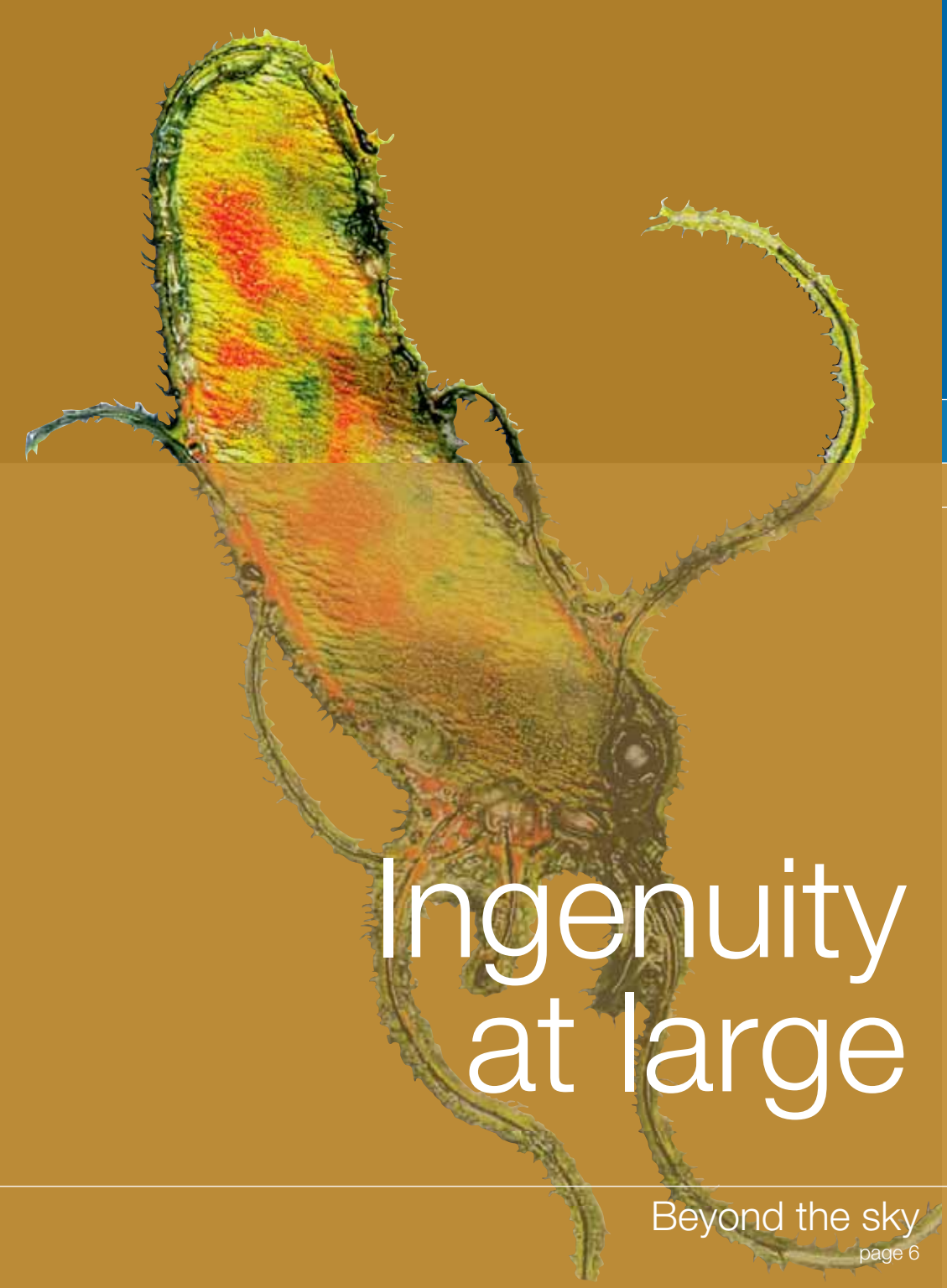


ABB Review

The corporate technical journal of the ABB Group

www.abb.com/abbreview

3 / 2006

Ingenuity at large

It is not totally unusual that technologies developed for industrial applications find their way into completely different areas of endeavour. It is, however, relatively rare for ABB to supply the medical field with advanced measurements. But in the hunt for the devious bacterium, *Helicobacter pylori*, ABB's infrared photometer has simplified the discovery of its existence in the human body.

This is an excellent example of identifying opportunities in new areas while applying the standard product portfolio of ABB. *Ingenuity at large* is the issue that gives this creative drive a stage upon which its performance can be shown to a larger audience through a number of case studies.

Ingenuity at large

When we speak of ingenuity at large, we refer to the engineering talents the ABB Group has developed over the years in our local engineering centers around the world. These experienced and competent engineers are the ones delivering our projects to our customers. They adapt our standard product portfolio, which provides customer advantages in terms of quality, cost and global services, to match the requirements of each individual project. They add particular knowledge related to the local market and to the application itself, primarily in our key traditional industrial and utility markets. Creativity and ingenuity are required to meet the customer's needs, while delivering on schedule and within budget. Challenging as this is in itself, our engineers have sometimes to tackle projects with an additional dimension. These projects originate in unusual applications for which ABB's standard products are suitable if cleverly adapted. In this issue of ABB Review, we portray in both short and long stories, an excerpt of such unusual projects from many different application areas.

Mission-critical systems from ABB support the launching of satellites from a launch pad located in the Pacific Ocean. Engineers from ABB participate in each launch opportunity.

Medical applications are not a segment in which ABB is involved in very often. However, the company has delivered some projects to this market. ABB Review writes about industrial robots exercising limbs as part of therapeutical work with patients. Spectral analysis is used to detect pathogenic bacteria that have a talent for hiding in the lining of the stomach wall.

Gas spectroscopy is also effectively used for environmental purposes for example to look at the quality of air and its constituents. Applications such as gas blending are somewhat more mainstream. A few brief articles towards the end of this issue describe the benefits of spectral analysis in a variety of such projects. The underlying technology of Imaging Fourier Analysis and the interferometer is explained in some detail in the same section.

In a block of short stories we cover such diverse applications as an automatic olive oil press, more energy-efficient rides in a Blackpool amusement park and filtering techniques for artificial snow cannons.

In a section on energy applications, we describe ABB's involvement in a large delivery to the world's second largest dam in Venezuela, combined heat and power on a beach in north-western Poland, LNG production and how London is benefiting from a new underground cable. Many approaches to capturing the energy in tidal- and ocean waves are being pursued around the world. We have chosen to exemplify this technology with a wave power project underway in Norway.

The G8 meeting in Gleneagles, Scotland in July 2005 proclaimed that energy efficiency in industry, building, households and transportation is paramount to decreasing oil dependency and CO_2 emission. In *ABB Review* 3/2005, ABB's ability to contribute towards a sustainable future was discussed in great detail. In this issue we give a few examples from our involvement with the transportation sector, starting with describing how the energy efficiency aspects of our Azipod technology with contra-rotating propulsion presented a Japanese Ferry company with new business opportunities. Also in this segment are articles about new technology for trains, a huge project to equip Rotterdam's harbor with modern crane technology, and a more unusual project in Canada, describing a solution for hoisting boats over land from one body of water to another.

And finally, those who might believe that today's newspaper is in decline because of the dominance of the electronic media should read the story related to ABB's printing automation systems. The partial customization of newspaper content for local markets without sacrificing volume is creating a networked production that keeps volumes high. Automation has become an essential part in handling the increasing complexity. The conclusion drawn is that a locally customized newspaper will keep arriving on your breakfast table for many years to come.

Ingenuity at large celebrates our engineers around the world through a plethora of interesting articles for your perusal.

Enjoy your reading

Peter Terwiesch
Chief Technology Officer
ABB Ltd.

Contents

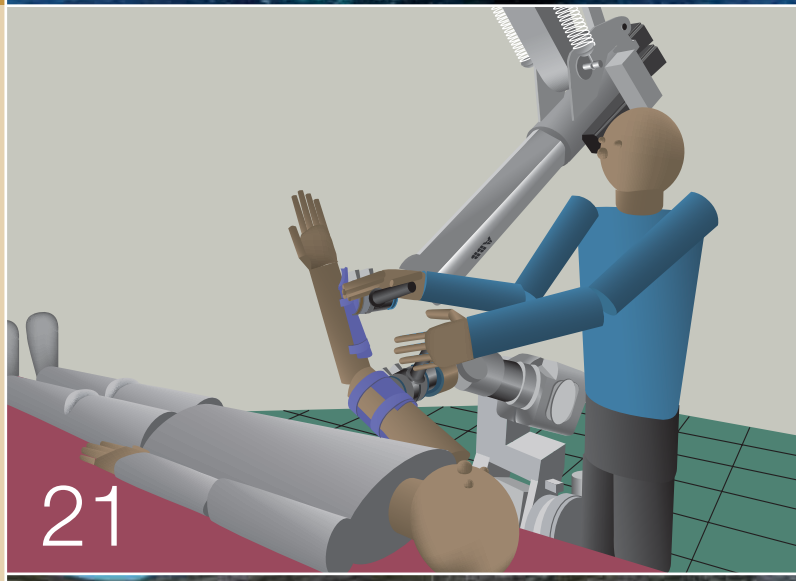
ABB Review 3/2006
Ingenuity at large

Ingenuity at large

Ingenuity in medicine

Ingenuity and energy

Ingenuity on the move



Ingenuity in analytics

Beyond the sky

An integrated solution for the world's first satellite launch unit at sea

Jane-Helen Pedersen, Jacqueline Rolffs

In recent years, launching satellites has become a viable commercial business and a number of companies compete for a share in this highly specialized market. One company that stands out from the crowd is Sea Launch, an international consortium that operates from a floating platform in the Pacific Ocean. ABB provides Sea Launch with mission-critical services. With its reliability and know-how, ABB is helping to ensure the continued success of the Sea Launch enterprise.

The Sea Launch Company is a market leader in the competitive field of commercial satellite launch services. This international consortium provides cost-effective, heavy-lift launch services and is the only company in the world that launches commercial satellites from a floating launch platform. The company has established its reliability through extensive heavy-lift launch experience and has a solid group of satisfied customers. ABB was instrumental in Sea Launch's early success and continues to provide mission-critical services to the company.

Unique capabilities

With its unique capability to launch satellites at zero-degree inclination on the Equator, Sea Launch is able to offer maximum lift capacity and the most direct route into orbit. This allows for an increase in payload mass and maximizes the lifetime of satellites in orbit. In seven years of commercial operations Sea Launch has established a firm customer base of leading global telecommunications companies who rely on Sea Launch and its world-class services to develop their own businesses.

Unique international partnership

After completing their initial research in 1995, the Seattle-based Boeing Commercial Space Company initiated Sea Launch by joining forces with Aker ASA (formerly Kvaerner) in Norway, Rocket and Space Corporation (RSC)-Energia in Russia and SDO Yuzhnoye/PO Yuzhmash in Ukraine. Their aim was to construct, build and manage a satellite launch unit, complete with payload and rockets. An offshore launch site on the equator was chosen for direct insertion into equatorial orbit – as well as to reduce environmental risks and to minimize costs.

Within five years, the platform and the Assembly and Command Ship 1 had been built and the first demonstration payload-launch was successfully carried out on March 27th, 1999. Since this first mission, the company has carried out a further 19 successful launches. This is a testament to the company's robust performance in a relatively flat market.

Unique location with advantages

Located on the Equator at 154° West in international waters of the Pacific Ocean, the launch site benefits from the uniquely calm weather of the doldrums. The light wind conditions in this region result from the convergence of the Northern and Southern Hemisphere trade winds and allow Sea Launch to provide a reliable launch schedule.

The systems delivered by ABB are classified as mission-critical and directly affect the rocket segment.

The Sea Launch Company also benefits from the diversity of skills and experience brought by its various partners. It has been able to optimize its resources by integrating diverse systems and technologies Factbox.

ABB's mission-critical systems

All launch operations are remotely controlled by the English- and Russian-speaking units on the *Sea Launch Commander*. These operations include the erection of the rocket on the launch pad, automatic mating of fueling and electrical umbilicals, countdown, liftoff and flight.

ABB's role is to deliver integrated automation, safety and complete electric power generation and distribution systems to both the self-propelled *Odyssey* Launch Platform and the *Sea Launch Commander* 1. All of these systems are classified as mission-critical and directly affect the rocket segment. They include, for example, the trim/heel control system (to keep the platform level) and the Russian oxygen-monitoring system, which is important during fueling of the rocket (around 900 I/O signals are integrated into the ABB system).

During the development stages of Sea Launch, ABB engineers were needed to deal with teething problems in software applications and some equipment. These, however, were quickly dealt with and ABB's main responsibilities are now to train operators, provide assistance during launch operations and to adapt the ABB systems to the modifications that are made after each launch. An engineer from ABB Marine in the Netherlands has participated in each Sea Launch mission to date 3.

Ingenuity at large

ABB Marine in Rotterdam was responsible for the installation and commissioning of the automation system on board the *Sea Launch Commander*, and for implementing, modifying and commissioning the human machine interface (HMI) for the KBTM

1 The *Sea Launch Commander*; a floating mission control center and rocket assembly factory

Ingenuity at large

Factbox The partners and their roles

Boeing, in the USA, is responsible for managing the Home Port facilities in Long Beach, California, and for the development and operation of the payload unit. Boeing also manages launch operations, including the operation of the launch control center, mission design and systems integration.

Aker ASA, based in Oslo, Norway, is responsible for the marine segment of the program. This included refurbishment of the launch platform (a modified, off-shore oil-rig) at Kvaerner Rosenberg in Stavanger, Norway, and construction of the Sea Launch Commander at Kvaerner Govan in Glasgow, Scotland.

The Yuzhnoye Design Bureau and the Yuzhmashzavod Production Association in Ukraine manufactures the two first stages of the Sea Launch rocket, the Zenit-3SL. This is a modified version of a reliable, quick-response system that was brought into operation in the early 1980ies.

S.P. Korolev RSC Energia in Russia is responsible for managing rocket operations. It also produces the upper stage of the rocket, the flight-proven Block DM-SL, which deploys satellites into geosynchronous transfer orbit.

Moscow (Russian) oxygen-measuring application that is implemented in ABB's UNIX-based operating system. The Rotterdam group also participated in the commissioning of the *Odyssey* Launch Platform.

ABB Marine in Norway designed and delivered the electrical equipment and the automation systems for both the *Odyssey* Launch Platform and the *Sea Launch Commander*.

The ABB engineers involved in the early design of the electrical and automation equipment had to accommodate the complexities of this multi-national project. Launching satellites from the sea was a totally new application and certain technologies had to be adapted. For example, to prevent potential damage caused by excessive vibration experienced during launch, all critical components of the electrical and automation systems are fitted with vibration dampers.

The complexity of the project was compounded by the requirements of individual pieces of equipment, which were sourced from the USA, Russia, Ukraine and Norway, and by the international companies involved at every stage of the proceedings. The success of Sea Launch is a testament to the flexibility of all involved.

Lift-off preparations

During the first stages of launch preparation, the rocket segments and the satellite itself are delivered to Sea Launch's Home Port facility in Long Beach, California. The satellite is encapsulated and mated with the rocket on board the *Sea Launch Commander*.

Two days prior to departure, the rocket is transferred to the rocket hangar of the *Odyssey* Launch Platform. The rocket is mounted onto the mobile transporter, which is used to erect it on the launch pad.

The *Odyssey* Launch Platform departs three days before the *Sea Launch Commander* and the two vessels meet near to the launch site to carry out final preparations.

At the launch site, the floating platform is ballasted to the desired draught of 21 m and specially trained personnel begin preparations. Most staff (240) are on board the *Sea Launch Commander*, while the remainder (68) work on the launch platform. Transportation between the two vessels takes place via a temporary bridge. Both vessels are equipped with dynamic positioning control.

The day before launch, the operators move from the launch platform to the command ship and control is transferred to a duplicate ABB console in the ship 2. This console communicates via the extended ABB network and a so-called line-of-sight (telecom-

2 ABB equipment used on board the commander vessel

3 The ABB engineer, who accompanies all launch missions, is viewed as a member of the crew

munication) connection with the platform.

ABB Marine designed and delivered the electrical equipment and the automation systems for both the *Odyssey* Launch Platform and the *Sea Launch Commander*.

After the rocket has been rolled-out and erected on the launch pad, the remaining staff are airlifted to the command vessel, by helicopter. At this point, full command is transferred to the remote unit on board the ship. The rocket is then fueled with a liquid oxygen and kerosene mixture and the transport/erector equipment withdraws to the hangar. Minutes after the hangar doors are closed, the rocket lifts off.

In 2005, Sea Launch celebrated the tenth anniversary of its inception, recognizing a decade of innovation in the launch services business. Progress continues with the support of a team dedicated to exceeding its customers' requirements and expectations. Sea Launch is committed to successful, on-schedule launches, building on its proven track record and strong reputation. It continues to win contracts from both new and returning customers in an endeavor that epitomizes the ingenuity with which ABB is so often associated.

Factbox ABB delivery of power and automation systems

Delivered for the Odyssey Launch Platform:
- Eight high-voltage generators (6 kV, 3600 kVA). 4 × 60 Hz, 2 × 50/60 Hz and 2 × 50 Hz.
- All high- and low-voltage switchboards for both the 60-and 50-Hz systems.
- All motors for the bow and azimuth thrusters.
- Silicon controlled rectifier (SCR) systems for the propulsion.
- Automation systems (2 × AC450 controllers, 2 x fireguards [ANX-95], 1 × safeguard 3000, 8 × AS500 operator stations, 1× 800xA trending station).
- Protocol converter for the interfacing between the oxygen monitoring system and the ABB Advant System (HMI)

Delivered for the *Sea Launch Commander*:
- 2 high-voltage generators (6 kV, 6250 kVA, 50 Hz).
- 4 low-voltage generators (380 V, 1525 kVA, 50 Hz).
- All motors for the bow and azimuth thruster (6 kV).
- All high- and low-voltage switchboards for both the 60-and 50-Hz systems.
- Automation systems (3 × AC410 controllers, 1 × safeguard 400/1.4, 2 × fireguards [ANX-95], 4 × AS500 operator stations, 1 × 800xA trending station).

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The “Silver Elephant”

A cavitation tunnel built to a precision of hundredths of a millimeter

Tadeusz Kobus, Agnieszka Gabrysiak

Experimentation and testing are among the most tangible and visible activities in a development process. Such moments are even more impressive when the parameters of the test reach dramatic dimensions. One such testing environment is the “Silver Elephant”, built to evaluate the hydrodynamics of ships’ propellers.

An important issue in the design of ships’ propellers is cavitation. Cavitation occurs when bubbles of water vapor formed in low-pressure areas enter areas of higher pressure where they collapse. This process can lead to the rapid erosion of adjoining surfaces.

The Silver Elephant left Poland in January 2005 for Vietnam, where it will serve the rapidly developing shipbuilding industry. The beginning of this journey marked the conclusion of one of the largest and most challenging construction projects in the history of ABB Zamech Marine in Poland.

It is said, that everything in the Far East has to have a name. The same is true of cavitation tunnels and large test installations in general. The "Silver Elephant" had already acquired its name in the production hall at Elbląg, Poland, but its formal baptism took place at the Ship Design and Research Center (SDRC) Factbox 1 in Gdańsk. The name reflects the silver appearance the tunnel exterior, acquired through passivation, and the resemblance of the entire tube to a pachyderm with a curled trunk.

A cavitation tunnel is used to analyze liquid flow around the screw propeller of a ship and to evaluate and optimize the design of such propellers.

Cooperation against cavitation

The story of this remarkable project began with a cooperation agreement signed by the Polish and Vietnamese governments. The developing shipbuilding industry in the Far East was one of the sectors to be offered Polish assistance. SDRC, as a leading specialist in hydrodynamics, was awarded a contract for the design and construction of a cavitation tunnel for a Vietnamese research center. SDRC prepared the conceptual design, and ABB Zamech Marine at Elbląg, Poland 1 was awarded the task of transferring this onto paper and manufacturing the tunnel. This was no normal order for that plant. Not only are such tunnels rarely built, but the tunnel's size Factbox 2 placed it far beyond anything so far supplied by the factory.

A cavitation tunnel is used to analyze liquid flow around the screw propeller of a ship and to evaluate and optimize the design of such propellers. However, marine propellers can be four or even eight meters in diameter. It is hardly practical to examine such large structures in such a tunnel. Not only would the tunnel have to be of gargantuan proportions, but the time and costs involved in iterating the design of the test propeller would not be acceptable. Models with a 20-centimeter diameter are used instead. The results of such tests can be scaled to permit accurate predictions about the properties of the full-size propeller 2.

Lethal bubbles

The action of a propeller causes currents and turbulences. The faster a fluid flows, the lower its pressure (Bernoulli's Principle). When its pressure is sufficiently low, water evaporates to form bubbles of vapor. These bubbles flow with the water until they enter zones of higher pressure where

1 Ready to take on great projects - the Elbląg factory of ABB Zamech Marine in Poland

2 A real ship's propeller is far too large to be tested in a cavitation tunnel. This propeller is for ship B 8276 built by Gdynia Shipyard, Poland

Factbox 1 Ship Design and Research Centre

The Ship Design and Research Centre (SDRC) was founded in 1971 as a design, construction and research centre for the needs of the Polish shipbuilding and repair industry. Following organizational hardships in the early 90ies, the SDRC has defended its leading position in the market for hydromechanics, ship construction, material technology and corrosion. The end of the past decade revitalized the ship design activity of the company. The SDRC laboratories are made accessible to students and staff of technical universities, and great emphasis is laid on increasing the education quality and development of science. In April 2004, the SDRC was transformed into a state-owned company.

Factbox 2 The "Silver Elephant" in numbers

Length:	21 m
Height:	12 m
Volume of water held:	130 m^3
Mass of structure (without water):	60 t
Accuracy in perpendicularity of measurement chamber walls:	0.1 mm
Smoothness of inner plates:	Ra 0.8 to Ra 2.5
Bolts holding segments together (see also title picture):	M36

they implode. This action releases significant bursts of energy that spread through the water in the form of shock waves. The results are high noise emissions and vibrations, but worse still, cavitation can strike microscopic particles out of solid surfaces (such as the propeller blades). Over time this leads to erosion modifying the shape of the propeller and reducing its efficiency – with critical effects on the screw-propeller's life, the drive system and the fuel consumption.

An investment in cavitation investigation is thus an investment in the life and efficiency of the propeller being developed.

The tunnel itself is a circulatory water duct composed of four sections varying in shape and cross-sectional diameter 3. The tunnel is filled with water, and the model to be examined placed in the measuring chamber 3g 5 in its upper part. Doing some injustice to engineering vocabulary, one can say that the cavitation tunnel is an enormous steel tube with water pumped 4 in closed circulation. By generating a defined and controlled flow inside the measuring chamber, operating conditions for the screw propeller are simulated. Sensors located in the tunnel allow the careful study of the dynamic behavior of the propeller under different conditions. The results of such a study permit corrective measures to be introduced to the design.

3 The "Silver Elephant" cavitation tunnel

A 90 kW, 1500rpm electric motor a drives reduction gear with a transmission ratio of 1:6.3. The sub-units of this shaft are mounted on a common frame and coupled elastically. The water in the tunnel is pumped b by a four-blade ship-propeller at up to 200 rpm. The propeller elements are made of high-strength bronze. The pitch of the blades is adjustable. After leaving, the propeller, the water flows through a diffuser c, ie, a section of tubing that changes the water pressure through increasing its cross-section and then through a honeycomb straightener d that stabilizes the flow. The tunnel elbows e contain water guide vanes whose number and shape are different for every elbow. Before entering the measurement chamber, the water flows through the so-called confuser f. This stabilizes the water-jet as it leaves the elbow, and also modifies its pressure by reducing the cross-section. Careful hydrodynamic analysis and precise machining went into every part of the confuser.

The entire tunnel is located in a building. An upper floor permits access to the measurement chamber g. The chamber contains sensors which monitor various water parameters. Plexiglas window plates of 80 mm thickness are fitted in all four walls of this section to permit visual observation and filming of the test from different angles and the use of external instruments such as stroboscopes. Although primarily designed for propellers, the tunnel can also be used to test other parts such as ship hulls. Upon leaving the measurement chamber, the water enters a diffuser h. Water de-aerating elements are located in the tunnel elbow i and equalizing tank j. These help achieve required working parameters such as a positive or negative gauge pressure. The tunnel is supported and stabilized by brackets k of construction steel.

An investment in cavitation investigation is an investment in the life and efficiency of the propeller being developed.

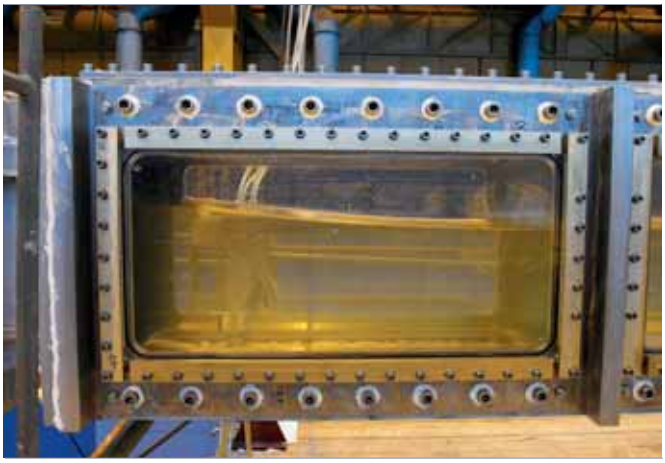
Chimera of a straight-forward project

In theory, everything looked great – a complete design, well specified requirements – all that was left to be done by ABB Zamech Marine was the preparation of detailed drawings and the welding and delivery of the tunnel. The contract was signed in December 2003 and ABB's engineers started work immediately. Each part of the construction – even the smallest and most insignificant detail was practically unique, adding to the challenge that lay ahead.

It was not, however, the design itself that posed the greatest challenge. The

4 The pump that keeps the water flowing is powered by an ABB frequency converter

5 A propeller design that has successfully braved the current in this measurement chamber is fit for the ocean



6 Numerous tests were required to verify and ascertain the tunnel's properties

seemingly "minor" requirement, specified by SDRC, to make the tunnel out of stainless steel became the key challenge. Precision engineering is a traditional strength of ABB Zamech Marine in Poland – the plant is able to work to accuracies of hundredths of millimeters. The key challenge, however, relates to the material chosen, ie, chromo-nickel plate. This material has a high thermal conductivity, making it impossible to join two plates by continuous welding. Work had to be interrupted repeatedly, prolonging the production time considerably. Construction of some sub-assemblies took twice or even three times as long as scheduled. The deformation of previously completed components posed considerable challenges. Frequently it was found that a part that had been prepared, assembled and welded on one day had, by the next day, acquired different dimensions. The steel grade selected has great strength, but is also quite ductile – requiring not only longer processing times, but also special tooling.

Despite all these challenges, the delivery date was met. Less than a year after signing the contract, SDRC could begin commissioning and calibrating the tunnel 6. Within two weeks, much specialized measuring equipment had been installed in the tunnel. Every cavitation tunnel has unique characteristics due to its shape and material. Hence, very detailed tests are required. These tests help determine scaling factors so that the results of model-based tests can be applied to the real propellers[1)].

Large numbers of pressure gauges, speed meters and specialized measuring instruments were fitted in all parts of the tunnel. The "Silver Elephant" was accepted by the SDRC with no reservations.

Precision engineering is a traditional strength of ABB Zamech Marine in Poland – the plant is able to work to accuracies of hundredths of millimeters.

Shipment for shipbuilding

The entire structure was disassembled into its components for shipment. Some of the smaller parts were packaged in containers, the larger ones were fixed on platforms, and finally the tunnel was loaded onto a ship.

Despite the complications encountered, this contract was profitable not only financially but also in terms of the lessons learnt. ABB's project team gained significant and valuable knowledge, with many established routines being reassessed leading to a more profound understanding of the underlying principles. Already at the design stage, knowledge was refreshed. The Elbląg factory is primarily a production plant, and although it does design new types of equipment, these activities are maintained within the confines of certain well-defined manufacturing processes. The "Silver Elephant" project has helped the factory step beyond this stereotype and attain new levels of creativity and flexibility in both mind and deed. From tackling various issues related to stainless steel, much new knowledge has been collected. This will provide access to new markets, both in terms of manufacturing know-how and as an endorsement for the company.

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Footnote

1) Water flow parameters are graduated on the basis of flow similarity (using Reynold's, Freud's Nuselt's and other numbers).

Uncommon problems, common solutions

The ultimate demonstration of a solution's portability and modularity is its successful deployment in an application its designers never dreamt of. The following block of articles takes a quick, but by no means exhaustive, tour of common ABB products in uncommon applications. Such solutions extend from the unusual to the downright exotic. The requirements placed on them are the same as in traditional markets – energy savings, quality and productivity. The magnitude of savings is often smaller than in standard solutions, but their significance for the customer sometimes greater.

On track with power savings

The cost of running one of Britain's largest tourist attractions looks set to fall. The introduction of power correction equipment from ABB at the Blackpool Pleasure Beach has reduced power consumption on new rides by around 25 percent, thrilling the operator as much as the customer.

Blackpool, on the north-west coast of England, is one of Britain's most popular holiday resorts. It is famous for its scale copy of the Eiffel Tower, its winter illuminations and the year-round entertainment of its Pleasure Beach. The Pleasure Beach attracts over 6.2 million visitors every year, all clamoring for the excitement of its famous rides.

Power consumption is a major challenge for a leisure facility that is constantly adding new power-hungry rides. With its latest addition, the dramatic "Bling" ride, which opened in 2004, the owners of the park looked to ABB to help them deliver the necessary electricity without having to undertake an upgrade of the overall power network supplying the Pleasure Beach.

This was not the first time that ABB had used its power factor correction (PFC) technology to help the park in this way. The first time was several years ago, when Blackpool first unveiled "the Valhalla", which, at the time, claimed to be the biggest and most spectacular dark (indoor) ride ever built.

The latest ride takes its name from the world of pop culture, "Bling". The white-knuckle experience involves a 95 kilometer per hour spin in three different directions, up to 30 meters above the ground, exposing riders to pressure two and a half times the force of gravity.

The "Bling" ride places major demands on the three-phase power network. It was expected to draw around 1,400A per phase, but with the installation of ABB's power factor correction equipment (a bank of capacitors totaling 300 kVAr) the supply current needed was reduced to 1,200A per phase. This means the power needed to operate the ride was cut by approximately 25 percent.

With total energy savings running at up to $3,800 per month in the peak season, the ABB equipment is expected to pay for itself within three years.

It was a similar story in terms of power and monetary savings when the Valhalla ride opened in 2000. Following the installation of the ABB automatic power factor correction equipment, which comprised two banks of capacitors totaling 900 kVAr, the supply current was reduced to 1500 A per phase. This meant that the power required to operate the ride fell from 1.5 MVA to a little over 1 MVA.

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Clean snow from a clean network

The equipment driving artificial snow cannons and mountain cable cars can interfere with power grids and result in flickering lights and poor television reception. But ABB has the perfect solution: network power quality filters (PQFs) for existing systems, and integrated supply unit (ISU) frequency converters for new devices.

Most artificial snow machinery and mountain cable-cars are located at the ends of valleys where the power grid is generally weaker. Unless appropriate counter-measures are taken, when the machinery is switched on, disturbances often occur in electricity-supply networks.

Simultaneous individually programmable filtering is provided for 20 harmonics up to the 50th harmonic frequency. Filtering efficiency is typically better than 97 percent.

The asynchronous motor with 4Q frequency converters is also successfully used in pump drives.

Network filters for existing artificial snow equipment

Older drive pumps on artificial snow machines are often fitted with conventional power converters that cause disruptive harmonics in the electricity supply system. ABB's goal was to eliminate these disturbances with a special network filter. The filter can be connected to existing drives or integrated into new systems with minimal effort.

These power quality filters (PQF) continuously monitor line current, in real time, to determine which harmonics are present, and then inject compensating currents into the network whose harmonics have exactly the opposite phase. The harmonics cancel out, leaving a clean sine wave.

Power Quality Filters are unaffected by changes in network parameters and cannot be overloaded. They are available in standard versions for 70, 100 and 130 A, and in other versions (ranging from 40 to 3,600 A) on request. They are already being used successfully in a variety of artificial snow systems.

Factbox The principle of the active filter

The principle of the active filter is to measure harmonic currents and actively generate a harmonic spectrum in opposite phase to the measured distorting harmonic current. The original harmonics are thereby cancelled.

The active filter has a parallel configuration, and monitors all three phases of low voltage line current in real time by means of a digital signal processor (DSP).

The output of the DSP unit, in combination with a microcontroller-based control system, generates a pulse width modulated (PWM) signal in order to control power modules based on IGBT (insulated gate bipolar transistor) technology acting as a current source. The PWM signal uses a fixed switching frequency.

The system operates under closed-loop control with a maximum response time not exceeding 40 milliseconds. The control system prevents the active filter from becoming overloaded.

Simultaneous individually programmable filtering is provided for 20 harmonics up to the 50th harmonic frequency. Filtering efficiency is typically better than 97 percent.

The operating power factor of the active filter is programmable over the range 0.7 inductive to 0.7 capacitive. The programmer may select both fixed and dynamic reactive power compensation.

The active filter is protected against overcurrent short-circuit, thermal overload and IGBT bridge abnormal operation.

Asynchronous motor for new systems
Five years ago, ABB came up with a brilliant idea for new cable car installations: the four-quadrant asynchronous drives. Compared to DC drives, these new three-phase AC drives are smaller, require minimal maintenance and save energy. They have very low current harmonics, no reactive power consumption and can easily handle voltage surges in the grid. The frequency converter makes start-up and operation a breeze, and eliminates the need for complicated and time-consuming measurements.

Power Quality Filters are unaffected by changes in network parameters and cannot be overloaded.

The PQFM power filter can be connected to existing systems as an individual component with minimal effort

This technique is now being applied to the pump drives of artificial snow cannons, where the problems are similar: collector problems in the DC motors, as well as mains harmonics and reactive power in the thyristor controllers.

Here, too, the solution was an asynchronous motor with an ISU-FU integrated supply unit and frequency converter. This was first used, to great effect, at the 2003 Ski World Championship in St. Moritz, Switzerland. Other snow-making systems followed in the Swiss ski resorts of Laax, Flumserberg and Ibergeregg, and for the 2005 Ski World Cup finals in Lenzerheide. The result: mains harmonic filters and compensation systems are no longer needed in pump drives ranging in output from 200 to 355 kW.

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Oiling the wheels of an olive press

Olive oil extraction is a complicated business. ABB is working with Rapanelli Fioravante to provide an innovative solution for automated machine control.

In continuous-cycle mills, the painstaking steps of olive oil extraction – crushing, kneading, decanting and separating water and olive residue from the oil – are performed in automated production systems with little operator intervention. While this brings numerous advantages over more traditional methods, olive oil production – unlike other oil extraction systems – still requires precise control of the temperature and kneading time.

The system can be monitored from remote stations through common transmission networks, for management, control and maintenance purposes.

In order to improve the systems used by olive oil makers, Rapanelli Fioravante Spa of Foligno, Italy – a manufacturer of olive oil extraction machinery – has been working with ABB to design and implement an innovative solution for automated machine control.

The new solution allows the three units comprising the mill to be controlled individually. These are the crushing/kneading group; the decanter (centrifugation of the paste consisting of olive residues and oily must); and the end-separators, for removing excess water from the oil.

Supervision software provides details of work sessions, date and time, kneading time, and product temperature through all operating phases.

The Rapanelli company of Foligno worked with ABB on the design and implemention of an innovative solution for the control of automatic mills

ABB's AC31 programmable logic controllers are used in the new system and software adaptations can be made to meet the needs of each individual oil producer – for instance, to accommodate the number of decanters or separators used in a particular configuration.

Individual processes within the oil-producing system can also be changed very easily. The system can be monitored from remote stations through common transmission networks (telephone, internet, etc), for management, control and maintenance purposes.

Each of the three units in the mill has specific control software. In addition, two types of supervision software are available for controlling machine operation. These generate reports, providing details of work sessions, date and time, kneading time, and product temperature through all operating phases.

Temperature monitoring and sampling can be carried out through each stage of the operation, thanks to the system's ability to identify the exact position of the product in the production cycle.

All of this information is presented to the operator on a general display page. From here, work pages can be accessed and dedicated to each of the three operating units that make up the system. All control activities can be documented in detail.

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A straight "torquing" formula

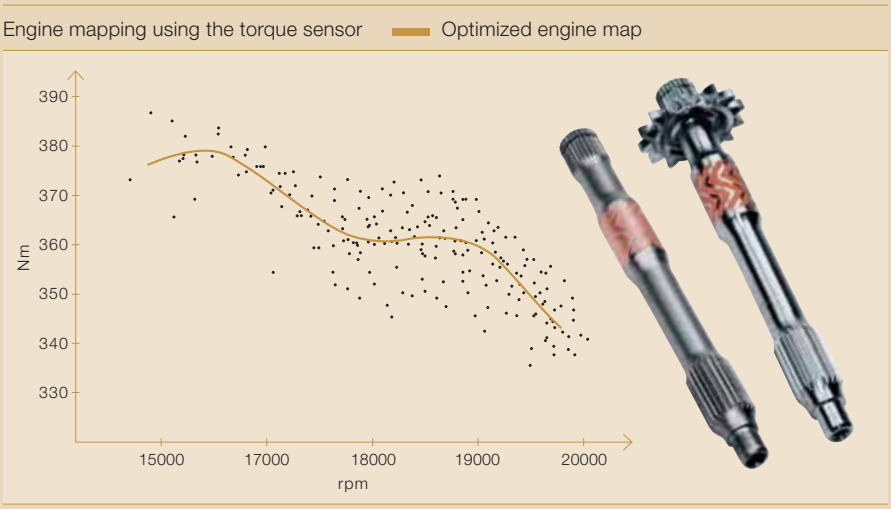
ABB has developed a torque sensor that can withstand the unforgiving environment of a Formula-one racing car.

The robust concept was originally developed for standard automotive applications and then adapted for extreme uses such as those found in Formula One installations. The sensor is small enough to be integrated directly into the power train on the gearbox input shaft. From here it has access to the actual engine torque, allowing a range of applications to be performed in terms of engine and drive train monitoring. An engine 'map' can be acquired directly, while the car is on the track, allowing the performance of gearshifts to be measured and optimized.

The conditions of Formula One racing are indeed demanding. For an installation on the gearbox input shaft, the sensor has to endure:

- Rotational speeds up to 20,000 rpm
- Temperatures up to 250° C
- Stress levels up to 1800 MPa

Other requirements include tolerance for high-level vibration, resistance to lubricants and a durability that en-



sures flawless operation, lap after lap. The sensor is also required to maintain its function without any special attention or recalibration, before or after the race.

When a ferromagnetic material is subjected to torque, its magnetic properties change. These changes (magnetoelasticity) can be measured and are the basis for ABB's Torductor-S, a non-contacting torque sensor used in the Formula-One cars. The sensor's ability to record data accurately and consistently in the harsh environment of a racing car makes it a unique and powerful tool for the optimization of engine performance. Correct tuning of the control system, which involves adjusting the engine to achieve maximum torque and power output, relies on detailed knowledge of the engine's output, as does the optimization of gearshifts for minimum torque interruption.

Engine tuning is usually carried out on a test rig before the engine is mounted in the racing car. However, experience has shown that conditions in the test rig do not entirely reflect those in the vehicle. This leads to sub-optimal tuning and sub-optimal performance. By positioning a torque sensor in the input shaft of the gearbox, it is possible to gather detailed information about the engine and the power train, while the car is actually racing. This allows an engine to be tuned to race conditions and allows performance to be monitored throughout the race.

When a ferromagnetic material is subjected to torque, its magnetic properties change. These changes can be measured and are the basis for ABB's Torductor-S.

In addition to measuring maximum output, the torque sensor also provides details of engine and gearbox performance, including engine response to driver input and equipment wear. In this most competitive of fields, reliable torque sensing is a most desirable feature.

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Automation moulds a competitive edge

A leading manufacturer of custom-molded plastic novelties, Characteristix Limited, has doubled its manufacturing performance with the installation of an ABB robot-based cell at its factory in Wadebridge, Cornwall, UK.

The GeKu manufacturing cell – comprising an ABB six-axis IRB 140 robot, Krauss Maffei plastic injection molding machine, GeKu beam robot, conveyors, and pneumatic printing press – is helping Characteristix to remain competitive, even when pitted against the Far East giants of the industry.

Characteristix, which has a prestigious list of license partners such as 20th Century Fox, BBC Worldwide, Disney, Universal Studios and Warner Bros, has exploited a niche in the market to supply quick turn-round, small-to-medium size batch products to UK and European-based customers – companies that would previously have placed their orders in the Far East.

Not only does Characteristix offer a total turnkey approach, including design and artwork, but its fast production also gives customers the flexibility to order relatively small batches for speedy delivery.

This compares favorably with supplies from China, for example, where customers are restricted to ordering extremely large batches, can expect three month lead times, and need to closely examine quality and product suitability before proceeding.

A small enterprise, based in rural Cornwall with 11 employees, may not seem the most likely of companies to install robots and take on the Far East.

The GeKu manufacturing cell has doubled production to 33,000 pieces a day, including birthday card badges, stand-up figures, pendants, figurines, pencil toppers, fridge magnets and plastic paper clips etc, molded in the unmistakable shapes of famous cartoon characters like Bob the

Builder, Spiderman and Shrek, to name but a few.

Not only has the cell ramped up production for the Cornish badge maker, but it has also brought interest and variety to much of the production work force. Many of the company's employees, who were previously employed in manual labor, have risen to the challenge of robot-based manufacturing, readily participating in robot programming and operator tuition to enhance their skills.

Summing up, director Andy Knight comments: "A small enterprise, based in rural Cornwall with 11 employees, may not seem the most likely of companies to install robots and take on the Far East. However, the GeKu-designed cell and its ABB robot have helped us to be ultra-competitive, while we have maintained and indeed expanded a client-base made up of some of the most recognized names in the world."

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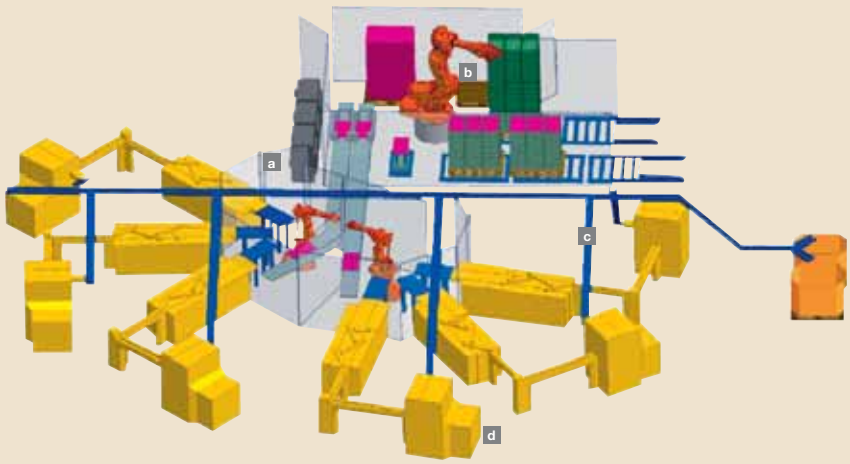
Toblerone – handled with care

Is there really anyone out there who hasn't heard of Toblerone, the most famous brand of Swiss chocolate? The unmistakable triangular chocolate bar is produced by Kraft Food Schweiz AG in Bern. Now available in individual portions, Toblerone chocolates are handled and individually packaged by ABB robots.

People around the world love Toblerone. Its shape – modelled on the most iconic of Swiss mountains, the Matterhorn – is unmistakable. What's new is that the three-cornered chocolate is now available in individual pieces. These can be

1 The Toblerone packaging system



a Transfer station
b Unload station
c Product collection and merging
d Wrapping machines 1–5 (spare machine 6)

enjoyed one at a time, with a coffee or as a little between-meal snack.

ABB robots work on the production line at Kraft Food, stacking full trays of individual chocolate triangles and 'feeding' them into the downstream packaging systems, where each one is individually foil-wrapped 1.

Kraft Food's goal

Kraft Food asked ABB to provide them with a system that would:

- automatically feed chocolates to five foil-wrapping machines
- collect and merge the packaged products for placement in palette containers
- prevent damage to the product
- maximize access for monitoring, cleaning, service and maintenance tasks
- accommodate a three-shift operation
- use simple component design
- provide a simple operating system to accommodate frequent changes in personnel

An ABB IRB 6600 robot, with a reach of more than three meters, transfers each container to a separating station.

ABB's solution

ABB's design concept for the complex and strictly specified system paid particular attention to the transfer of the chocolates from trays to the feed conveyor for the wrapping machine. If the chocolates were to fall during this procedure, they would cause machines to shut down. The chocolates must be precisely positioned to ensure optimum wrapping performance.

ABB's solution divides the overall job into several subtasks

Containers carrying trays filled with chocolate pieces are stacked on pallets and sent to an unloading station. Here, an ABB IRB 6600 robot, with a reach of more than three meters, transfers each container to a separating station. The trays are removed from the stacks and placed, several trays at a time, on one of two unstackers 2. A conveyor belt below each unstacker delivers the lowest tray to a transfer station.

The tray is pulled from beneath the chocolates so gently that they end up precisely arranged on the conveyor.

Trays filled with chocolates are picked up by an IRB 2400 robot at each of the transfer stations. To enable individual wrapping, the chocolates must remain evenly spaced when they are transferred onto the conveyor. To achieve this, the tray is pulled from beneath the chocolates so gently that they end up precisely arranged on the conveyor. This handling process is much more precise than manual transfer and also prevents the product being damaged.

After wrapping, the chocolate pieces are picked up by bucket conveyors that merge the product on a central collection conveyor, which runs along the entire length of system. At the end of this conveyer, the chocolates are collected in a large container. The delectable Toblerone chocolates are then ready to be delivered all over the world!

2 Unstacking the trays of chocolates

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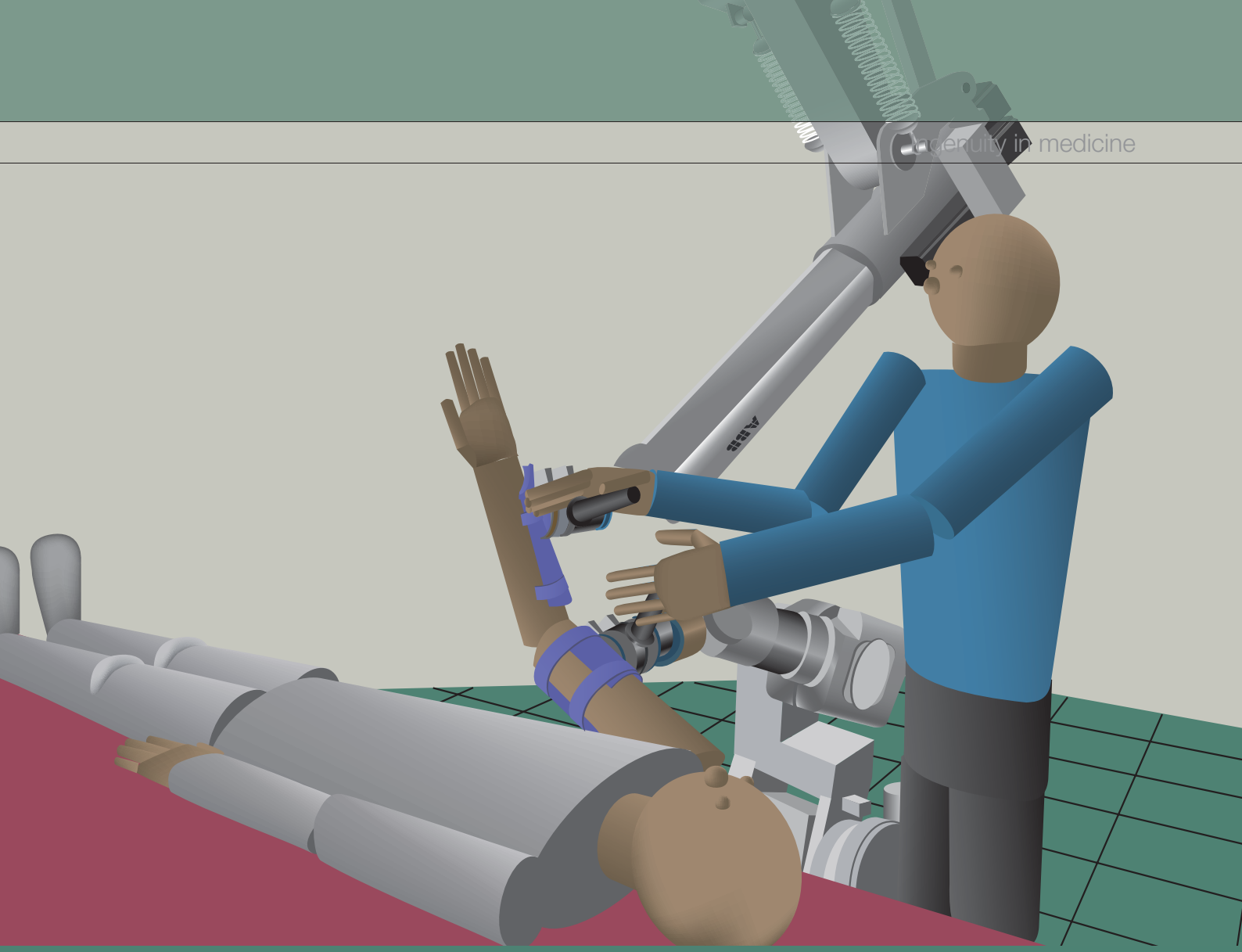

Robots with patients

Can robots really be used to enhance physiotherapy programs alongside their human counterparts?

Andras Toth, Ivan Ermolaev

Industrial robots can perform a wide range of three-dimensional movements. They are accurate, powerful, and compliant, and they can perform many of the highly repetitive tasks required of physiotherapists. The idea of using robots to assist physiotherapists in the treatment of impaired limbs is an attractive one, but is it too simplistic? This question was the subject of a research project based on industrial robots built by ABB. With the advent of mass-produced, highly reliable robots, the prospect of robot-assisted physiotherapy for neuro-rehabilitation is now a reality.

The physical rehabilitation of patients suffering from spastic hemiparesis (paralysis on one side of the body) is a great challenge. The paralysis can be induced by a number of causes, including brain hemorrhage or infarct (stroke), trauma, tumor, multiple sclerosis, and birth defects. The most common cause is stroke, which can result in permanent damage. Stroke is one of the most common major neurological disorders affecting Europe's citizens, with 80 percent of survivors having significant neurological impairment and 31 percent needing help in everyday activities. In the European Union (EU), the average incidence is between 150 and 400 per 100,000 population, but there is wide regional variation. In the Netherlands, the incidence is 526, and in Sweden, it is 941 per 100,000. In Middle Asia and in the new independent states of the former Soviet Union, the incidence is 600, whereas in the United States it is 214 per 100,000. It is necessary to improve the medical care of these patients, not only in the field of acute therapy, but also in the area of rehabilitation.

1 The REHORAB Theraputic System

a Housing
b IRB 140 industrial robot
c IRB 1400H industrial robot
d Upper-arm instrumented orthosis
e Lower-arm instrumented orthosis
f Couch
g Operating panel
h Patient enabling device ("dead man's lock")

Stroke patients have been shown to respond positively to the passive movement of their impaired limbs: the brain can be retrained and a degree of functional recovery can be achieved. In the case of the upper limbs, passive movement involves a physiotherapist simultaneously grasping the patient's elbow and wrist and then repeatedly flexing the patient's arm for 40–45 minutes. For effective rehabilitation, this passive exercise should be repeated twice a day over a period of at least a month, and followed by several months' active exercise, in combination with an active physical contribution from the physiotherapist. Such levels of care are often unavailable, but even in cases where patients have ready access to trained physiotherapists, treatments could be enhanced by the assistance of robots.

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The beginnings

The history of rehabilitation robotics goes back to the 1980ies. However, because of their perceived poor accident record and heavy motion patterns, industrial robots were then deemed unsuitable for use in rehabilitation robotics. It was only in 1999 that researchers at the Budapest University of Technology and Economics in Hungary had the idea of using standard, full-scale industrial robots for human therapeutics. The REHAROB project was the first in the world to target the use of standard, mass-produced, industrial robots for the physiotherapy of spastic hemiparetic stroke patients. An international consortium, comprising organizations from Hungary, the UK, Germany and Bulgaria, was set up and began work on developing a commercially viable, two-arm robotic system. The aim was to supply personalized, three-dimensional, upper-limb motion therapy for patients suffering from spastic hemiparesis and other limb disabilities. The initial work was co-funded by the European Commission and its participants, and a follow-up project was funded by the Hungarian Medical Research Council.

The REHAROB Therapeutic System

Commercial success of the project will be dependent on the use of commercially available sub-systems. Consequently, the REHORAB system was developed around two co-operating ABB industrial robots that could be programmed by demonstration (teaching-in) using force/torque measurement. These robots are reprogrammable manipulators that can move a part or tool through a prescribed path at a defined velocity and orientation. In a therapeutic role, their capabilities can be used to move the arm of a patient, but here, there is the additional complication of patient and operator safety to consider. For this reason, components for the REHAROB Therapeutic System were selected from certified, reliable and mass-produced devices and the system was fitted with multiple and redundant safety devices. In addition to these measures, the REHAROB team also reduced the maximum speed of the robots from 3 m/s to 0.25 m/s.

The prototype of the REHAROB Therapeutic System is shown in 1 and the instrumented orthoses (custom-made braces) that hold the patient's upper and lower arm during therapy are shown in 2a. The orthoses are equipped with the standard six degrees-of-freedom force/torque transducer and a safety release mechanism. The safety release can be triggered by an emergency signal from either the patient, the physiotherapist, or the system. The machine responds by immediately disconnecting patient's limb from the robots, while continuing to support it in the orthoses, as shown in 2b.

Robot-mediated therapy is set up in three main steps: the physiotherapist programs the robots by demonstrating a number of basic exercises, with the

patient in place. Individual exercises are then edited to suit the patient's needs and combined to produce a tailored, complex therapy program. Finally, the robots play back the program, allowing the physiotherapist to change the order, the speed, and the number of repetitions for each step 3. Because the patient is present during the programming phase, each therapy regime is perfectly suited to the patient's needs and the REHAROB Therapeutic System can administer the program without the personal supervision of medical staff.

All participants showed a significant improvement in their condition according to a number of impairment and disability indicators. Patients found the robotic exercises as effective and calming as traditional manual passive physiotherapy.

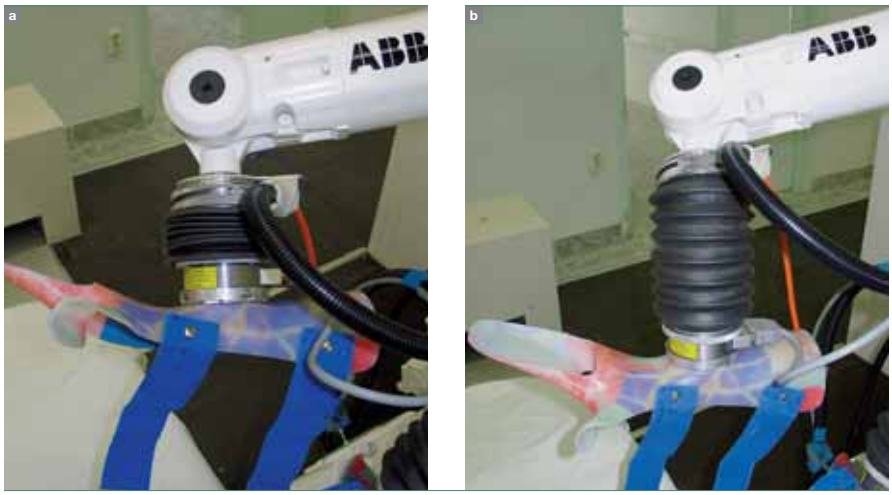
Robots are very flexible products, but since they are fixed to the housing of the Therapeutic System and work cooperatively, there are some limits on patient weight and height. Patients must weigh no more than 150 kg and must be between 160 cm and 190 cm tall. The height restriction is imposed by movement limitations on the robot arms rather than by safety issues: If the patient is too short or too tall, the robot arms will not be able to accommodate the appropriate range of movements for the therapy program. Such problems will be identified in the programming stage by a "joint of out of range" signal to the therapist during teaching-in.

Clinical trials

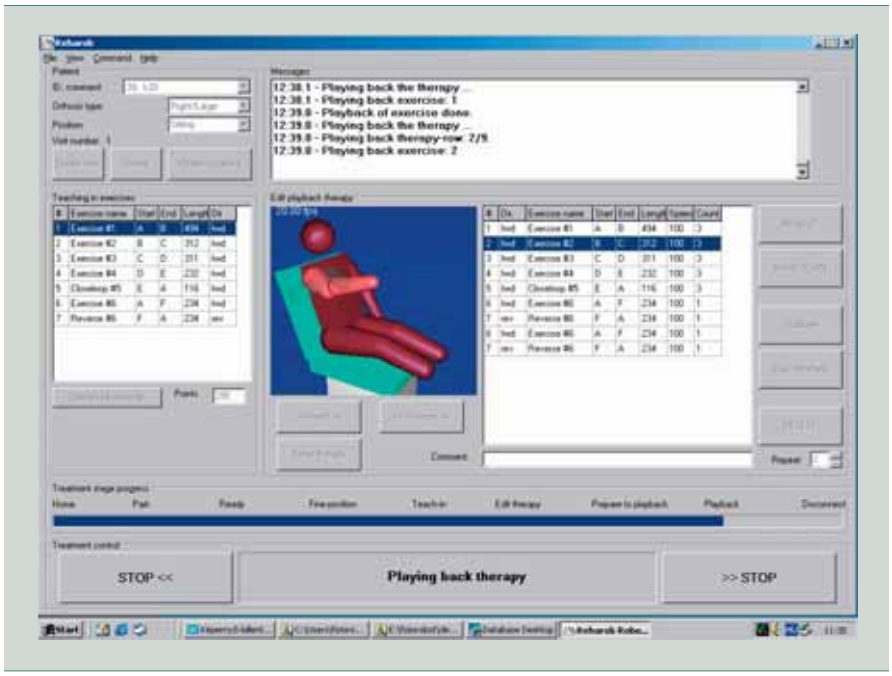
Clinical trials of the REHAROB Therapeutic System were carried out at the National Institute for Medical Rehabilitation, Budapest, Hungary, in compliance with the Declaration of Helsinki [1] and both local and national scientific and research ethics committees. The first trial, which was carried out over a period of four months, demonstrated that the robotic physiotherapy system worked safely and reliably, that patients were not afraid of the robots and that physiotherapists had no difficulty in learning how to operate the system. Twelve participants, suffering from varying degrees of disability, were subjected to a combined total of 240 robot-mediated physiotherapy sessions (20 thirty-minute sessions each). All participants showed a significant improvement in their condition according to a number of impairment and disability indicators[1)]. Patients found the robotic exercises as effective and calming as traditional manual passive physiotherapy.

Following the conclusions of the first clinical trial, the system's force controller, the graphical user interface, the instrumented orthoses, and the patient enabling device ("dead man's lock") were modified in the FIZIOROBOT project. To investigate the effectiveness of the new system, a controlled clinical study was made on the FIZIOROBOT, following the same ethics approval procedure used in the initial trial. In this investigation, 30 patients with hemiparesis were

2 The instrumented orthoses of the REHAROB therapeutic system



3 The human machine interface of the REHAROB operating panel



randomly divided into two groups of 15, the robotics and the control group. Patients in both groups received 30 minutes of Bobath-therapy[2] on each of 20 consecutive workdays. Members of the robotic group received an additional 30 minutes of robot-mediated therapy on each of the same 20 days. These patients received a combined total of 150 hours of robot-mediated therapy, during which no adverse events occurred. Several parameters were measured to assess the effectiveness of the treatments. There was a significant improvement in the mean modified Ashworth score[3] of shoulder aductors in both groups, but a more marked improvement was seen in the robotics group. For elbow flexors, the same score did not change in the control group and, while a small improvement was observed in the robotics group, this change was not statistically significant. However, overall results showed that, for the majority of measured parameters, improvements observed in the robotics group were better (higher mean values) than those seen in the control group.

The future of REHAROB

The system is about to be upgraded with a new controller from ABB: A single IRC5 Multimove control unit will replace the two S4C Plus controllers. The next task will be to obtain medical certification from the Hungarian authority, ORKI, which will allow the system's use in regular robotic therapy. Depending on the outcome of a second controlled trial, which is planned for 2007, Dr Gusztav Arz, the REHAROB project coordinator, expects the system to be optimized and prepared for mass production. A detailed market survey will be carried out prior to the system's market launch. Dr Arz adds that "Embryonic business plans are drafted, but it is very likely that external contributions will be required for the production and marketing of REHAROB."

The robots also help to monitor patients' progress by keeping detailed records of exercise regimes and patient responses.

The REHAROB Therapeutic System offers the potential for biomechanical and physiotherapist-administered upper-limb treatments based on intelligent physiotherapy. The role of the robot is not to replace the physiotherapist, but rather to widen the treatment options. The robots also help to monitor patients' progress by keeping detailed records of exercise regimes and patient responses. This helps to refine treatment programs and could be used to develop rehabilitation strategies for other neuro-motor impairments. The development of new treatments will be the focus of future work, once medical certification has been obtained and the REHAROB Therapeutic System is in regular clinical use.

4 A patient undergoing robot-mediated physiotherapy at the National Institute for Medical Rehabilitation, Budapest, Hungary

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www.rescuer-ist.net

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Footnotes

[1] Indicators include range-of-movement measures, FIM (functional independence measure), self-care score and the Barthel index of the activities of daily living.

[2] The Bobath therapy is a widely-used interdisciplinary approach to the treatment of patients with impaired motor function caused by damage to the brain or spinal cord [2]

[3] A six-point rating scale used to measure muscle tone.

References

[1] "http://www.wma.net/e/policy/b3.htm"

[2] Bobath B. Adult Hemiplegia: Evaluation and Treatment. 3rd edition. Butterworth-Heinemann. Oxford. 1990

Breathtaking – the Sherlock Holmes of gastroenterology

A breathalyzer that catches bacteria in the act

Walter Fabinski, Thomas Weyrauch

In December 2005, the Nobel Prize for Physiology and Medicine was awarded to Barry Marshall and Robin Warren for the discovery of the bacterium *Helicobacter pylori* and its significance in gastritis and gastric ulcers. Their discovery led to a sea change in the treatment of gastric disease, but diagnosis remained reliant on uncomfortable gastroscopy procedures or the use of expensive mass spectrophotometers. A simple, cost-effective solution to this problem was developed by Hartmann and Braun, which is now part of ABB. The new device, based on infrared spectral analysis, is now in use throughout the world.

Marshall and Warren discovered that *H. pylori* lodges in the walls of the stomach with its flagella and can trigger widespread diseases such as gastritis, ulcers and, in the event of chronic infection, cancer. *H. pylori* infection affects roughly half the world's population and is therefore one of the most common bacterial infections. In Germany alone, more than 30 million people are infected with the bacterium, with 5–10 percent going on to develop a gastric or duodenal ulcer. Until Marshall and Warren's discovery, it was believed that no living thing, including bacteria, could survive in the highly acidic environment of the stomach. Patients suffering from ulcers were encouraged to change their lifestyles by avoiding smoking, stress and alcohol, and were treated with histamine blockers. However, this treatment produced only short-term relief and in no way solved the problem. The impact of Marshall and Warren's discovery should not be underestimated. It overturned the fixed worldview in medicine and brought about a paradigm shift. It triggered the search for new methods of diagnosis and treatment through extensive research in a number of scientific fields.

Clarification and concept for diagnosis and treatment

Early research focused on the physiology of the bacterium and its pathogenicity. *H. pylori* 1 is a rod-shaped bacterium that lodges in the protective mucus layer of the stomach wall using its flagella. From this position, it is able to feed and reproduce, while producing toxic substances that further damage the stomach's protective lining. It is this damage that allows corrosive gastric acid to attack the stomach wall, leading to inflammation and more serious complains. It is estimated that practically all duodenal and roughly 80 percent of all gastric ulcers are triggered by *H. pylori*. Chronic inflammation can ultimately lead to cancer. Research revealed that the bacterium is able to convert the urea, which it absorbs as it feeds, into CO_2 and ammonia. The ammonia forms a protective, alkaline coat around the bacterial cell that neutralizes the acidic gastric juices and allows the bacterium to survive. The CO_2 produced by the bacterium is released into the stomach and then escapes via the breathing air. It is this mechanism that betrays the bacterium.

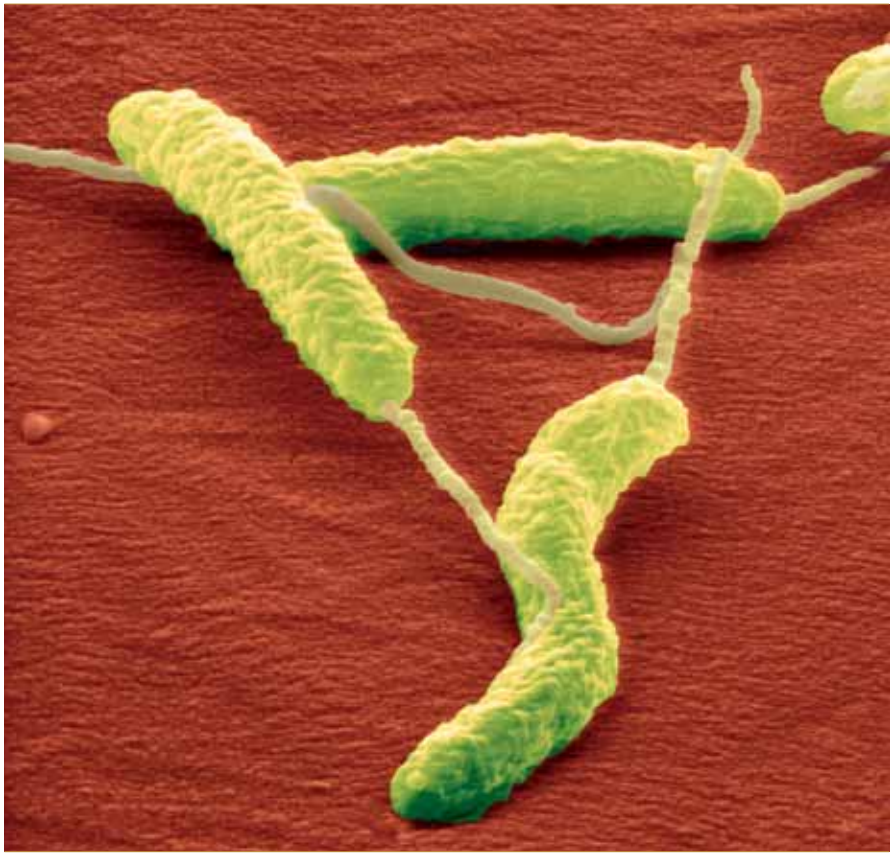
Research revealed that the bacterium is able to convert the urea, which it absorbs as it feeds, into CO_2 and ammonia. The ammonia forms a protective, alkaline coat around the bacterial cell that neutralizes the acidic gastric juices and allows the bacterium to survive.

Carbon exists in the form of several naturally occurring isotopes, eg, ^{12}C, ^{13}C, and ^{14}C. Most of the World's carbon is ^{12}C (almost 99 percent), with ^{13}C comprising approximately 1 percent and the rest existing only in very small amounts. In contrast to ^{14}C, which is radioactive, ^{12}C and ^{13}C are stable and completely harmless to man. This means that it is possible to administer an oral dose of ^{13}C-labeled urea to patients suffering from gastritis. After taking the urea, the ratio of $^{13}CO_2$ to $^{12}CO_2$ in the breath of infected patients is altered by the bacterial conversion of ^{13}C-urea into $^{13}CO_2$. Mass spectrometers can be used to determine the ratio of the two isotopes in patients' breath, but these are expensive instruments that are costly to operate and maintain. To solve this problem, a simple, robust, cost-effective, and yet highly sensitive, measuring instrument was required for use in the clinical environment. This was the situation in the early 1990ies when the analytical technology specialist, Hartmann & Braun (which became part of ABB in 1998) was approached.

Development of a diagnosis and treatment concept

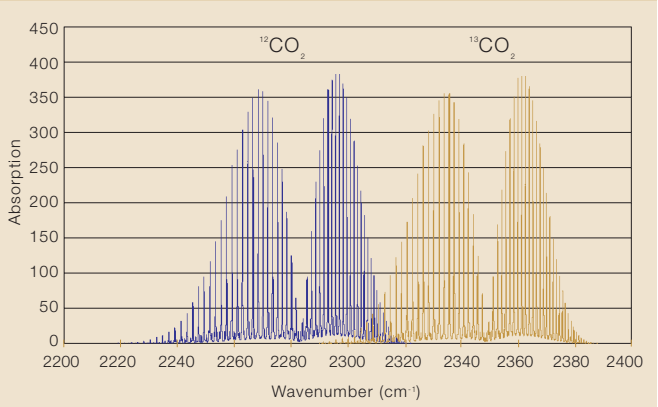
The non-dispersive, infrared, Uras analyzer, which had already proved itself in process-measurement technology, was considered as a potential starting point. The task was to use the Uras measurement technology to

1 View of the *Helicobacter pylori*, taken with a scanning electron microscope



determine the ratio of $^{13}CO_2$ to $^{12}CO_2$ in patients' breath at high resolution, in a drug-compatible system. $^{13}CO_2$ and $^{12}CO_2$ have many common properties, but differ significantly in their atomic masses. This difference is readily detectable by infrared spectral analysis, as shown in 2.

2 Vibration rotational bands of $^{12}CO_2$ and $^{13}CO_2$ in the central infrared range



Because the Uras measurement principle does not require any means of dispersion such as a grating or filters (it uses the gases themselves for selection), results can be compared directly with the unchanging natural spectrum Factbox.

Initial laboratory tests were encouraging and, together with the University of Düsseldorf (Institute for Laser Medicine), Hartmann & Braun developed an adapted Uras instrument for use in the clinical environment. Several specialized manufacturers of medical technology later became involved and took over the global distribution of OEM (original equipment manufacturer) modules from ABB Analytical. The result of the work was a technical appliance capable of comparing breath tests in two steps. The patient simply breathes into the first respiratory bag (the "zero" breath test) and then takes the ^{13}C-labeled urea. Twenty minutes later, the patient provides a second breath sample by breathing into a second bag. The carbon ratios in the two samples are measured and compared. A significant difference in the ratios between the two samples indicates the presence of *Helicobacter*. Recommended therapy for infected patients is usually a 7-day course of so-called "triple therapy," comprising two different antibiotics and an acid blocker.

Practical design and use

The final technical appliance for use in clinical environments was developed by sales partners. The core, however, is the ABB Uras analyzer. This device has been integrated into a small OEM module that has itself been incorporated into a unit suitable for use in clinics. The required sensitivity was achieved by optimizing both the measurement and system technologies. As a result, relatively little substrate is required (a dose of only 75 mg ^{13}C is sufficient), which reduces the cost of the tests (as do reusable respiratory bags).

If results indicate an infection, treatment is carried out in combination with regular breath tests to measure the effectiveness of the therapy. 3 compares the results of a patient infected with *H. pylori* with those of an uninfected patient.

Because the Uras measurement principle does not require any means of dispersion such as a grating or filters, results can be compared directly with the unchanging natural spectrum.

After developing the instrument technology, extensive clinical trials were carried out and appropriate licensing was obtained. Meanwhile, it was recognized that the global distribution of

Factbox Uras measurement principle

The measurement principle of the Uras gas analyzer is based on the capability of gas molecules to specifically absorb infrared (IR) radiation. This means that energy is removed from a light beam within a certain frequency range, depending on the gas constituents and their concentration, as well as on the length of the absorption cell. In most infrared gas analyzers, a photo detector is used to detect this effect. This is not the case with the Uras analyzer.

The Uras analyzer contains gas-filled, so called, "optopneumatic" detectors, in which the sample of interest is held. The radiant energy absorbed by the sample gas causes a change in temperature and a consequent change in pressure. This pressure change has a magnitude of some nanobars, which is sufficient to evoke an electrical signal via a membrane capacitor. The comparison between the detector gas and the sample gas is highly sensitive to components such as CO, CO_2, SO_2, NO, CH_4, and N_2O – to name but a few.

In the Uras26, serial detectors can reliably determine the concentrations of up to four process gas components. The length of the sample cells installed upstream of the detectors determines the provable concentrations, which range from a few parts per billion by volume (ppbv) (<10–5 percent volume) to 100 percent volume.

The Uras26 also has integrated calibration cells, which automatically move into the optical beam path [1]. These supply a reference signal and ensure long-term stability. Maintenance costs are markedly reduced because built-in calibration dispenses with the need for expensive test gas-cylinders.

A stable measurement is provided by periodic modulation of the IR radiation source with an interrupter disk ("chopper wheel") and subsequent frequency- and phase-selective amplification. This type of signal processing is generally referred to as a "lock-in" process [2].

H. pylori is quite variable. In central and northern European countries, the rate of infection is approximately 30 percent, while in Africa and Asia, the rate can be more than 90 percent. The trials also revealed, however, that infection does not necessarily lead to disease. It is estimated that only around 5 percent of those infected with *H. pylori* experience seriously harmful effects.

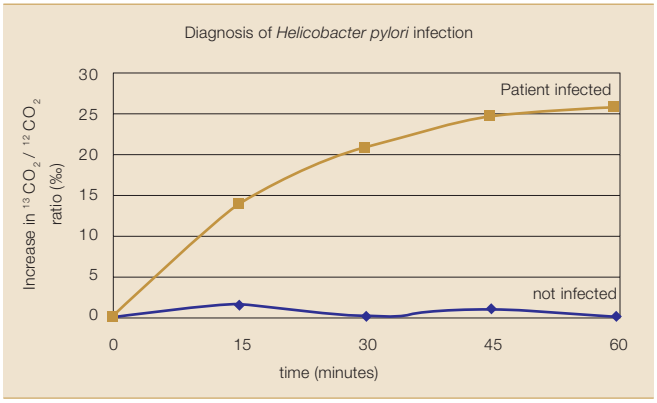
The instrument, sold under the names of Fancy or Iris, has been marketed in industrial countries since the mid-1990ies and is now in use all over the world. In Germany and many other European countries, the costs of the breath tests are borne by health insurance.

ABB is involved in further clinical trials for additional applications. A project is currently examining use of the technology in intensive care units.

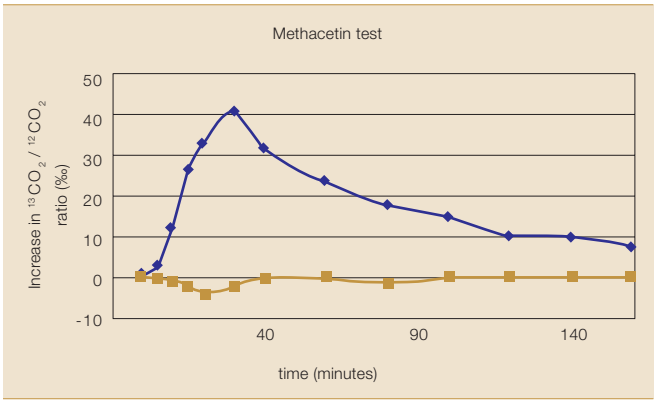
Additional uses

Now that such a convenient method for breath testing has been developed for *H. pylori*, it would seem sensible to adapt it for use in other diagnostic tests. Such efforts are underway for a number of applications, including a liver function test, the assessment of amino acid metabolism, and the tracing of fat malabsorption. These tests rely on ^{13}C-marked substrates that interact only with the organs under scrutiny and on appropriate modifications to the software of the device. These novel applications must also undergo clinical trials and obtain appropriate licensing in accordance with statutory regulations. While gastroscopy clinics are the main market for this application, there are now more than 20 diagnostic tests for other disorders that rely on the accurate and highly-sensitive breath analysis provided by the Uras system. 4 shows an example of liver test. ^{13}C-marked methacetin is administered for this procedure. The upper curve shows the course of $^{13}CO_2/^{12}CO_2$ in a healthy participant. The lower curve shows the course in severe cirrhosis of the liver.

3 Example of a test involving an uninfected patient and one infected with *Helicobacter pylori*. Samples were taken 1 hour after the patients were administered the ^{13}C-labeled urea



4 Example of a liver test



5 The HeliFANplus ^{13}C-infrared analyzer

The instrument is also used worldwide in veterinary medicine and animal nutrition, as well as in biochemical research areas.

The future

The use of the isotope-specific technology described here has great potential in medical diagnosis. In part, this is due to the performance of Uras technology. As a non-dispersive method, it is compact, while providing the required resolution and limit of detection, as well as the necessary robustness for use in a clinical environment. Because it is based on the ratio of two stable isotopes, there is now no need to use radioactive isotopes. ABB is involved in further clinical trials for additional applications. A project is currently examining use of the technology in intensive care units. The German partners are Münster College of Higher Education, the vendors, FAN GmbH with HeliFANplus 5 and WAT GmbH with IRIS, the university clinics in Ulm and Giessen, and the Charité in Berlin. Work is being conducted under the title "Multi-organ function test".

So, if you have a stomach complaint and want to avoid a gastroscopy, ask your doctor for a breath test!

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A wave of renewable energy

There's no such thing as bad weather

Albert Leirbukt, Peter Tubaas

Troubled water is full of energy and the North Sea has it in abundance. If wave energy could be captured cost-effectively, it could help meet the ever increasing demands for energy. ABB is playing a major role in a remarkable initiative by Fred Olsen Ltd, to develop a profitable wave energy conversion device.

Ingenuity and energy

When it comes to energy production, the rough waters of the North Sea have more to offer than their vast oil and gas fields. At least, that is the view of the famous Norwegian ship owner and entrepreneur, Fred Olsen. ABB is helping him to realize his dream of producing a financially sustainable system for harvesting wave power.

Increased energy demands have spurred many technology development projects to harness renewable energy from a variety of sources. Wind power technology has already come a long way. Wave power could be next in line.

While watching one of his platforms being erected close to the Scottish coast, Fred Olsen began thinking about how the energy in the waves could be turned into usable power. But it was not until a few years later that he found out exactly how this kinetic energy could be converted into electricity. On a vacation in Spain he observed the behavior of oil barrels floating in the sea. And that was the starting point of an initiative to develop his wave energy converter (WEC) concept, which has been named FO3.

Converting wave energy into electrical power

Many attempts to design wave energy converter (WEC) devices have been made in the past, and many have failed due to the hostile environment the devices have to endure. The challenges involved in WEC cover a range of engineering disciplines, including civil-, electrical-, and control engineering. Projects that fail to consider all of these disciplines will not succeed. The most critical aspect of a WEC development project is the structural design. The device must be extremely robust, while material and manufacturing costs must be kept to a bare minimum. These design objectives are hard to combine, which explains why wave power has not yet been commercialized on a wide scale.

ABB is globally committed to developing environmentally friendly energy solutions based on renewable resources.

ABB receives many inquiries from people wanting to develop WEC devices, but Fred Olsen's initiative was in a class of its own. Thanks to their many years of offshore experience, Olsen's engineers have learned a lot about the perilous challenges of the North Sea.

ABB's contribution

ABB is globally committed to developing environmentally friendly energy solutions based on renewable resources. ABB has been a partner in the wave power project since the initial testing in 2004 and is heavily involved in what could become the next industrial venture along the Norwegian coast.

ABB is a leading supplier to the oil and gas industry, in both on- and offshore systems for automation and safety, for power equipment, such as switchgear and transformers, and for instrumentation. More specifically, for Olsen's FO3 project, ABB has contributed its know-how in the area of power conversion and automation, and has supplied the power and automation components.

The underlying principle of conversion is simple

The WEC device looks like a traditional rig, but one striking difference is the floating, egg-shaped cylinders hanging underneath it 1. Energy is absorbed from the waves as they move the cylinders up and down. This linear, vertical motion is then converted to rotational motion by means of a hydraulic system – a hydraulic motor drives a generator to produce electricity. Another important difference is that the rig structure is built using lightweight composite material instead of steel.

Initially, a 1:20 model of the rig structure was built at the Marintek/Sintef laboratories in Trondheim, Norway. Promising results from these tests led to the building of Buldra – the 1:3-scale research model of Fred Olsen's wave power dream 2. It measures 12 by 12 meters and is 8 meters high. The hydraulic towers are 7 me-

1 WEC platform concept

2 Buldra as a 1:3 scale research platform

ters high. The full-scale version will be 36 by 36 meters.

According to Fred Olsen's power production estimates, the full-scale model will produce 2.52 MW from 6-meter high waves with a period of 9 seconds. This is power enough to supply 600 households, and is approximately the equivalent to the productivity of one wind turbine. The goal is to produce power at a cost of 2.8 EUR/kWh. Each full-scale platform will cost an estimated 3–4 million euros to build.

The current state of the project

The Norwegian authorities have granted Fred Olsen permission to build a wave power plant off the island of Karmøy on the west coast of Norway. The project is currently in its engineering phase and is scheduled to be completed in 2007.

Assuming that Fred Olsen's initiative demonstrates the financial viability of wave power, ABB will be in a favorable position to deliver automation and electrical equipment for the large-scale production of WEC platforms. The required technology is similar to that supplied by ABB to the wind turbine industry. Hence the company's experience and product portfolio match the needs of a potential WEC industry.

3 Fred Olsen, the entrepreneur (far right)

The required technology is similar to that supplied by ABB to the wind turbine industry.

Fred Olsen 3 has proved that his wave power project is realistic, but he still has some way to go in proving its competitiveness. The keyword is optimization. The considerable margins of the oil and gas industry do not apply to wave power. The construction, operation and maintenance costs must be minimized and the power output maximized to ensure profitable long-term operation.

The multidisciplinary Sustainable, Economically Efficient, Wave Energy Converter (SEEWEC) project is currently assessing every aspect of the FO3 concept to see whether improvements can be made. Testing is being pursued on several different levels, eg, new cylinder shapes, new platform design, and the use of new materials. Testing is also under way to establish whether a linear or rotating generator would be more efficient, how to maximize the power production given a certain wave climate, how to connect several WEC installations together, how to bring the power ashore and so on.

In the SEEWEC project, ABB have a particular interest in power generation efficiency and in the design and manufacturing of second-generation systems and components. ABB's main contribution to SEEWEC is at the corporate research center in Västerås, Sweden. ABB is also involved in field testing and data collection activities.

Future perspective

In Norway, there is a saying – there's no such thing as bad weather – and when it comes to wave power this is true. It is too early to say whether WEC will become a new industry, but if it does, ABB is well position to capture a significant share of the new market and it will be yet another showcase for ABB's state of the art power and automation technologies.

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Guri Dam

Modernization of the Guri hydroelectric plant's control, protection and instrumentation system

Eduardo Colmenares, Daniel Rubinstein, Miguel Florez

In 2005, ABB was awarded a contract to design, supply and install the unit control, protection and instrumentation systems for the Guri Hydroelectric Plant, Venezuela's largest supplier of hydroelectric power. The plant is located in the Nekuima Canyon, 100 km upstream from the confluence of the Caroní and Orinoco rivers. The modernization project, which will extend the plant's life by 30 years, is being carried out by a three-way consortium comprising ABB Venezuela, ABB Canada and ABB Switzerland. First delivery is scheduled for January 2007.

The construction of the Guri Dam was initiated in 1963. The first powerhouse, containing ten generation units, began commercial operation in 1978, with a total installed capacity of 2,065 MW. In 1985, a second powerhouse was built to house an additional ten generation units, each with a capacity of 730 MW. This brought the plant's total capacity to 10,000 MW, making the Guri the second largest hydroelectric plant in the world in terms of power production capability. The plant has three high-voltage switchyards operating at 800 kV, 400 kV, and 230 kV, each arranged in a breaker-and-half configuration. It provides the Venezuelan power market with 12,900 GWh of indispensable firm energy to meet the growing demand of the sector.

The Guri Dam is the second largest hydroelectric plant in the world in terms of power production capability.

The modernization project being carried out at the plant by its owners, C.V.G. Electrificacion del Caroni C.A. (EDELCA), involves activities and works that will provide the echnological and functional upgrading to see this national asset through the next 30 years. Among the improvements is a complete mechanical overhaul of the generation units, which is being carried out by different turbine suppliers and mechanical contractors. The modernization of the control system, protection and instrumentation is being carried out by ABB under a separate contract.

As well as extending the plant's life, the project will improve the plant's availability to levels over 90 percent and should also increase the efficiency of the generating units. The main objective of the modernization project, however, is to maintain the continuous production of clean and reliable electricity.

Control system generalities

The Distributed Control System (DCS,) designed by ABB for the plant, will integrate the first three levels of the existing hierarchical control system. The first level contains the field devices (smart transmitters and remote I/O stations) that communicate with the next control level via a Profibus network. The second level has the Unit Control System (UCS), which will be based on ABB's Industrial^{IT} Controller, the AC800M. This level supports all the automatic control sequences for running the generating units. The redundancy incorporated into the design of the system ensures its reliability. Each UCS will have two redundant human machine interfaces (HMIs) based on the ABB Power Generation Portal (PGP). The controllers, HMIs and accessories will be integrated into existing cabinets at the plant.

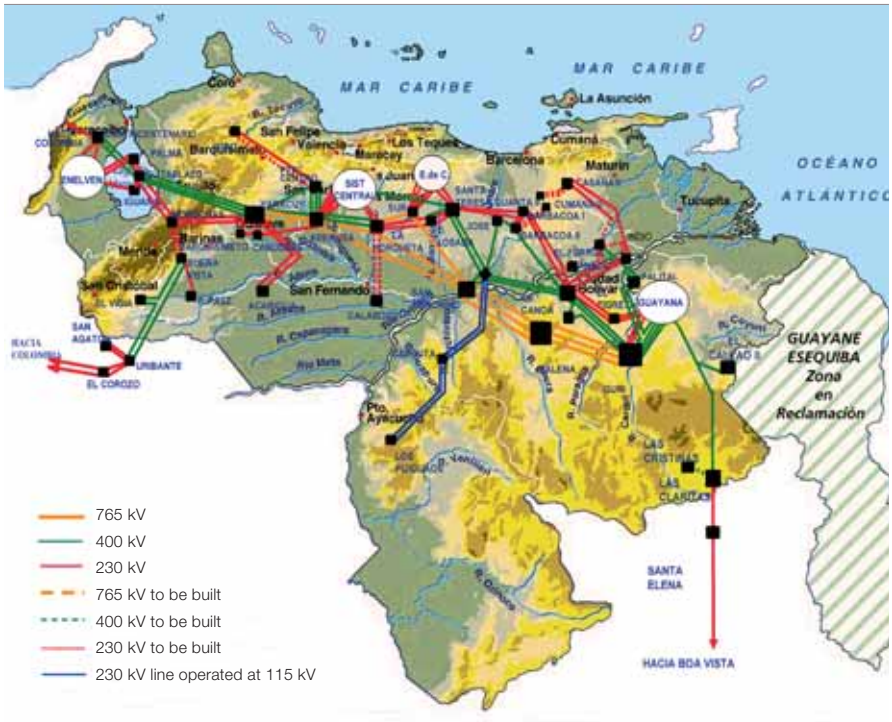
The next level of the control system comprises operator consoles for each unit, which will be located in the existing control rooms of each powerhouse. This level will interface with an existing centralized control system that was installed by SNC Lavalin in the late 1990ies. It will support the entire plant control level and all advanced control applications, including automatic generation, schedule and control, automatic voltage control, river flow control and others.

Distributed Control System (DCS) overview

The distributed control system comprises the ABB Power Generation Portal consoles at the operator level, the ABB Industrial^{IT} AC800M controllers at the process level and the ABB S800 I/O modules, as well as smart transmitters, at the field level. At the operator level, the operators are able to control and monitor the hydroelectric plant using the functions of the control desk, main control panel (MCS) and UCS. The status of the process is presented on color-monitors in the form of the process-, object- and curve displays, alarms and message lists.

At the process level, the control system consists of redundant controllers for each unit, and common system in the two powerhouses. The controllers have the capacity to provide analog and digital processing, loop and logic control, as well as monitoring-, acquisition-, arithmetic-, and communication functions. Each controller has local Ethernet ports that allow peer-

Electrical network fed by the Guri Dam



to-peer communication over a redundant, Ethernet-based Local Area Network (LAN). The controllers can also function independently of the LAN. The operator and controllers communicate with each other using OPC Server/Client. Communication modules are used to enable Profibus connections to remotely located I/O stations and smart transmitters, as well as RS232 serial connections to third party devices. Communication ports built into the controllers are used to communicate with the local I/O clusters.

At the field level, the field input data and process outputs are managed by the ABB S800 I/O modules, which are either grouped in remote I/O stations and located throughout the plant, or in clusters of local I/Os situated within the same enclosure as the controller. In addition to the S800 I/O, smart transmitters are located throughout the plant. The field inputs that are defined as Sequence of Events (SOE) points are managed by special SOE modules within the S800 family. SOE points are recorded at 1 ms resolution and all the SOE points are located within the UCS cabinets.

Plant control philosophy

The station is operated either from the existing Centralized Control System (Master SCADA Station) in Powerhouse #2, the control rooms in Powerhouses #1 and #2, or at the UCSs. Local/remote control transfer between the UCS, the control room and the Master SCADA Station is provided.

As well as extending the plant's life, the project will improve the plant's availability to levels over 90 percent. The main objective of the modernization project, however, is to maintain the continuous production of clean and reliable electricity.

Within the DCS, the plant is controlled at the unit level. An operator at the Unit 1 UCS, for example, has access to Unit 1 graphics, I/O and control functions. All units operate in the same fashion. The DCS does not perform plant-wide control. This is performed by the existing Master SCADA Station, which exists at a control level above the DCS. The existing Master SCADA Station communicates via an interface with the DCS.

The I/O modules and smart transmitters are distributed throughout the plant and the I/O devices are located close to the device(s) that are being controlled and monitored.

Control path

Operator control can take place in a number of different areas throughout the plant. It is therefore important to manage the location of control and to prevent a device from being operated from two different points at the same time.

Operator control can be performed at the following locations within Powerhouse #1:

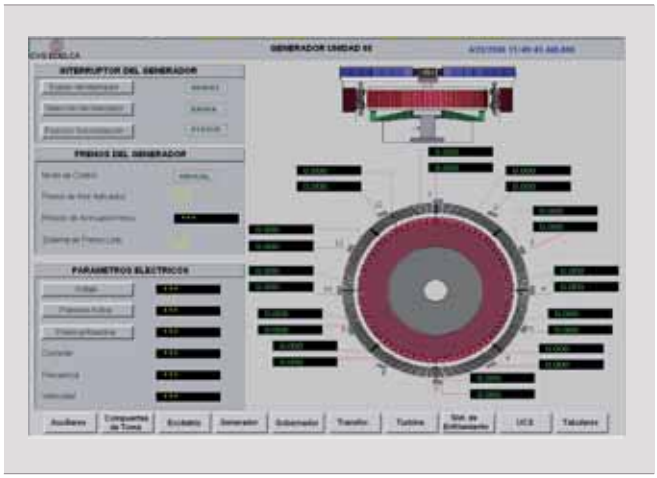
- The control room – bench board and main control panel (MCS)
- Unit 1 – 10 UCSs – on the plant floor. There are 10 UCSs at Powerhouse #1. Individual units can be controlled at each UCS. Control and monitoring functions include unit startup/shutdown and unit monitoring and annunciation.
- 4.16KV auxiliary services – on the plant floor
- PH1 sump pump and drain system – locally on the plant floor
- 440V auxiliary services (local control only)
- Plant control services (local control only)
- Spillway – channels 1,2,3
- Dam sump pump and drain system

Operator control can be performed at of the following locations within Powerhouse #2:

- The control room – bench board and the MIMIC panel (MIMIC)
- Unit 11 – 20 UCSs on the plant floor. There are 10 UCSs at Powerhouse #2. Individual units can be controlled at each UCS. Control and monitoring functions include unit startup/shutdown and unit monitoring and annunciation

Overview display of turbine

Overview display of generator



- PH2 sump pump and drain system on the plant floor
- 4.16KV auxiliary services

The AC800M controller.

General DCS structure

Human Machine Interface

The ABB Process Generation Portal system will be used for the operator stations. The console system is based on industry standards and the XP Windows Operating System.
It has an open architecture that allows for a wide range of communication protocols with the ability to interface to third-party software and databases.

The operator station provides the operator with a graphical interface to the plant. In addition, the operator can make use of the alarm management, sequence of events reports, data-logging functions and user authorization mechanisms.

The AC800M controller

The AC800M uses ABB's newest controller technology. The controllers are built as rail-mounted modules with two built-in Ethernet ports. They comprise central processing units, communication modules, power supply modules and various accessories. The controllers will be setup in a redundant configuration.

Field I/O - S800 I/O modules and smart transmitters

The S800 I/O modules and Fieldbus Communication Interface (FCI) modules are combined to form I/O station or I/O clusters. An I/O that is connected to the controller via Profibus-DP[1)] is considered an I/O station. An I/O that is connected to the controller via ModuleBus is considered an I/O cluster.

Smart Tramsitters and instruments will be installed across the plant. Since these devices will communicate via Profibus-PA[2)], Profibus-DP/PA converters will be needed to allow communication with the controllers.

Protocols and media

There are a number of communication protocols and media used by the controller. These include the following:

- Control network (LAN) communication
- Modulebus communication
- Profibus DP communication
- Profibus PA communication

Control Network Communication

A controller communicates with other controllers and HMIs across the Ethernet LAN and WAN (wide area network). The control network operates at 100 Mb/s.

The control network is structured as a ring with parallel independent lines. Thus, if there is a break in line A, then communication will continue along line B and, if both lines A and B are broken, then the ring structure will change to a bus structure.

I/O Network Communication

The I/O network connects all of the plant's I/O devices to the controller. There are three types of communication protocols used for the I/O network. These are:

ModuleBus: used to communicate directly with the local I/O clusters via plastic fiber optic cable. ModuleBus supports the SOE functionality.

Profibus DP: used to communicate directly with the remote I/O stations and indirectly with the smart transmitters.

Profibus PA: which is used to power the intelligent electronic devices (IEDs) as well as transfer information from the IED.

Protection systems

ABB Switzerland's Power Systems group is providing a redundant generator and transformer protection systems for the modernized plant. Fourteen numerical REG216 systems will protect three 230-MW units, plus four 360-MW units in Power House #1, while 14 numerical type REC316*4 IEDs will protect the corresponding seven short transmission lines at 400 kV from the interconnection switchgear and the step-up transform-

ers at Power House #1. The protection system of the medium voltage auxiliary services of the complete power plant will also be replaced with the most up-to-date relays.

ABB Switzerland is also contracted to modernize the 20 automatic synchronizers and 20 synchro-check devices at the 230/400/800 kV switchgear of the power plant, as well as install a completely new disturbance recording system for the 20 generator units and SMS530 station monitoring system for all of the protections supplied.

Instrumentation system and miscellaneous

ABB Venezuela is acting as the consortium leader and is responsible for the internal coordination and the contract management. Its contribution to the project is the design of the instrumentation system, which will comprise smart transmitters located throughout the plant. Communications between the field devices and the control system will be supported by a Profibus network.

ABB Venezuela is responsible for the preparative engineering works required for the installation of the various new systems at the plant and will be responsible for their installation and integration at site.

Other systems within the remit of ABB Venezuela are:

- The vibration and air gap monitoring systems for the generating units
- A closed circuit television system for process monitoring and security surveillance
- Communication systems: Tele-protection equipment and fiber optic networks

The Guri power plant modernization scheme demonstrates how the successful coordination of people and products can meet the needs of a large-scale project.

A team effort

ABB is a world leader in state-of-the-art control system technology. This technology is being deployed in modern hydro power plants to address users' needs for highly automated, secure and reliable control and to provide access to plant-wide information.

The Guri power plant modernization scheme demonstrates how the successful coordination of people and products can meet the needs of a large-scale project. ABB has experienced, dedicated staff, located around the world. The expertise acquired during ABB projects in a variety of applications ensure that clients will be provided with the personnel best suited to their requirements. ABB offers a comprehensive line of fully compatible products that meet the needs of process control projects from the smallest to the largest applications, like the Guri project. The ABB project team has been able to meet the requirements of this unique project and adapt its products and services to respond to specific customer requirements.

The challenges of the Guri modernization project demand a solid team effort. ABB Venezuela, ABB Canada and ABB Switzerland understand the challenges and are working together, combining expertise and sharing experience. A group of engineers and technicians from EDELCA are also involved in the design of the control system as part of an "on-the-job" training program in ABB's facilities in Canada. This training will facilitate the integration of the new systems into the plant and will guarantee the transfer of technology from ABB to EDELCA.

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Footnotes

1) Profibus-DP: Process Field Bus – Decentral Peripherals

2) Profibus-PA: Process Field Bus – Process Automation

The “shore” way to clean energy

A combined heat and power generating plant in Władysławowo, Poland

Anita Romanowska

Many production processes have traditionally been geared towards a single end-product. Any by-products were primarily considered waste, and if a use could be found for them at all, this was usually coincidental and not by design. Increasing environmental awareness and rising energy costs are sparking a re-think, but rarely can a by-product that was previously discarded be put to not one but four good uses.

A drilling platform off the Polish coast used to flare off the gas that was produced with the oil. Meanwhile, the coastal resort of Władysławowo was heated by a multitude of coal and oil-fired plants that had detrimental effects on the local air quality. What better use for the waste gas than to replace these units by a combined power and district-heating plant? ABB was entrusted with supervising the construction and also with delivering the control system and much of the electrical equipment. Besides providing electricity and heat and improving air quality, the new plant on the beach supplies LPG (liquefied propane gas) and gasoline to other users. Not bad for a product that would otherwise be going to waste!

Ingenuity and energy

The idea of constructing a combined heat and power generating plant right on the beach in a tourist town on the shore of the Baltic Sea emerged in 1997. A thorough technical and financial analysis was performed demonstrating the economical and ecological viability of the investment. The results of this study were so convincing that the proposal easily attracted the financial support required.

The project’s cost exceeded $ 56 million. It was funded by shareholders’ loans and loans from participating institutions that finance ecological projects such as the Ecofund Foundation, the National Fund for Environmental Protection and Water Managemen,t and the Bank for Environmental Protection.

The construction of Władysławowo’s combined heat and power generating plant finally resulted in:

- elimination of about 120 local coal- or oil-fired boilers and boiler houses
- reduction of discharged pollutants (dust) by 134,000 tons per year
- decrease of solid waste as a result of replacing solid fuel (coal) with gas
- reduction of sulfur dioxides, carbon dioxides and nitrogen oxides

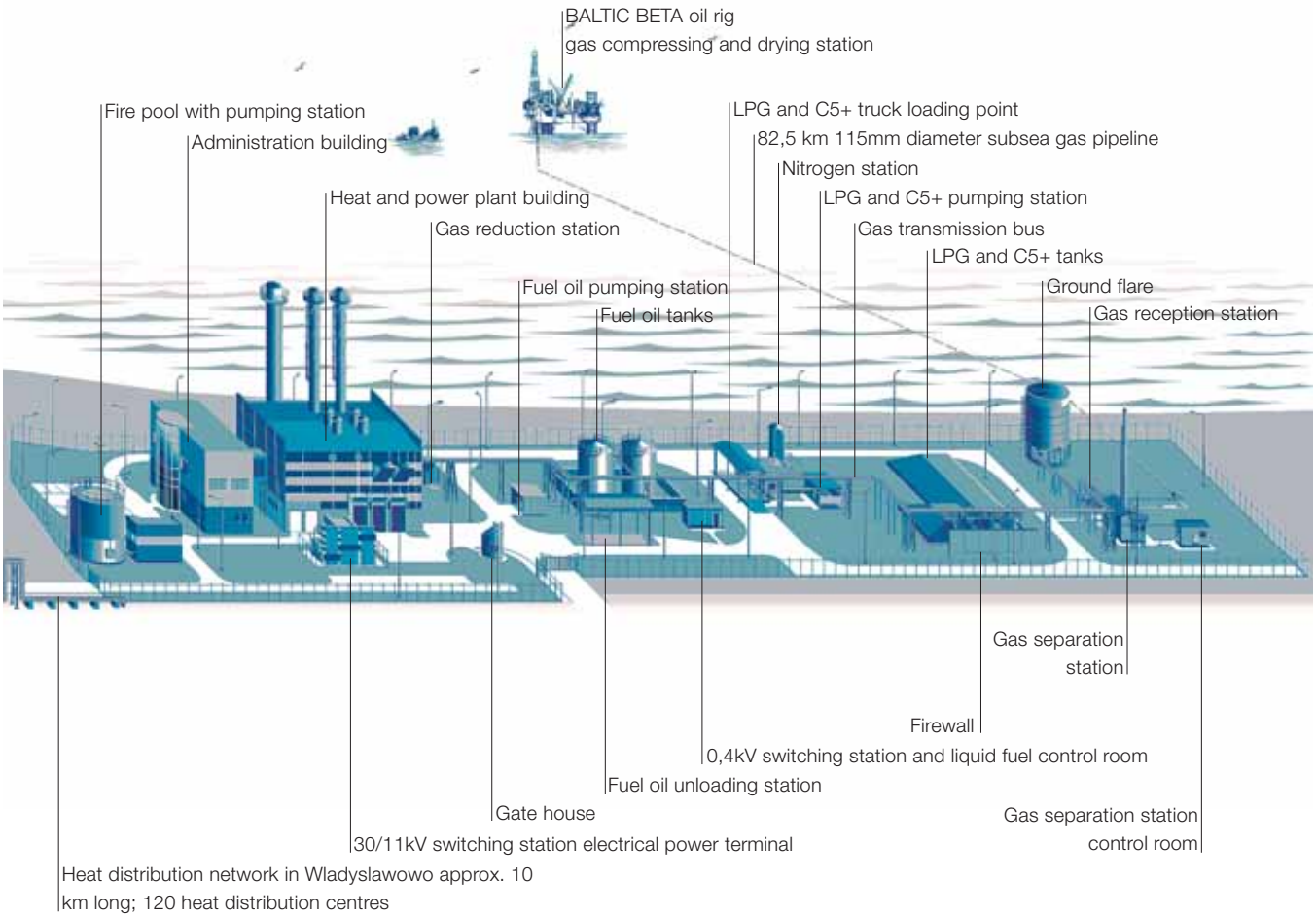
How it all came about

The main idea of the project was to utilize 100,000 m³ of gas that was unproductively flared every day at the drilling rig in the Baltic Sea – a waste with negative environmental consequences. Only a small part of this (10 percent) was used for the power requirements of the rig. The heat and power generating plant in Władysławowo 1 turned out to be a unique enterprise in the national or even European region. It utilizes the natural gas associated with the extraction of crude oil. At present, about 100,000 m³ of natural gas per day are supplied via a newly laid submarine pipeline.

In 2001 Energobaltic, the company that was established to carry out that investment, was looking for a contractor to manage the project. The selected company would have to supervise the construction of an installation combining three different technological processes. These processes are the transport of gas from the drilling rig to the shore, gas treatment on the shore and safe and reliable production of heat and power for local requirements.

Following negotiations with several international companies of renown, Energobaltic conferred responsibility for the project’s supervision and execution on ABB Zamech Gazpetro in February 2002. For more than a year a team of engineers and experts was

1 A single plant providing electricity, district-heating, LPG and gasoline – from gas otherwise wasted



engaged in the coordination of all project activities. These included the process of appointing suppliers and contractors through tendering, verification of technical documentation on a current basis, supervision and coordination of work at the construction site, supervision of start-up and commissioning of the sites and the settlement and financial controlling of the project.

All technological processes in the complex are connected to a central control system built on elements of ABB's Advant process control architecture.

The project was divided into two main phases. The first included construction of the heat-generating plant and district-heating system. The target was to start up the heating system no later than mid-September 2002 so that heat could be available for the Winter of 2002/03 heating season. Despite the very short period allowed for construction (only seven months) the deadline was met and heat supplies to the town officially commenced on the 18th of September 2002.

The second implementation phase included the construction of the gas supply from the offshore drilling-rig to the mainland. It also included the realization of the on-shore gas treatment and storage facility and of the gas turbines with waste-heat boiler.

The whole project was complete and went into full operation on the 30th June 2003.

Working to protect a sensitive location

The heat and power generating plant is situated in the industrial and harbor area of Władysławowo.

Władysławowo is located at the foot of the Hel Peninsula, near the Nadmorski Coastal Landscape Park. The facility has been constructed on the site of a disused coal-fired boiler and sewage treatment plant. Particular consideration was given to the aesthetic design to ensure that it blended well with the local environment. The town of about 12,000 inhabitants is a health resort. In the summer season, the number of inhabitants increases five-fold.

The waste-gas that was previously flared at the rig turned out to have an interesting chemical composition. It included only 45 percent methane but was very rich in heavy hydrocarbons – over 20 percent propane and butane, and its calorific value amounted to 54 MJ/Nm^3. Therefore the heat and power generating plant was extended by a gas refining facility, where liquid fractions propane-butane and chemical gasoline are separated from the so called "wet gas". This represents an important element of the project in terms of income. CHP Władysławowo therefore now manufactures four products: electricity, heat, LPG and gasoline (C5+). After separation of LPG and C5+, a light gas (a mixture of methane and ethane) is transferred to feed gas turbines and water boilers. Liquefied propane-butane and C5+ is stored and sold.

The waste-gas that was previously flared at the rig turned out to have an interesting chemical composition. It included only 45 percent methane but was very rich in heavy hydrocarbons.

Because of its atypical chemical composition, the waste gas associated with the production of crude oil had to undergo an initial treatment on the offshore "Baltic-Beta" drilling rig 2 in the Baltic Sea (ca. 75 km from the shoreline). Due to the presence of significant quantities of propane and butane the gas is considered to be a "wet" gas – it is transferred under very high pressure. After drying the gas and compressing it to up to 130 bar (so called "dense phase"), the gas is transferred by undersea pipeline to the gas separation station in the heat and power generating plant in Władysławowo.

The most interesting element of the project is the system of gas supply to the shore. The gas flows through a pipeline laid under the sea bed. The line measures 82.5 km in length and 115 mm in diameter and reflects state-of-the-art technology. Flexible steel pipes with polyethylene coating were unreeled from a multi-purpose vessel

2 Initial treatment of the gas on board the "Baltic-Beta" drilling-rig – previously this gas was wastefully flared off

3 The gas pipeline was reeled out in 11 km sections

3 (similarly to electrical energy cables) in ca. 11 km sections. They were joined and positioned with the help of precise marine navigation systems. The pipeline was then buried using special marine equipment.

All technological processes in the complex are connected to a central control system 4 built on elements of ABB’s Advant process control architecture. It connects to all local control systems as well as the safety system that ensures the secure operation of the whole installation. The heat and power generating plant on the shore and the off-shore drilling rig are connected by satellite, providing personnel at both sites with continuous access to all necessary information. In fact, the control system supervises all process stages, both on- and off-shore, with the exception of the oil-drilling stage itself.

ABB also provided numerous electrical devices 5 for Władysławowo. These include drives for the automation system, medium voltage switchgear and power transformers for the drilling rig and the electric motor for the compressor on the drilling rig.

Winning by not wasting

The operation of CHP Władysławowo enabled the utilization of 100,000 m^3 of gas per day – gas that was previously flared unproductively. This eliminates the use of ca. 750,000 tons of coal per year.

The investment has made it possible to shut down about 120 coal/oil-fired boilers and boiler houses with a total power of 18 MWt, and to supply ca. 76,000 MWh of electricity to the national power grid annually. Of the boiler houses closed, ca. 90 percent were coal-fired. Others were oil-fired units whose operating costs were much too high for their owners. Their replacement required the construction of a district-heating system. This was built with the latest pre-lagged technology.

The operation of CHP Władysławowo eliminates the use of ca. 750,000 tons of coal per year.

Besides a significant improvement in air quality, the intended ecological effect consists of limiting the use of coal, eliminating the inconvenience connected with rail and road transport of coal and its handling and storage, while also reducing the amount of solid waste produced by its combustion.

The implemented solution aligns with the latest trends in world power engineering solutions. It is also in accordance with the Polish power engineering law, which itself takes into account recommendations of the European Economic Commission, the Second Sulphur Protocol and the Framework Convention of United Nations (concerning climatic change).

The gas turbines have a joint generating capacity of ca. 11 MWe and heat to a total capacity of 18 MWt. Two waste-heat boilers, each with a capacity of 8.85 MWt, use hot waste combustion gases from the turbines to heat water, which in turn is used to transfer heat to the district heating system. Control systems regulate the boilers to meet the demand of Władysławowo accurately.

Three emergency back-up water boilers with a capacity of 5 MWt each are maintained as reserve in case of any stoppage of the gas separation plant or gas turbines. This helps ensure that the inhabitants of Władysławowo always have a secure source of heat.

The ABB experience

The execution of this complex investment extended the knowledge and competence of ABB Zamech Gazpetro’s engineers. It required the application of much technical know-how and creativity to combine the various sophisticated technological processes and acheive the fully automated and safe operation of the whole installation.

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4 The control system is based on ABB’s Advant architecture

5 Metering technology from ABB – a small but important component

The Arctic challenge

The enormous Snøhvit project beyond the Arctic Circle is a challenge for ABB engineers

Peter Tubaas

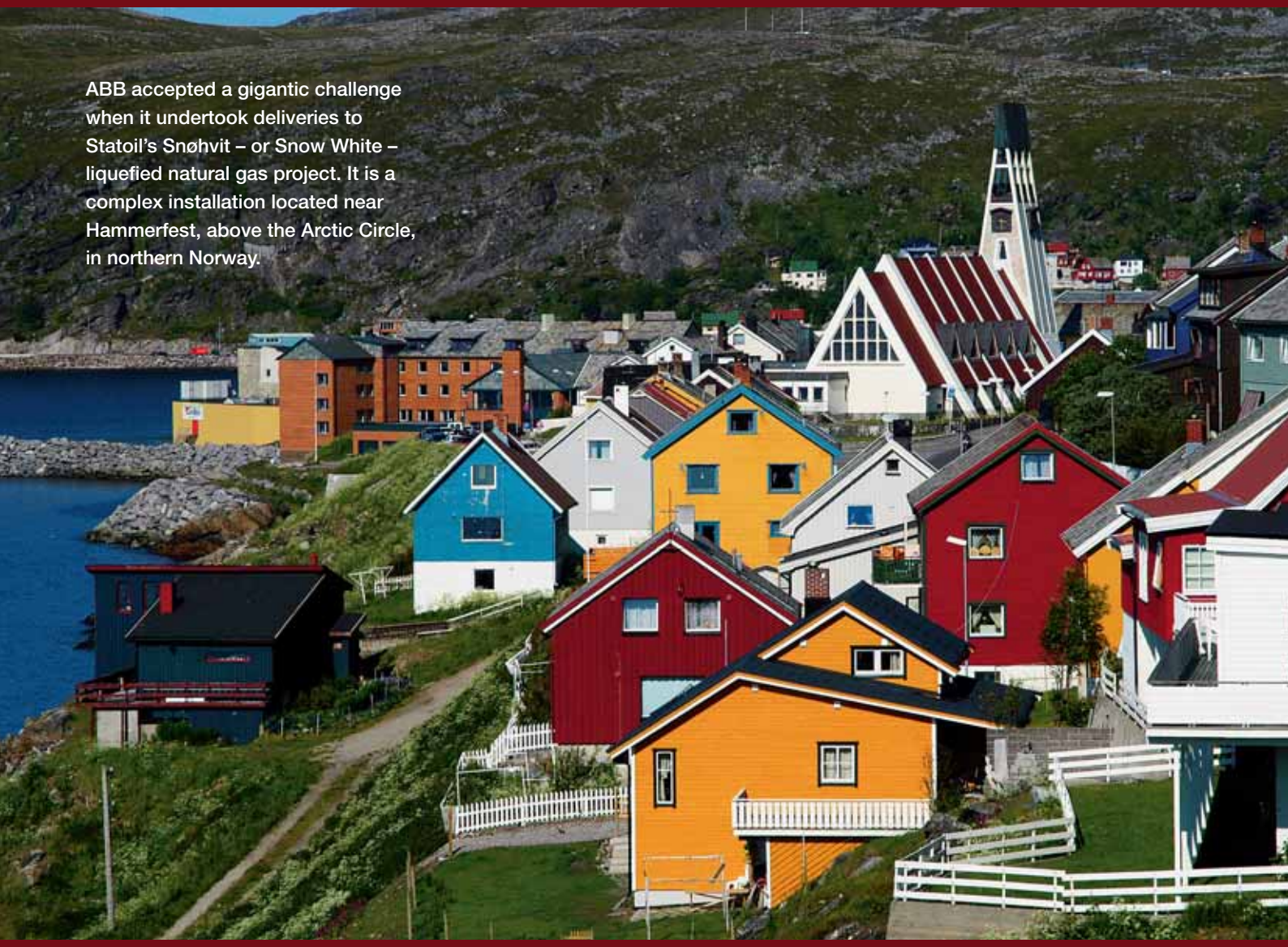


ABB accepted a gigantic challenge when it undertook deliveries to Statoil's Snøhvit – or Snow White – liquefied natural gas project. It is a complex installation located near Hammerfest, above the Arctic Circle, in northern Norway.

Ingenuity and energy

Named after the famous fairytale character – the vast Snøhvit gas field might become a true fairytale itself, and not only for Statoil Factbox. It is located in a part of Norway that has traditionally been dependent on the fishing industry and the installation will be a boost for the local community. As a major contractor, ABB will also benefit, along with other companies involved in the project. The road has been long and winding since Statoil discovered the field in the early 1980ies, but the project is due to be commissioned in the summer of 2006.

ABB and LNG

The global centre of excellence for the Liquefied Natural Gas (LNG) business is hosted by a department within ABB in Oslo, Norway. It is from here that most of the Snøhvit project has been coordinated. The automation system was designed and fully tested at ABB's department in Bergen.

ABB's role in the project is highly significant. ABB supplied the gas processing plant with a range of electrical equipment and control systems. In the initial contract, the customer specified short delivery times combined with high-quality products, solutions and services. ABB met these requirements, delivering first-rate equipment and services, on time, throughout the project.

"Snøhvit is an example of excellent co-operation with the customer. Thanks to thorough planning and close dialogue with Statoil, we have been on schedule from day one. It has been a most challenging project, which has brought [out] the best [in] ABB's employees and products," says Sturle Riple, project manager for the Snøhvit safety and automation system (SAS) deliveries.

Snøhvit background

The past four years have turned the uninhabited island of Melkøya 1 3, not far from the town of Hammerfest, into the largest building site in Northern Europe, and the largest construction project that Norway has ever seen.

In a few years' time, gas from the Snøhvit field, approximately 140 kilometers offshore in the Barents Sea, will be flowing into the gas processing plant for treatment and shipping to the global LNG market. The core products of the plant are liquefied natural gas (LNG, 5.75 billion m^3 / year), liquefied petroleum gases (LPG, 247,000 tonnes/year) and condensate (747,000 tonnes/year). All products are exported by ship.

Snøhvit is the first development in the Barents Sea. The oil and gas fields were discovered in the early 1980ies. Combined with the adjacent Albatross and Askeladd fields, Snøhvit contains more than 300 billion m^3 of natural gas. Gas will be extracted from the seabed using subsea solutions, which are operated remotely from Melkøya. The subsea control system was delivered by ABB in the UK (now Vetco Aibel). The Top side of the subsea control system, which is an integrated part of the overall SAS, was delivered by ABB at Stord in Norway.

Safety systems have long been an integral part of ABB's technology. The objective of such systems is to monitor hazardous situations and to handle any safety-related issues, safely and securely.

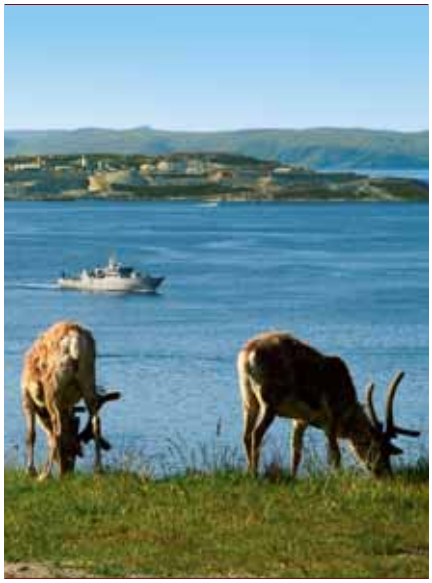
Arctic challenges

Snøhvit is an extremely complex installation, which, combined with hostile weather conditions, presented ABB with a number of challenges.

At 70 degrees north, Hammerfest 2 is well above the Arctic Circle and claims to be the most northerly city in the world. The equipment used in the Snøhvit project will be exposed to severe conditions.

"The climate has been a major issue for us. Outdoor equipment has to meet extreme requirements. A lot of installations have sensitive electronics. All of the equipment [has been] tested in all conditions and we are con-

1 Reindeer with Melkøya in the background [Photo: Marit Hommedal/Statoil]



2 Map of northern Norway

Men at work on the Snøhvit installation [Photo: Marit Hommedal/Statoil]

vinced it will withstand the cold and moist weather in the Barents region", ensures Sturle Riple.

In complete control

By working closely with customers over the years, ABB has developed a proven methodology for the delivery of integrated automation systems, including a complete range of standard and specialized products and systems addressing the industry's particular requirements and challenges.

Safety systems have long been an integral part of ABB's technology. The objective of such systems is to monitor hazardous situations and to handle any safety-related issues, safely and securely. The first integrated safety and control system was supplied by ABB in the mid 1980ies. The current Industrial^{IT} 800xA, which is now the leading automation system in the oil and gas industry, has a secure safety system at its core.

No system is more critical to the processing plant than the combined safety and automation system. The number of signals running through the Snøhvit process plant is enormous; the control system has to handle more than 30,000 signals simultaneously. An unscheduled halt in production is extremely expensive. Therefore, ABB's control systems are constructed and tested to provide the highest level of security and minimal downtime.

"We tested the complete system in Bergen before we shipped it to Hammerfest in December 2005. The equipment is now fully installed and powered up on site", says Sturle Riple.

The installed ABB 800xA system is fully redundant on all levels.

Process overview

The process of the Statoil's Snøhvit field is extensive, encompassing subsea control processing, complex LNG processes, storage and loading of the final products.

The philosophy of Statoil has been to provide its operators with "a single window" into this large process plant. To accomplish this, the 800xA Extended Automation system from ABB was chosen as the operator interface for the safety and automation systems.

High reliability and availability were additional criteria required of the Snøhvit automation system. The installed ABB 800xA system is therefore fully redundant on all levels, ie, it contains redundant Profibuses, controllers, network, 800xA servers and clients.

Ergonomics

The project phase has lasted more than four-years, during which emphasis has been placed on providing operators with the best possible ergonomic environment. Under normal production conditions, this large and complex plant will be controlled by only three operators, located in a single control room. A fourth operator will be mobilized during loading.

A large projection screen, forming a 1.5-m × 16-m curve in front of the operators, displays key, top-level process information from the 800xA system. Eight ceiling-mounted projectors are used to display information from the 800xA system projects in one continuous graphic. Video information from the plant's closed circuit television system is also integrated into the display, allowing process information and live video to be presented alongside project data on the screen.

The purpose of such a large screen is to provide operators with a complete process and status overview, enabling optimum cooperation between operators. Special symbols have been developed in the 800xA system so that information can be delivered in a way that speeds the identification of abnormal process situations. The large-screen layout and symbols are based on the Rich Information Display concept developed by the Institute for Energy Technology (IFE) in Halden, Norway.

Alarm functionality

To reduce the workload of the operators, the built-in alarm management functions in the 800xA systems have been used extensively. The alarm management is based on the following key points: prioritization of alarms, routing of alarms to the responsible operator, easy access to alarm classification information, group alarms, trip alarms, and alarm suppression.

From the alarm list, the operator can access detailed alarm classification information by just clicking on the Alarm classification object in the context menu of the 800xA system. The alarm classification window, which then appears, provides information such as time to react, possible causes and consequences of the problem, and suggests corrective actions to be taken by the operator.

Plant power demand

The total annual power requirement of the Snøhvit plant is approx 1,65 TWh. The plant has five gas turbines, generating 5 × 50 MW of electrical power. These drive three liquefaction compressors. Exhaust heat is used to meet process temperature requirements.

All electrical equipment, including the electrical control and supervision sys-

Factbox Statoil

Statoil is an integrated oil and gas company based in Stavanger, Norway. It is engaged in exploration and production in 15 different countries and operates 24 oil and gas fields on the Norwegian Continental Shelf. It is represented in 33 countries.

The company accounts for 60 percent of all Norwegian petroleum production and, as operator of 23 seabed facilities, it is a leader in subsea production.

The company operates approximately 2,000 service stations in the Scandinavian countries, Poland, the Baltic states, Russia and Ireland.

Statoil is one of the world's most environmentally-efficient producers and transporters of oil and gas.

In 2005, the group had 25,644 employees and its total revenues came to NOK 393 billion (approximately $65.5 billion).

tem (ECSS), was delivered by ABB as a single package. Originally, four separate purchase orders had been issued: high-voltage switchgear, medium-voltage switchgear, low-voltage switchgear and ECSS. These were later merged into one to help meet the different interface challenges associated with such a large electrical scope.

Electrical power requirements

ABB's electrical deliveries to Snøhvit are vast and consist mainly of systems based on ABB's wide portfolio of electronic components. They include high-voltage, medium-voltage and low-voltage switchgear and ECSS. The delivery represents a full range of electrical distribution and drive solutions, all delivered in accordance with oil and gas industry standards. These solutions generate customer benefits in terms of lower operating costs and reduced emissions, while at the same time increasing safety.

The high voltage switchgear is of the EXK-0 type, which is rated for 145 kV. The installation includes a medium-voltage switchgear, UniGear ZS1, with three switchgears rated for 11 kV and one for 6,6 kV. Both switchgears are equipped with an optical arc detection system.

ABB has delivered a total of 28 low-voltage switchgears of the MNS type to Snøhvit, rated for 690 V and 400 V. They consist of 500 cubicles with 2500 consumers. Many are equipped with intelligent motor starters, which provide the customer with all of the necessary system-critical information. Troubleshooting and correction of errors will be quicker and can be performed remotely, ie, with fewer resources on site.

To ensure the highest level of security, the high-voltage and medium-voltage panels, as well as the low-voltage equipment, are equipped with ABB's protection and control unit, the REF542.

The ECSS is at the heart of the electro system and communicates with the vast range of equipment using serial links and Ethernet. It is also linked with the automation system and third-party deliveries. The system consists of 48 AC800M controllers. With more than 43,000 signals being processed at any one time, the ECSS provides a wide range of functions, enabling stable power to be supplied to the LNG facility.

3 Overview of the liquefied natural gas factory on Melkøya, northern Norway [Photo: Eiliv Leren/Statoil]

Changing requirements

Meeting the strict requirements of the LNG business in such a short time was the biggest challenge for ABB. The time available to design and complete the deliveries was limited and, when the contract was signed, the design of the electrical installations was very preliminary. The scope of electrical equipment, especially low-voltage switchgear, increased tremendously during the project phase.

Due to Snøhvit's remote location and challenging climate, the equipment had to be extremely reliable, and yet compact enough to fit within the limited space available. Additional constraints were placed on electrical equipment because they had to be pre-installed on a barge. This was done in the quiet Mediterranean Sea to avoid the impact of the weather in Northern Norway. The barge was then transported to Melkøya, where it was cemented into a prepared dock and connected to the rest of the facility.

Snøhvit is a challenging project and all of the different operations systems must interact with each other to ensure safe operations and maximum efficiency. This requires thorough planning. ABB has delivered all of the

engineering services, including a wide range of necessary studies conducted in cooperation with ABB in Germany. ABB also ran tests on all of the modules and the systems prior to installation, and also on site after installation.

Power management

To prevent multimillion-dollar shutdowns, liquefied natural gas complexes must have a reliable and stable energy supply. In areas where the public electricity supply is unreliable, or non-existent, LNG companies rely heavily on their own power generation capabilities; if an inconsistent power supply causes a single unscheduled trip, several days of production will be lost, at a cost of more than $10 million.

In response to this problem, almost every new LNG facility now includes a power management system (PMS). But most systems begin and end with SCADA (supervisory control and data acquisition), which simply isn't enough. An effective power management system must achieve several goals. It must withstand large disturbances, from inside or outside the system, while maintaining stable operation. It must balance energy demands with the available energy supply, thus preventing disturbances and blackouts. It is necessary to ensure that the plant power system design is correct, in order to control energy costs, enhance safety and mitigate environmental and health impacts.

ABB has now delivered and commissioned more than 30 Power Management Systems, demonstrating that the PMS substantially improves plant uptime, efficiency and reliability.

The power management system should monitor equipment continuously to ensure optimal performance and stability over time. The extremely fast dynamic properties of the electrical process require quick response times – on the order of milliseconds – to prevent protection relays from issuing trip commands that lead to equipment overload and eventual shutdown.

If a system is capable of handling all these criteria, the return on investment for an LNG facility can be measured in weeks, not years. The principal gains can be made in the areas of power generation efficiency, import and usage under varying operating conditions, and minimized capital expenditure on the power system.

For example, ABB's Industrial^{IT} Power Management System (PMS) contains not only traditional SCADA functionality, but also a full complement of electrical solutions, including power control and load shedding. ABB has now delivered and commissioned more than 30 Power Management Systems, demonstrating that the PMS substantially improves plant uptime, efficiency and reliability. These results have a very positive impact on both capital and operational expenditure.

Experience counts

With the global demand for fossil fuels continuing to outpace supply, the production and delivery of oil and gas have never been more challenging. Customers like Statoil rely on experienced and proven companies, such as ABB, to meet the demands of these difficult endeavors.

With more than 50 years of experience, in over 40 countries, ABB is the premiere supplier of the critical systems and technologies that make the supply of oil and gas possible. Innovation through experience and a proven ability to handle large projects in automation, telecommunication and electrification distinguish ABB as a leading supplier to the industry.

"We are proud of what we have achieved in such a short time and we are sure that Statoil once again will be pleased with our deliveries", concludes Riple.

Process maintenance [Photo: Marit Hommedal/Statoil]

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Electrifying London

Underground cable connects substations to placate London's insatiable demand for power

Stephen Trotter

ABB is helping to secure London's power supply for many years to come. Recent projects completed for National Grid on London's power infrastructure have provided a 20 km long, high-voltage, underground cable link, together with two major new GIS (gas insulated switchgear) indoor substations – all to help satisfy the capital's fast-growing demand for electricity.

Demand for power continues to increase throughout the UK, but in London, the rate of increase is around twice the national average. Projections indicate that this growth rate will be sustained for at least another 10 years. Since 1990, to ensure the future of London's power supply, National Grid has invested over Euros 1,000 million ($ 1,270 million) in the reinforcement of the transmission network in and around London. This represents approximately 20 percent of National Grid's total capital investment in the whole of England and Wales.

One of the measures taken by National Grid was to commission ABB with a three-year turnkey project, to be completed in the summer of 2005. The project was to create the "London Connection" to meet electricity demand in the capital and the area north west of London.

The "London connection"

Running in a 20km long three-meter diameter tunnel, the cable links an extended substation at Elstree to a substation built by ABB at St John's Wood. It was the largest tunneling project that National Grid has ever undertaken.

The "London Connection" uses high-technology, low-maintenance cross-linked polyethylene (XLPE) insulation technology and is currently Europe's longest 400-kV XLPE underground cable 1. A similar underground cable was installed by ABB in Berlin in 1998.

For the London project, ABB installed, commissioned and tested 61 km of

150-mm diameter cable, weighing a total of 2,440 tonnes that was delivered on 63 massive drums 2.

St John's Wood substation

In addition to meeting the generally increased power demand for the capital, there was a specific need to upgrade the existing St John's Wood substation in West London to cope with extra local demand.

National Grid therefore decided to build a complete new substation at St John's Wood. Even though there had once been a power station at the site, there was very little non-operational space and since land is at a premium in this part of London, there was no way of purchasing any extra space. So the new 18-bay, 400-kV substation had to fit onto a footprint of just 90 m by 30 m.

1 ABB 400-kV XLPE underground cable

In order to minimize the visual impact of the substation on the local community, and to contain the equipment within such a confined area, ABB's state-of-the-art compact gas insulated switchgear (GIS) technology was used 3.

For the London project, ABB installed, commissioned and tested 61 km of 150-mm diameter cable, weighing a total of 2,440 tonnes that was delivered on 63 massive drums.

As the main contractor, ABB was responsible for all aspects of the St John's Wood project, including the decommissioning of the old plant, installation of the new plant, refurbishment of remaining old plant components and interfacing the old with the new. Because of the lack of "laydown" space on site, very careful planning was required. Deliveries had to be coordinated on a "just-in-time" basis and accommodate all the extra complications of working in a congested residential area. Some idea of the scale of the undertaking is given by the number of vehicle movements on the site: 200 vehicles were needed for the GIS equipment alone, and nearly 7,500 for the civil works.

GIS switchgear

The switchgear installation at St John's Wood is currently the largest 400-kV GIS substation in the UK. The ABB equipment is designed to minimize gas leakage, and monitoring for gas leaks can be performed both locally and remotely.

In the rare event that maintenance or repair is required, the switchgear design maintains maximum system availability by requiring only the affected components and bay to be switched out.

The constraints on the height of the building were met by constructing a six-meter deep basement below the switch-house.

Autotransformers

Four ABB autotransformers (240-MVA, 400/132-kV) were installed to reduce the voltage of the electricity in order to feed the local substations. The massive transformers, each weighing 171 tonnes, were brought by sea to the London port of Tilbury. To minimize disruption to traffic, each transformer was moved to the site during the early morning (see title picture). Street furniture had to be removed along the route and certain sections of roads and bridges had to be strengthened to take the weight.

Control and protection

The substation can be controlled remotely from National Grid's UK Control Centre in Wokingham. A standby control room also allows local supervision of the substation and tunnel, including switchgear, protection, power measurements, building systems and security. Fiber optics is used as the main communication medium to support high data transmission rates with immunity to electrical noise. All the equipment is synchronized to absolute time using GPS (global positioning system) technology.

Local community

The ABB site team worked closely with National Grid in order to maintain a good relationship with the local community. For example, mail drops were carried out to around 1500 local addresses to keep residents informed of major activities such as pile driving or deliveries of heavy loads. There was also a 24-hour call center for concerned residents. ABB responded quickly to solve any problems. This attention to detail included a swift response when the erection of the 30-m tower crane affected TV reception for a few residents.

Very high standards of health and safety were observed throughout the project and, in 2004, ABB was awarded a certificate for the successful com-

pletion of 250,000 hours with no time lost due to injury.

City Road North

While one ABB site team was busy in West London, another team was hard at work on the other side of the city creating National Grid's new "City Road North" substation. This contract was part of the urban regeneration of the City Road canal basin in Islington, North London.

The new City Road North substation, which was constructed adjacent to the existing City Road substation, is a key part of a program by the local utility, EdF, to reinforce the power grid serving the North London area. The substation is housed inside a new brick building, designed by Markwick Architects, to minimize its visual impact on the area. This was in line with Islington Council's redevelopment plan to improve access and recreational opportunities, thereby enhancing the local urban environment.

ABB was responsible for all engineering design and civil works at City Road North, as well as the complete installation and commissioning of the substation switchgear and ancillary equipment. The project team's first task on site was the demolition of an existing office block to make way for the construction of the new substation. The nature of the site, in a busy inner-city site in Islington, was a major challenge. It was surrounded by residential, commercial and industrial premises, and backed on to the Regent canal. A great deal of logistical planning was required just to move heavy plant and materials in and out of the site.

The project also included diversion of an existing 400-kV cable into the new substation. The existing cable had linked the old City Road substation to the substation in West Ham, six miles away in East London, and the diversion was necessary to complete the West Ham/City Road North and City Road North/West Ham circuits.

The work continues

The excellent performance of ABB technology at St John's Wood and City Road North, coupled with the company's proven ability to meet tight delivery schedules, has resulted in National Grid awarding two extension projects to ABB. These projects are currently in progress.

ABB is responsible for the engineering design and civil works of both the St. John's Wood and the City Road North substation extension projects, as well as providing a complete installation and commissioning service. The new substation protection and automation systems for City Road will be based on National Grid's standardized NICAP (National scheme for Integrated Control and Protection) philosophy. This approach enables ABB to reduce delivery times significantly by using pre-engineered, pre-tested and pre-approved solutions to swiftly integrate the new bays into the existing substation systems.

2 ABB power cable on massive drums

3 ABB's compact gas insulated switchgear has the right footprint.

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Trained to fit

A transformer for a train that will go anywhere

Joel Vauchel, Harry Zueger

ABB offers a broad palette of products to the rail sector. The company produces power supply systems for rail networks as well as most of the electrics for locomotives. Notably, ABB is the global market leader for traction transformers. Currently, such a transformer is being elaborated, that makes the new AGC trains of the French Railway Company (SNCF) fully versatile – the same train will be able to draw its power from the overhead line regardless of the different voltage levels provided, or from a diesel generator where no such line is available. Such a train will be able to use France's entire rail network flexibly and seamlessly.

The achievement is especially remarkable, as the train was developed from a platform that was specified to permit certain combinations of the three power supply systems (two electrification voltages and diesel power), but not all three on the same vehicle. Consequently, the transformer was designed to fit in the same space on the train as the generator, making the two modes mutually exclusive. But when a three-system train was called for, ABB jumped to the challenge and showed it could be done.

At the beginning of the 20th Century, most electric railways used a DC power supply with voltages in the range of 600 V to 3 kV. These relatively low voltages could be fed directly to the traction motors, so keeping the construction of locomotives simple. However, the currents required to deliver the necessary power were very high (often in the order of several thousand Amperes over prolonged periods), calling for either a third rail or a heavy catenary[1)].

The Geneva plant of ABB Sécheron Ltd. has been manufacturing traction transformers since the introduction of AC supply systems.

Starting from the early years of the 20th Century, and increasingly during the 1920ies to 1950ies, higher transmission voltages were implemented (notably in the US but also Germany and France). These permitted lower currents and consequently reductions in both the weight and the cost of the catenary or the elimination of the third rail. Modern state-of-the-art railway networks use high voltage AC systems in which the catenary voltage ranges from 15 kV/16.7 Hz (in Switzerland, Germany, Austria, Sweden and Norway) to 25 kV 50/60 Hz (in many other countries). The lighter catenary construction not only saves costs but also permits faster running. Speeds above 250 km/h would not be feasible without an AC system.

Besides the lighter catenary, the major advantage of the higher voltage lies in

the reduction of the number of feeding substations required (typically every 20 to 25 km at 15 kV and 50 km for 25 kV, instead of every 10 km at 1.5 kV DC).

On board the locomotive, however, the catenary voltage must be adapted to a voltage level suitable for the propulsion system – typically between 1000 and 2000 V. This requires a traction transformer.

Fifty percent market share

The Geneva plant of ABB Sécheron Ltd. has been manufacturing traction transformers since the introduction of AC supply systems. Six years ago, the Geneva plant concentrated its transformer activity on traction applications – a sector where it already leads with a fifty-percent share of the world market. Today, the company has strategic alliance contracts with the rolling stock manufacturers Stadler Rail, Bombardier, Siemens, and Alstom.

A traction transformer must meet key performance criteria such as:

- It is a single transfer point for energy between catenary and motors, imposing the highest reliability demands as any transformer breakdown stops the train.
- Smallest size, as space is at a premium.
- Lowest weight as the axle weight limit may not typically exceed 22.5 t. The restraint is even tougher for high speed or narrow gauge trains.
- Multiple low-voltage output levels are required to deliver power, not only to the traction system but also to auxiliary systems (air conditioning, lighting, signaling, information systems) and safety systems (brakes, battery chargers).

Key rolling stock manufacturers such as Bombardier are launching versatile train "platforms" permitting diesel and/or electrically powered variants to be easily derived from a common design. The new AGC (autorail à grande capacité) family of trains 1 being delivered to the French National Railway Company (SNCF) is an example of such a design Factbox.

When deliveries are complete, more than 500 AGC trains will be in service. ABB is delivering the traction motors for all units, the generators for diesel operation, and the traction transformers for AC operations.

Designed for diesel and electric operations

When deliveries are complete, more than 500 AGC trains will be in service. These trains will be used throughout the 29,500 km SNCF network, of which 15,800 km is not electrified, 5,800 km is electrified at 1.5 kV DC and 7,900 km at 25 kV AC. Bombardier is supplying diesel, diesel/DC and AC/DC variants of the AGC. ABB is delivering the traction motors for all units, the generators for diesel operation, and the traction transformers for AC operations.

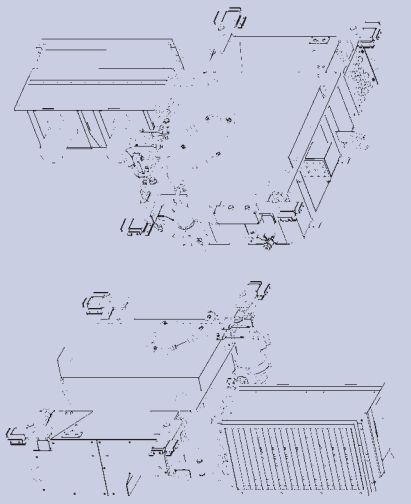
In order to meet these requirements, ABB had to design a small, sturdy and reliable traction transformer for mounting in the same volume and location as the diesel engine/generator power pack. This allowed Bombardier to manufacture the same body, irrespective of the propulsion system.

Transformer mounted under-floor

This transformer is mounted under-floor just behind the front bogie – the rest of the train is fully low-floor,

2 The under-floor transformer for the AGC

rated power	1800 kVA
primary	25 kV / 72 A
secondaries	932 V / 484 A
filter winding	1 x 110 kVA, 1000 V / 110A
overload	2750 kVA
thermal class	A (H for wire)
dimensions	2951 x 2583 x 842 mm
weight	3040 kg
impedance	28 percent (1.72 mH)
tank material	steel
standards	IEC 60310 NFF 16-101,2,3 NFF 65101



1 Modularity permits both diesel a and electric b variants of the AGC railcar for SNCF (French Railways). ABB is supplying the generators, transformers and traction motors.

3 The transformer for the AGC XBiBi

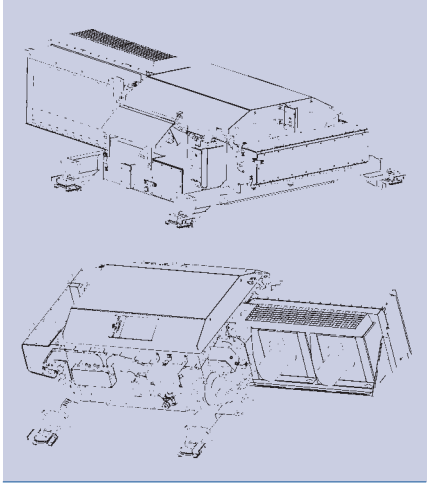
Factbox Key parameters of AGC trains for SNCF (French Railways)

	Diesel			Electric 25kV & 1.5 kV			Diesel & 1.5kV	
Number of cars	2	3	4	2	3	4	3	4
Bogies	Bo' 2' 2'	Bo' 2' 2' Bo'	Bo' 2' 2' 2' Bo'	Bo' 2' Bo'	Bo' 2' 2' Bo'	Bo' 2' 2' 2' Bo'	Bo' 2' 2' Bo'	Bo' 2' 2' 2' Bo'
Max speed (km/h)	140	160	140	160	160	160	160	160
Motor Power (kW)	622	2×622	2×622	1300	1300	1300	2×622/1300	2×622/1300
Acceleration (m/s²) 0-50km/h	0.45	0.66	0.52	1	0.82	0.67	0.81	0.66
capacity (seated/standing)	144/130	208/200	272/251	144/130	208/200	272/251	208/200	272/251
Mass (t)	92.6	130.6	158.5	94.6	121.6	149.5	131.6	159.9

providing easier access for disabled passengers, passengers traveling with bicycles, baby-carriages etc. Low floor also enables shorter dwelling times at stations, permitting faster services and better utilization of line capacity.

The transformer module 2 integrates the oil expansion tank and the cooling system. This means that the oil circuit no longer has to be completed after the mounting of the transformer on the train. Supervision and protection devices such as fast fuses and current transformers are also mounted inside the terminal box. The cooler is equipped with two-speed motors and is over-dimensioned in order to offer more surface reserve than usual – this makes the transformer more robust under heavy service conditions. The under-floor resilient mounting minimizes structure-borne noise.

4 The roof-mounted transformer for the AGC XBiBi – electrical properties are the same as for the under-floor variant 2, but dimensions are 3216 × 2382 × 860 mm



Fully versatile – the train that will go anywhere

Shortly after the delivery of the first transformers by ABB, SNCF expressed the intention of obtaining fully versatile trains being able to run on all three power supply options. In other words: the dream train capable of running everywhere in France from Dunkirk to Nice and Brest to Strasbourg.

This new "model", called AGC XBiBi (bi-mode and dual voltage) was not included in the original AGC concept – the traction transformer and diesel engine were mutually exclusive because they occupied the same position. ABB met the challenge by elaborating a solution with minimal cost, short delivery time and a high modularity impact that did not affect the overall AGC design. The low floor construction had to be retained and modification of the diesel coach was also no option.

SNCF expressed the intention of obtaining the dream train capable of running everywhere in France from Dunkirk to Nice and Brest to Strasbourg.

Roof mounted traction transformer for AGC XBiBi

Drawing on its past experience with roof-mounted traction transformers as delivered for Bombardier's NINA trains, but also for Stadler's FLIRT[2)] and Alstom's X60, ABB designed a flat roof-mounted traction transformer 3, electrically identical to the under-floor one 2. This enabled its application without requiring adaptation of the propulsion or control system.

The key parameters of AGC XBiBi traction transformer are identical to the standard AGC under-floor transformer electrically. Mechanically the dimensions were modified to 3,216 × 2,382 × 860 mm 4. Both transformer models are layer types in order to minimize vibrations.

On the right track

Today, the notion of "platform" is being promoted by all train manufacturers. It is therefore important to investigate all possible solutions at an early stage so as to minimize subsequent time-consuming engineering efforts for product adaptation.

Besides the transformers presented here, ABB Sécheron also offers a broad range of state-of-the-art traction transformer technologies. The company has developed weight-saving solutions for the integration of the DC line-filter and chopper reactor functions inside the transformer's active part. These are used on Bombardier's latest multi-system locomotives (TRAXX family) and on high speed trains.

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Footnotes

1) Catenary is the structure of the overhead line.

2) See also "The compact converter" on page 52 of this edition of ABB Review.

The compact converter

A new generation of compact low-voltage IGBT converters for traction applications

Peter Dähler, Gerold Knapp, Armando Nold

In Switzerland, one rarely needs to travel far to see a multiple-unit train supplied by the rolling stock manufacturer, Stadler Rail. Most prominent are the successful FLIRT and GTW type regional trains, whose high levels of performance and comfort are widely appreciated. What fewer people realize is that the power converters of these units are supplied by ABB. The compact low-voltage IGBT converter CC750® is an integral part of the success story.

Regardless of the power supply under which it is called to operate, this compact and versatile converter supplies the correct voltage and frequency to the traction motors as well as the on-board power supply for lighting, braking and other auxiliary systems. ABB's CC750® uses the latest generation of semiconductor modules and a high-performance programmable control platform.

The purpose of a converter is to adapt the power from the catenary (overhead cable) to the voltage and frequency desired for the operation of the motor at the desired speed and torque. ABB's CC750® is the converter that powers the traction motors of Stadler Rail's FLIRT[1)] [1,2] and GTW[2)] trains 1, which are used by Swiss Federal Railways (SBB) and many other operators. The CC750® also feeds the on-board power supply for lighting, braking, and HVAC systems. It uses the latest generation of low voltage IGBT[3)] modules and is equipped with a programmable fast-control platform.

The CC750® was presented in a recent *ABB Review* article [3]. Whereas this report focussed mainly on the CC750®'s AC 800PEC control system, the present article will discuss the converter itself.

A Compact Converter CC750 AC system consists of an input transformer, two drive converters with integrated auxiliary power converters and battery charger and ABB's AC 800PEC [4] control system 2. The CC750® can be used with many common catenary configurations such as 15 kV / 16.7 Hz and 25 kV / 50 Hz and also combinations of different systems (for cross-border services). Configurations with either two or four converters per train exist, providing a total traction power of 1.3 MW or 2.6 MW at wheel. The converters can be placed within the vehicle or mounted on the roof or under the floor.

Advanced control technology allows the converters to be operated without a series resonant circuit in the DC link, resulting in a substantially lighter drive system. .

Each converter in its own cabinet

A key feature of the CC750® is the vibration-proof mounting of each converter in its own cabinet 3. The water-cooled converter is located in a closed cabinet with internal forced air circulation and an air-to-water heat exchanger.

The control hardware is mounted on a swivelling frame to facilitate easy access to the power part.

The DC link capacitors 4 are situated directly behind the IGBT modules, forming a low-inductance capacitor bank.

The connectors for water cooling as well as the interface to the vehicle control are located at the top of the converter.

Semiconductors in drive converters

The compact converters are rugged units incorporating modern IGBT technology. Each individual unit is built on a PowerPak 4 Power Electronics Building Block (PEBB). Both the grid and motor converters are furnished with integrated semiconductors and gate drivers. On the grid converter side, a parallel connection of two power modules is required to handle the maximum current. In contrast, one power module is provided per phase on the motor side.

Regardless of the power supply under which it is called to operate, this compact and versatile converter supplies the correct voltage and frequency to the traction motors.

Both inverters are operated over the whole speed range with a single standard PWM (pulse-width modulation) pulse pattern using a carrier frequency of 2 kHz. The distortions of the sinusoidal phase currents on both the grid and motor side of the converter are very low 5.

In the event of fast transients, such as pantograph bouncing, a voltage-limiter restricts the DC-link voltage to 800 V.

No tuned Filter in DC link

In contrast to state-of-the-art single-phase converter designs, no tuned filter is installed in the DC-link.

Instead, to absorb power fluctuation from the single-phase grid, the DC-

1 Regional railways are gaining in attractivity and efficiency through the deployment of modern lightweight railcars:
a FLIRT[1)] train of Swiss Federal Railways (SBB) and
b GTW[2)] train of THURBO (Thurgau-Bodensee Bahn). Both use CC750® power converters from ABB

link capacitance has been enlarged significantly to maintain a voltage ripple even at full load. Due to the high energy density of the electrolytic capacitors in the DC-link, the cost and volume of the DC link components was reduced massively compared to a standard solution using a tuned filter.

Protection in case of semiconductor failure

A large DC-link capacitance 4 is advantageous for DC-link voltage stability. It does however, pose fresh challenges in terms of short-circuit protection. An autonomous desaturation switch-off, as is frequently-used today to intervene in the event of a semiconductor failure, is insufficient in preventing a total short-circuit of the DC-link when additional energy from the connected phase (eg, grid or motor) is flowing into the faulty semiconductor. A heavy IGBT fault, shorting the entire DC link, will lead to the failure of the second switch of the affected half-bridge through excessive arcing and voltage transients. Consequently, further measures are required to prevent extensive mechanical damage to the IGBT and surrounding equipment in such a situation:

The 50 kVA three-phase supply is fully overload and short-circuit proof and provides a low-distortion sinusoidal output voltage.

Desaturation detection switch-off is retained as a first attempt to clear an IGBT failure that shorts one switch of the half-bridge. This switch-off is only successful if the short-circuit energy of the connected phase is small, eg, an auxiliary converter IGBT failure, or a motor converter IGBT failure if the motor is operating at low speed and torque.

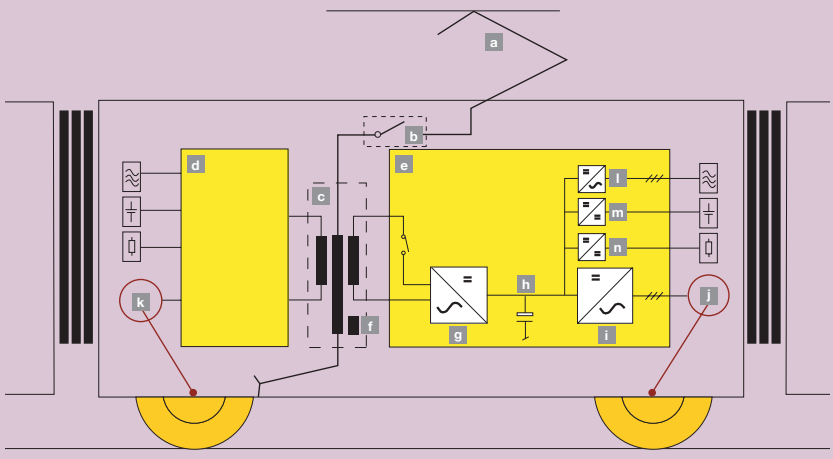
Rather than wait for the breaker to open, a short-circuit detection unit detects the fault within microseconds and signals this to the control system, which then takes remedial action. This can reduce the mechanical damage to the system from a heavy explosion to local damage in the causal semiconductor switch – without rupturing the semiconductor casing.

Following a heavy IGBT failure, the faulty semiconductor, as well as the fuses and the thyristor of the DC link crowbar 6, must be replaced. But these protection components (fuses and thyristor) are low-cost components.

The benefits offered by this protection system include the elimination of impact on neighbouring parts (deposition of conductive remains on isola-

2 Traction converter arrangement on THURBO GTW with two CC750® units delivering a total of 1.3 MW of traction power

a pantograph (15 kV, 16 2/3 Hz cantenary)
b main circuit breaker
c transformer
d and e CC750® power converter units
f auxiliary transformer winding for train heating supply
g grid inverter (390V input)
h DC-link (750V)
i traction inverter (480 V / 0 – 170 Hz, 750 kVA traction power)
j and k asynchronous traction motor
l three-phase auxiliary supply (50 kVA / 3 × 400 Vac)
m battery charger (12 kW / 36 Vdc)
n brake chopper



3 The control hardware of the CC750® swivels aside to permit access to the power part

4 DC-link capacitor bank – the high-density capacitors contribute to operational stability, but the greater energy stored requires precautions

tion surfaces), which also simplifies the job of cleaning them afterwards. The repair time is further shortened by the good accessibility of the components to be replaced. Additionally, the reinforcement of walls and measures to channel plasma in case of such an incident can be reduced or eliminated, simplifying the construction without compromising on passenger safety. Finally, the noise impact of such a heavy semiconductor failure is significantly reduced.

Auxiliary supplies

The auxiliary supplies 2 l–n are integrated into the main converter cubicle, making the CC750® converter a complete system for the entire traction and auxiliary power demand of the train vehicle.

These supplies are fed directly by the main traction DC link and use the same semiconductor family and protection layout as the main traction unit. The sharing of the large DC link with the main converters means short interruptions of the feeding catenary do not affect the operation of the auxiliary supplies.

The 50 kVA three-phase supply 2l is fully overload and short-circuit proof and provides a low-distortion sinusoidal output voltage. The 12 kW battery charger unit 2m feeds the 200 Ah vehicle battery and can easily be adapted to different battery charge algorithms. It also feeds the 36 V vehicle line, which supplies the vehicle control, door drives, lighting etc.

Field experience

Due to the very stable control structure and the large DC link capacitance, the system has proved very reliable, even in the event of pantograph bouncing or poor track conditions. The protection system of the converter has proved to be an effective measure in avoiding mechanical damage in the converter cubicle in the event of semiconductor failures. Nevertheless, improvement of the reliability of semiconductors in general is an ongoing task to ensure that modern converter systems meet the high reliability and availability standards expected by customers.

Due to the high switching frequency of IGBTs, a simple PWM modulation strategy can be applied.

Utilizing the latest generation of low-voltage IGBT modules, a compact and low-cost design of the entire converter system for use in local transit vehicles is achieved. Due to the high switching frequency of IGBTs, a simple PWM modulation strategy can be applied with no need for complex transitions between different modulation strategies. The control system is set up with a new in-house platform using FPGA technology and MATLAB®/Simulink® based programming environment. Thanks to these advanced tools [3], high-quality software can be provided and modifications can be easily implemented, even during operation.

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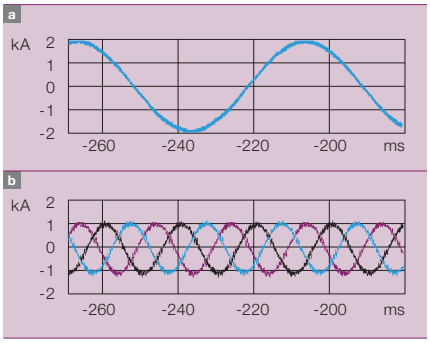
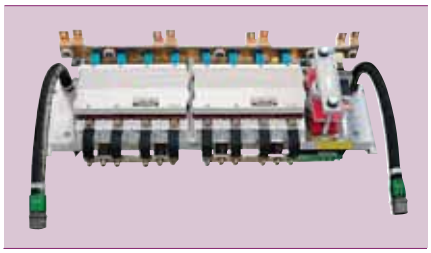
5 The 2kHz PWM (pulse width modulation) minimizes current distortion of grid a and motor b currents (measurement at 50 km/h vehicle speed and 80 percent motor torque)



6 A short-circuit in the DC-link can cause considerable damage. Protection assembly with IGBTs, busbar, fast short-circuit detection and DC crowbar



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[2] Steffen Obst, Ruedi Beutler, Der FLIRT – das Resultat hoher Kundenanforderungen, Eisenbahntechnishe Rundschau, 12/2005 pages 767–771

[3] Armin Eichmann, Andreas Vollmer, Fast control in a traction application (Roll and Control – The AC 800PEC control platform in a broad range of applications), ABB Review 2/2006 pages 26–28

[4] Ernst Johansen, Design patterns – Co-design patterns for advanced control with AC 800PEC, ABB Review 2/2006 pages 62–65

Footnotes

[1] FLIRT: “Flinker Leichter Innovativer Regional Triebzug” or “Fast, Lightweight Innovative Regional Train”

[2] GTW: “Gelenktriebwagen” or articulated railcar

[3] IGBT: “Insulated Gate Bipolar Transistor”

Cranes with brains

Euromax – The modern automatic container terminal

Uno Bryfors, Hans Cederqvist, Björn Henriksson, Andrew Spink

Containerization has been a catalyst in the growth of global trade. One of the ingredients of its success is that it has driven down transportation costs significantly – to the point that shipping accounts for only a small part of the product's price-tag. To further raise productivity, the ports of the world are seeking to automate handling.

In a modern container terminal more than 10,000 boxes are moved every day. Every one of these moves is unique – it has to be performed quickly and to the right destination without interfering with other containers, cranes or vehicles. These moves were previously performed using manually operated equipment – but technology from ABB now facilitates the full automation of these operations.

The shipping container – which was introduced during the 1960ies – has revolutionized shipping and port operations. During 2006, the world's ports will handle approximately 300 million containers, shipping an innumerable variety of products. With the push for increased productivity and enhanced efficiency, the automated handling of cargo is becoming a necessity.

The introduction of the shipping container has reduced costs and significantly increased the volume of goods that is being transported by ship. Sea containers are 8 feet wide and 8,5 or 9,5 feet high. The most common container lengths are 20 feet long – defined as one TEU (twenty feet equivalent unit) and 40 feet (2 TEU). Before the container was introduced, the on and off-loading process was so slow that ships had to remain in port for weeks at a time. Today, a large container ship carrying a total of 6000–9000 TEUs can typically exchange 4000 to 5000 TEUs (up to 50,000 tons) in less than 24 hours.

This breakthrough in efficiency has been an important factor in the rapid globalization of world trade and manufacturing. Transport costs now make up a very small part of the product's price-tag.

In recent years, automation has revolutionized many industries. Port operators have been slower to take advantage of automation. The size of the containers, cranes and terminals as well as around the clock operation in

all kinds of weather conditions, present substantial challenges. This has called for development of dedicated equipment and control concepts.

Today proven automation technology is available to reliably handle the machines and conditions required for efficient and economical operation . . .

ABB takes the lead

ABB is leading the way in the automation of the container port industry, resulting in better utilization of resources and reduced costs for the ship owner, the port operator and, ultimately, the consumer. ABB has delivered automation and electrical systems to a large number of automatic yard cranes and ship-to-shore cranes all over the world – thereby becoming the market leader in this segment. ABB played the leading role in supplying 52 fully automated yard-cranes to Container Terminal Altenwerder (CTA) in Hamburg (title picture) – the most advanced container terminal in the world – operation of which started in 2002.

This year, automation systems for six yard cranes in the port of Kaohsiung, Taiwan have been put into service, and deliveries to the large Euromax project in the Dutch port of Rotterdam have begun.

Euromax

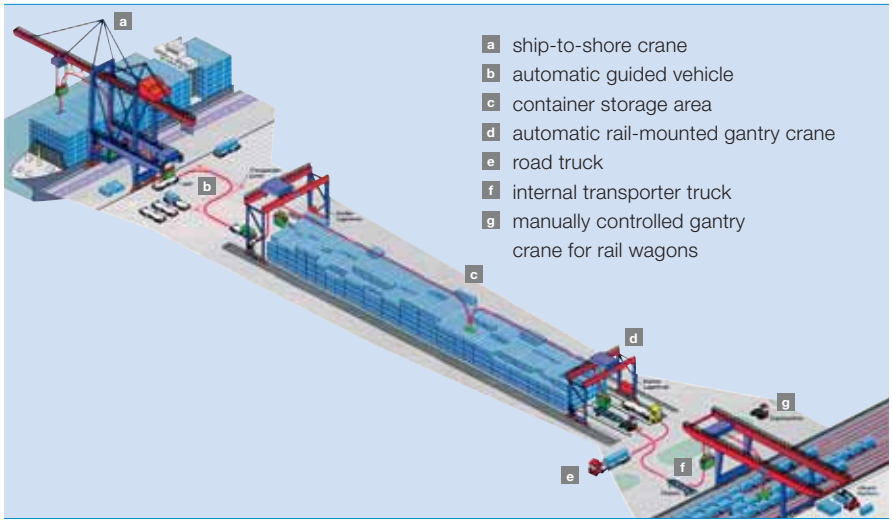
The Euromax shipping terminal is a joint venture by Hutchinson-Whampoa of Hong-Kong, and AP Möller of Denmark – two of the largest terminal operators in the world. Their objective is to design, build and operate a new terminal in Rotterdam, utilizing advanced technology in order to keep ship berthing times short and cost per handled container low.

During 2005, potential suppliers for the automatic terminal were evaluated. ABB won the order for electrical and automation equipment, with Zhenhua Port Machinery Company (ZPMC) of Shanghai, China, being chosen for the mechanical part of the cranes.

Process flow in Euromax

The process flow 1 and the types of cranes used, will be basically the same as what is used in CTA. Containers are unloaded/loaded from the vessel by means of a ship-to-shore crane (STS) 1a 2. Such a crane typically weighs 1500–2200 tons and makes 35 to 50 moves per hour. In each move one to four containers are trans-

1 Container handling within an automatic terminal



2 With modern ship-to-shore cranes a ship with 4000-5000 TEU (twenty feet equivalent) to unload/load can be handled in less than 24 hours

Euromax at a glance

Phase I of the terminal, built for 2,100,000 TEU/y, will be taken into commercial operation in 2007 and will require the following handling equipment:

- 12 large ship-to-shore cranes
- 4 barge cranes
- 58 automatic RMGs (rail-mounted gantry cranes)
- 2 manual RMGs for rail wagons

The ABB integrated crane control system includes:

- Over 300 ACS 800 crane drives
- 1600 AC motors from 10 to 700 kW
- Medium voltage switchgear and transformers
- Low voltage crane distribution
- AC 800 crane control systems
- Advanced sensors
- Terminal wide maintenance and monitoring
- Cameras and remote operating equipment

The crane equipment is fitted to the cranes at the crane manufacturer's site and is commissioned at the Euromax terminal.

ported between the ship and the dock. STSs are operated semi-automatic with a driver located in a cabin on the trolley about 50m above the quay. The container is automatically loaded on an AGV (automatic guided vehicle) 1b 3 which takes the container to a storage area 1c. This area is divided into blocks, each covered by two automatic rail-mounted gantry cranes (ARMG) 1d 3. The container is picked up by one of these and moved to the desired position in the block – this operation is performed fully automatically.

The location of the container in the storage area is chosen by the Terminal Operating System (TOS) – an advanced process control system from which the ARMGs receive their work-orders.

Containers to be forwarded by land are loaded onto road trucks 1e or onto internal trucks 1f for transport to a railway loading point 1g inside the terminal area. All operations of the ARMGs are fully automatic except the handling of road trucks at the land-side interface, where manual supervision of the movement is a safety requirement due to interaction with the truck driver. From when the load reaches a limit a few meters above a road truck, until it clears the same level on the way back to the container stack, the motion is controlled by an operator in a remote office 4 (one supervisor for eight to twelve ARMGs) using four to six compact cameras located on the crane.

Port operations

The key performance indicators for a container port are:

- Berth productivity – how fast is a vessel unloaded and re-loaded.
- Yard-crane productivity
- Number of containers handled per yard area
- Service time for road trucks
- Energy cost per TEU
- Labour productivity – how many containers per man-year

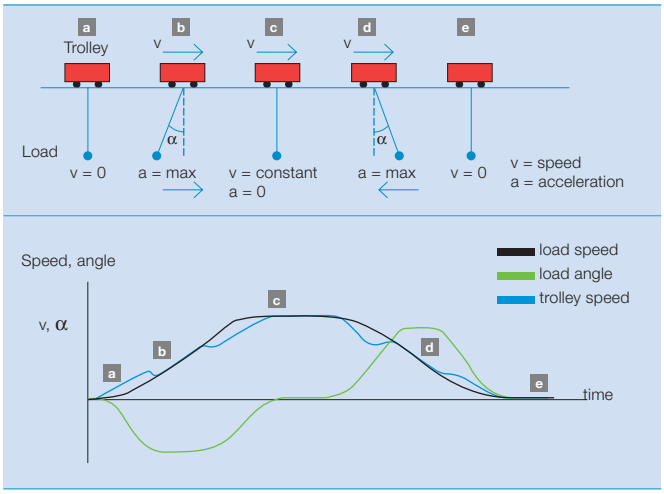
In order to meet these targets, several technical issues had to be resolved:

- Design of equipment for the harsh crane environment, enabling reliable operation with minimum maintenance
- Handling of large flexible crane structures
- Fast and accurate automatic operation
- Handling of ground/rail conditions allowing cost efficient civil engineering concepts
- Flexibility – handling of various container as well vehicle types
- Safe interfacing to manned equipment

3 Automated handling of containers using automatic guided vehicles and automatic rail mounted gantry cranes

4 Supervision of automated rail-mounted gantry cranes at CTA Hamburg

5 The load positioning system uses infrared sensors to identify the precise load position



During 2006, the world's ports will handle approximately 300 million containers.

ABB automation technology

The ABB standardized ARMG and STS crane automation packages are based on fast and accurate measurement of

- Load position
- Target position
- Obstacles positions

combined with advanced load control

Load position measurement

The Load Positioning System (LPS) 5 consists of a camera equipped with a video processor and an infrared transmitter box mounted on the spreader. The transmitter includes a number of infrared markers, each of which the camera identifies to an accuracy of better then a millimeter.

The control system then uses the positions of the markers to calculate the position and orientation of the load relative to the trolley. This information is used as feedback into the position and motion controllers to ensure maximum precision.

Target and obstacle position measurement

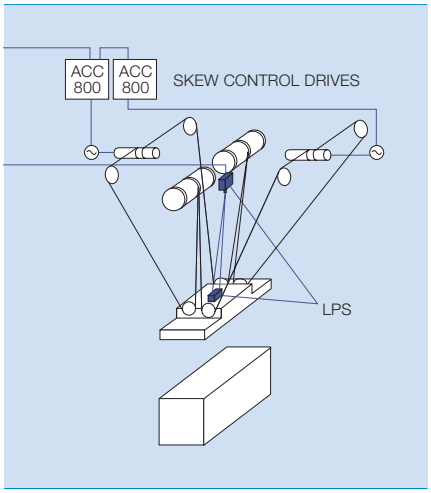
The TPS (Target Positioning System) uses a high precision laser beam that is directed by a series of controlled mirrors to enable three-dimensional scanning 6. In ARMG appli-

cations, one or two of these scanners are mounted on the trolley and used for a number of tasks within the automatic sequences. During automatic operations within the stack, the TPS is used to locate the exact position and size of the target container, check the clearance to adjacent stacks and verify the positions of the containers as they are stacked.

The TPS is also used to generate correction references when operating containers in transfer areas with both automatic and manually driven vehicles. Additionally, the TPS is used to identify positions of obstacles which can influence the path of the hanging load.

The LPS and TPS jointly enable the ABB yard cranes to swiftly and with a high reproducibility build stacks of loaded containers of up to 25m in height with a tolerance of just a few cm.

6 The target positioning system uses a precision laser and mirrors to identify with great precision the box to be grabbed



The Target Positioning System is used to locate the exact position and size of the target container, check the clearance to adjacent stacks and verify the positions of the containers as they are stacked.

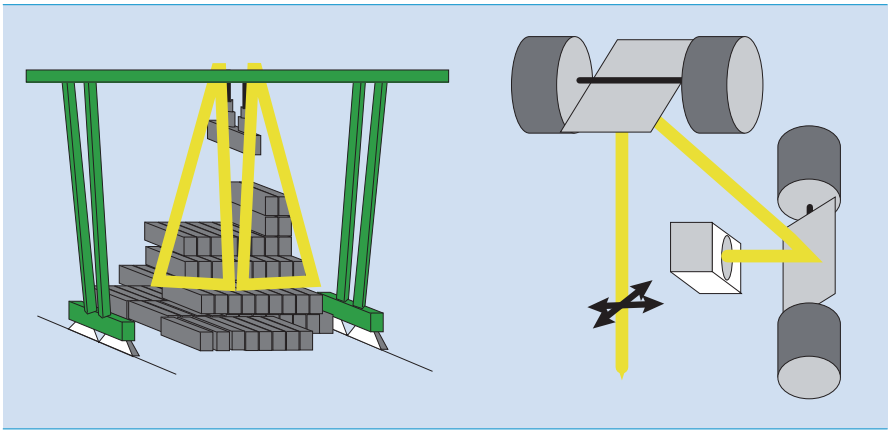
Load control

The ABB load control is based on a software model of the physics of the hanging load. This include algorithms to control the pendulum movements in trolley, gantry and skew (rotation around the plumb line) directions, which ensue every time a container is lifted and transported 7.

With the position feedback from the load position sensor external influences such as wind and asymmetrical loading can also taken into account. Optimum productivity is reached based on:

- Short but safe load path
  By traveling the shortest route, over the landscape of containers, substantial time is saved. The path is calculated based on measurements by the TPS.
- Fast approach to target
  The model based load sway and position control calculates the optimum approach for the load, with rope lengths of 3–50 meters and with trolley and hoist speeds of 300 m/min and 200 m/min respectively.
- Positioning without final adjustments
  The TPS provides continuous measurements of the target position enabling the load control to aim directly for the actual target position.

7 The automated movement of the trolley must take into account the sway of the container



Integration of information

Automatic cranes receive orders from the Terminal Operating System (TOS). The TOS optimizes the yard utilization, while the crane control system find the optimal transport path and is responsible for collision avoidance.

The crane control system manages the interaction with and deployment of remote crane operators. It also controls safe access for vehicles and staff into the automated area.

Large fleets of cranes makes it necessary to integrate the terminal wide maintenance and monitoring functions with the logistic and operations information. This provides operations as well as maintenance staff with a complete overview and control of the terminal as well as decision making support.

ABB and ports

ABB has developed an automation concept for container cranes enabling automation to be combined with efficient crane and terminal designs. Modern control theory ensures fast handling. Innovative sensors provide the flexibility needed in practical operation.

By providing standardized integrated systems including electrical and drive equipment and automation and terminal wide information management, ABB enables the rapid introduction of automation in new as well as existing terminals.

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Hoist and haul

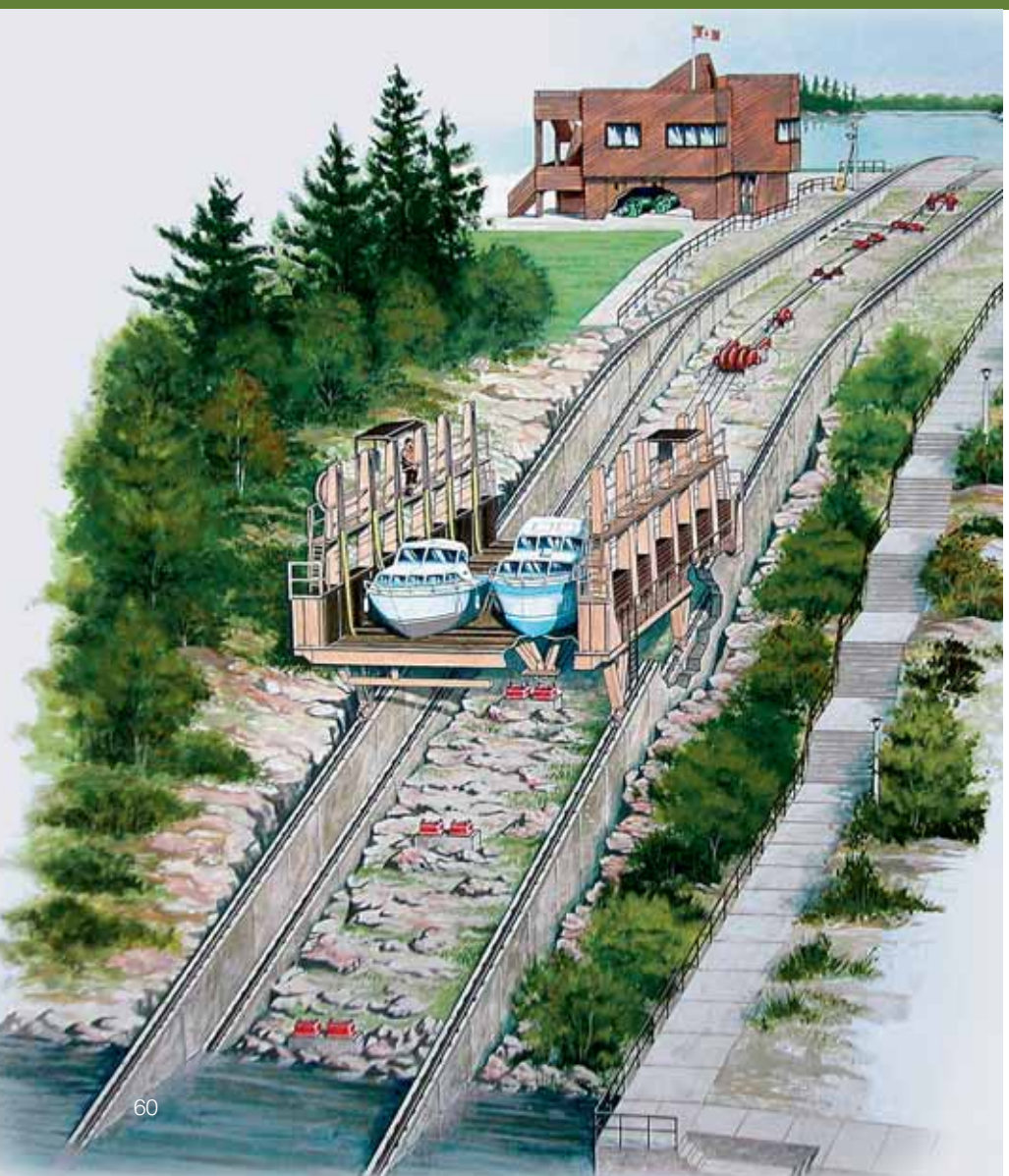
ABB delivers a unique hoisting system for a marine railway

Klaus Kacy

Boating along the waterways of Canada, few people think of ABB or of mine hoists. Even fewer are aware that it is this technology that is making their trip possible.

The Trent-Severn Waterway is a 386 km long waterway through Central Ontario between Lake Ontario and Georgian Bay. Its main purpose is recreational. A boat traveling along this route passes through a system of 44 locks. The Big Chute Marine Railway (BCMR) is one of these.

The implementation of the hoist was complicated by the variable incline, which changes from plus 20 percent to level and then to minus 20 percent – a transition the payload is expected to make without a jolt (wine glass test). ABB has risen to this challenge by adapting a hosting system using equipment otherwise used in mining hoists, and adding a number of novel features.



The Trent-Severn Waterway is a National Historic Site of Canada operated by the Parks Canada Agency. It is important to all Canadians as a symbol of their human heritage and identity.

The Big Chute Marine Railway (BCMR) is part of this waterway. Boats with passengers wanting to pass through the site are floated onto a partially submerged conveyance where they are cradled by slings. This conveyance runs on an inclined railway taking the boats out of the water, over an incline and back into the water on the other side 1. The whole process takes on average about 15 minutes. The operators of the hoist travel on the conveyance and control it using a two-way radio system. Because the people on the boats and on the conveyance are traveling in a horizontal direction and, for the most part standing, the smoothness of the trip is important.

The original BCMR system experienced operational problems and after several incidents, the Parks Canada Agency decided to replace it with a more reliable, safe and robust system based on mine-hoist technology. ABB was awarded a contract for a new system with four single-drum hoists, in-

cluding all necessary electrical equipment and engineering. The conditions of this contract were challenging. Only six months were allowed for delivery (including commissioning) and the warranty period was set to five years. Taking into account the unique character of the system and scope of the work (which included extensive civil engineering work within the hoist house), finalizing the order within the set time was a remarkable achievement.

Rope runs

The BCMR employs elaborate rope runs 2. There are four single drum hoists i, two on the east side (E1 and E2) and two on the west side (W1 and W2). The ropes from the east side hoists run via horizontal sheave wheels (S1 and S2) towards the vertical set of sheaves forming the east transition point e, from where they run to the hauling plate below the conveyance b. Likewise, the ropes from the west side hoists run via the west transition point f to the conveyance.

In the situation shown in 2, the hauling plate is between the two transition points e and f. In this situation, the ropes are attached to the plate from either side 4. Beyond these transition points, however, all ropes attach from the same side 3.

New hoisting system for BCMR

The configuration of the track and arrangement of the rope runs requires different modes of operation of the hoist drives, depending on the direction of run and position of the conveyance. When travelling from east to west (left to right in 1) the hoist drives operate as follows:

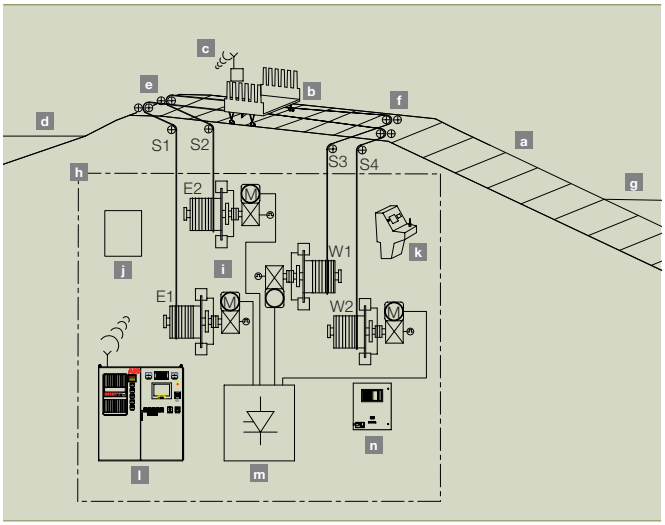
Between the east end d and east transfer point e, all four hoists are pulling the load (all are in motor mode). On the section between the transition points e and f, the conveyance is running downhill and hoists E1 and E2 are in braking (regenerating) mode. In order to keep the ropes of the hoists W1 and W2 tensioned, both these hoists must provide pooling torque. They therefore operate in motor mode. The total rope force seen by the conveyance is the difference of the braking force from hoists E1 and E2 and the pulling force from hoists W1 and W2.

When the conveyance is between the west transition point f and the west end of the track h, all four hoists are holding the descending load (regenerating mode).

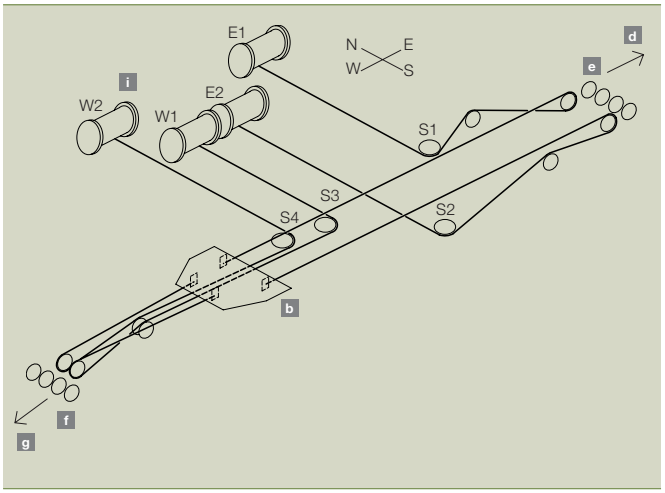
In the opposite direction, similar transitions in operational modes are necessary.

A distinct feature of the system is the reversal of the speed of one pair of hoists when the transition point is passed. For example when the conveyance is passing the east transition point e, hoists W1 and W2 maintain their speed equal to the conveyance speed, whereas hoists E1 and E2 slow down, stop and reverse their direction (switching from winding to unwinding).

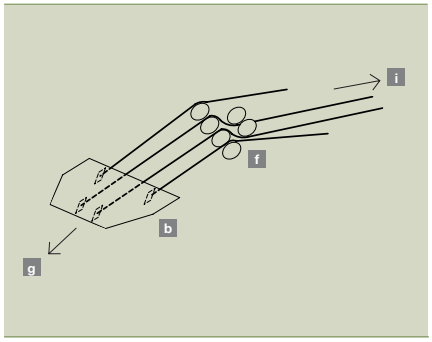
1 The railway and its hoist house a rail tracks b boat conveyance c control panel mounted on conveyance, d east end of railway e east transition point f west transition point g west end h hoist house i four single-drum hoists j brake-control unit k control pulpit, l hoist control cubicle with local control panel, m DC-drive system, n "electronic lilly"



2 The rope runs of the marine railway. The ropes change direction as the conveyance passes the sheave wheels (S1-S4)



3 In 2, ropes are shown attached to the conveyance from both directions. After passing the transfer point f however, all ropes run in the same direction



The requirements on the hoist control, drive and braking system are discussed in the Factbox.

A tour of the system

Hoists

The system has four single-drum hoists 5, each with a 2.14 m drum. The drum shell has spiral grooves for the 32 mm rope. Each hoist has four high pressure brake units - two on each side – acting on the same disc. The hoist drum is driven by a DC motor through a gearbox. Due to space restrictions, the motors are mounted

vertically. The relatively small size of the hoist room is dictated by environmental requirements for the whole hoist house (it is located in the regional park and its external appearance and size may not have industrial character).

Brake control

The brake control system consists of two independent units, each equipped with an emergency brake regulator providing gentle but effective deceleration under all load conditions. In an emergency stop situation, it must handle several scenarios of braking torque distribution between the hoists. This is achieved by differentiating the brake pressure between the two control systems and also by delayed application of the brake units for the hoists when in "pulling" mode.

The hydraulic part of the brake control systems 6 are standard ABB dual hydraulic stations, as used for mine hoists. They are stand-alone units with two pumps (one running, one on stand-by), an oil tank, oil conditioning components and valves providing regulated and unregulated braking.

4 The ropes are attached to the conveyance so that all four can pull from the same side, or two from either side

Hoist control

This is housed in the hoist control cubicle, the front of which has a control panel with a modern MMI (man-machine interface). This panel is used mainly during maintenance work.

The implementation of the hoist was complicated by the variable incline, which changes from plus 20 percent to level and then to minus 20 percent – a transition the payload is expected to make without a jolt.

The hoist control PLC (programmable logic controller) deals with all control and safety aspects of the hoists. It is basically a standard ABB mine hoist control system with additional functionality to cater for the specific features of this hoisting plant. One of the distinctive features of this system is the position determination of the conveyance. The system receives position signals from all hoists via incremental encoders. The position and speed of the hoists in transition areas do not reflect the speed and position of the conveyance. The hoist control PLC therefore has a software function to ensure a "jolt-free" and accurate transition of speed and position signals from one pair of the hoists to the other.

Hoist control stations

The BCMR hoisting system has a total of seven hoist control stations. In normal operation, the conveyance control station is used. This communicates with the system using a radio link. The other control stations are for maintenance and inspection purposes.

Hoist drive system

The railway has two digital ABB drives of type DCS-502. One drive controls the east hoists and the other the west hoists. For maintenance purposes, each drive can be switched to permit operation with a single motor.

The drive software has many features that were purpose-designed for this hoisting system. They include:

- Speed or torque control mode, depending on the load scenario (direction of run and position of the conveyance).
- In torque control mode, the torque (current) can either follow the torque of the other hoist pair or be set to provide minimum rope tension.
- A gentle "jolt-free" transition occurs between the modes.
- Different logic and parameters are used when operating with a single motor.

Both drives feature EMF (electromotive force) Control as is frequently used in ABB hoist drives. In this hoisting system, both motors reach their rated voltage when the speed attains 70 percent. After this speed-up, the voltage of the motors (EMF) is maintained constant by controlling the motor field. Such a control strate-

Factbox Requirements for Big Chute Marine Railway

The requirements on the hoist control, drive and braking system include:

Drive and control system

- To ensure equal rope tension in each pair of hoists, that pair must at all times maintain an identical rope pull and rope displacement.
- When all hoists operate in the same mode (motoring or regenerating), the momentary rope pull of all 4 hoists must be identical.
- To prevent the slackening of ropes, when one pair of hoists operates in motoring mode and the other in regenerating mode, the rope pull of the hoist pair acting on the conveyance from the downhill side must be constant.
- Because in the transition point area, the speed of one pair of hoists does not reflect the speed of the conveyance (in fact this pair changes direction in this area), the other pair of hoists must control the speed (and position) in that area, ie in the east transfer point area, the west hoists are responsible for speed and position control. The transition of speed/position control from one pair of hoist to the other must be "jolt-free" and accurate.
- There must be a smooth and gradual torque (rope pull) change in each transition point from constant torque providing minimum required rope pull of one pair of the hoists to equal torque for all hoist and vice versa. This is to minimize speed oscillation which could be amplified by the combination of rope flexibility, rope weight suspended in horizontal runs and high mass of the conveyance with payload (close to 200t).

Brake system

- Regulated emergency braking controls are used because emergency braking must be smooth and safe under different load conditions.
- Emergency braking torque must de differentiated between each pair of hoists when needed. For example, during downhill running from the eastern to the western transition point, the emergency braking force (torque) acting on the conveyance is to be provided only by the east hoists. The braking torque on the west hoists must be smaller than that required to slow down the rotating masses of these hoists, thus preventing slack rope condition and at the same time eliminating "bounce", which could occur if these hoists did not provide braking at all.
- When running uphill on the west slope (all hoists in motoring mode), the emergency braking torque must be minimal, so that the hoist drums do not decelerate faster than gravity can slow the conveyance. This prevents excessive slack rope condition. Furthermore, after stopping, a reduced mechanical braking torque must be applied initially to provide gentle roll-back of the hoists (and conveyance) during the "whiplash" effect caused by the slackened ropes. This reduces rope tension during the "whiplash" action and also reduces the "bouncing" effect the conveyance would be subjected to if full braking force were applied immediately after the hoists stopped.

5 This view of the hoist room showing all four hoists gives an idea of how restricted space is in this building

6 Mine hoist technology from ABB is not out of its depth when hauling ships. These are the brake control valves.

gy has numerous benefits: Negative effects of the drive on the network are reduced (through better power factor, lower voltage drop, and lower harmonic distortions). The AC ripple current in the motors is reduced, as is the DC short circuit current (motor short circuit torque).

Plain sailing thanks to ABB

The hoist can handle a payload of up to 90t. A single journey takes 15 minutes, and since opening, 11,000 boats have been transferred.

The hoisting system has proven its reliability and operated without a problem throughout the guarantee period. Parks Canada is very satisfied with its performance. This unique installation confirms ABB's mine hoist expertise and the quality of this equipment.

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Skipping constraints

CRP Azipod® propulsion creates new business opportunities for Shin Nihonkai ferries of Japan

Lars Anderson, Thomas Hackman

Shin Nihonkai Ferry, the leading ferry operator in Japan, took delivery of two innovative new-builds in 2004. The new RoPax (roll on – roll off passenger) ferries were the first vessels in the world to be installed with ABB's Contra-Rotating Azipod® propulsion. In their first months of operation, the ferries documented a remarkably improved fuel efficiency and transportation economics.

Shin Nihonkai Ferry, SNF Factbox 1, was the first company to open a ferry route in the Sea of Japan in 1970. It was the first to operate large high-speed ferries. In 1995, it had the two ferries, *Suzuran* and *Suisen*, built with maximum speeds of 31 knots. Another example of SNF's innovation was when it selected contra-rotating propulsion (CRP) with electric "pod" propulsion [1] for their two large high-speed ferry new-builds.

The largest and fastest ferries in Japan

The two newest additions to the SNF fleet, Hamanasu and Akashia, were delivered by Mitsubishi Heavy Industries (MHI), Nagasaki, in 2004.

With an overall length 224.5 meters, and with a service speed of 30.5 knots, these two RoPax ferries are the largest and fastest in Japan Factbox 2. They are also the first vessels in the world to take advantage of ABB's contra-rotating Azipod® propulsion system.

Major benefits from CRP pod propulsion

Shin Nihonkai Ferry operates an extensive network of ferry routes between the islands of Honshu and Hokkaido in northern Japan. The main reason for choosing CRP Azipod® propulsion was the increasing cost of bunker fuel. But a number of additional benefits were also gained.

At 573 nautical miles, the Maizuru-Otaru route is the longest in the network. Because of its length, the route had always required three ferries to provide a daily service. These three ferries, operating at 20 knots, covered the distance in 30 hours and were able to keep consistent arrival and departure times in both ports.

In order to provide a daily service with only two ferries, the vessels needed to be larger and able to maintain a cruising speed of 30.5 knots. Shin Nihonkai Ferry had been investigating how this might be achieved, but realized that the cost, in terms of fuel consumption, at these speeds would have been prohibitive.

For a two-ship solution to be viable, a remarkable (yet realistic) reduction in fuel consumption would have to be demonstrated to SNF.

When presented with the CRP Azipod propulsion concept, which promised high fuel oil cost savings, Shin Nihonkai Ferry became interested. After intensive research, MHI chose a single-skeg hull solution with CRP Azipod propulsion, an azimuthing 17.6 MW Azipod unit installed in a contra-rotating mode, aft of the main propeller 1.

There is always a risk involved when building a prototype. But, as CRP pod propulsion was the only solution able to achieve a 24-hour schedule and a daily ferry service, the decision to go ahead with the CRP Azipod propulsion was taken. In doing so, SNF and MHI broke the decades-long deadlock in the marine industry's attempt to seize the full benefits of contra-rotating propulsion Factbox 3.

Deliveries from ABB Marine included a 17.6 MW Azipod unit for each of the two ferries, working in tandem with a reduction-gear-driven CP (controllable pitch) pod propeller. ABB also delivered the control systems and the 27-MW, 6.6-kV power generation and distribution systems.

The layout of the propulsion plant features two Wärtsilä 12V46 engines driving a CP propeller through a twin-in/single-out gearbox. Another pair of 12V46 engines drives alternators that feed electrical power to the Azipod unit. The power distribution is 25.2 MW on the CP propeller and 17.6 MW on the Azipod, making 42.8 MW in total. In order to achieve the same vessel speed, a conventional twin-shaft propulsion system would require a total installed power of approximately 47 MW.

Demanding weather conditions

The weather conditions in the Sea of Japan can be divided into two distinct seasons, winter and summer. The winter season lasts from November through March and, during this time, the Sea of Japan is infamously stormy. The air temperature can drop below zero and, even though the sea never actually freezes, ice build-up on ships can be a problem. The winds during the winter storms often reach speeds of more than 30 m/s, with waves in excess of eight meters high.

Shin Nihonkai normally delays or cancels ferry departures when the height of the waves exceeds 5 meters but, because of the length of its routes, weather conditions vary and ferries can be delayed by unexpected storms. Maintaining a high average

Factbox 1 Shin Nihonkai Ferry Co., Ltd.

Trade name	Shin Nihonkai Ferry Co., Ltd.
Personnel	585 (land 231, sea 354)
Head office	Osaka, Japan
Branch office	9 offices in Japan
President	Yasuo Iritani
Main group companies	Kanko Kisen, Hankyu Ferry, Kampu Ferry, Orient Ferry, Japan Cruise Line, Kyowa Shoji

Factbox 2 Ferry specifications

RoPax ferries *Hamanasu* and *Akashia*

Length	224.82	meters
Breadth	26.0	meters
Depth, to 2nd deck	10.0	meters
Draught	7.4	meters
Gross Tonnage	34,131	tons
Deadweight	6,649	tons
Passengers	820	persons
Passenger cabins	144	pcs
Trailer	158	pcs
Private car	65	pcs
Max speed	32.04	knots
Service speed	30.5	knots
Power, installed	50,400	kW
Propulsion power, total	42,800	kW
Azipod® unit	17,600	kW

ABB Scope of Supply per vessel

- 1 × 3,450 kVA, 6.6 kV main generator
- 2 × 14,353 kVA, 6.6 kV main generators
- 3 × neutral point cubicles
- 3 × voltage regulator cubicles
- 1 × 6.6 kV main switchboard
- 2 × propulsion transformers
- 1 × excitation transformer
- 1 × propulsion converter
- 1 × 17.6 MW CRP Azipod® propulsion system
- 2 × thruster motors
- 2 × distribution transformers
- 2 × propulsion transformer pre-magnetizing device
- 2 × UPS
- 1 × CRP propulsion control system

speed is essential: a reduction in speed of as little as 1.5 knots can cause an hour's delay on this route.

During the summer season, the weather is calmer but the ferry routes are prone to relatively frequent typhoons. These are fairly easy to predict as they tend to be slow moving. Nonetheless, a ferry can be forced to sail through a typhoon to maintain the daily service.

Built to expectations

Mr. Yasuo Iritani, President of Shin Nihonkai Ferry, explains that he decided to go ahead with the project based on the positive result of their studies of the concept.

"The ships are somewhat more expensive than conventional ferries but the operational savings are big enough for us to recover the initial expense," he explains. Mr Iritani also comments that, with the new ferries, SNF has achieved its main objective of operating a 24-hour service on the Maizuru-Otaru route.

Compared with the existing service, the vehicle turnaround time is reduced by 25 percen.

"Compared with the existing service, the vehicle turnaround time is reduced by 25 percent, which is attractive to cargo distributors. For example, the reduced transportation time makes us an alternative to air cargo for high-grade perishable foodstuffs. This means we are not only improving our operations, we are also opening up new market opportunities."

Fuel consumption reduced by 20 percent

The target for *Hamanasu* and *Akashia* was to make a 10 percent saving in fuel oil consumption, as compared to conventional twin-screw ferries.

In May 2004, *Hamanasu* was the first ship to embark on the much-anticipated initial sea trials. In the speed tests, with a power split of 55 percent for the forward propeller and 45 percent of the aft, the vessel logged a maximum speed of 32.04 knots – a remarkable achievement.

Even more remarkable was the fuel oil consumption, which set a new benchmark in the industry. The sea

Factbox 3 General benefits of contra-rotating propulsion

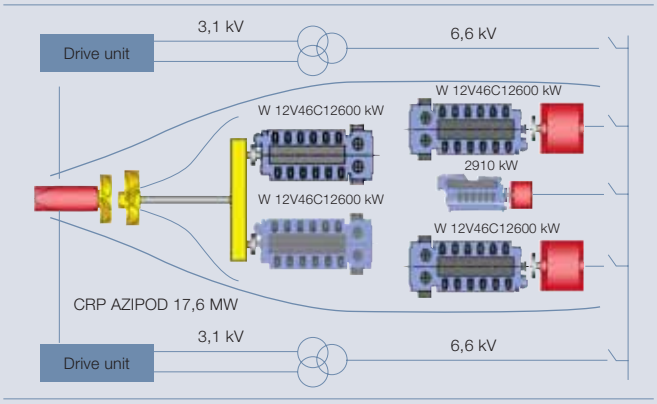
There are two main reasons for owners to consider contra-rotating propulsion. One is improved efficiency by being able to absorb rotational losses with the contra-rotating aft propeller. Contra-rotating propulsion also gives the benefit of thrust load distribution over a larger number of propeller blades in a confined space. The added total blade area results in improved cavitation characteristics, by which more power can be fed to a CRP propulsion system with smaller diameter propellers. This is especially important for powerful shallow-draught vessels. Without diameter restrictions, a third benefit is a system with less noise and cavitation. Additionally, by using an azimuthing electric propulsion unit aft, maneuvering characteristics are much improved.

Summary of benefits at Shin Nihonkai

The RoPax ferry Akashia and her sistership Hamanasu are the first vessels to be fitted with CRP Azipod® propulsion. The new ferries equipped with CRP Azipod® consume 20 percent less fuel than their forerunners – while providing a 15 percent increase in transportation capacity. Further savings are expected to be made through the reduction of operating costs related to maintenance and spare parts of the diesel engines.

The Route:
Daily service between Maizuru – Otaru:
573 NM
The options:
3 ferries – 20.0 knots, 30 hours
2 ferries – 30.5 knots, 20 hours
The challenge: high power needs with high fuel costs
The solution: The four-bladed main (CP) propeller with a diameter of 5.6 meters and an Azipod® propeller with a diameter of 4.8 meters and 5 blades.

From the hydrodynamically-efficient, single-skeg hull to the submerged, podded CRP Azipod® propulsion system, these vessels are designed for smooth sailing. Because power is shared between two propellers, the size of each propeller can be reduced, resulting in less noise and turbulence.



The Azipod® unit also serves as a rudder, smoothing out flow and increasing power. This improves steerability, especially at low speeds, facilitating maneuverability in harbor and reducing docking time.

Shin Nihonkai Ferries – Generic Machinery Arrangement

The total propulsion power is 42.8 MW with 25.2 MW (60 percent) distributed on the forward propeller and 17.6 MW (40 percent) on the Azipod unit.

The *Hamanasu* and *Akashia* ferries experience a remarkable hydrodynamic efficiency gain of 10–15 percent as compared to vessels with conventional twin-shaft arrangements. This ultra-high propulsion efficiency is achieved by combining two separate propulsion systems in a single-shaft configuration; a steerable azimuthing podded propulsion unit installed in a contra-rotating mode, aligned directly downstream of a mechanically driven main propeller but with no physical connection.

trials confirmed the findings from the extensive test made in MHI's model basin in Nagasaki. After several months of operation on their intended route, the owner has learned that the new vessels, for the same 24-hour service, will save some 20 percent in fuel consumption compared to the two old twin-shaft, diesel-driven ferries, which operated temporarily on the route. The service speed of the twin-shaft ferries was only 29.4 knots and their transportation capacity was 15 percent less than that of the new ships.

Improved maneuverability with Azipod® propulsion

The maneuverability of the ship was also of great interest. When maneuvering at low speeds and in port, the Azipod unit can be used as a rudder and side thruster. At cruising speeds the steering range of the Azipod is restricted, but, despite their size, *Hamanasu* and *Akashia* are able to maneuver at low speed, without tug assistance, in winds up to 18 m/s. Under these conditions, smaller, conventional, twin-screw ferries require assistance.

Flexible operation

The propulsion plant also offers great flexibility in terms of power distribution. For example, the ships carry a lot of perishable foodstuffs from Hokkaido, including dairy produce and vegetables. The cargo is transported in refrigerated trailers that require electrical power. However, on their return trip to Hokkaido, refrigeration is not required and the electrical power can be used, if necessary, for propulsion. Conversely, if weather conditions are favorable, the ship can sail one trip with only three engines, and still remain on schedule.

1 Contra-rotating propellers

The new vessels, will save some 20 percent in fuel consumption compared to the two old twin-shaft, ferries.

Operational experience

Mr Kiyoshi Takaoka, Marine Department Manager, says that the company is very pleased with the performance of the new ships. The maneuverability is excellent and the ships are very stable in rough seas.

Mr Takahashi, *Hamanasu's* captain, is also more than satisfied with his ship:

"Under normal weather conditions the course stability is excellent. We do not normally go out if the wave height is above five meters, but sometimes typhoons are unavoidable. Last summer we experienced typhoons and wave heights above eight meters with extreme winds. We reduced speed to 20 knots and, although it was a rough ride, the ship was fully maneuvrable. When maneuvering in port, I feel very safe because of the high thrust available from the Azipod unit; equaling that of two tug boats."

"When slow-steaming at five knots and below, the steering performance with the Azipod is still remarkable. The acceleration when leaving port is much better compared [to that of] other ships and, at full speed, the stern wave is very small, which indicates good fuel economy."

Having built these first two vessels, MHI can recommend Azipod CRP propulsion both for ferries and for high-day-rate vessels such as LNG (liquid natural gas) carriers, where redundancy is important.

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Gas spectroscopy

Fourier transform spectroscopy is an effective way of determining the chemical composition of gases. It is used from gasoline blending, through weather forecasting, to astronomy. Whereas the latter example uses visible light, the former two cases use the near-infrared band. Three interesting applications are presented in the following articles. The principle of the interferometer and the mathematics involved in making sense of the output are discussed in the fourth.

Helix Nebula, picture taken with Hubble Telescope (NASA, STSCI)

Counting photons

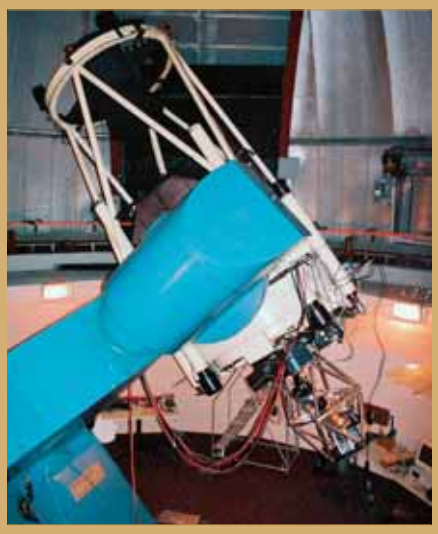
Fourier Transform Spectroscopy (FTS) was developed for astronomical telescopes in the 60ies, but found a far broader market in chemical monitoring in industrial processes. Refined and enhanced the technology is again equipping high-tech telescopes with measurement precision that almost counts individual photons. Today these telescopes are revealing the secrets of matter in the furthest reaches of the universe.

In late 2000 Laval University and ABB launched a joint effort to design an operational ground instrument for the 1.6 meter telescope of the Mégantic observatory in Canada 1. The instrument was first tested on the telescope in February 2004. In terms of the number of pixels (1.7 M) and the field of view (12 arc minutes), this IFTS (imaging FTS) is by far the largest ever used on a ground telescope and the only one to operate in the visible band. ABB is the integrator of the complete instrument, which includes an innovative step-scan FTS module, two CCD (charge-coupled device) cameras, two output optics lens assemblies and a collimating lens set. The instrument's overall dimensions are 133 × 80 × 80 cm and its weight is approximately 110 kg.

The design goal of this instrument is to maximize throughput and transmission to help astronomers collect as many photons as possible. The instrument operates in the 350–950 nm band to match the sensitivity of the two 1340 × 1300 pixel CCD cameras at the interferometer output ports. As the interference occurs at visible wavelengths, a mechanical control is required in the nanometre range. A piezo-based frictionless translation stage has been designed to control the angle and position of the moving three-inch mirror of the interferometer. A sophisticated laser-based metrology system optically reads the position and angle of the mirror 8000 times per second. A dedicated computer determines corrections to apply to the piezo translators in order to stabilize the fringe images and maximize the contrast recorded on the CCDs.

The dual output port design (2 CCDs) is achieved using flat mirrors and by inserting the science beam off-axis. This is the first implementation of this kind described in literature. The arrangement reduces the number of reflections encountered by the science beam. The beam splitter has a sophisticated multilayer dielectric coating that strongly modulates light in the specified waveband without contributing undesired absorption. The seven lenses used for collimating and re-imaging enable the fulfilment of the light-collimation requirement, and also the sub arc-second panchromatic point spread function at the image plane. About a million independent

1 The Mégantic telescope in Canada uses an imaging Fourier Transform Spectroscope from ABB

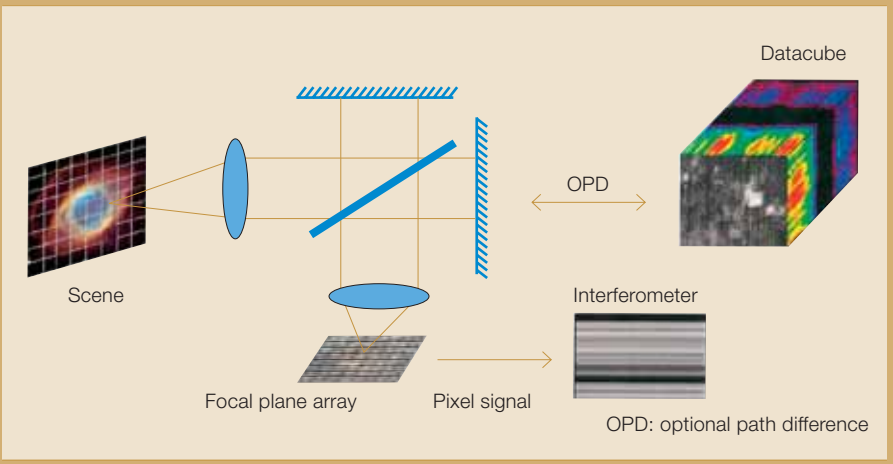


spectra can be collected from distinct scene elements. This is more than what is offered by traditional multi-objects/imaging spectrometers by a factor of about a thousand. The total system transmittance reaches over 60 percent (30 percent per CCD) at 500 nm thanks to the 90 percent quantum efficiency detector used. This is a value that is unmatched by any other spectrometer. The cameras are cooled with liquid nitrogen, enabling a very low readout noise (three electrons) and hence a high sensitivity. This instrument can literally count photons.

About a million independent spectra can be collected from distinct scene elements.

An imaging spectrometer produces cubes of data. This means that not only the two spatial coordinates of a light source are recorded but also the wavelength (or energy) of the photon. In other words, multiple images of the scene are recorded at various wavelengths. This set of images is called a datacube 2.

2 Schematic representation of an imaging FTS forming a datacube



The wealth of data from this IFTS comes at the cost of measurement time. A typical cube acquisition runs from minutes to hours depending upon selected parameters. However, as astronomers are accustomed to sitting and waiting for light to shine into their instruments, this is no impediment.

The instrument is still under commissioning at the Mégantic telescope. It is foreseen that it will be released to the astronomers in 2006 for use on any type of science programs. ABB hopes the interest raised in the community from the scientific papers published using this instrument will bring opportunities to build other units for the current generation of large ground based telescope (>10 m) or future space based facilities.

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Eye on the storm

The chemical composition of the atmosphere is rapidly being modified by gas emissions. High-quality measurements of the concentration and geographical location of these gases are keys to the understanding of the long term effects of these changes on weather patterns and the environment of the Earth.

Each molecule possesses a fingerprint signature in the infrared spectrum. These fingerprints can be visualized with Fourier Transform Infrared Spectroscopy (FTIR). Satellites equipped with ABB analyzers are providing data for a deeper understanding and early warning of environmental risks.

Human activity continues to increase emission of gases into the atmosphere. These are transforming its composition and properties. The resulting environmental effects, such as global warming, ozone layer depletion and air quality problems, have drastic consequences. (See also “Fourier analysis and the Greenhouse Effect” on page 71). Global warming accelerates water evaporation, which in turn increases average global precipitation. Soil moisture is likely to decline in many regions, and intense rainstorms could become more frequent. Air quality and climatic change also have significant economical and social impacts: Extreme weather conditions pose risks to human populations, either directly or, more frequently, to their means of production. To improve our ability to predict these phenomena accurately and to improve the scientists’ atmospheric models, more powerful data capturing tools are required. ABB Analytical Business in Quebec City makes Fourier Transform Spectrometers (FTS) that are carried onboard weather observing satellites.

The thermal infrared radiance emitted by the Earth’s atmosphere contains all the relevant information about the column of air being observed. When dealing with pollution measurement, atmospheric chemistry or the monitoring of ozone, the concentration of molecules is determined by measuring the absorptivity or emissivity of the molecules in the infrared band. For weather applications, the absorption and emission behavior of carbon dioxide at wavelengths around 15 micrometers allows an indirect measurement of the atmosphere’s temperature. Atmospheric windows, ie, parts of the spectrum where the

atmosphere is transparent to infrared light, permit the temperature of the Earth's surface to be determined. The portion of the spectrum between five and eight micrometers permits an indirect determination of the water content or moisture in the air. Not only do these measurements provide a total apparent temperature or humidity at the top of the atmosphere but they can also be used to retrieve precise profiles of temperatures and water vapor concentrations. This retrieval process transforms the FTS instrument into a powerful sounder, dedicated to the measurement of valuable atmospheric parameters, which are used to feed weather forecasting models.

The thermal infrared radiance emitted by the Earth's atmosphere contains all the relevant information about the column of air being observed.

Atmospheric infrared sounder

These atmospheric infrared sounders can be carried on two types of satellites. The first type is the Low Earth Orbiting (LEO) satellites, whose orbits are at altitudes between 700 and 850 km. The second type is at an altitude of 36,000 km in an orbit that is said to be geosynchronous[1]. These two types of orbits address different needs but also come with different technical challenges and constraints. On a low Earth orbit, the spacecraft takes 100 minutes to circle the planet. To avoid smearing effects (because of the great speed of the satellite relative to the Earth's surface), the measurement time must be very short. This sets high demands on sensitivity.

Geosynchronous instruments, on the other hand, always align with the same location on the surface permitting the measurement to take far longer. However, the greater distance between the spacecraft and the Earth's surface means that the amount of light reaching the sensor is small, again affecting sensitivity requirements. Also, geosynchronous sounders cannot provide global measurements of the earth (because they are "locked" at a given latitude).

The sensors currently used for the atmospheric sounding in the thermal infrared area use an array of narrow band filters to provide spectral information. The number of filters that can be carried is limited (often not more than 20). Moreover, due to the nature of the filters and the width of the required spectral coverage, the spectral bands are not contiguous, meaning there are many gaps in the spectrum and hence missing information. An infrared sounder based on a dispersive spectrometer or on a Fourier transform spectrometer (FTS) offers a much more contiguous spectral view. For instance, the CrIS[2] (Cross-Track Infrared Sounder) will provide over 1300 spectral channels of information and will be able to measure temperature profiles with a vertical resolution of one km and to an accuracy approaching one degree Celsius. Due to its on-board spectral reference – a monochromatic laser diode – the instrument spectral response is also very stable over the life of the mission. Furthermore, the FTS technology is very robust and highly reliable – making it ideal for long-term operational missions.

ABB is currently under contract from ITT Industries to build CrIS sounders for the NPOESS (National Polar-orbiting Operational Environmental Satellite System) satellites. ABB is designing and building the interferometer and its metrology system, and the blackbody that will be used for the in-flight radiometric calibration of the instrument. ABB is also involved in

Footnotes

[1] A satellite in geosynchronous orbit appears stationary to an observer on the Earth's surface.

[2] The Cross-track Infrared Sounder (CrIS) will replace the High-resolution Infrared Radiation Sounder on the next generation of National Polar-orbiting Operational Environmental Satellite System (NPOESS) in the USA. The CrIS will provide improved measurements of temperature and moisture profiles in the atmosphere from an altitude of about 850 km. See "http://www.ipo.noaa.gov/" for more details.

[3] The Canadian SCISAT satellite helps a team of Canadian and international scientists to improve their understanding of the depletion of the ozone layer, with a special emphasis on the changes occurring over Canada and in the Arctic. The ACE-FTS instrument on-board SCISAT measures simultaneously the temperature, trace gases, thin clouds, and aerosols found in the atmosphere from an altitude of 650 km. The satellite was launched by NASA on August 2003 and is successfully operational.

Fourier analysis and the Greenhouse Effect

The Earth receives large amounts of solar radiation (about 1.7×10^{17} W outside the atmosphere, or 1366 W per square meter, with a peak wavelength at 500 nanometers). If all this energy were trapped on the Earth, the planet would heat up very quickly. Fortunately, the Earth reflects about 30 percent of this radiation. The remainder is absorbed by the planet (16 percent by the atmosphere, 3 percent by clouds and 51 percent by land and water). It is this radiation that makes life on Earth possible. It drives photosynthesis in plants and powers the water cycle and other natural phenomena. This energy is eventually re-emitted as radiation over a broad frequency range (peaking at about 15 micrometers in the infrared). About 71 percent of the surface radiation is, however, re-absorbed by the atmosphere, slowing down the Earth's natural cooling rate. Without this absorption, the average surface temperature on the Earth would be –17° C instead of +15° C. The observed increase in concentration of greenhouse gases is boosting the ability of the atmosphere to absorb radiation, so further increasing the surface temperature (CO_2 concentration has risen from 313 ppm in 1960 to 375 ppm in 2005 according to Mauna Loa observatory in Hawaii).

To obtain further data, the Japanese Space Agency is developing a satellite mission. Its Greenhouse gases Observing SATellite (GOSAT) uses an interferometer designed and built by ABB. It will certainly provide much more information on the concentrations of the molecules that contribute to the warming effect of the Earth's atmosphere.

The mechanism now known as the Greenhouse Effect is no new discovery. It was first postulated by Joseph Fourier in 1824 and quantified by Svante August Arrhenius in 1896. It is interesting to note, that Fourier was working on the problem of mathematically describing heat conduction and infrared radiation – making it all the more fitting that Fourier's other great discovery, Fourier Analysis, remains an indispensable part of the instrument.

the definition of the level-one data processing algorithms.

The CrIS will be able to measure temperature profiles with a vertical resolution of one km and to an accuracy approaching one degree Celsius.

To increase reliability, complete redundancy is implemented for the metrology sub-module and for the electronics.

The scanning mechanisms are of a frictionless, flexure-mounted design. These avoid the wearing down of the moving assembly that is so often a problem in space instrumentation.

Delivery of the first flight unit took place in November 2005 and flight models two and three were added in the following months.

Decades of experience

FTIR technology was originally designed to look into Space. After finding its way into a whole range of other applications, the technology has been launched into orbit and is looking back at Earth from Space. ABB's expertise in the design and manufacturing of Fourier Transform Spectrometers, which modulate the IR beam in a wavelength selective way by means of optical interference, (see "Waves to data" on page 73), is based on its experience in the early 1970s with balloon-borne FTS instruments and later on with several additional projects[2),3)]. This elegant and powerful method of obtaining a spectrum will continue to serve atmospheric observation needs for many decades to come.

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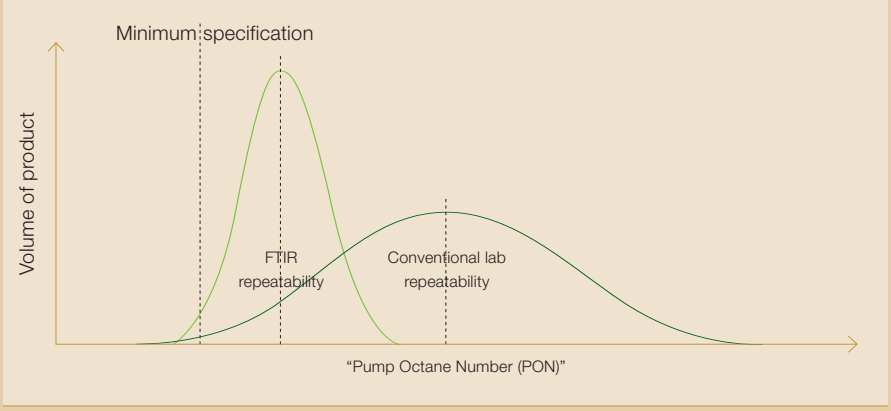
Spectrum of blending

Product blending is an important technique in the refining industry. It is the final stage in the conversion of crude oil into useful fuels. The blender mixes several streams from various process units to provide fuel that meets government, international or customer specifications. As it represents the final stage in a refinery process, its optimization is vital – the benefits of upstream process optimization are easily negated when poor blending produces either a substandard fuel or – more frequently – sacrifices refining margin through suboptimal use of expensive blend feedstocks. This is the step whose optimization frequently offers the greatest benefits in terms of payback.

A sustained global increase in the demand for light fuel, driven by the emerging economies – especially China and India – has led to the strengthening of refining margins. This development is continuing despite the rising crude oil prices of recent months. The availability of high production margins for final products has re-emphasized the role of on-line

process spectroscopy using Fourier Transform Near Infrared techniques, FT-NIR, in high-value final product optimization applications, including gasoline product blending. The benefits offered by process FT-NIR include multi-property, multi-stream analyses, high analysis repeatability (normally significantly better than conventional on-line analyzers), and accuracy meeting ASTM (American Society for Testing and Materials) norms. In addition, process FT-NIR analyzers are able to model not only direct chemical compositional information, but also bulk process stream properties such as octane, aromatics, distillation curves, cetane, cloud point – which are often the properties most required by unit optimizers, or the most constraining in terms of product release. All of these properties can be extracted from a single FT-NIR spectrum.

1 Reducing giveaway with precise blending control



The analytical accuracy of FT-NIR is as good as the ASTM laboratory reference data used to develop the calibration models, provided good statistical practices are followed. It is perhaps not always fully appreciated how much analytical repeatability and analyzer availability can be improved by the use of process FT-NIR as compared to conventional multi-analyzer blend optimization schemes. For light hydrocarbon streams, the inherently ultra-low-noise optical technology of FT-NIR can yield exceptional analytical repeatability.

The outstanding repeatability of ABB's FT-NIR gasoline property measurement is of significant benefit to the blend operator. Changes in blend properties can be tracked precisely during blending. Such changes would otherwise be "lost" in the noisy or infrequent results that are retured by classical analyses. The operator or multi-variable control scheme can make process decisions with the confidence that the observed deviation is real. In addition, the increased repeatability as compared to the traditional laboratory method, means that a reduction in property giveaway can be achieved through tighter control closer to the lower boundary 1.

Giveaway can never be reduced to zero, but minimizing it as far as possible makes a decisive contribution to the refinery's overall margin.

Since the process FTIR analyzers used in refinery process stream analysis and unit optimization are secondary analyzers (depending for their operation on correlation models using laboratory reference data), it is important for validation purposes that an on-going SQC (Statistical Quality Control) track-record of performance relative to laboratory standards is maintained.

Better earnings through better analytical accuracy

It is possible to calculate "baseline" giveaway associated with an analytical uncertainty of 0.1 Pump Octane Number (PON). This giveaway can never be reduced to zero, but minimizing it as far as possible makes a decisive contribution to the refinery's overall margin. For every 100,000 bbl/day of plant production a very conservative improvement (an analytical precision of 0.02 to 0.05 PON) in final product leads to a saving in the range of $ 1.5 M to $ 3.0 M per year [1].

Clear arguments for FTIR

FTIR is the technology that currently offers the best trade-off in terms of price, performance, value and risk. As an optically-based technology, it allows for the highest flexibility in multi-stream, multi-property applications. It is compatible with both local, fully extractive sampling and remote, multi-cell extractive fiber-optic based analyzer systems. It offers a multi-property analysis with rapid analysis cycle times, well tuned to the requirements of an APC (Advanced Process Control) optimizer. It is also well established with hundreds of installations globally, providing examples of successful implementation. Historically, the limitation to any spectroscopic measurement for on-line, final blended product control has been the difficulty in developing, and more particularly maintaining, robust stable calibration models. This has been to a large extent mitigated by recent developments, including very well-controlled analyzer-to-analyzer variability, which permits easy maintenance and transportability of developed calibrations. The exploitation of novel chemometric modeling procedures has helped to minimize the sensitivity of developed calibrations to changes in blending recipes.

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Reference

[1] ABB Review Special Report Instrumentation & Analytics, May 2006, pages 54–59

Waves to data

The light transmitted or emitted by a gas contains a wealth of information on its chemical composition in the form of spectral lines. A Fourier transform spectrometer is a device that extracts this spectrum. ABB Review takes a quick tour of two of the basic principles behind the instrument – the interferogram and the Fast Fourier Transform.

The Michelson interferometer was developed in the 1880ies by the physicist Albert Abraham Michelson. In a Michelson interferometer 1, the incoming light 1a is split in two parts by a half-mirror beam-splitter 1b. The reflected part twice travels the distance d_1 to mirror 1c before returning to the beam-splitter. Similarly, the transmitted part twice travels the distance d_2 to mirror 1d. At the output 1e, interference occurs between the two rays. It is from this interference that spectral information is extracted.

Interference

2a shows waves spreading from a point source. In 2b and 2c a second identical source is added and the wave patterns are superimposed. In places, the patterns combine to form waves of up to twice the amplitude (constructive interference). Elsewhere, they cancel out leaving areas of calm (destructive interference). In contrast to these two-dimensional examples, the interference in an inferometer occurs principally along a single axis (shown in red in 2).

Fourier Transform Spectroscopy (FTS) was developed for astronomical telescopes in the 60ies, but found a far broader market in chemical monitoring in industrial processes.

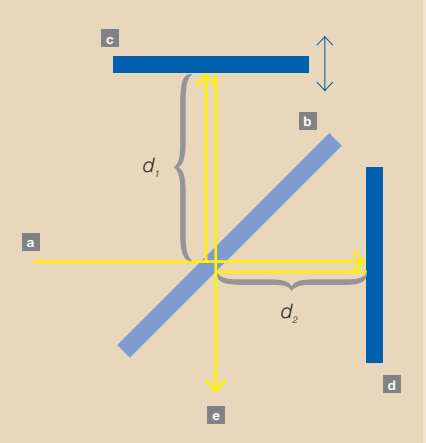
In 2b, the distance between the sources – or difference in path length $2(d_1–d_2)$ – is a multiple of the wavelength. Maximum constructive interference occurs along the axis. In 2c, the distance is shortened by half a wavelength leading to destructive interference. More generally for such a monochromatic input, the strength of the signal at any point on the axis varies sinusoidally as a function of the path difference, and at a wavelength that is identical to the signal wavelength.

$$I(d_1;\lambda) = \frac{I_0}{2}\left\{1+\cos\left\{2\pi\,\frac{2(d_1-d_2)}{\lambda}\right\}\right\}$$

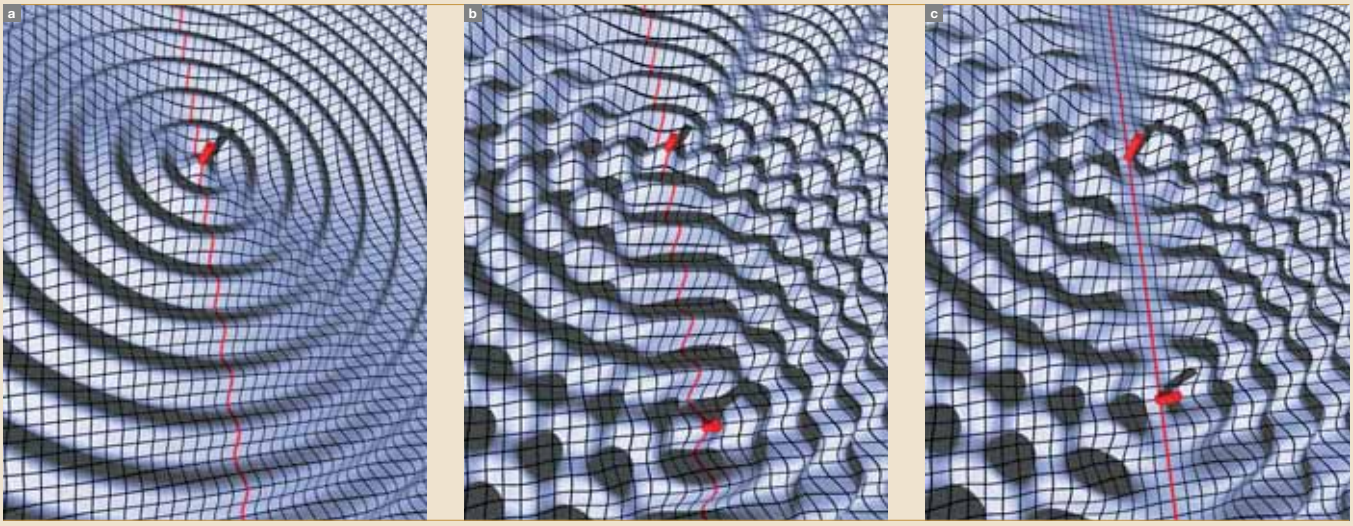
Where I_0 is the amplitude of the incoming ray 1a and λ is its wavelength. Using a detector at the interferometer output 1e and varying d_1, this function (the interferogram) can be plotted and the values of I_0 and λ determined.

A real measured signal usually has a broad range of superimposed frequencies. The resulting interferogram is the sum of the interferograms of its monochromatic components.

1 Principle of the Michelson interferometer



2 Interference of two identical wave patterns: The distance between the sources determines whether constructive b or destructive c interference occurs along the red axis. The sides of the small squares are equal to a quarter wavelength.



$$I(d_1) = \int I_0(\lambda) \frac{1}{2} \left\{1+\cos\left\{2\pi \frac{2(d_1-d_2)}{\lambda}\right\}\right\} d\lambda$$

Further processing is required to separate these signals.

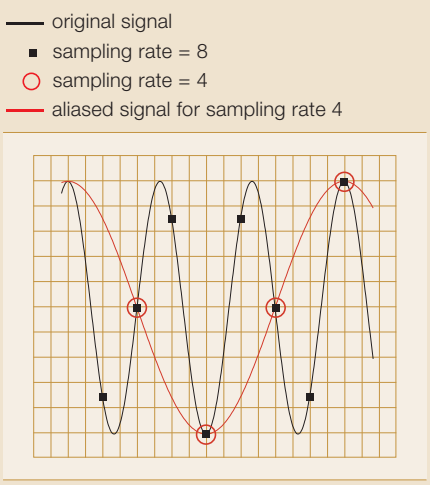
From Fourier to Fast Fourier

In the early years of the 19th Century, the mathematician Jean Baptiste Joseph Fourier developed a transformation that maps a function to its frequency spectrum:

$$F(k) = \int_{-\infty}^{\infty} f(x)\, e^{-2\pi ikx} dx$$

Where $f(x)$ is the function to be analyzed and $F(k)$ its frequency spectrum.

3 Low sampling rates mean frequencies cannot always be identified unambiguously



Digitally recorded signals usually consist of a finite series of numbers acquired at a regular interval. The corresponding Discrete Fourier Transformation (DFT), derived from the general formula is:

$$F_n = \sum_{k=0}^{N-1} f_k\, e^{-2\pi ink/N}$$

Where f_k is the k-th element of the recorded series, F_n is the n-th element of the corresponding frequency series and N is the number of samples. This algorithm has one major shortcoming: Its complexity rises quadratically with N. Historically, its use was often beyond available computational means. Various, often inadequate, approximations were adopted.

The light transmitted or emitted by a gas contains a wealth of information on its chemical composition in the form of spectral lines.

All this changed in 1965 when Cooley and Tukey published their Fast Fourier Transformation (FFT) algorithm.

How does it work?

One effect of reducing the sampling rate is that information is lost. 3 shows a sinusoidal curve (black) sampled at a rate of eight (black points) and again at four (red circles). At the latter rate, the sampled signal cannot be distinguished from the red curve and consequently its DFT is identical (the red curve is called the *alias* of the black – such aliasing occurs for all frequencies above half the new sampling rate). A separate DFT performed on the omitted points returns an equally ambiguous result, but comparison of the two DFTs restores the lost information. Instead of calculating one eight-point DFT, two four-point DFTs are performed, each of which requires a quarter the computing power of the original. This reduction is repeated recursively. The FFT algorithm is thus most efficient when the number of samples is a power of two.

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For further information on applications of Fourier transform spectroscopy, see *ABB Review Special Report Instruments and Analytics*, June 2006, pages 46–60 and 76–79.

AquaMaster™ flowmeter

Maintaining groundwater levels and detecting water leakage are but two important applications of the latest model of ABB's flowmeter the AquaMaster™ equipped with remote signal transmission.

AquaMaster™ helps mining giant protect wetlands

Maintaining groundwater levels in the marshes surrounding the open-cast lignite mines in Germany is a responsibility the power company RWE takes seriously.

The mining company RWE Power uses ABB's electromagnetic water meters to help preserve groundwater-based marshes and wetlands around its German coal mines. The meters monitor the amount of water being pumped back into the nature reserves from RWE's open-cast lignite mines, where constant pumping is needed to control groundwater levels in three large mines. Recently RWE ordered 25 AquaMaster™ instruments for this purpose.

In the past, RWE used mechanical flowmeters to measure the amount of water pumped back into the marshes. The need for more accurate measurements and automatic data monitoring made electronic flowmeters an attractive proposition. However, with many of the meters located beyond the reach of mains electricity, it was difficult for RWE to find a suitable electronic alternative for the sites.

AquaMaster™ meters from ABB provided the solution. Fitted with their own battery power supply, the flowmeters can be installed in locations where no mains supply is available.

Whenever RWE maintenance engineers find that a mechanical meter has failed, they now replace it with an AquaMaster™ meter. With a measurement accuracy of ± 0.5 % over a turndown range of 1000:1, the meters can deliver precise measurements, even at extremely low flow rates, compared with their mechanical counterparts, which can offer an accuracy of only ± 2 %.

In addition, ABB has now become RWE Power's preferred supplier of meters to monitor pumping stations in the mines. Here, since the availability of mains power is not an issue, RWE has opted for ABB's COPA XE, compact electromagnetic flowmeters.

Erosive particles in the untreated mine water attack and wear the mechanical meters, so the company decided to test 11 such units in its mines over a period of nine months. The units proved so successful that RWE has already ordered a further 35 instruments, ranging in size from DN50 to DN300.

Whenever RWE maintenance engineers find that a mechanical meter has failed, they now replace it with an AquaMaster™ meter.

The AquaMaster™ and COPA XE are just two examples of ABB's wide choice of electromagnetic flowmeters for conductive fluids such as water, pastes, acids, dyes, juices and emulsions, including fluids with a conductivity as low as 0.5 µS/cm. For more information, please visit www.abb.com/instrumentation.

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Tracing water leaks

In the past several years much of the world's attention has been focused on global warming, greenhouse effects and the conservation of precious natural resources. Clean water is part of this latter group and the significant losses seen in most water networks represent a major concern.

In direct response to this challenge and customers' requirements to conserve drinking water, ABB has developed and commercialized a revolutionary new product for the water industry. The new enhanced flow meter, AquaMaster™ SMS that delivers measurement data from remote locations direct to customers via the Internet, heralds a new era in water leakage management.

The AquaMaster™ is a product that is on the cutting edge of technology with features and applications that are unique within the water conservation and distribution market.

The latest models of AquaMaster™ have built in options such as an integrated pressure sensor but also data logging capability and GSM SMS radio technology. The data logging capability is significant in that it allows recording of flow and pressure at a normal rate of every 15 minutes, saving three months of data locally. But in addition, and by virtue of the digital connection between the flow measurement and the data logger, high resolution data can be logged at rates not possible with traditional solutions. This is much more significant than it first appears.

Measuring transient flows

With a traditional external data-logging solution, pulses are captured over the logging interval, but, due to upper frequency limitations by the flowmeter, only a limited number of pulses can be counted in the log interval. So for a meter with a large turndown ratio, it is not uncommon to get measurement or "quantization" errors of around 10 percent or more, the data being very stepped or "quantized" as a consequence. AquaMaster™, with its direct digital connection to the data logger, reduces quantization associated errors to insignificant levels. In addition, in a second channel, it offers high speed,

high resolution logging at an interval of up to 15 seconds. This is invaluable for capturing transients during network step testing. Within water networks, step testing is a well established technique for localizing water loss in a zoned distribution system. It requires the establishment of zones, where water can be supplied through a single meter after all boundaries and circulation valves have been closed.

Water leakage management

Closure of a valve isolates a specific section of the zone. A large drop in flow indicates a leak within that section. The benefit of AquaMaster™ in such step testing is best illustrated by comparison of 1a, on a traditional 15 minute log interval with 1b, captured in great detail from the second channel's one minute log.

In this step test, one zone valve was closed at 02:30, with a further zone valve closed at around 02:40. From the one minute log, the zone with a significant leak was clearly identifiable from the sudden drop in flow, with a second smaller leak within the second zone. The magnitude of the leak in the two zones is substantial – at around 2 m³/hr.

Step testing with AquaMaster™ is far simpler, cheaper and faster than established practises. It no longer requires a skilled technician with an external step-test data logger. All that is necessary is a simple procedure and a person to close a valve at specific pre-agreed times. Also, any disruption to water consumers is minimised by restricting the time a valve needs to be closed to only a few minutes. Within the following week, the high resolution logger can be downloaded and analysed to identify the source of the water leak. This step testing process is significantly enhanced by the use of radio communication to obtain meter data.

Traditionally, data is logged externally from the flow measurement and recovered manually by sending someone on site to download the data, or sometimes by retrieving the entire data logger and exchanging it with a second one. More recently, customers have switched to using radio for meter reading.

Radio equipped AquaMaster™

ABB's innovation is to equip AquaMaster™ meters with the option of GSM SMS radio technology. In 2005 this feature was upgraded to use SMS text messaging to convey flow and pressure data. SMS text messages are automatically sent, typically once per day to conserve power in the case of a battery powered device. In the event of a fault, an SMS message is sent as an alarm, eg if the meter is being tampered with.

The AquaMaster™ also responds to SMS text messages sent to it, such as configuration changes or requests for specific data. Up to three months of data can be stored internally.

AquaMaster™ offers high resolution logging at an interval of up to 15 seconds. This is invaluable for capturing transients.

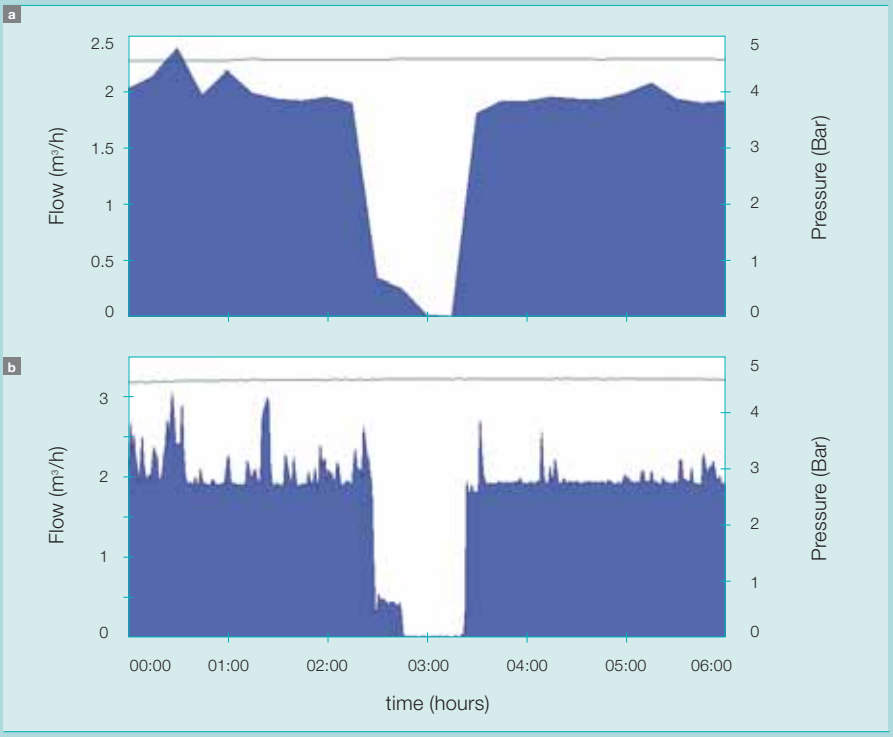
Measuring and logging the flow and, optionally, pressure are only part of the equation. Getting the collected data onto the customer's computer, management information or leakage-management system is the other part. Discussions with key global customers showed that they could be partitioned into two groups with different requirements:

1) Customers with an existing infrastructure and established water management system.
2) Greenfield customers who have measurement requirements but no back office system to handle the measured data.

To address both customer needs, ABB devised a solution based on delivering remote meter data via SMS text messages to virtually any database, using industry-standard programming mechanisms.

AquaMaster™ SMS is unique in that the volume totals from the instrument index register are also sent by SMS text message.

1 Leak detection: Step testing – 15 min a and 1 min b data logging



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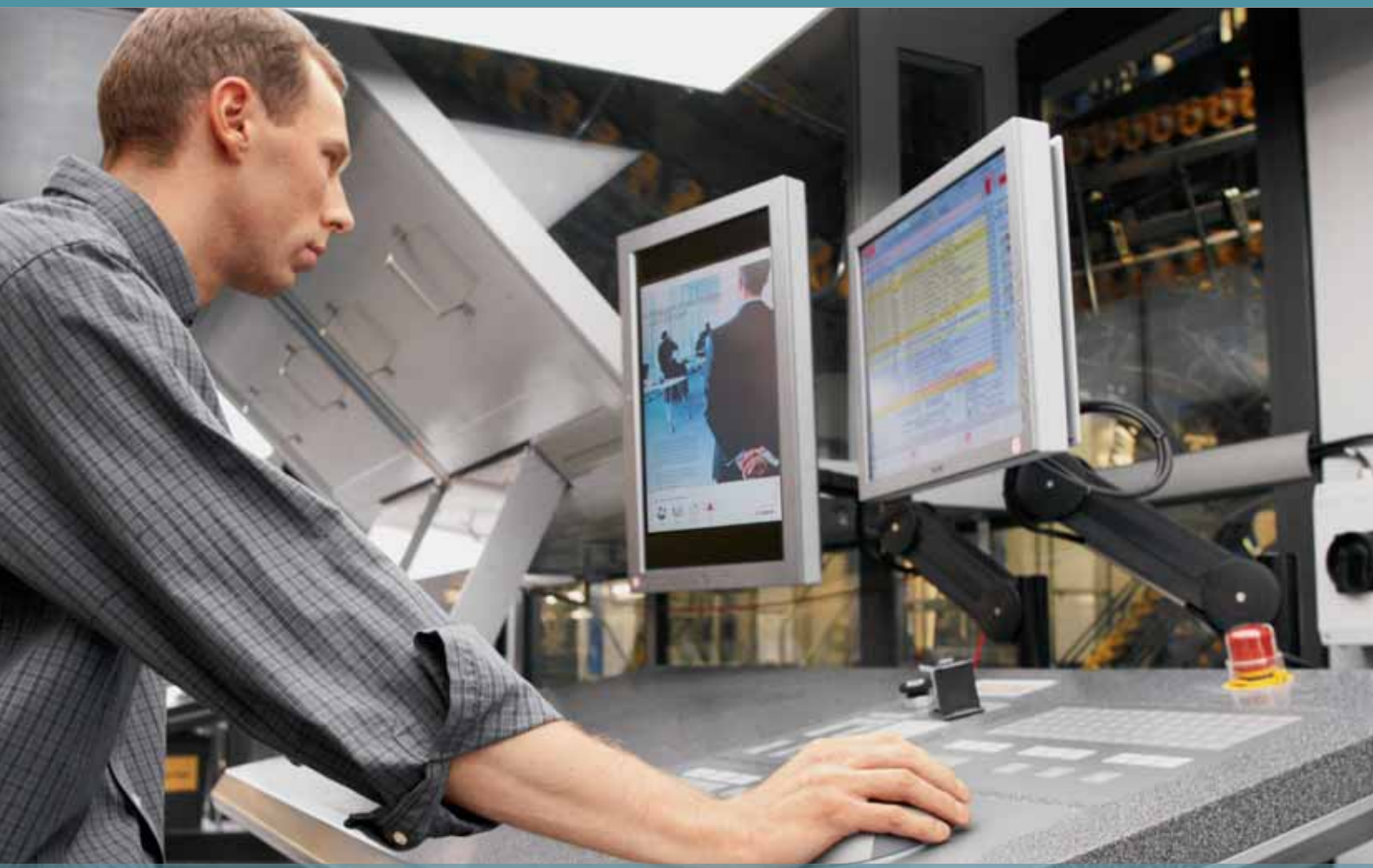
Making news

From automation supplier to system integrator

Steve Kirk

Reading the newspaper at the breakfast table is a long-held tradition, but rumor has it that the printed page is in decline. Happily, that rumor does not stand up to scrutiny. Although growth is indeed stagnant in some markets of the world, in others, it is growing in leaps and bounds. Automation is playing an ever-greater role in the high-tech printing process and ABB is leading the way. Developments in automation and systems integration will ensure the presence of newspapers at the breakfast table for a long time to come.



Commercial newspapers have been around since the early 17th Century, but some now believe that printed news has had its day. Others say that the future of newspapers is assured until we can swat a fly with a PC! However, the fact remains that newspaper publishing is a high-tech industry with an annual turn over of billions of dollars, and while circulations are rather flat in some countries, in others they are booming. Even in countries with stagnating circulations, the trend towards increased color advertising is driving major investment in printing technology. At the forefront of innovation in this technology is ABB's Center of Excellence for Printing, in Baden, Switzerland.

Newspapers have to be delivered on time. A steel works or a shoe factory can always sell yesterday's production, but yesterday's newspapers are worthless.

Newspaper printing process

The process of newspaper production runs under intense time pressure. Production has to start as late as possible (maybe at 11 pm) so that the latest news and sports results can be included. But the newspapers still have to be delivered on time early the next morning. A steel works or a shoe factory can always sell yesterday's production, but yesterday's newspapers are worthless.

1 shows an overview of the newspaper production process. The first step is to define the structure of the newspaper according to the needs of the editorial and advertising departments.

Editorial offices are often located in city centers, while production facilities are generally situated on the outskirts. Despite this separation, the two entities must work together to combine the editorial contributions with advertising material to assemble complete page layouts and, ultimately, the finished newspaper. The page layouts, usually in the form of one PDF file per page, are transmitted to the production facility, where they pass through a RIP (raster image processor) device. This generates TIFF files (ie, bitmaps) for the different color separations. Color printing is normally achieved by combining the four process colors Factbox 1. Because each color is printed separately, four separations are needed, with one printing plate for each color. These plates are produced in a device known as a plate-setter.

Ink supply

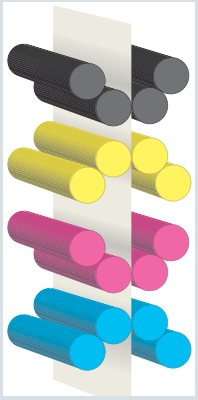
The TIFF data are analyzed to calculate the optimal amount of ink coverage for the various zones across each page. The press management system uses these data to compute the correct ink supply settings on the press. The press management system also knows which impositions[1)] are required. The user selects the preferred variant and the press management system obtains the optimum settings for the adjustable elements on

Newspaper printing press with ABB controls at Singapore Press Holdings

Factbox 1 Offset printing

Almost all newspapers are printed using the offset process. To produce full color images it is necessary to print four different process colors: cyan, magenta, yellow and black. In a typical newspaper press, the web of paper, which can be up to 6 pages wide, passes through four pairs of printing couples, one pair for each process color./box The outermost cylinders in the diagram are the plate cylinders on which the printing plates are mounted. The image to be printed lies on the plate in the form of a water-repellant material. As the plate cylinder rotates, it is first dampened with water, which adheres only to the non-image areas, and then ink is applied. The ink adheres only to the dry areas and therefore corresponds to the image. As the plate cylinder rotates further, the ink is transferred to the blanket cylinder, producing a reversed image. The blanket cylinder then rotates further and transfers the ink to the paper.

To produce a sharp image, the different colors must be aligned very precisely with each other. In the past, this was done using gearwheels and shafts, but almost all modern presses now achieve this by providing each printing couple with its own motor. All of the motors are then synchronized electronically – another technique pioneered by ABB.



the press (eg registers or compensators, web tension control elements) from its database of previously used values. The press management system also stores the curves for adjusting the ink and water supply based on the press speed. As soon as the operator at the press control console is ready to prepare the production, the values are sent to the press controls and set on the press.

ABB Printing diversified and evolved into a true IT supplier, providing software solutions for managing the entire newspaper production process.

Paper feed

The press also needs paper, of course. This is handled in a separate process. The goods-in department registers the reels of paper as they are delivered and transfers them to the main storage area. Reels are then unpacked and prepared for use according to the production plans for the coming 24 hours. They are transferred as required to the reelstands – the part of the press that runs the paper into the printing units and changes reels at full production speed (typically about 12 m/s) by gluing the new web of paper onto the old one and cutting through the remainder of the old web. In larger print works, the movement of paper reels is fully automated using automatic guided vehicles (AGVs).

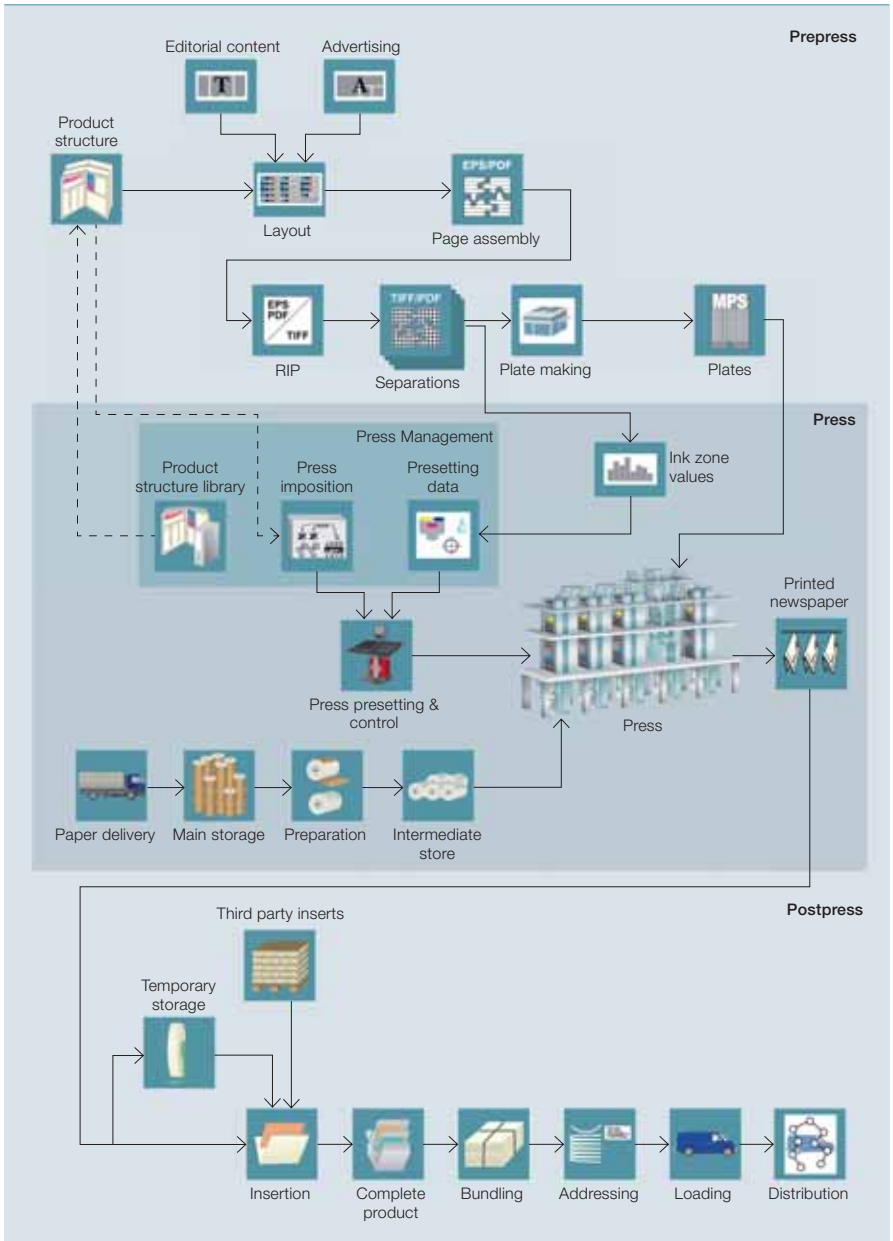
Post-press

After printing, the printed papers are transported from the press into the post-press area, also known as the mailroom. If the product is a preprint that belongs to a later newspaper, it is wound onto disks for storage 2. Otherwise, the newspaper goes on to the inserting drums. These machines are used to insert additional print products into newspapers. These can be either preprints, as mentioned above, or third-party inserts, such as brochures and other advertising material. This completes the newspapers, which are then bundled together, addressed and loaded onto trucks for distribution.

ABB as integrator

Where does ABB come into all this? The answer these days is – just about everywhere. ABB's Center of Excellence for Printing was originally a standard automation supplier providing drives and control systems for the printing press and the press management system, MPS (Master Printing System) Production. See also Factbox 2. However, as the press manufacturers began to deliver the drives, and later the low-level controls themselves,

1 Overview of the newspaper production process.



Factbox 2 Pioneering history

ABB has a long history as a pioneer in the newspaper printing industry. Some of the past highlights are:

1973: first programmable controllers on newspaper printing presses
1977: first computer-assisted production planning and press presetting in the world
1985: first screen-based control consoles for a newspaper press
1994: first shaftless printing press with individually driven printing couples

ABB Printing diversified and evolved into a true IT supplier, providing software solutions for managing the entire newspaper production process. It extended the MPS family step by step, with many new applications. Factbox 3.

Integration is the keyword here. While other suppliers can provide systems to support one or other of these sub-processes, ABB can provide its customers with tightly integrated system modules for the entire process. An example makes the benefits clear. Consider the integration of the three system applications MPS Production, MPS PageManager and MPS PlateWorkflow. MPS Production knows what the press can produce. It passes this information to MPS PageManager so that this system can ensure that only products that can be printed are defined by the users. The integration between MPS Production and MPS PlateWorkflow means that MPS PlateWorkflow automatically knows, what imposition is to be used and can mark the plates with the location on the press at which they should be mounted. MPS PlateWorkflow also receives the production planning data, and can therefore optimize the plate production based on the priority of the different print jobs.

Similarly, the integration of MPS Production with MPS Roll Handling makes the production planning available here too. MPS Roll Handling knows in advance which reels are required for which production, and can ensure that the correct reels are prepared and made available without manual intervention. The reel stock levels in the main storage can also be managed according to long term production plans. When the print runs have been completed, information from MPS Production is transferred to MPS Roll Handling. MPS Roll Handling then generates statistics related to which reels were used for which products and produces quality-assessment data such as number of web breaks per 1000 km of paper for each manufacturer.

MPS Cockpit 3 makes it possible to optimize the overall management and planning of the entire production process rather than just the individual sub-processes. Bottlenecks between sub-processes can be identified and eliminated. The printing process can be driven from one system with all key data being entered once, and once only, across the entire production chain and across multiple sites.

Factbox 3 Application modules for the printing process

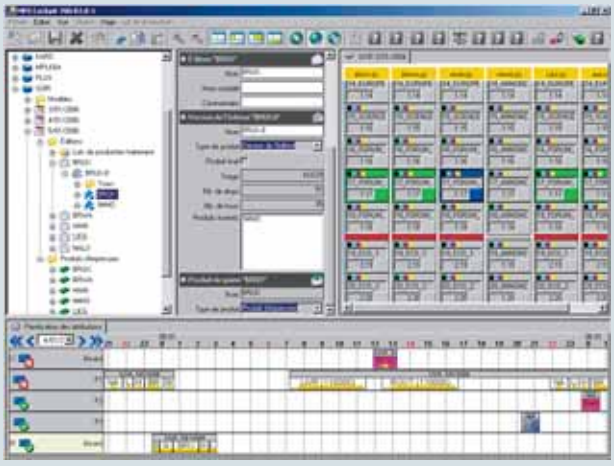
- MPS PageManager – for product structure definition and page assembly.
- MPS PlateWorkflow – for the generation of the RIP-data for the pages, and the control of the full integration of the plate setters with the page planning and the press production management system.
- MPS Roll Handling – for complete automation of the newsprint reel supply from delivery to the press.
- MPS InsertManager – for supporting the sale, planning, production, storage and the fine distribution of newspaper inserts, ie, ensuring that relevant inserts are delivered to selected areas only.
- MPS Cockpit – for managing the entire production process including all sub-processes.
- MPS Insight – a browser-based tracking tool that makes an overview of the current plant-wide production status, available on the Intranet or Internet.

Pragmatism prevails

Although a complete set of tightly integrated modules will generate the best results, pragmatism must prevail. Few customers are going to want to replace all existing system applications in one go, not least for financial reasons. Existing modules need to be accommodated in the integration concept. ABB's printing team recognized this at an early stage and the ability to integrate third party systems into the ABB product landscape was

2 Preprints stored on a rotary disk

3 MPS Cockpit screenshot showing different editions of a newspaper (left), page and color content (right), and production scheduling (below)



incorporated into the original design. This made total system integration affordable for a much larger number of customers.

An example of ABB's integrated workflow can be found at the Rossel Printing Company in Belgium, which has recently opened a brand-new print center at Nivelles, near Brussels. Rossel's aim was to achieve the highest possible level of integration and thereby maximize efficiency. ABB helped to turn this vision into reality. The workflow is illustrated in 4.

Total integration at Rossel Printing of Belgium

Rossel prints a range of newspapers that includes "Le Soir", from Rossel's own editorial department, "Vlan", a free newspaper from a separate office and "La Capitale", which comes from the offices of Sud Presse. Rossel also handles other customers with a further range of products. As a result, their software systems must cope with inputs from more than four different editorial sites.

The initial long-term plan is laid out using MPS Cockpit, for both the printing and the mailroom areas. The size of the newspaper is typically supplied by the editorial systems on the day the product is to be printed. The Hermes editorial system, used for Le Soir, is fully integrated with MPS Cockpit and MPS PageManager, which itself is also fully integrated with MPS Cockpit. To ensure that users of the Hermes system can define products that can be printed on the new presses, the Hermes system is supplied with ABB's Product Structure Library, in which all permissible structures are specified. Products from other editorial offices are defined directly in the MPS PageManager.

Developments in automation and systems integration will ensure the presence of newspapers at the breakfast table for a long time to come.

The size of the print run is defined by a completely different system: Rossel's circulation management system, which automatically transfers the print-run data to MPS Cockpit. This system contains all the production planning data required by the sub-systems that handle the different aspects of production.

The newsprint requirements for upcoming productions are passed to MPS Roll Handling, which controls the movements of the AGVs and the reels from goods-in to disposal.

The production planning data are passed automatically to MPS Production, which then calculates the plate imposition and passes the data to ABB's MPS PlateWorkflow. The data are used to control and optimize the entire plate production process, including the four plate-setters. The page content is imported directly from the various editorial offices, and MPS PlateWorkflow calculates the required ink zone values and supplies them to MPS Production so that the presses can be preset.

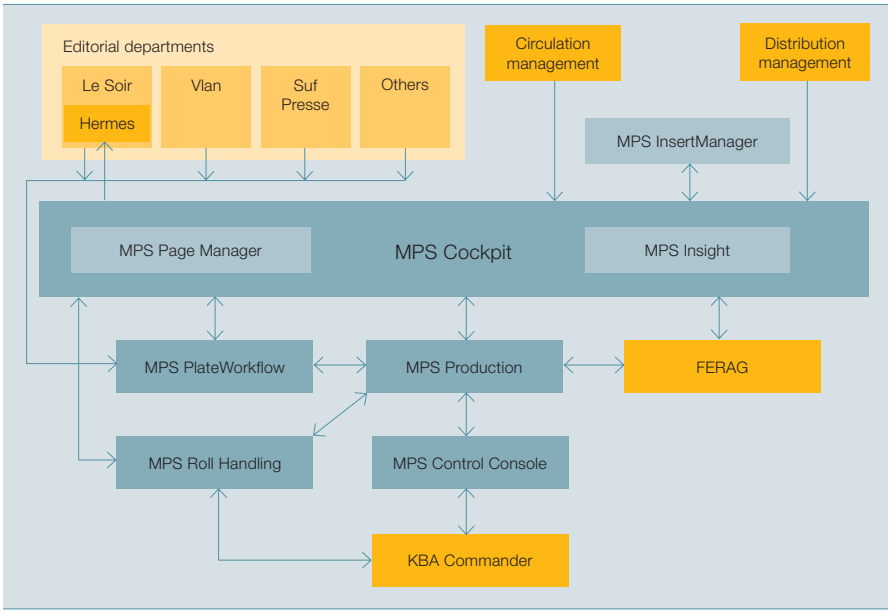
MPS Production also passes the production plan data, complete with preset values, ink and water curves, to the MPS Control Console, where it is made available to the printers for their preparation of the presses for production.

The FERAG mailroom management system receives all the required production planning data from MPS Cockpit. The sale of insertion capacity and the storage of inserts are supported by MPS InsertManager, which also works with MPS Cockpit.

When production is running, data flows upwards through the system to keep MPS Cockpit, and MPS Insight, supplied with tracking data. MPS Insight displays the plant overview with copy counters situated at various locations on the presses and in the mailroom.

Rossel is just one of many companies profiting from ABB's integrated workflow system. Integration has become a recipe for success, not just for ABB's customers but also for ABB itself.

4 Workflow overview at the Rossel Printing Company, Belgium



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Footnote

[1] Impositions are the configurations of paper and plates required to produce the correct sequence of pages.

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Every year, technological innovations are built into new products and older ones are enhanced with new features. Evaluating the potential value of these products for our customers and for ABB's competitiveness is no easy task, but the technology and innovation management team within the group tackles this challenge valiantly every year. The outcome is a list of the year's best innovations. *ABB Review* 4/2006 is centred around this theme. Brief articles present the chosen innovations and a selected few are expanded into full-length stories.

An innovative flexible manufacturing concept permitting the production of multiple and different products on the same line is show-cased with implementation examples. New solutions for the safe and harmonious co-operation between humans and robots are also discussed.

A special section on advanced color-measurement and control for the paper industry explains the complexities of measuring color on-line and in real time in a harsh environment. A creative control algorithm optimizes the use of dyes by applying multivariable control to the color kitchen, in which the different dyes are formed. This algorithm is described in some detail.

Self healing networks are of major importance in many different applications. *ABB Review* discusses the use of this technology in controlling electrical grids.

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