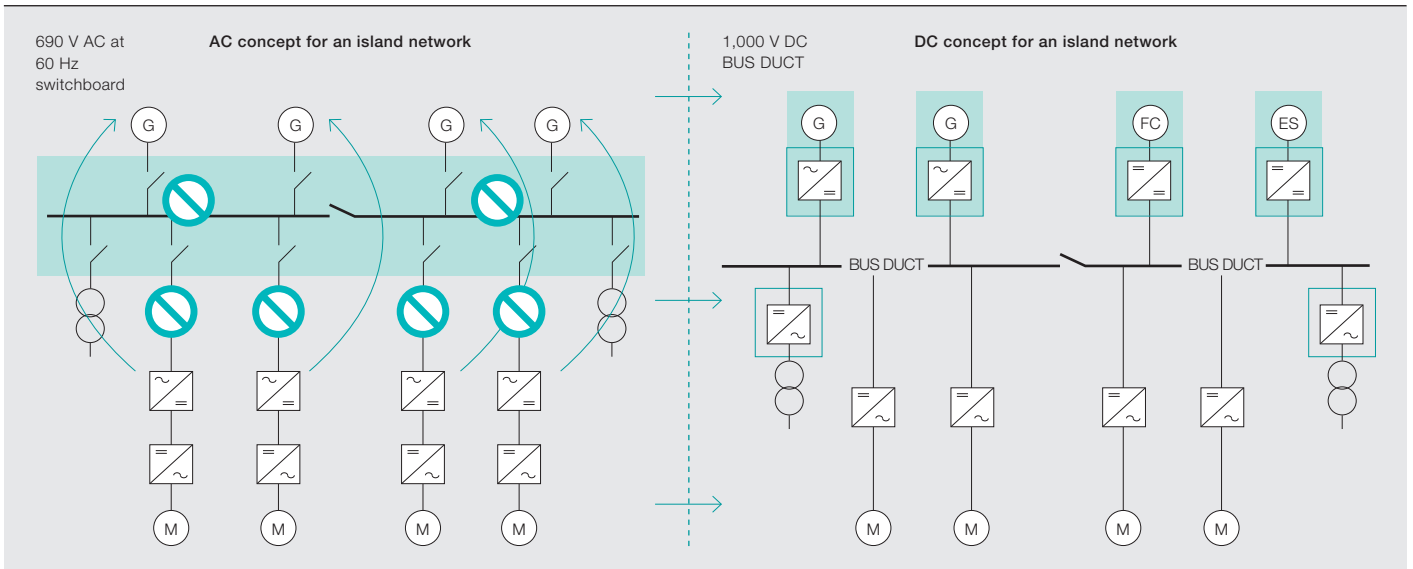
The system has been remodeled in such a way that most of the well-proven products used in today's electric ships such as AC generators, inverter modules, and AC motors can still be used.

The onboard DC grid can be configured in several different ways. With a centralized approach all converter modules are located in one or multiple lineups within the same space that the main AC switchboards used to occupy → 3.

Footnote

² The term hotel load is used with respect to ships to describe their non-propulsion energy requirements, such as lights, air conditioning, computers, water purifiers, radios, etc.

2 AC to DC transformation of a generic electric propulsion system



With a distributed approach, the various converters can be placed where it suits the vessel operation or design best → 4. The AC generators can have either integrated or stand-alone rectifiers installed in cabinets. As a result of the novel approach to protection, the volume of components that, by regulation, must be installed in the main switchboard room is drastically reduced. This affords the vessel designer a new level of freedom in designing the electrical power system around the vessel function, increasing the vessel functionality and value.

Protection and safety

With the main AC switchboard, AC circuit breakers and protection relays omitted from the new design, a new protection philosophy that fulfills regulatory requirements for selectivity and equipment protection is essential. Proper protection of the onboard DC grid is achieved through a combination of fuses, isolating switches and controlled turn-off of semiconductor power devices. Since all energy-producing components have controllable switching devices, the fault current can be interrupted much faster than would be possible with traditional circuit breakers with associated protection relays.

In case of a serious fault in a module, fuses are used to protect and isolate inverter modules just as with current LV frequency converters. In addition, input circuits separate the inverter modules from the main DC bus and afford full con-

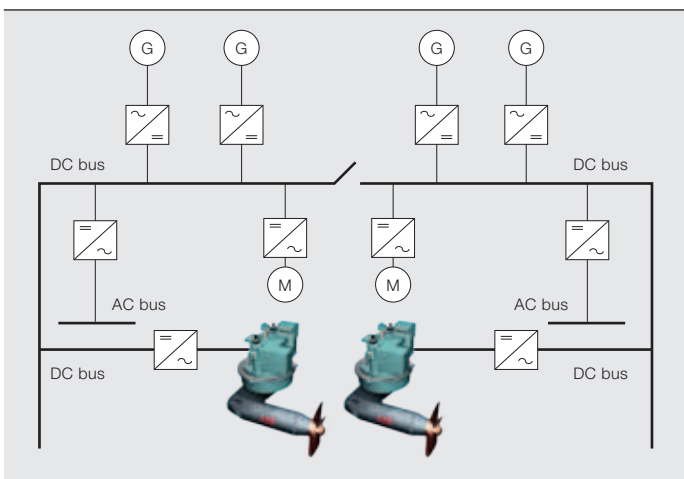
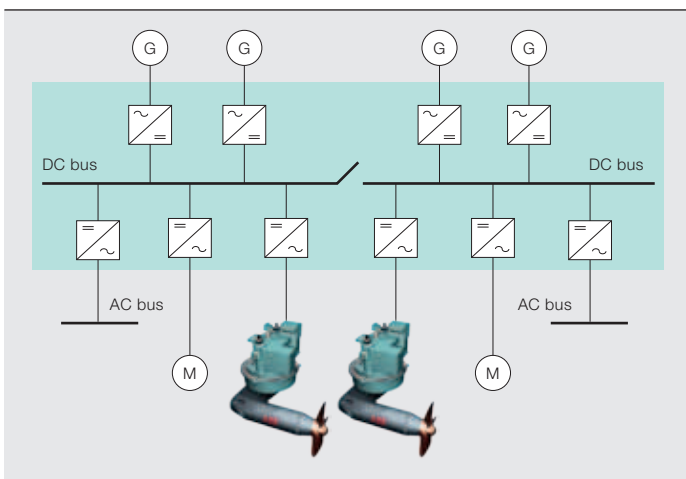
trol of reverse power, both in fault and normal conditions (as for example in propeller braking mode). This means that faults on a single consumer will not affect other consumers on the main DC distribution system. In the event of severe faults on the distributed DC bus, the system is protected from generator fault currents by means of a thyristor rectifier, which also doubles as a protection device for the generator. Isolator switches are installed in each circuit branch in order to automatically isolate faulty sections from the healthy system.

In close cooperation with Det Norske Veritas, a global organization that provides classification and risk assessment services to the maritime industry, ABB has ensured that the onboard DC grid system philosophy meets or exceeds the demands of current rules and regulations. Fault currents can be controlled in as little as 10 to 20 ms. This results in a drastic reduction in the DC grid's fault energy levels as compared with traditional AC protection circuits where fault durations can reach up to 1 s. This low-energy fault protection scheme, combined with the new flexibility in designing generator parameters, allows the onboard DC grid system to be used for installed power up to 20 MW.

Efficiency with fuel and space

The DC grid concept utilizes well-proven AC generators and motors, but allows for increased efficiency because the system is no longer locked to a specific fre-

Proper protection of the onboard DC grid is achieved through a combination of fuses, isolating switches and controlled turn-off semiconductor power devices.



The new concept helps solve the traditional fuel efficiency challenge faced in dynamic positioning operation.

quency (usually 60Hz on ships), even though any 60Hz power source may still be used. The new freedom of controlling each power consumer independently opens up numerous ways of optimizing fuel consumption.

When operating marine combustion engines at constant speed, the fuel consumption is lowest at a very small operating window, typically around 85 percent of rated load. With the introduction of variable-speed operation of the engine, this window of optimal efficiency can be extended as far down as 50 percent, depending on the engine → 5. If the engine is operated at loads below this, the engine efficiency remains significantly higher than that of the traditional fixed-speed equivalent. The end result is that a typical offshore support vessel can achieve fuel savings of up to 20 percent → 6.

By eliminating bulky converter transformers and main switchboards previously needed with the traditional AC system, the onboard DC grid also reduces the footprint of the electrical equipment

used → 7. This creates more space and provides greater flexibility in the positioning of system components in the vessel. In addition, the system enables simpler integration of supplementary DC energy sources such as solar panels, fuel cells or batteries into the ship's DC electric systems, creating scope for further fuel savings.

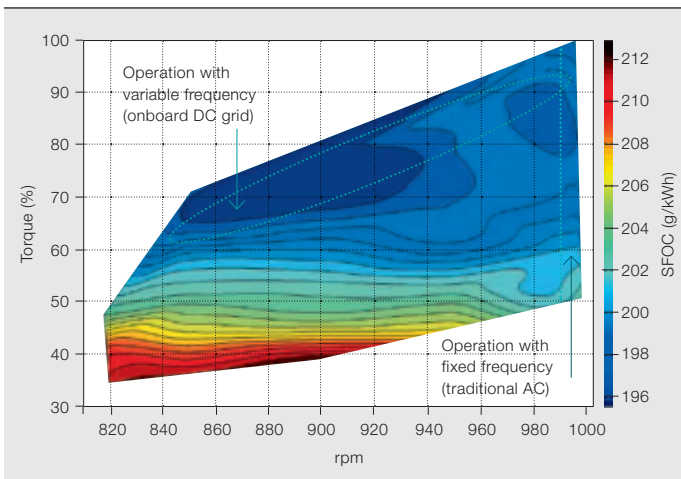
The reduced weight and footprint of the installed electrical equipment will vary depending on the ship type and application. One comparison using a distributed variant of the onboard DC grid system instead of the traditional AC system for a platform supply vessel (PSV), reduced the weight of the electric system components by 25 percent from 115 to 86 tons.

Dynamic positioning vessels

The variable power consumption of anchor handling vessels and other offshore support vessels make them very good candidates for the onboard DC grid system → 8. The new concept helps solve the traditional fuel efficiency challenge faced in dynamic positioning (DP) operation. DP vessels often need to run several diesel generators in parallel due to redundancy considerations. This means that the connected diesel engines spend most of their running hours at relatively low loads, where fuel efficiency is significantly lower than at, eg, 85 to 90 percent load.

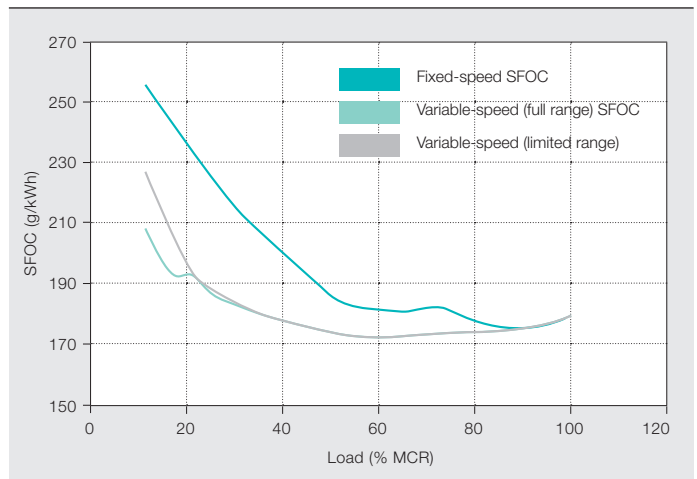
DP is when the propellers (thrusters or main propulsion or both) are used to stay at a given geographical position (+/- a few meters) and heading (to minimize the impact of wind, current and wave action

5 Engine fuel tests at variable speed (specific fuel oil consumption); university test engine



Test results are of fuel consumption as a function of applied torque and rpm for a small test engine at Helsinki University. Results show that it is possible to run this type of engine with the lowest possible fuel consumption at least down to 50 percent loading.

6 Engine fuel characteristics at variable speed (specific fuel oil consumption)



Further analysis has been done, in cooperation with an independent engine manufacturer, on a medium-speed engine range typically used in OSV power plants showing a reduction in SFOC of over 20 percent at low loads.

7 Benefits of the onboard DC grid

- More functional vessel layout through more flexible placement of electrical components
- Reduced maintenance of engines by more efficient operation
- Improved dynamic response and maneuverability
- Increased space for payload through lower electrical footprint and more flexible placement of electrical components
- A system platform that allows “plug and play” retrofitting possibilities to adapt to future energy sources
- Up to 20 percent fuel savings

on the vessel hull). This is sometimes used for work orders close to a drillship or when performing operations like loading/unloading close to an installation (eg, a drillship or platform). In severe DP operations – for example, in extreme weather or in critical operations where loss of propulsion power could cause significant damage to the vessel, other installations, or personnel – the electrical plant is split into a minimum of two separate sections to achieve a higher level of redundancy in the power system. By doing so, the vessel can maintain its position even if one side of the power plant fails. However, running in split mode generally does not utilize the full benefits of electric propulsion because

8 New order

ABB will equip a “newbuild” platform supply vessel (PSV), owned by Myklebusthaug Management and located at the Klevan shipyard in Ulsteinvik, Norway, with a full onboard DC grid system, including all power, propulsion and automation systems.

The 93m long, 4,800gt type MT 6015 PSV, a multipurpose oil field supply and construction vessel designed by the Norwegian company Marin Teknikk, is due for delivery in the first quarter of 2013. The vessel has five variable-speed diesel generators, four rated at 2,240 kW and one at 920 kW, two 2,200 kW main propulsion units and three additional thrusters for DP operation.

total optimization of running engines is not possible. Fuel efficiency has therefore often been sacrificed in favor of safety. With the onboard DC grid the split mode operation can run more efficiently as the engine speed can be adjusted and optimized to the required load without the need for changing the number of generators online.

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Further reading

Hansen, J. F., Lindtjörn, J. O., Vanska, K. (2011, October). Onboard DC grid for enhanced DP operation in ships. Paper presented at the Dynamic Positioning Conference, Houston, TX, United States.



Raising the waters

Lift irrigation is getting a boost from ABB's synchronous motors

JARI LINDSTRÖM, TAPIO RAUHALA, MAGNUS REJSTRÖM – In India, the scarcity of water is unfortunately a harsh reality. Still, the country's economy relies on agriculture. But how is farming possible on land located in high or arid regions? The answer is lift irrigation, a technique that involves lifting large volumes of water from a river or reservoir to be redistributed in channels, transforming farming conditions in these areas. The process involves both a vertical pump and a motor. Synchronous motors in particular are well-suited for the combination of high power and low speed found in vertical pump applications. The motors operate with high efficiency under normal constant speed conditions and can handle the demanding counter-torque curve of a pump during start-up. ABB has supplied more than 20 custom-built synchronous motors from 4 to 30MW – most of which have individual pumping capacities varying from 10 to 25 m³/s – for lift irrigation projects in India.



ABB has designed and supplied more than 20 synchronous vertical pump motors ranging from 4 to 30 MW for lift irrigation projects in India.

With more than 70 percent of the world's fresh water consumption dedicated to agriculture [1], it is no wonder that in a land as geographically diverse as India, lift irrigation systems are required to maintain the country's agricultural productivity.

Lift irrigation systems are comprised of one or more pumping stations with three to 10 pumps per station. Installations may also include a storage dam and – when pure gravity is insufficient to redistribute the water – a series of pump-equipped booster stations. Thanks to this technology, water distribution can be provided at pumping capacities of close to 700 m³/s to large areas involving distances of up to 300 km, and 60 m altitude differences.

Title picture

ABB's high-efficient synchronous motors help farmers irrigate dry farmland in Andhar Pradesh, India's fourth-largest state, increasing crop yields and improving revenues.

ABB has designed and supplied more than 20 synchronous vertical pump motors ranging from 4 to 30 MW for lift irrigation projects in India → 1. The equipment was provided in cooperation with a large pump manufacturer, which was responsible for delivering, erecting and commissioning the pumps.

Pump up the volume

Pumping is typically performed at a constant speed, and the combination of high power and low speed makes a synchronous motor the most economical choice for lift irrigation applications → 2. The pump arrangement is a vertical assembly with the motor on top, connected to an impeller through a bolted flange coupling → 3. As a result, the motor and the pump must be regarded as one system from a calculation point of view. This influences the mechanical design in terms of the shaft dimension and the position of the bearings.

Although they can be made to other specifications, the motors delivered to India were designed for a power supply of 11 kV at 50 Hz. Each motor has an electrical design customized for its particular pumping application, taking into account the required head and pumping volume (m³/s). (Head refers to the vertical distance a pump can lift a column of water.)

Starting position

Depending on the capacity of the grid, the motors are either started as direct-on-line (DOL) or fitted with a frequency converter. Motors in water-pumping applications must be accelerated against the full pump counter-torque curve. At zero speed the load will be 20 percent of the maximum, depending on the properties of the pump itself. During start-up, the load torque will increase exponentially up to 100 percent; this is a demanding challenge when a motor is started DOL and moves to full speed in about 3 to 6 s. Therefore it is essential that the supply network has sufficient short-circuit capability and that the mo-



Type:	Synchronous motors in vertical pump applications
Delivered:	2008–2011
Purpose:	Lift irrigation projects in India
Designation:	AMZ
Voltage:	11 kV
Frequency:	50 Hz
Power output:	4–30 kW
Speed:	300–600 r/min
Poles:	10–20
Shaft height:	1,250–2,500 mm
IP class:	54 and 55
Cooling:	Air-to-water

With frequency-controlled starting, the motor is started and accelerated to full speed by a variable-speed drive before it is synchronized to the network.

tor is designed to withstand the resulting heat generation and current in the rotor. An alternative to DOL starting is frequency-controlled starting, which is the most common method in large-volume pump applications → 4. Here, the motor is started and accelerated to full speed by a variable-speed drive before it is synchronized to the network. This type of starter consists of switchgear, transformers and a load-commutated inverter (LCI).

As soon as the motor has been synchronized, the frequency converter is bypassed and the system moves to operation at constant speed. The starting time is about 60 seconds longer than with DOL starting, but this difference is usually acceptable in water-pumping applications. Most importantly, the electromechanical stress during starting is significantly reduced. Frequency-controlled starting lim-

its the current that a motor draws from a network to between 50 and 60 percent of the rated current, avoiding voltage dips that could damage the motor and cause network disturbances.

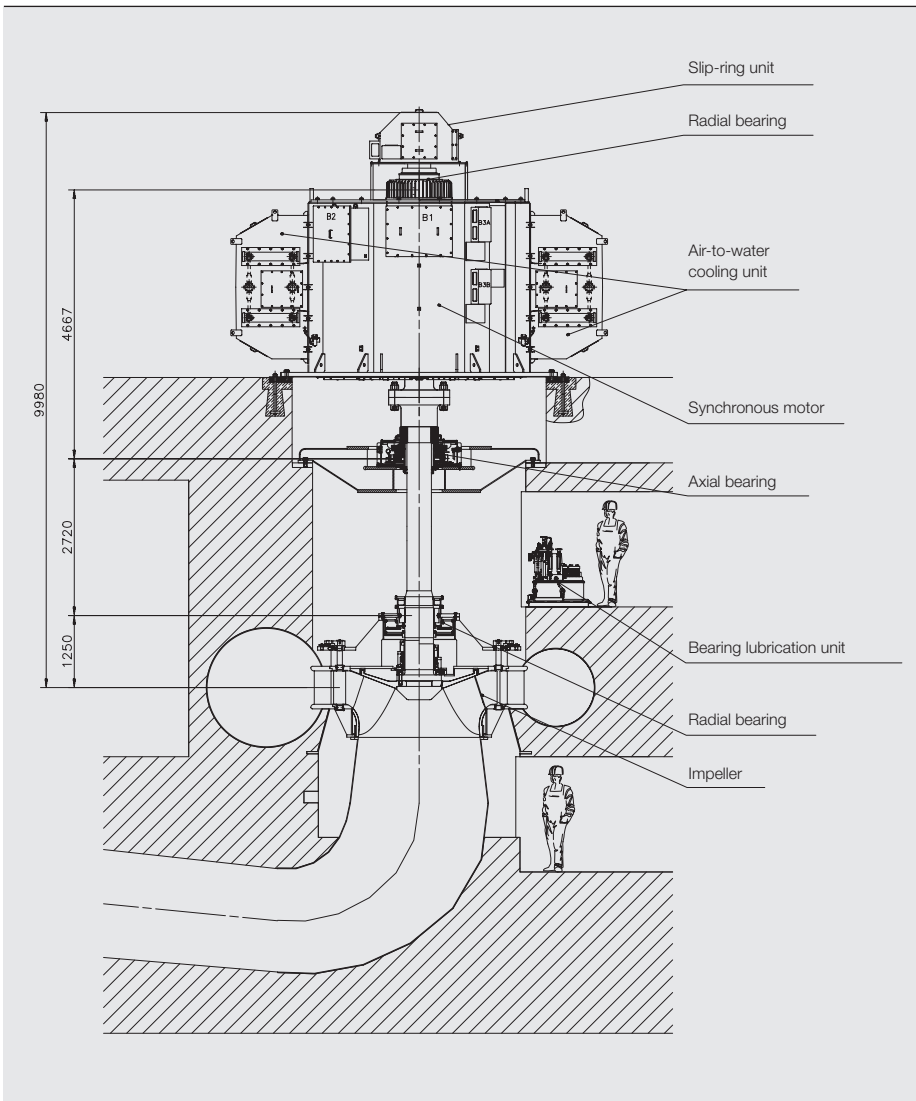
Starting the motor with a frequency converter also offers technical and commercial advantages in terms of smaller motor size, lowering the investment required. The motor consumes less energy and does not need to be larger than the size required for constant-speed operation.

Excitation control

The excitation equipment, however, is slightly more complicated when a frequency converter is used for starting. To supply the field current to the rotor, slip rings are installed on the motor shaft with access via removable inspection covers. The slip rings, together with the mounting flange or hub, are usually made of steel and are normally mounted as a single unit. Slip-ring units with brass rings, as well as split flange-mounted units, are available on request. The slip-ring unit is equipped with brass connection pins for installation.

In addition to voltage and excitation control, the system also has functions for motor protection. Once the motor is running at constant speed, the excitation system will react if the operating conditions change, for example when a valve is opened. The system corrects the power factor back to the desired value, ensuring stable operation.

3 The pump assembly is vertical, with the motor on top of the impeller.



Pumping is typically performed at a constant speed, and the combination of high power and low speed makes a synchronous motor the most economical choice in lift irrigation projects.

Shafts and bearings

When it comes to the mechanical design of synchronous motors in vertical pump applications, each project demands customization. The main variables are the required speed and power for a specific pump, as well as the actual pump design. From these data, the shaft dimension and bearing arrangement can be derived.

From a design point of view, the motor-pump assembly should be regarded as one system. The shafts are connected through a rigid coupling, so stress calculations must consider them as one long shaft. Consequently, the design involves shaft lengths of up to 10 m, which increases the risk of resonance between the operating speed and lateral frequen-

cies. There may be excessive vibration in the assembly, resulting in fatigue damage and shortening of the lifetime of the

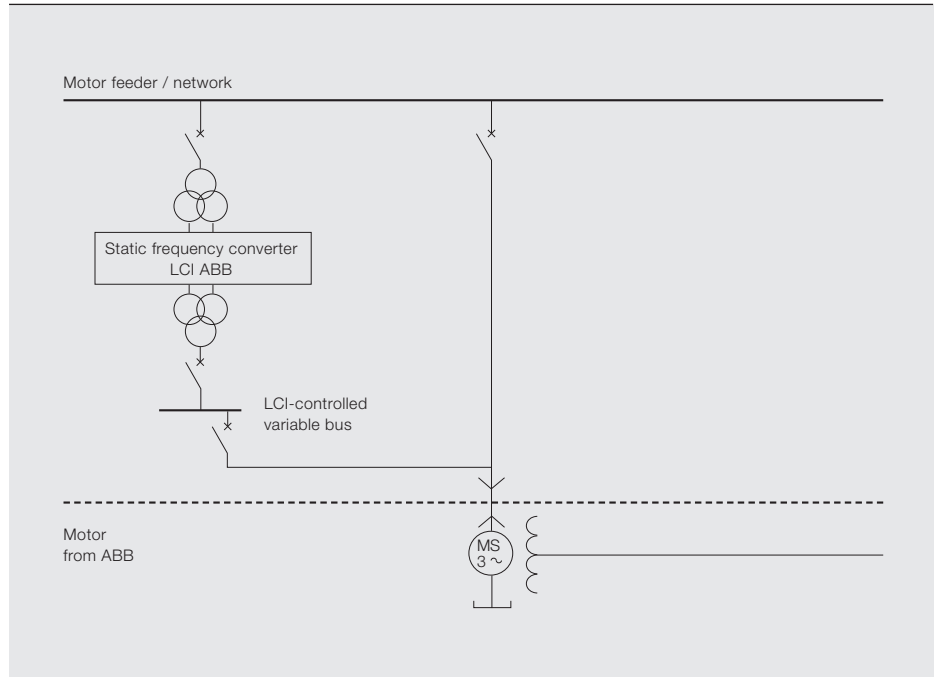
Synchronous motors in vertical pump applications are a cost-efficient and reliable solution.

shaft and bearings. This problem is solved by adapting the diameter and length of the shaft, or by changing the position of the bearings, so that the operating and lateral frequencies are safely separated → 5.

The motor and pump shafts are forged in solid steel, and the bearing arrangement includes two guide bearings and a thrust bearing for axial loads.

ABB's synchronous motors are built in a self-supporting full frame and are customized for the expected environmental conditions.

4 The most common starting method is via a frequency converter.



The bearings are all journal bearings specially designed for vertical operation and are fitted with an oil circulation and cooling system. Axial loads range from 300 to 1,100 kN, while radial loads are relatively low. Journal bearings are preferred over rolling bearings because they can bear high axial loads.

Structural support

ABB's synchronous motors are built in a self-supporting full frame and are customized for the expected environmental conditions. The stator frame is a rigid steel structure designed to withstand vibration induced by the driven equipment. The core is built of stacked, high-grade, low-loss laminated electrical steel sheets insulated on both sides with a heat-resistant, inorganic coating. Radial cooling ducts ensure uniform and effective cooling of the stator.

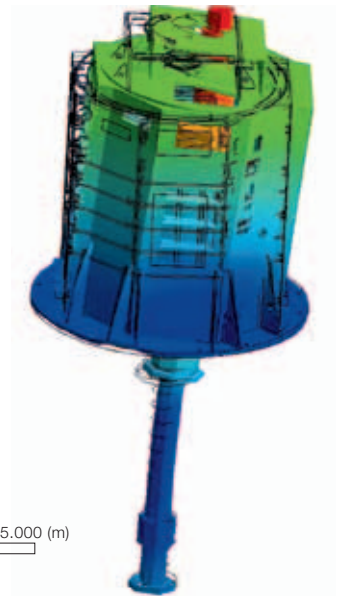
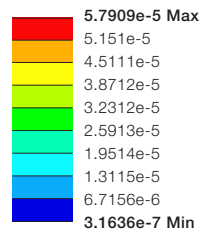
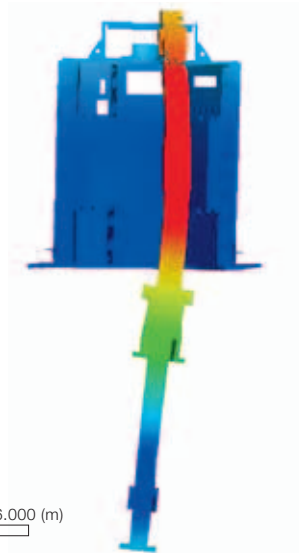
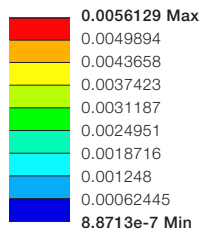
Stator windings are made of form-wound rectangular copper wire insulated with multiple layers of fiberglass-reinforced mica tape. All materials used, including the vacuum pressure impregnation (VPI) resin, exceed thermal class F (155°C) requirements. After insertion into the corresponding slots and prior to VPI, the coils are held firmly in place by slot wedges and surge ropes at the coil heads.

For 30 years, ABB has been using the Micadur® Compact Industry (MCI) insulation system based on the VPI method.

MCI windings require very little maintenance; usually it is sufficient to ensure that the ingress of moisture or dirt does not compromise the cooling ability of the winding when the motor is not operating.

The rotor is also made to match the insulation class of the stator, and it is normally equipped with a separate rotor center that is shrink-fitted onto the shaft. Wound rotor poles are normally manufactured from 2 mm laminated steel sheets, pressed together by steel bars that are welded to the end plates. The pole structure is either integrated or the poles are secured to the shaft or rotor center with bolts from above or below, or they are secured by dovetails. The poles are often fitted with a damper winding designed to suit the application.

The cooling for this type of pumping application is adapted to accommodate the fact that the motors are typically placed in an enclosed machine room, from which excess heat must be expelled. This expulsion is achieved by circulating cooling air through the active parts of the motor and then through air-to-water heat exchangers. This configuration passes almost no heat to the immediate motor environment, which helps create good operating conditions in the machine room. In terms of protection, the motors are rated IP 54 or IP 55, depending on the operating conditions.



5a The lowest undamped lateral frequencies are 8.6 Hz and 10 Hz, and the damped maximum responses are 9.6 Hz and 11.4 Hz. The shaft's lateral frequencies are close to operation speed, so the design is not acceptable. A stiffer rotor shaft and shorter shaft assembly should be considered.

5b The lowest undamped lateral frequencies are 13.3 Hz and 13.4 Hz, and the damped maximum responses are 14.8 Hz and 15.3 Hz. This gives adequate margin – about 20 percent – to runaway speed of 12.5 Hz (750 rpm).

An efficient solution

Taking into account the costs related to energy consumption and maintenance, as well as the initial investment, syn-

ABB is a major worldwide supplier of large synchronous motors. Backed by the resources of ABB's global organization, the company provides reliable and efficient service in process industries, the marine and offshore sectors, utilities, and a number of special applications. And the future for synchronous motors is promising, as ABB foresees an increasing number of lift irrigation projects in other areas with inconveniently located water.

Water distribution can be provided at pumping capacities of close to 700 m³/s to large areas involving distances of up to 300 km, and 60 m altitude differences.

chronous motors in vertical pump applications are a cost-efficient and reliable solution. The motors have low losses, resulting in high efficiency – and the network power factor can be compensated for by adjusting the motor's power factor during operation.

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Reference
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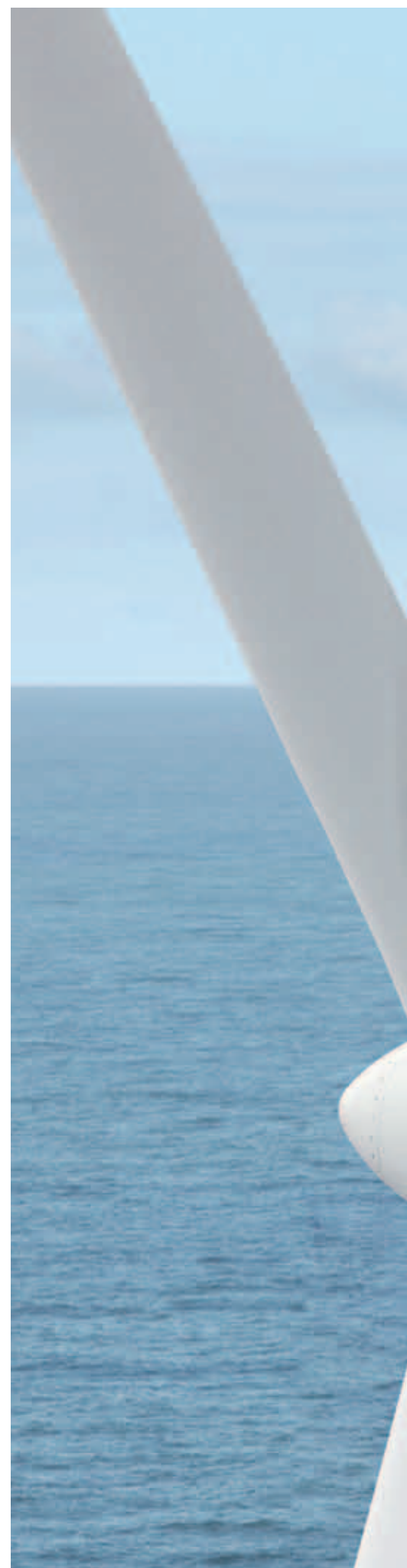
Distribution goes green

ABB's amorphous metal distribution transformers are maximizing energy savings

V. R. RAMANAN, MARTIN CARLEN – With the ever growing global population and an increasing global demand for energy consumption, sustaining our power-hungry world calls for energy efficient products and reliable grids. Current energy-saving programs and efficiency requirements are being driven both by global and local initiatives focused on the reduction of CO₂ emissions. When it comes to distribution transformers, which are a crucial component of the electricity supply system, there is still a large total loss of energy due to their vast installed base, even in modern transformers. Globally, these losses are estimated to account for around 2 to 3 percent of all electric energy production – some 25 GW. For each gigawatt saved, there is the potential for an annual reduction of 5 million tons of CO₂ emissions. As the global leader in transformer manufacturing, ABB has developed liquid-immersed and EcoDry amorphous metal distribution transformers that allow a reduction of no-load losses by about 70 percent compared with conventional core materials.

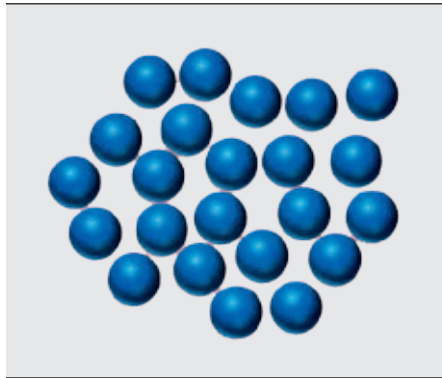
Title picture

Amorphous metal distribution transformers can minimize no-load losses in wind power applications. The offshore wind farm shown here is the Danish *Horns Rev I*.

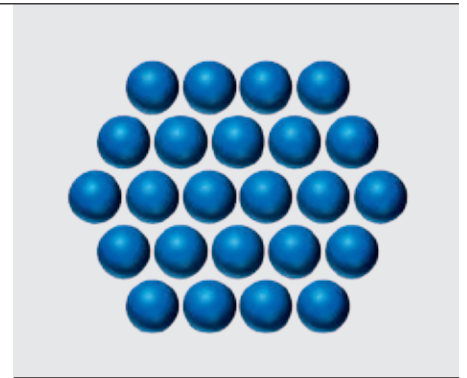




1 The disordered structure of amorphous steel and the ordered crystalline structure of regular grain-oriented steel



1a Amorphous steel



1b Regular grain-oriented steel

Amorphous metal cores have been in use for over 20 years in liquid-filled transformers, and this technology is now being applied to dry-type transformers.

As part of its green transformer portfolio for distribution transformers, ABB's new amorphous metal technologies are helping to maximize energy savings. There are two types of amorphous metal distribution transformers (AMDTs):

- Liquid-immersed transformers with amorphous metal cores, with either conventional mineral oil, or vegetable-oil-based liquids (BIOTEMP)
- EcoDry ultra-efficient dry-type transformers with amorphous metal cores

Not only are there clear economical benefits to using amorphous metal core transformers, but there are environmental advantages as well.

Amorphous metal

The amorphous metal used by ABB is a metallic alloy of iron, boron and silicon (Fe-B-Si) produced by solidifying alloy

of conventional regular grain-oriented (RGO) silicon steel (a Fe-Si alloy), which has an organized crystalline structure. The largest volume usage of amorphous metal is in the cores of electrical distribution transformers. These materials offer, in concert, excellent magnetic characteristics and economy in production costs. In fact, the advent of Fe-B-Si amorphous metal alloys in the mid-1980s has been the most important advancement in materials for distribution transformers in the second half of the 20th century.

Solidification rates of 10^6 K/s are necessary to produce Fe-B-Si amorphous metals. The high heat extraction rates constrain the solid in the form of a thin ribbon, about $25\mu\text{m}$ thick. Since the material is thin, the application of amorphous metal is restricted to wound transformer cores. Amorphous metal cores have been in use for over 20 years in liquid-filled transformers, and this technology is now being applied to dry-type transformers.

is now being applied to dry-type transformers.

The performance stability of amorphous metal at the transformer operating temperature is very high and significant changes in its loss performance would take more than 1,000 years.

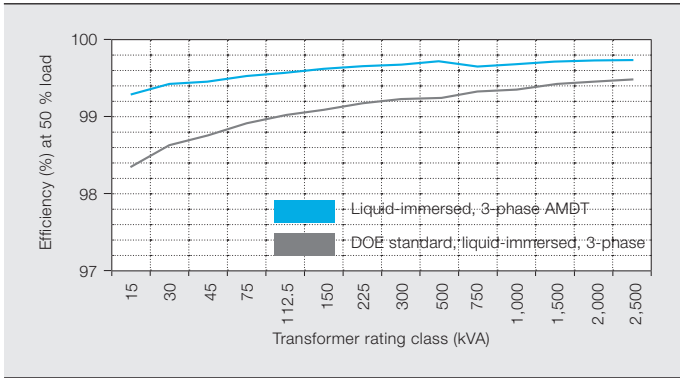
Significantly lowered core losses

The most notable characteristic of an amorphous metal in a transformer is that it yields a much lower core loss than even the best grades of

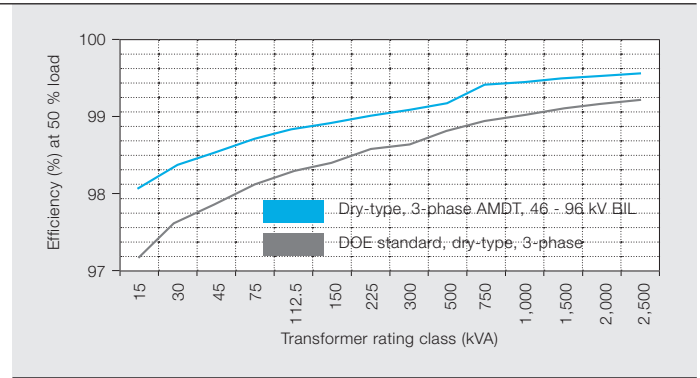
melts at rates rapid enough to prevent crystallization of the metal [1]. Such rapid solidification leaves a vitrified solid with a random (amorphous) atomic structure, essentially as in the liquid phase → 1. This differs from the atomic structure

RGO steel, by up to 70 percent. In a transformer core material, there are two major types of losses: hysteresis loss and eddy current loss. The former reflects the ease of magnetization of the material when the core is energized,

2 Comparison of US DOE mandated minimum efficiency standards across a wide range of transformer ratings



2a Liquid-immersed 3-phase distribution transformers



2b Dry-type 3-phase distribution transformers

and the latter results from internal currents generated in the material. The absence of a crystalline structure in amorphous metal allows easy magnetization of the material, leading to lower hysteresis losses. The eddy current losses are also lower in amorphous metal due to a combination of its thinness and a high electrical resistivity of $130 \mu\Omega\text{cm}^{-1}$, compared with $50 \mu\Omega\text{cm}^{-1}$ in RGO steels.

Optimization via anneals

The low losses in amorphous metal are achieved through optimized anneals, ie, exposure to a temperature close to the material's Curie temperature (668 K) for a selected amount of time in the presence of an externally applied magnetic field. Annealing is an essential step for amorphous metals.

Magnetic anisotropy in a ferromagnetic material is a measure of the ease of magnetization away from a given direction. In RGO steels, the crystal structure primarily defines this anisotropy, whereby there are predefined easy axes for magnetization. The random atomic architecture in amorphous metals precludes such magnetocrystalline anisotropy. However, a magnetic anisotropy may be induced to define easy directions for magnetization in these materials. As a result of the very rapid cooling rates, amorphous metals have high quenching stresses, resulting in stress-induced anisotropy. With annealing, the quenching stresses are relaxed and by applying an external magnetic field of typically $1,000 \text{ A/m}$, a preferred axis of magnetization (along the ribbon length) is introduced in the material. A consequence of the anneal step is that the previously ductile amorphous metal becomes brittle, which

requires more careful material handling in subsequent processing steps.

Lower design induction level

Due to the presence of boron, amorphous metal has a lower saturation induction (1.56 T) than RGO steels (2.1 T). Therefore, the design induction with

The most notable characteristic of an amorphous metal in a transformer is that it yields a much lower core loss than even the best grades of regular grain-oriented steel, by up to 70 percent.

amorphous metal is lower than that available from RGO steels. As a result, amorphous core transformers often have a larger core cross-sectional area, resulting in larger coils and transformer footprint.

Transformer sound level

Transformers with amorphous metal cores generate about 3 to 5 dB higher sound levels than those with RGO steel cores. Techniques to mitigate these higher sound levels are the focus of ongoing ABB research activities. Sound is generated within transformer cores due

Country	Annual transformer loss (TWh)	Annual savings potential (TWh)	Annual CO ₂ reduction (million tons)
United states	141	84	60
EU-25	55	22	9
Japan	44	31	12
China	33	18	13
India	6	3	3
Australia	6	3	3
Total	285	161	100

The use of an amorphous metal core could prevent the emission of 140,000 tons of CO₂ – equivalent to 60,000 kg of oil – during an operation period of 20 years for a 1,000 kVA transformer.

to an intrinsic characteristic of the core material called magnetostriction. When the magnetization direction has to rotate under an applied field, the material undergoes a dimensional change and sound is generated. In RGO steels, the crystalline axes for easy magnetization are well aligned between grains. This is not so in the case of amorphous metal, since the quenching stresses are never fully relaxed from annealing an amorphous metal. Therefore, during operation of a transformer, a greater degree of magnetization rotation is called for from amorphous metal than from RGO steels. The dimensional change is consequently higher, leading to greater sound levels.

Stable losses over time

In the 1990s it was shown that the performance stability of amorphous metal at the transformer operating temperature is very high and that significant changes in its loss performance would take more than 1,000 years [2]. Those aging tests were carried out with small toroids protected from oxygen. Since then, the composition of the amorphous metal alloy has changed slightly and manufacturing methods have been further developed. In order to guarantee the stability of today’s material (and to see the influence of an ambient air) ABB repeated accelerated aging measurements at high temperature (490 K) with a full-size core under air atmosphere for more than 200 days. But the results were similar, suggesting that no degradation of losses during the transformer lifetime needs to be expected.

Energy-savings potential

→ 2 compares the efficiency of AMDT with the mandated minimum efficiency standards for the same by the US Department of Energy (DOE), across a wide

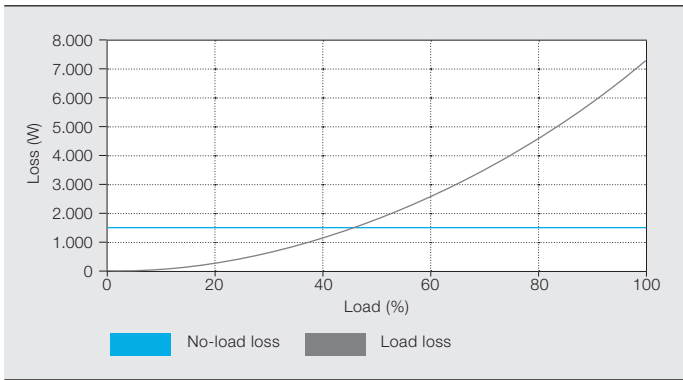
range of transformer ratings. The improved energy efficiencies attained are quite clear. A quick back-of-the-envelope calculation may be used to highlight the energy savings potential from the deployment of AMDT. As mentioned, use of amorphous metal cores can reduce transformer core no-load losses by about 70 percent, when compared with RGO steel cores. Assuming that about 1 percent of the installed US generating capacity of 1.4 TW is lost in distribution transformer no-load losses, this reduction of losses from the use of amorphous cores suggests a potential annual energy savings of about 85 billion kWh.

The energy savings are sizable, even if only a fraction of all distribution transformers are replaced by AMDTs. This savings from existing generating capacity allows deferral or cancellation of plans for additional generation to meet ever-growing demand. The environmental benefits associated with reductions in noxious gas emissions and in the CO₂ footprint are clear, as are the economical benefits accrued from energy and cost savings. The consequent social benefits are self-evident. Similar summary estimates for energy savings and CO₂ reductions have been made for representative major nations [3], as presented in → 3. If CO₂ emissions are to be taxed by \$25/ton, this amounts to \$2.5 billion annually.

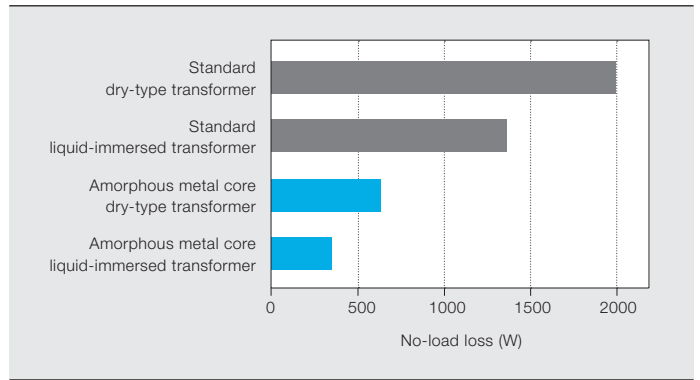
ABB’s green transformers

The broad portfolio of ABB’s green distribution transformers allows customers to select the most appropriate product to fit their needs. Some of the major criteria for product selection are the following.

4 No-load and load loss components of a 630 kVA conventional dry-type transformer



5 Comparison of typical no-load loss values of standard and amorphous metal core liquid-immersed and dry-type 1,000 kVA transformers



Transformer losses

As in any transformer, the losses in amorphous metal transformers consist of two parts: the no-load loss (P_o) generated in the core, and the load loss (P_k) mainly occurring in the transformer windings. P_o is always present and constant during normal operation, whereas P_k only occurs during transformer operation and is load dependent → 4. The no-load loss of ABB's AMDT is only 30 percent of the no-load loss of a standard transformer → 5. Thus, the use of an amorphous metal core could prevent the emission of 140,000 tons of CO₂ – equivalent to 60,000 kg of oil – during an operation period of 20 years for a 1,000 kVA transformer.

where TOC = total ownership cost, C_T = transformer purchase price, A = capitalization factor for no-load loss, and B = capitalization factor for load loss.

AMDTs have a higher first cost. However, if life-cycle costs are considered, they are still the most economical choice.

Environmental sustainability and friendliness

ABB has done a comparative life-cycle assessment (LCA) for AMDT and RGO steel core transformers. LCA is an environmental management tool that is used to compare the potential environmental impact caused throughout the product life-cycle phases (ie, manufacturing, utilization, end-of-life) by different types

of products or systems, with respect to several environmentally critical criteria.

As illustrated in → 6, the environmental impact of the high-

efficiency AMDT is substantially lower than that of standard transformers. This lower impact is dominated by benefits during the use phase and the low no-load loss of the amorphous metal core.

Green transformers in applications

The use of ABB's amorphous core transformers can have a significant impact on energy consumption in many different applications, such as utilities, wind power generation and photovoltaic power plants.

Transformers in the utility distribution grid

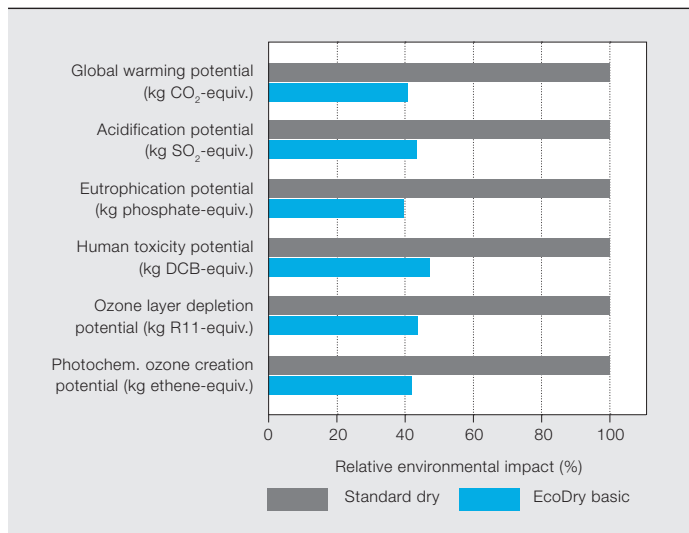
For utilities, the reduction of no-load loss is a major focus, since the average loading of a distribution transformer is gener-

The environmental impact of the high-efficiency AMDT is substantially lower than that of standard transformers.

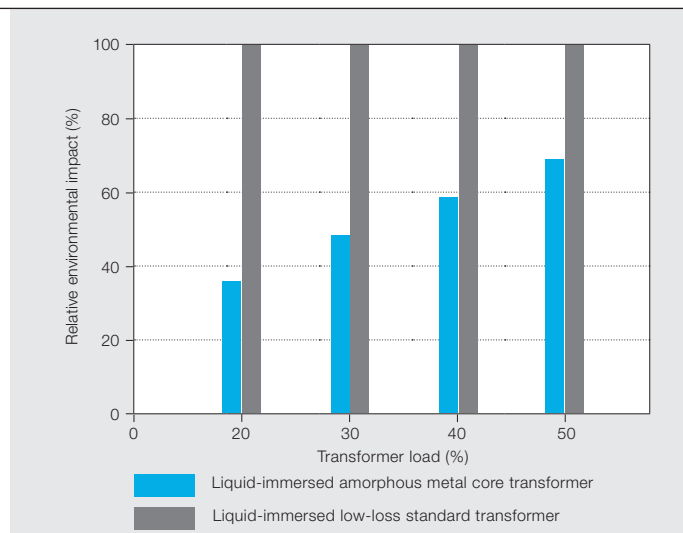
Transformer costs

When selecting a transformer, a variety of costs may be considered: first costs, life-cycle costs, or costs including all additional infrastructure expenses. Life-cycle costs include capitalization of the transformer losses. This is usually done by using the TOC (total ownership cost) approach, in which specific valuations are assigned to P_o and P_k . These valuations, among other considerations, depend on the cost of electricity, on the cost of providing the lost power and on the utilization of the transformer. The values used by most utilities range between \$5 and \$10/W for P_o and between \$1 and \$2/W for P_k .

$$TOC = C_T + A \cdot P_o + B \cdot P_k \text{ (\$)}$$



6a Relative environmental impact of amorphous metal core with respect to standard dry-type transformers calculated for 20 % load



6b Relative environmental impact of an amorphous metal core with respect to standard low loss (B_kA₀) liquid-immersed transformers as a function of transformer load

ABB’s amorphous metal core technology for liquid-immersed and dry-type distribution transformers is a significant step toward improving energy efficiency.

ally low. AMDTs are the perfect choice to achieve this goal. Although first costs of AMDTs are higher, they are often the preferred choice if TOC is considered. This is shown in → 7 for 1,000 kVA transformers having the no-load loss values depicted in → 5 and with capitalization factors $A = \$10/W$ and $B = \$2/W$. Additional cost savings may be achieved if dry-type transformers need to be actively cooled, or if CO₂ taxation is considered.

Transformers for wind power generation

Energy is produced from the turbines on a wind farm for only short periods

The use of ABB’s amorphous core transformers can have a significant impact on energy consumption in many different applications.

throughout the day. Therefore, transformer no-load losses need to be minimized in wind power applications. As discussed above, the advantage of AMDTs in such applications becomes evident from TOC considerations.

EcoDry transformers for photovoltaic power plants

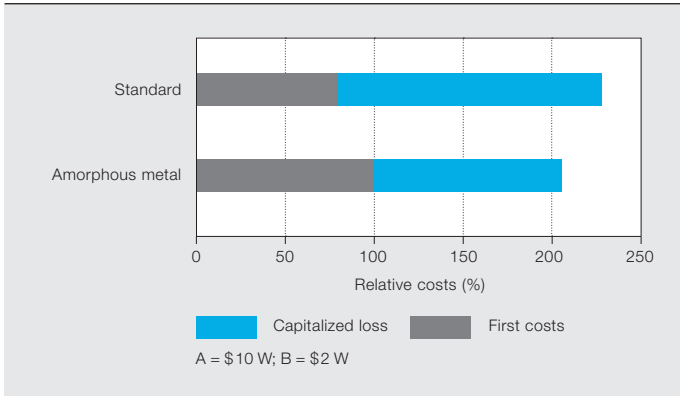
To promote solar energy, many countries have established a feed-in tariff system for electricity generated by photovoltaics

(PV). For example, for a free-standing PV plant, which began operation in 2010, the tariff is 0.26 euros/kWh (about \$0.34/kWh) in Germany and 0.32 euros/kWh (about \$0.42/kWh) in Spain. The operator of the PV plant wishes to maximize his income by maximizing the plant output and minimizing losses. A transformer in a PV power plant experiences a heavily varying load, depending on the time of day, the season and weather conditions. At night, the transformer consumes the no-load loss that the operator has to pay for, unless the transformer is disconnected from the grid. The dry-type EcoDry transformer is the ideal choice for such applications.

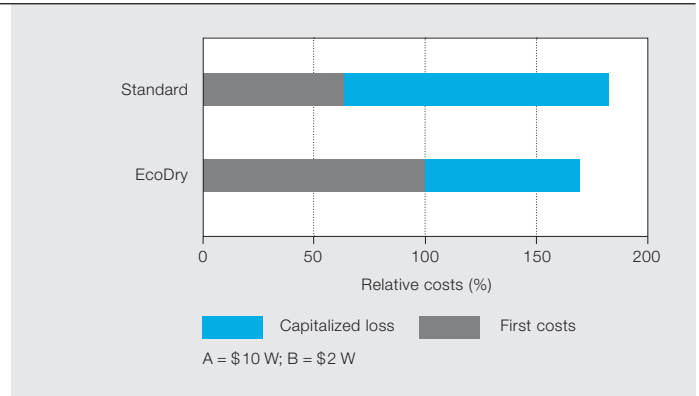
A simple model allows the calculation of the benefits. In the model, a certain number of

sunny days per year is assumed, with a number of hours per day with an output of 95 percent and a number of hours with an output of 15 percent (morning and evening). The remaining days of the year are assumed to be cloudy and the output of the PV plant is 15 percent during the whole day. These conditions result in a certain specific annual output (kWh/kWp). For example, a specific output of 1,700 kWh/kWp is realized by having 240 sunny days with 6 hours at

7 Comparison of TOC (total ownership cost) of standard and amorphous metal core transformers

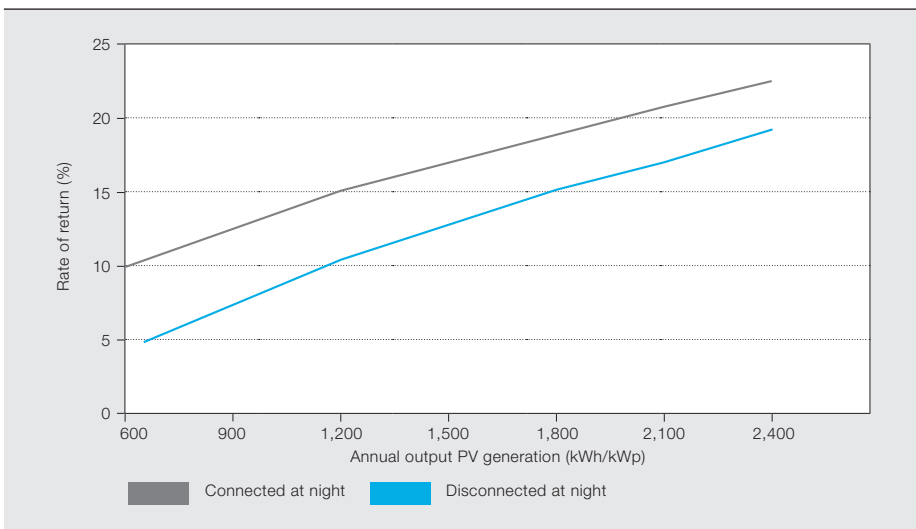


7a Liquid-immersed 1,000 kVA transformers



7b Dry-type 1,000 kVA transformers

8 Return on investment for the additional costs of a high-efficiency EcoDry transformer in a photovoltaic installation



95 percent load and 4 hours at 15 percent load.

If the price difference between the standard transformer, which has low first cost but high losses, and the EcoDry transformer is considered as an additional investment, the return on the investment can be calculated as shown in → 8. Electricity costs of 0.08 euros/kWh (about \$0.10/kWh) and revenues of 0.28 euros/kWh (about \$0.37/kWh) are assumed in these calculations.

A clear choice

ABB's amorphous metal core technology for liquid-immersed and dry-type distribution transformers is a significant step toward improving energy efficiency. For customers, the selection of AMDTs requires no new considerations in the decision making process. The focus on energy efficiency and environmental sustainability, along with the cost competi-

tiveness now available, make them an attractive choice.

To learn more about ABB's BIOTEMP® insulating fluid, please see "Transformers transformed" on page 48 of this issue of *ABB Review*.

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Transformers transformed

Using vegetable oil as an insulating fluid reduces transformer fire risk

GEORGE FRIMPONG, STEPHANE PAGE, KJELL CARRANDER, DON CHERRY – Every year, a number of transformer failures result in a fire. Because the transformer’s insulating fluid is flammable, fires can be sustained for several hours or days. The fire, smoke and possible fluid leakage can pose a risk not only to human and animal health and to the environment, but also to adjacent equipment. Moreover, the event can impact both the reputation and balance sheet of the parties involved. It comes as no surprise, then, that the industry continues to place ever more emphasis on transformers that have a reduced risk of fire. ABB has introduced BIOTEMP®, a high oleic, high fire point natural ester dielectric insulating fluid, which has a much reduced risk of fire initiation and propagation compared with the conventionally used mineral oil. What is it about a BIOTEMP-filled transformer that makes it one of the safest liquid-filled transformers on the market?

Thankfully, cases of transformers catching fire are rare. A major North American utility reported an overall failure rate of 1.21 percent per year on their entire fleet of 765 kV transformers over a 20-year period [1]; only 0.14 percent of these involved fires.

Title picture

It may come as a surprise to find vegetable oil based products in modern high-voltage equipment, like this 138 kV compact mobile substation, bound to supply energy for 50,000 people in Brazil. But this bounty of Mother Nature helps make ABB’s BIOTEMP-filled transformers some of the safest on the market.

When fires do occur, the consequences can be dramatic. The highly flammable insulating fluid found in many transformers can feed a fire for a long time and the smoke may contain toxic substances that are harmful to humans and other living species. If the tank ruptures, fluid may leak and cause soil or water pollution. Adjacent equipment may be damaged. Unsurprisingly, the consequent financial and reputational costs can be extremely high.

One way to greatly mitigate the risk of a transformer catching fire is to use a high fire point, readily biodegradable dielectric insulating fluid, such as ABB’s BIOTEMP.

BIOTEMP is a natural ester-based dielectric insulating fluid made from high oleic sunflower or safflower seed oil.

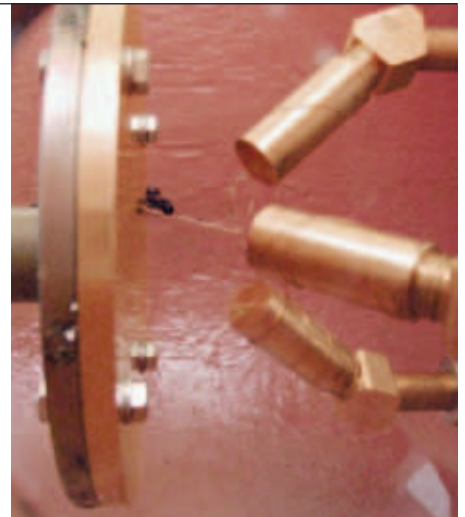
1 Fire risk properties

	Mineral oil (typical values)	BIOTEMP (typical values)	BIOTEMP advantage
Flash point (°C)	148	314	+
Fire point (°C)	160	347	+
Auto-ignition temperature (°C)	204	>400	+
Net calorific value (MJ/kg)	≥42	37	+

2 Test setup for high-energy arcing fault experiment



2a Steel chamber



2b Electrode configuration

What is BIOTEMP?

BIOTEMP is a natural ester-based dielectric insulating fluid made from high oleic sunflower or safflower seed oil [2]. Its molecular structure features three long chains of fatty acids attached to a glycerol backbone. It is considered a high oleic natural ester because the oleic fatty acid content is greater than 75 percent of the total composition of the vegetable oil. With a fire point above 300 °C, BIOTEMP is listed as a “less flammable” dielectric fluid by the FM Global insurance company and UL, the independent product safety certification organization. It has a K2 fire hazard classification according to the IEC standard 61100.

By its nature, BIOTEMP is also readily biodegradable. This means that any spill need not be treated as hazardous waste, which saves disposal fees and possible regulatory penalties.

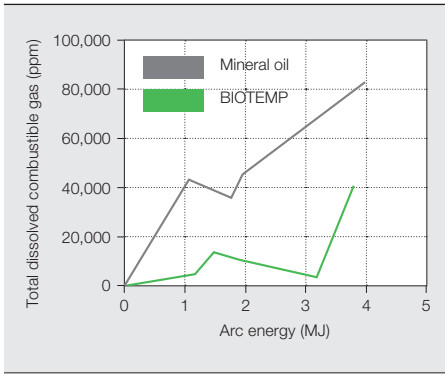
But just how does a fire in a transformer start? And what characteristics of BIOTEMP help thwart it?

Anatomy of a transformer fire

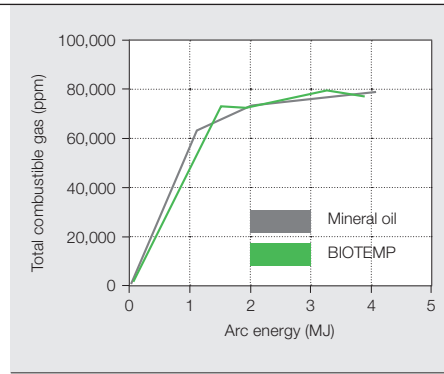
Every fire needs all three elements of the “fire triangle”: fuel, oxygen and a source of ignition. In a liquid-filled transformer, the insulating oil can be considered as the fuel. In a sealed transformer there is a limited supply of oxygen dissolved in the oil. In the case of a free-breathing transformer, the oil may become saturated with air. Even in this latter case, where the maximum amount of oxygen (about 30,000 parts per million) may be present in the oil, it is fully dissolved. Consequently, in both cases, there is no “free” oxygen available to support a fire inside the transformer. This underlines the low probability of a transformer actually catching fire.

When a low-impedance fault occurs in a transformer, it creates an electrical arc that may heat up the oil in the immediate vicinity to several thousands of degrees Celsius. Under normal conditions, the transformer’s high-current protection will interrupt the fault current and only a small volume of oil in the vicinity of the arc will experience a high temperature. However, if the protection system does

3 Total gas generation during high-energy arcing fault tests



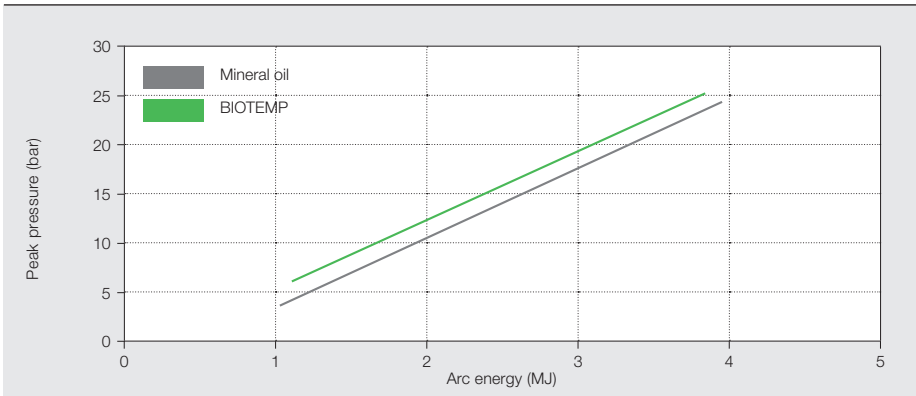
3a Dissolved in liquid



3b In gas space

Though very rare, transformer fires can have dramatic consequences.

4 Peak pressure generated during high-energy arcing fault



not operate properly, then a fire becomes a distinct possibility: The arcing vaporizes the oil and produces a relatively large quantity of combustible gases, some of which will dissolve in the oil, but some

es depends primarily on the rate that heat is released from the liquid.

Fire – important risk parameters

There are several different properties of an insulating fluid that determine its propensity to burn. The most important of these are flash point, fire point, auto-ignition temperature and heat release rate. It is also worth noting that it is the flammable vapors from the liquid that serve as fuel – and not the liquid itself.

Even where the oil is fully oxygen-saturated, there is no “free” oxygen available to support a fire inside the transformer.

of which will escape to the gas space, should one exist.

Depending on the severity of the fault, the increasing gas concentration can cause a pressure buildup large enough to rupture the tank. Then, hot oil and combustible gases will be released, and oxygen-rich air will rush into the tank. If the volume of vaporized liquid present is within the explosive limits of the liquid, and a source of heat is still present, combustion will initiate. At this point, whether the fire builds or self-extinguish-

The flash point is the lowest temperature at which a liquid can vaporize to form an ignitable mixture in air, without necessarily maintaining a fire.

The fire point is the lowest temperature beyond the flash point at which the mixture of vapors and oxygen will burn continuously if ignited. High flash point and high fire point are very desirable.

5 Explosive limits of BIOTEMP and mineral oil vapors

Dielectric insulating fluid	Test temperature	LFL	UFL
Typical mineral oil	200 °C	0.6 % vol	4.8 % vol
BIOTEMP	350–400 °C	> 9.0 % vol	ND*

*The UFL could not be measured because a higher temperature was required in order to increase the fuel volume but the test temperature was already too close to the auto-ignition temperature of BIOTEMP.

6 High-energy arc fault test



6a With mineral oil



6b With BIOTEMP

The auto-ignition temperature is the lowest temperature at which a material will self-ignite and sustain a fire even in the absence of a flame or spark. A liquid whose temperature stays above the fire point will supply a continuous stream of fuel to a fire.

Once a fire has started, the heat release rate determines its ability to propagate. The heat release rate is defined as the amount of thermal energy released per

0.6 percent vaporized mineral oil in an air/fuel mixture is explosive; for BIOTEMP, this has to be 9 percent. And it has to be 200 °C hotter.

unit of time. A steady or increasing heat release rate will lead to a self-sustaining fire, while a declining heat release rate will result in a fire that self-extinguishes after a period of time.

The vapors produced by different insulating liquids have different concentrations of flammable or explosive ele-

ments. There are lower and upper concentrations of these vapors in the air, within which range a mixture would be considered flammable. These are referred to as the upper and lower flammability (or explosive) limits (UFL and LFL, respectively) and the range between these two is referred to as the flammability (or explosive) range. The higher the lower explosive limit is, the larger the volume of vapors needed before a fire can be ignited and then maintained.

When the key fire risk properties of conventional mineral oil and BIOTEMP are compared, the advantages of BIOTEMP become clear → 1. In an effort to assess these, experiments were conducted to measure the differences in pressure buildup, explosive limits and heat release rate between the two.

Pressure buildup during arcing

A total of 10 multicycle, high-energy (1 to 4 MJ) arcing tests were performed in BIOTEMP and a typical mineral oil by an independent laboratory. The tests were performed in a T-shaped steel chamber, including a 30 to 35 L nitrogen gas cushion → 2. Three rod electrodes with 4 cm electrode gaps were immersed in the fluids.

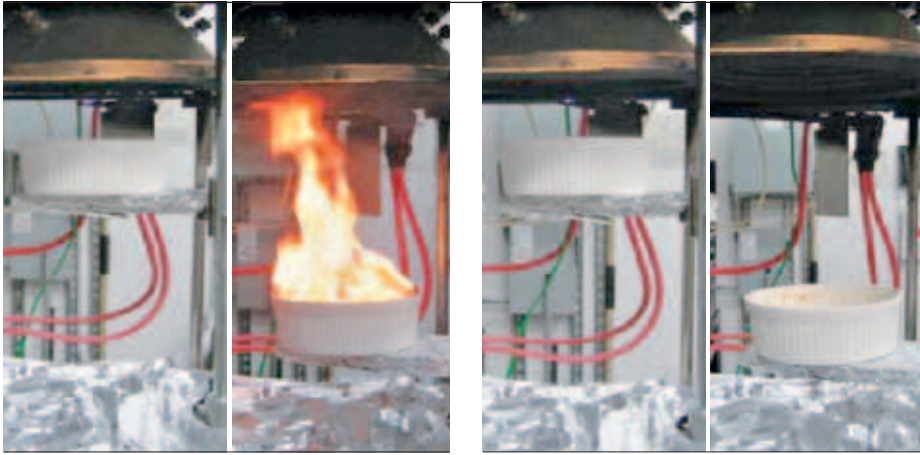
Three-phase AC short-circuit tests at 12 kV and 5.5 kA rms current were carried out with variable short-circuit durations to simulate different arc energies. After each test, about 1 L of gas in the head space and 40 ml of oil were sampled and analyzed.

BIOTEMP had only about 25 to 50 percent as much dissolved combustibles as the mineral oil, but the total amount of gas in the head space was similar, giving comparable pressures → 3. The peak of the measured pressure wave shows a slight increase in BIOTEMP over mineral oil → 4. The conclusion is that the pressure generated by both fluids during the tests is similar.

Explosive limits

The LFL and UFL of BIOTEMP and a typical mineral oil were measured according to the ASTM E 918 standard test method by another independent laboratory. The sample was injected into an appropriately prepared test vessel through a septum, followed by the addition of air up to the required test pressure (14.7 psi). Ignition attempts were made using a high-voltage constant arc (10 kV, 0.25 mA). The concentration of the test mixture was varied between trials until the LFL and UFL for the sample was determined. The results show that an explosive environment will exist if more than 0.6 percent of the volume of an air/fuel mixture

7 Heat release rate test set-up

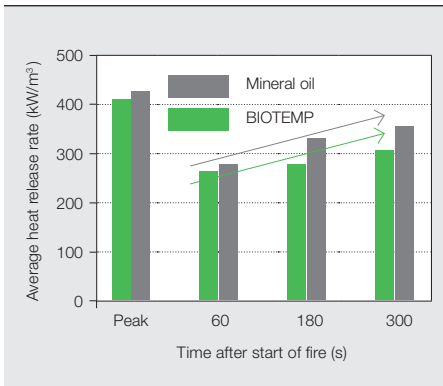


7a Mineral oil sample at ignition location and while burning

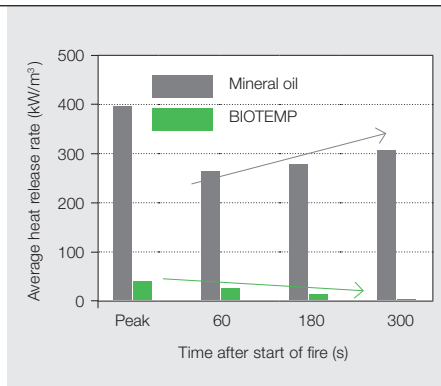
7b BIOTEMP sample at ignition location and after self-extinguishment

The BIOTEMP sample actually self-extinguished after a few seconds of combustion.

8 Heat release rate measurements



8a The heat source is maintained.



8b The heat source is turned off.

is comprised of vaporized mineral oil → 5. For BIOTEMP, this level must be much higher – 9.0 percent – for an explosive environment to exist. Not only that, but, for BIOTEMP, the temperature has to

the mineral oil setup was blown apart and a fire started after the hot oil was exposed to the atmosphere. In the corresponding test with BIOTEMP, the lid vented and, although a small amount

With BIOTEMP, the lid vented and, although a small amount of carbonized oil and vaporized oil escaped, there was no fire.

be about 200 °C higher, too, for an explosive environment to exist. This gives BIOTEMP a significant advantage over mineral oil.

The explosive nature of mineral oil compared with BIOTEMP was illustrated using oil-filled pole-mounted transformer tanks through which up to 8,000A flowed for up to three cycles. The lid of

of carbonized oil and vaporized oil spewed out of the tank, there was no fire → 6.

Heat release rate

Heat release rate measurements were also made by the same indepen-

dent laboratory following an adaptation of the ASTM 1354 standard test method. Fluid samples in a ceramic bowl were placed under a heat source delivering 25 kW/m². When vapors formed, an ignition source above the fluid was triggered until a fire started.

The smoke production from BIOTEMP under this test condition is 31 times less than that of the mineral oil.

9 Heat release rate parameters

Dielectric insulating fluid	Heat source maintained			Heat source turned off		
	Time to ignition (s)	Time to flameout (s)	Smoke production rate (m ² /s)	Time to ignition (s)	Time to flameout (s)	Smoke production rate (m ² /s)
Mineral oil	58	1,027	0.0547	57	1,160	0.0495
BIOTEMP	724	1,762	0.0253	723	731	0.0016

Two test cases were investigated: In one, the setup was maintained after ignition, and, in the other, the heat source was turned off and the sample removed, to simulate a disconnect breaker trip → 7.

In the first case, it was observed that the average heat release rates for both fluids increased with time. This is consistent with the fire being fed with volatiles due to the heat source keeping the oil temperature above the fire point. In the second case, when the heat source was turned off, it was observed that the peak heat release rate for BIOTEMP (48 kW/m²) is eight times less than that for mineral oil (397 kW/m²) → 8. For mineral oil, the peak heat release rate and the increase of average heat release with time is similar to that of the first case. In contrast, the BIOTEMP sample shows a decrease in heat release rate with time. The BIOTEMP sample actually self-extinguished after a few seconds of combustion.

Several other parameters were also measured during the experiment, such as the time to ignition, the time to flameout, the peak heat release rate and the smoke production rate → 9. When the heat source is maintained, the time to ignition, a strong indicator of a material's fire resistance, is about 12 times longer for BIOTEMP (724 s) than that for mineral oil (58 s). The smoke, and therefore pollutant, production rate of burning BIOTEMP is less than half that of burning mineral oil. When the heat source is turned off, the time to ignition for BIOTEMP (723 s) is again about 12 times longer than that for mineral oil (57 s). The smoke production from BIOTEMP under this test condition is 31 times less than that from the mineral oil.

Oil futures

The industry drive toward transformers that are ever more fire-resistant under fault conditions is well served by

BIOTEMP. Though the chances of a tank rupture are the same as with mineral oil, BIOTEMP demonstrates a much reduced risk of fire initiation and propagation, not to mention outstanding self-extinguishing properties. This makes a BIOTEMP-filled transformer one of the safest liquid-filled transformers on the market.

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Software

Most readers of *ABB Review* associate ABB with its various products and services for the power and automation sectors. Very few would consider ABB a software company. The latter perception is becoming increasingly inaccurate as the role of software within the company is growing.

Starting on the embedded level, software is an important component in such products as drives, meters and protection devices, where it enhances functionality and flexibility. Moving up to the system level, software is a central part of control and automation systems: It permits numerous individual devices to join forces and exchange data in real time with the whole becoming much more than the sum of its parts. In addition to the individual sensors and actors, such systems have control devices for coordination, often executing sophisticated algorithms. As a third category, ABB also creates standalone software packages for higher level control and optimization tasks.

Besides examples illustrating all these categories, edition 3/2012 of *ABB Review* will look at some more general aspects of software, such as how ABB assures quality in its software development cycle, or how cybersecurity threats can be mitigated.



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