ABB review

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The corporate technical journal

Oil and gas

The cover and inside cover of this issue of *ABB Review* depict Statoil's Melkoya LNG (liquefied natural gas) plant located near Hammerfest in the far north of Norway. ABB delivered a complete range of power and automation products and systems to the plant. Gas from the Snohvit (Snow White) field is recovered through subsea templates, transported in pipelines to the plant, where it is liquefied for onwards transportation by ship.

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Oil and gas

Peter Terwiesch
Chief Technology Officer
ABB Ltd.

Dear Reader,

Oil and gas account for well over half of mankind's primary energy consumption. One of the factors that makes oil so valuable is its extreme versatility, both as a source of energy and as a raw material. The ease with which it can be transported and stored permits it to be used as a source of energy virtually everywhere. More than just a commodity among many, oil is arguably the leading global commodity of our age. Its price is scrutinized and commented more than any other. Whether we are looking at projections of global economic trends, or just filling our car at the pump, we cannot escape the price of oil.

Natural gas is not a global physical commodity in the same manner as oil, but technologies such as pipelines and LNG tankers are increasingly facilitating its trading over longer distances.

Maintaining the dependability and reliability of this supply is thus a fundamental objective. This translates into a technological challenge, ie, that of enabling the exploration, extraction, processing and transportation of oil and gas in manners that are safe, clean, energy efficient and affordable; and this despite the ever-increasing geographical and geological challenges of the locations from which they are being extracted.

In an interview with Texas state geologist, Professor Scott Tinker, *ABB Review* takes a more detailed look at some of the challenges and trends faced by the oil and gas industry. The subsequent articles provide examples of ABB technology at work for the industry. Through examples from across the world, we looks at ABB's offering as engineering, procurement and construction (EPC) provider, integrated control systems, trends in electrical houses, the separation of oil and water, large adjustable speed drives, getting more information out of process data, and the use of robots in harsh environments.

Beyond the scope of oil and gas, further articles in this journal look at ABB's contribution to Sweden's Aitik copper mine, efficiency in drives, the aerodynamic performance of surge arresters on the roofs of high speed trains, and retrofitting a substation with the IEC 61850 standard for substation communication.

I trust that this issue of *ABB Review* will cast a spotlight on some of the facettes involved in assuring the continuity of the energy supply that is so important to our economy.

On a different note, after six years as Chief Technology Officer of the ABB Group, I will shortly be taking up a new role as regional manager for Central Europe and head of ABB Germany. This is therefore the last issue of *ABB Review* to be published with myself on the Editorial Board. I would like to thank all authors and readers for their keen interest in and support of this journal over the years, and trust that this will continue in the future.

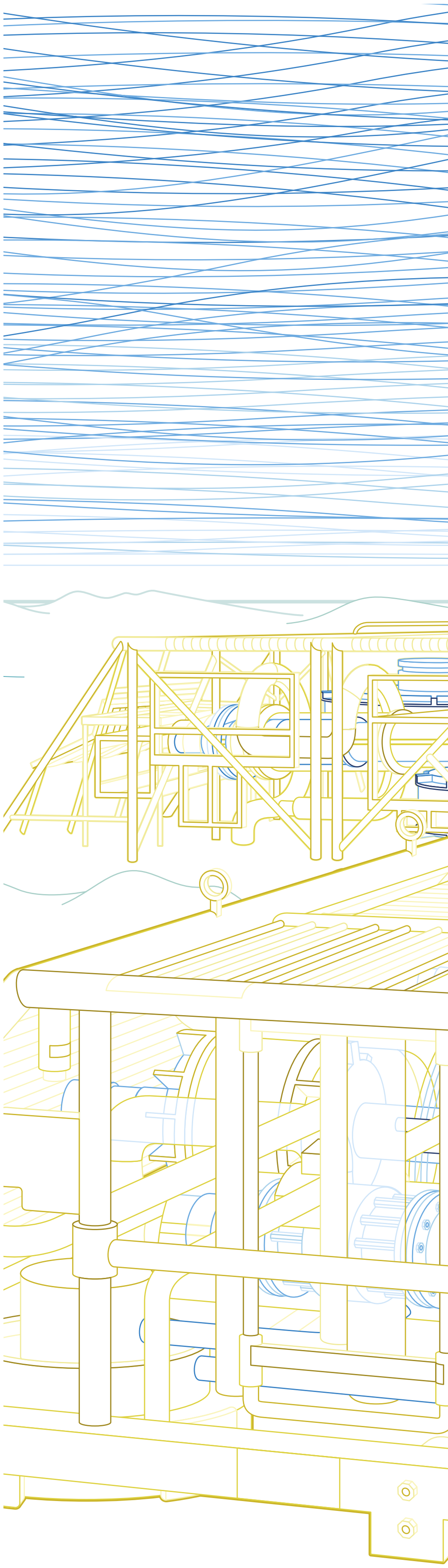
Enjoy your reading!

Peter Terwiesch

Peter Terwiesch
Chief Technology Officer
ABB Ltd.

Oil and gas

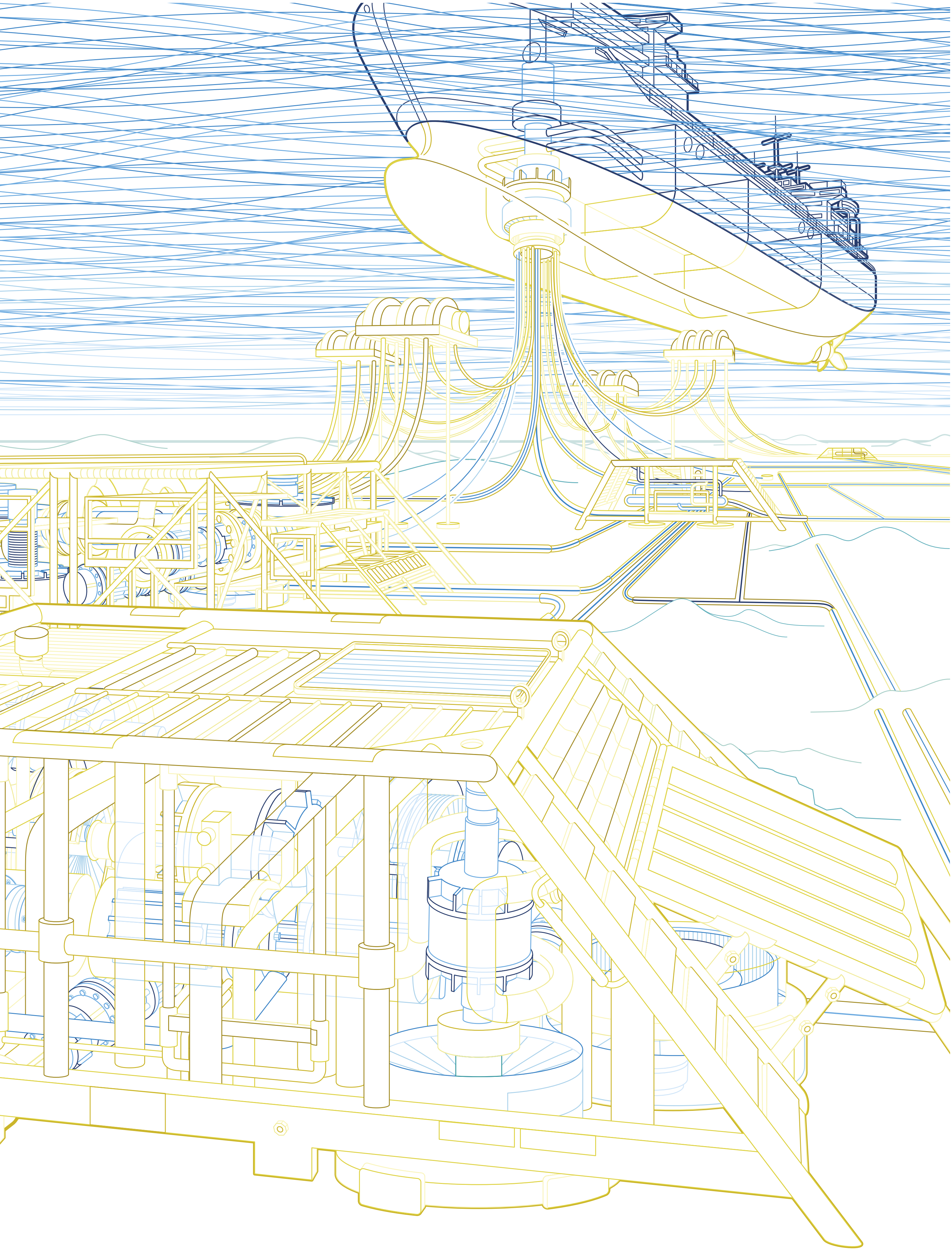
The energy we love to hate



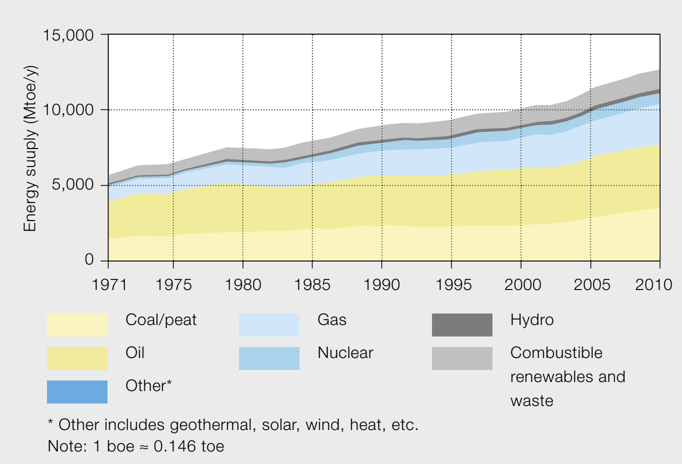
HÅVARD DEVOLD, SANDY TAYLOR – Oil and gas account for more than half of all primary energy consumed globally. Nevertheless, perceptions of the industry and its activities are mixed, with questions such as pollution, global warming and fluctuations in oil prices affecting people and the economy in numerous ways. The sheer volume of oil and gas consumed means that these fuels will continue to feed a large share of the world's hunger for energy for the foreseeable future. Assuring a reliable and dependable supply depends on the technologies used in their extraction. As ever-more challenging fields are commercialized, demands on technology are increasing to assure the economic, efficient and safe extraction of the fuel. ABB offers a comprehensive portfolio of technologies and solutions ranging from integrated automation and electrical products and systems, instrumentation, analytics and telecommunication systems, engineering and service.

ABB has been a supplier of products and services to the global oil industry for more than 100 years. A significant shift occurred during the 1970s when, in the wake of the oil crisis and with oil becoming scarcer, new fields were being opened in more and more challenging locations, with technology progressing to meet the changing demands. During this decade, ABB started to provide microprocessor-based control systems, a technology that gradually began to replace mechanical and pneumatic hardwired single-loop controls. The company also broadened its base technologically, adding further offerings for the sector. In 1973 oil and gas production was 76 Mboe/d (million barrels of oil equivalent per day), about 20 percent of which was from offshore fields in relatively shallow waters.

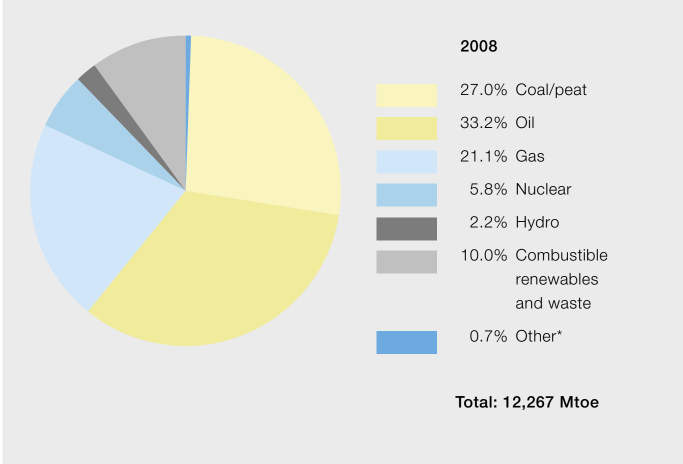
ABB soon established the rapidly growing offshore industry as its main market in the oil and gas sector, with many reference projects in the North Sea as well as huge offshore fields being developed in the Arabian Gulf. It was the age of large offshore field centers with gravity bases and fixed structure platforms. These were characterized by new requirements for fire and gas systems and by process control and integration across multiple



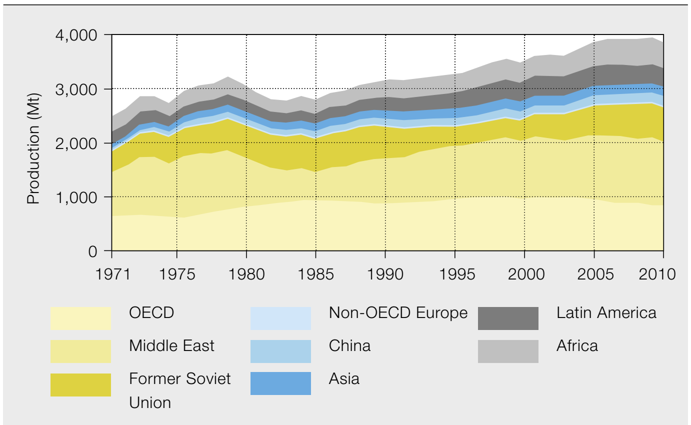
1 Evolution of the global primary energy supply



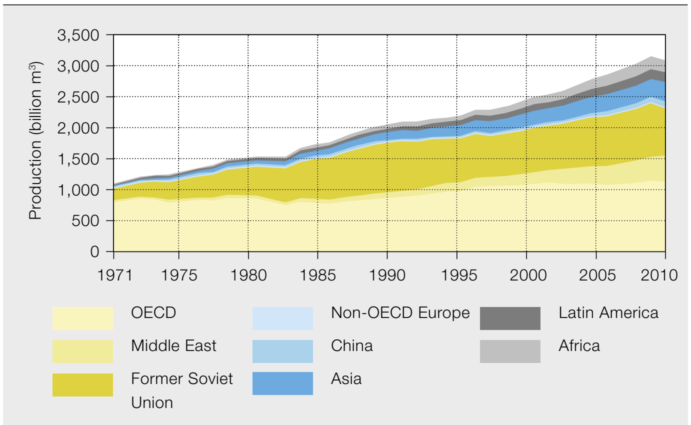
1a Evolution of world energy supply and mix



1b Oil and gas account for more than half the world's energy supply (2008 figures)



1c Crude oil by region



1d Natural gas by region

Thanks to EOR (enhanced oil recovery), the recoverable reserves of many fields have more than doubled over the lifetime of the fields and are expected to rise further.

systems that had previously been stand-alone. Areas covered by this integration included safety, metering, process and supervisory systems. With a long history in the marine sector, it was natural for ABB to extend its scope for floating production as well as deepwater subsea. This field development concept gradually replaced many large fixed installations. Today offshore accounts for more than 40 percent of all oil and gas production, and new offshore capacity is coming from fields in water depths of more than 500 meters. Recently, the Chinook and Cascade field (offshore of Louisiana in the Gulf of Mexico) received a new FPSO (floating production storage and offloading vessel), the BW Offshore Pioneer, which sets a new record by working in more than 2,500 m of water. The vessel features automation and electrical systems from ABB.

Setting the stage for the years to come

Combustion of fossil fuels – coal, oil and gas – are generally accepted to be the direct cause of much of the measured and forecasted global warming. Fossil fuels accounts for 81.3 percent of all energy consumed → 1. Oil and gas make up 51 percent, with the balance coming from coal [1]. Despite these dire consequences, there is presently no practical source or carrier of energy that can replace oil and gas on a large scale in its application in transportation or as an industrial feedstock. Battery-powered electrical cars represent a promising potential with improving technology and range, but can currently only replace a few percentage points. Even if a revolutionary new source were to be identified, development of practical vehicles and distribution infrastructure would take well over a decade. Presently at 142 Mboe/d, combined oil and gas production is

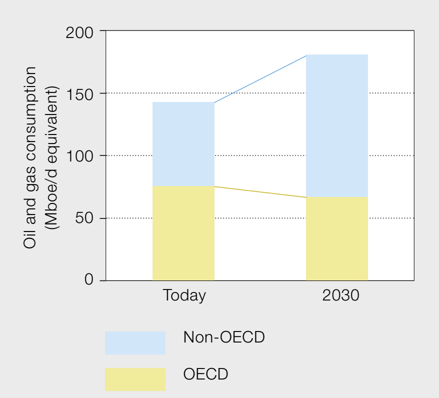
Footnote

1 IEA Key world energy statistics 2010 (www.iea.org)

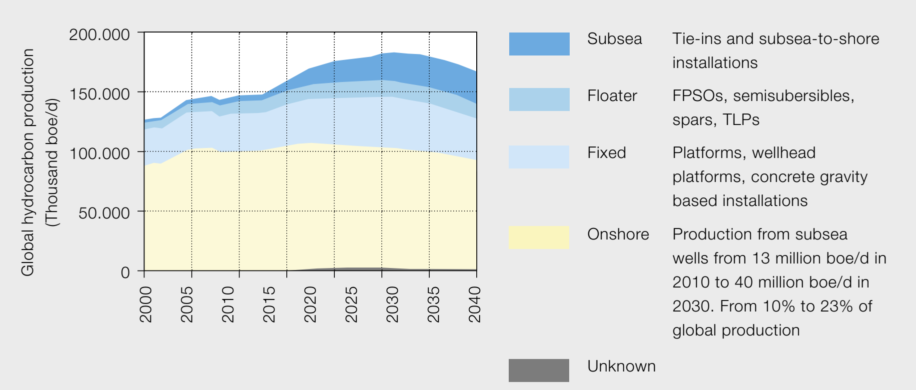
Title picture

An FPSO (floating production, storage and offloading vessel) is connected with a network of wellheads located on the sea bed.

2 Making optimization and new discoveries match future demand is a major challenge

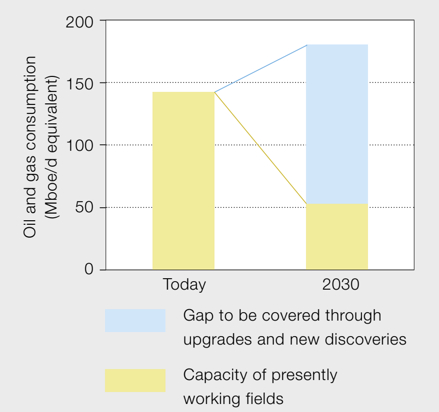


2a Non-OECD versus OECD demand



Source: Rystad energy UCube

2c Production by source



2b Present fields versus required optimization and new discoveries

almost double what it was in 1973. Despite progress in energy efficiency and the introduction of renewable sources such as biofuel, it is likely to grow further, reaching 180 Mboe/d by 2030. In a few years, non-OECD consumption will surpass that of the OECD, and is predicted to grow by 120 percent by 2030. It will by then be double that of the OECD. The latter will fall slowly by about 12 percent over the same period due to increasing energy efficiency and limited population growth ➔ 2a.

A typical field's production increases steeply to a maximum (the plateau) and then slowly drops off (the tail end). The world average production of oilfields in this phase declines at about six percent annually – if no upgrades take place. This means that in 2030, the gap between new demand and remaining tail capacity will be 70 percent of total consumption. This capacity must come from fields upgraded or developed between now and then, or from new unconventional sources. The gap is only slightly smaller than today's total production, placing high demands on exploration and production technology ➔ 2b.

Different from the easy oil of yesterday, a significant fraction of this oil and gas must come from fields characterized by such adjectives as arctic, deepwater, cold, heavy, high in water content, high sulfur content, to name but a few. In addition, improved oil recovery (IOR) technologies can be used on existing reservoirs to extract additional oil that would otherwise not be extracted. In most cases, IOR features flow assist (eg, pumping), heating, processing, water treatment, software models and similar technologies. IOR works: Whereas a recovery rate of 20 to 30 percent was considered acceptable half a century ago, many fields are now targeting 50 percent, with best practice surpassing 70 percent. For many fields, this means that recoverable reserves have more than doubled over their lifetime, and still continue to rise as even more sophisticated enhanced oil recovery (EOR) technologies are developed as a combination of 3-D and 4-D seismic modeling, fracturing and stimulation of the reservoir, advanced modeling and other technologies.

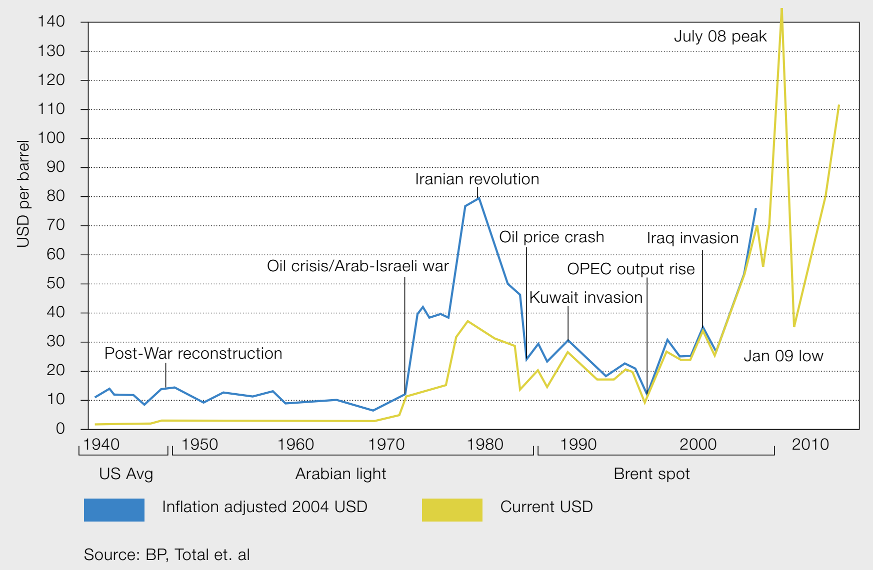
Fracturing and stimulation are technologies that open up channels in the reservoir rock to increase hydrocarbon flow out of the porous structure. Fracturing is achieved by applying high pressure (hydraulic fracturing), explosive shocks (explosive fracturing), chemicals (eg, acid fracturing) and other technologies as well as other solutions to prevent the channels from closing (eg, proppants) and the loss of permeability.

Power and automation play a key role in realizing the IOR/EOR potential as well as extracting from the more complex deep and cold newly discovered fields. One example is the deepwater type of oilfield with relatively shallow reservoirs found in Angola which generally requires subsea multiphase pumping.

As the oil price continues to rise beyond 100 $/bl (April 2011) ➔ 3, and gas prices recover in the longer term, focus is again returning to unconventional resources. There is a boom in unconventional gas (shale gas, coal bed methane) and also oil/tar sands. These sources are not only more difficult to produce from but also require more energy, which in turn implies more corresponding emissions, both directly and indirectly eg, from produced water. Therefore, future production must be done with an increased focus on such topics as emissions,

Presently at 142 Mboe/d, combined oil and gas production is almost double what it was in 1973, and is likely to rise further, reaching 180 Mboe/d by 2030.

3 Evolution of oil price



As reservoirs get colder, deeper and more geographically distant, the energy needed to extract has increased, and with it the importance of energy efficiency.

discharges, accidental spills and leakages as well as industrial accidents. As a result, relative capital expenditure (CapEx) will triple over the next decades, and suppliers will be required to supply new technology at acceptable cost → 4.

Subsea and FPSOs

The early 1990s saw the end of the large gravity base (GBS) installations, culminating with the Troll A platform at 656,000 metric tons, standing 472 meters tall in 369 m of water → 5 (there are taller structures in the Gulf of Mexico, but not as massive). GBSs are still preferred in some shallow to medium depth arctic areas such as in Canada (eg, Hebron field), Kara Sea and Sakhalin island in Russia due to sea ice and iceberg problems. However, both the cost level and the fact that almost all new discoveries made since then have been made in more than 500 meters of water depth, have led to a gradual change of concept. Subsea production systems in which the wellhead was placed on the sea bottom, later also with part of the processing systems replaced so called “dry trees” sitting above water on structures or vessels, and floating production facilities are being increasingly used instead of fixed platforms. The most popular form is the FPSO (floating production storage and offloading vessel), often based on a tanker hull with oil and gas processing equipment placed on the deck. One factor supporting this is the availability of used tanker hulls that are reaching the end of their life certification for open sea transport, but can still provide 10 or more years in stationary use. As ABB was already a major player in the marine market, the company was able to gain a leading position in this sector, supplying installations for more than 50 FPSOs. Because these facilities are generally of modular design, they also provided ABB with an opportunity to expand electrical module activities to large eHouses for FPSOs (as described in the article on Electrical Houses on page 29 of this *ABB Review*). Also, FPSO projects are generally implemented quickly and with a desire to minimize interfaces and achieve higher standardization on board. This favors ABB’s integrated electrical, instrument and telecom (EIT) focus, in which all wired and wireless systems (including electrical) on board are handled by a single integrated concept. This not only reduces operational cost but has also been proven to enable 15 to 20 percent lower overall CapEx for EIT systems and system engineering, as well as reducing delivery time by several months.

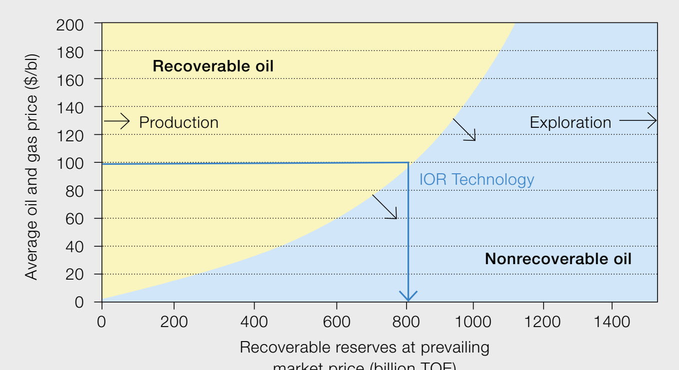
Initially, subsea installations were clusters of four to six wells tied back to an FPSO over a distance of less than a few kilometers. Over the years, subsea structures have developed into full subsea production systems in their own right, with large “offsets”, often in the range of tens of kilometers between satellite subsea systems. The most recent trend is to remove all surface facilities and tie the subsea production system directly back to shore. This often means pipeline, power and communication distances of 100 kilometers or more under water.

Even in tropical regions, the water temperature at depths of more than 2,000 meters are close to freezing. Since lighter hydrocarbons such as propane and butane can freeze around these temperatures under high pressure, additives are often required to prevent the freezing of flowlines should production slow down and the wellflow temperature no longer be able to heat the flowlines sufficiently. In other fields the production is heavy crude (below 20 API[2]) where the viscos-

Footnote

2 API (American Petroleum Institute) gravity is a measure of the gravity or density of a fluid. API 10 is equivalent to water, with higher numbers being less dense (float on waters) and lower numbers denser (sink below water).

4 IOR can increase recoverable reserves



Source: Technip, IEA

5 The Troll A platform weighs 656,000 metric tons and stands 472 meters tall in 369 m of water

ity can become too high due to cooling from the surrounding seawater. Also long distances, high risers from the seabed and other effects necessitate flowline heating, downhole pumps and other multiphase flow-assist devices such as pumps or compressors. These all require large amounts of electrical energy and accurate control. However, transferring energy over such distances with acceptable losses is itself a challenge. ABB has been able to design systems optimizing offset distance to power. It is likely that this trend will continue, particularly for arctic and environmentally sensitive areas where offsets of up to 500 km have been envisioned.

IOR/EOR

By the end of the 1990s, the most important factors that differentiated control-system products started to evolve away from basic functionality (such as operating systems, screen resolution and clock frequency) to oil and gas oriented applications and emerging technologies such as fieldbus and IOR solutions. It is not commonly known that the oil price fell as low as 8.70 $/bl and many technology conferences in the second half of the 1990s had as a main theme technology optimized for an oil price of 10 $. Focus was on reducing the cost of developing new oilfields by leveraging engineering efficiency, standardization and simplification, but also achieving cost reductions by getting more out of the existing reservoirs. ABB first established IOR technologies under the heading "Enhanced Oil Production" in 1997. Throughout the last decade, this portfolio evolved into today's "Integrated Operations" portfolio and is tailored to increase throughput, decrease energy consumption and decrease the cost of operation by advanced use of available data, such as real-time process data and asset condition monitoring.

The integrated operations business has evolved into a collaborative environment between the local facilities, centrally located operations centres and expert resources both within the oil company and with key providers of products and services.

Electrification and energy efficiency

With the development of deeper and more difficult reservoirs, focus shifted to energy efficiency. As reservoirs get colder, deeper and geographically distant, the energy needed to lift the oil up from the well, pump oil or compress gas into pipelines or convert gas to LNG has dramatically increased the specific power rating of energy from some 200 kW per 1,000 barrels per day in a typical offshore facility in the 1980s to 1 MW or more in some installations today. Unconventional resources can require considerably more than even that, with up to one barrel of energy consumed for every five barrels shipped.

Extraction of oil and gas is an energy consuming process, and on the average, 11 percent of what comes out of the well is consumed before the gas or crude oil can be sold. The primary use is heating, pumping, compression and associated treatment processes, and often this energy is generated locally by relatively low-efficiency thermal generation equipment. Efficiency ranges of 20 to 40 percent are most common with a reasonable average around 25 percent. Many case studies have demonstrated that significant savings can be made by utilizing variable speed drives both for smaller loads such as pumps as well as for driving large compressors, pipelines and loading pumps. In the latter case they can even replace gas turbines in direct drive arrangements, delivering substantial savings not only in emissions and fuel (in the order of 40–70 percent) but also in reliability, uptime and maintenance costs. ABB is a leader in this technology with installations in compressor stations, LNG Plants, NGL facilities (natural gas liquids) and gas treatment plants.

Even in tropical regions, the water temperatures at depths of more than 2,000 meters are so low that many hydrocarbons freeze.

Downstream

The refining business is constantly affected by crude-oil market fluctuations, high cost of energy, environmental regulations, and consumer needs. These factors all contribute to very tight margins. During such times, the need for innovative "value-added" applications increases greatly, as refiners seek to squeeze as much product out of a barrel of crude oil as possible, whilst optimizing energy costs, meeting environmental regulations and supplying the market with products to the required specification (Euro III and IV gasoline, and ultra-low sulfur diesel).

ABB's "Integrated Operations" portfolio is tailored to increase throughput while decreasing energy consumption and operating costs.

Despite discovery and production becoming more complex, there is still enough conventional and unconventional hydrocarbon in the ground to last mankind through the next century.

ABB has many years of experience in refining with its instrumentation, analytics, control and safety system product ranges. The company is well established in the market and provides a stable platform for advanced applications such as:

1 Early fault detection and diagnosis, which provides early detection of potential events, reducing / preventing unplanned outages.
2 multi-vaiable advanced process control, which optimizes production.
3 energy management, which optimizes the use and thus cost to run a refinery.
4 Asset management to monitor integrity of the plant assets.
5 A full compliment of consultancy services, ensuring full plant safety assured solutions.

ABB continuously develops its own core solutions in electrification, control, safety systems and instrumentation.

ABB's recent major successes have come as a result of the upgrade and enhancement of the oil movements, storage and blending solution (RBC/ABC, regulatory blend control, advanced blend control). In 2010 ABB successfully implemented and commissioned blending solutions which significantly improved refiners' margins.

EPC (engineering, procurement and construction)

ABB has many years of experience in the main contracting business, both in construction activities and as main contractor for large oil and gas projects. In the early 2000s, ABB reinforced its offering to the oil and gas segment with a dedicated EPC centre of excellence based in Italy, inheriting the long tradition and know-how of a former Italian contractor.

ABB recognized emerging requirements of industry and expanded its large systems capabilities with multi-discipline project execution, integrating EPC capability with its traditional electrical and automation project execution capabilities. ABB provides complete turnkey solutions (both onshore and offshore) for oil and gas applications in the upstream and midstream fields, including: gas/oil separation plants, gas treatment plants, gas/water injection plants, compressor and pumping stations, terminals, compact power plants, and water treatment. These activities contribute to ABB's significant oil and gas business. At present, few players in the market can boast such a capacity to offer world-class products, advanced integrated systems and proven EPC capabilities.

One example of the extent of these activities is presented in an article featuring the challenges of the El Merk project, currently underway in Algeria (see page 20).

And beyond . . .

ABB meets the future challenges of oil and gas in two ways: Firstly, the company continuously develops its own core solutions in electrification, control, safety systems and instrumentation. Secondly, it has over the years been a partner for strategic customers and demonstrated the capability to develop unique enabling

ABB provides complete turnkey solutions (both onshore and offshore.)

technologies such as subsea electrification, power from shore and integrated operations. These solutions would not have been possible without risk sharing, financing and real proof of concept/field trials. In particular, projects on the Norwegian continental shelf and the long term commitment of companies such as Conoco Phillips, Shell, BP and Statoil to joint research and development projects with ABB and others in what has been referred to as “Laboratory North Sea”.

Also partnerships and research and development agreements with such companies as Sonatrach, Dow, and Petrobras continue to enrich ABB’s technology. The next step is increased focus on such partnerships in the Middle East, especially in Saudi Arabia, Qatar and UAE that would focus on sustainable and efficient solutions with particular relevance to this region. These projects will include themes such as IOR, water and water management and unmanned remote inspection and intervention. The article “Remote inspection and intervention on page 50“ focuses on one of these technologies.

Despite discovery and production becoming more complex, there is still enough conventional and unconventional hydrocarbon in the ground to last mankind through the next century. Reducing the environmental footprint will be the greater challenge than getting enough product. In an energy-hungry world where per capita energy consumption is almost synonymous with wealth, there still seems to be little choice despite how much we love to hate our dependence on oil and gas.

For more information on ABB’s oil and gas offering, please visit www.abb.com/oilandgas.

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Energy trends

Interview with University of Texas Professor Scott W. Tinker, state geologist of Texas and Director of the Bureau of Economic Geology, on trends and challenges in the oil and gas industry

With hydrocarbons representing the majority of primary energy consumed, the continuity and reliability of their supply are of fundamental importance to all other parts of the economy. No wonder that the price of oil is followed, commented and analyzed like no other commodity. Besides its economic importance, there are many other reasons to be fascinated by the oil and gas industry. In this interview, Scott W. Tinker talks to *ABB Review* about the challenges, developments and future of the industry.

Prof Scott Tinker, thank you for joining us. Where do you see the major trends in the oil and gas industry?

There are several macro developments going on. I'll start with the industry structure. International oil companies (IOCs) have been merging and acquiring one-another for some time now. In parallel, what were once national oil companies are becoming international oil players. These companies are all seeking to increase their reserves through exploration and acquisitions.

Another macro trend is the transition from conventional to unconventional reserves. The unconventionals include heavy oils but also unconventional natural gas such as tight gas[1], shale gas, coalbed methane, methane hydrates and others.

What these trends and challenges have in common is that they are about access and reserves. The successful players of the future will be those that, through various means, have access to the largest reserves.

Another trend concerns what I call "above-ground" challenges. "Below-ground" challenges are about exploration and technology; above-ground are environmental, legal and regulatory. The industry must inform and educate people, be transparent, understand their concerns and dispel many myths that surround the industry.

Oil and gas account for more than half of global primary consumption and are thus fundamental to the economy. People are concerned about the volatility of energy prices.

If we look at the last eight global recessions, seven were preceded by a spike in the price of oil. Every one of the last four major recessions in the United States was preceded by a spike. I'm not saying that that correlation is causation; recessions are much more complex than that. But energy is a critical – even foundational – part of any economy. As oil is a proxy for energy (at least historically) its price is a strong signal.

What is it that makes oil and gas so irreplaceable?

Oil is a unique fuel – it's a miracle fuel – you can convert it into so many things,

Title picture
The Ormen Lange onshore gas processing plant in Norway, operated by Shell

Footnote

1 Tight gas is natural gas that is difficult to access because of the low permeability of the rock that surrounds it. Special treatments are required to extract it.

LNG tankers are making natural gas a physical global commodity. This is Gaz de France's tanker Provalys, equipped with an ABB propulsion system.

It is easier to create state-of-the-art systems from scratch than it is to retrofit old facilities to bring them up to the same standard.

the most important of which is gasoline or diesel. You put it into your gas tank, burn it, and it leaves no trace in the tank that you need to clean. It has a high energy density and it is safe. It is remarkably affordable. It is very difficult to replace oil and that is why the transport sector is dominated by it.

Natural gas is very versatile: It is used in power generation, for heating, and its use is also increasing in transportation. It is cleaner than coal or oil in terms of CO_2 emissions, but also in terms of SO_x, NO_x, mercury and other pollutants from coal. Its position in the energy mix is significant and set to grow further.

One significant difference between oil and natural gas is that natural gas is not yet a physical global commodity. We don't move it around as we move oil yet. The market is much more regional.

You say "yet" ...

The development of facilities to both export and receive natural gas is progressing. As they grow, we will be able to move natural gas to places that don't have it, and be able to mitigate some of the volatility and deliverability of its supply. Natural gas is going to be a big part of the economy of this century.

Will LNG tankers do for gas what oil tankers did for oil?

Potentially, but LNG has been slowed a bit by the accelerated development of unconventional gas. Eventually, I think LNG will be quite important. I was in Qatar looking at the largest LNG facility in the world: an Exxon Mobil – Qatari government partnership called RasGas. They have seven trains finished and I think an eighth in progress – and these are large trains. There is a city of about 40,000 people there to build and maintain them. The installation moves about one LNG tanker a day, loading it with more than 140,000 tons in 12 hours. Such a ship is about 300 m long, 100 m wide and 10 stories tall. The propeller is about 10 m in diameter. It runs on either diesel or (not surprisingly) natural gas, depending on the Btu price, and can do over 20 knots. They have a fleet of more than 50 such tankers!

An oil tanker is not too dissimilar. Of course it doesn't need to be cooled. A water "curtain" runs down the side of an LNG tanker while it is being loaded because if LNG hits the hull of the ship, it can crack. A typical oil tanker may have 500,000 to 750,000 barrels of oil on it. It runs largely on diesel. In both cases, it takes a lot of energy to move but there is an awful lot of energy on the ship.

So the technology for moving LNG efficiently is already here. It is now a question of adding capacity?

Yes, the facilities are large, expensive and require permitting. People are a little worried about them and there is some misunderstanding about the safety of LNG tankers. Although it hasn't been tested yet – and I hope it never will – simulations show that even if you put a torpedo through the dual hull, the LNG would basically "flow" out, change its state and burn. That would generate a lot of heat and wouldn't be good for the immediate vicinity but the tanker wouldn't really explode like a bomb. The event would basically be self-cleaning. In some sense it would be preferable to an oil spill, which is much more difficult to contain and clean. But having said that, you still wouldn't want such an incident to occur in a port close to communities and infrastructure. Offshore facilities will allow docking some tens of kilometers out at sea and a pipeline will bring in the gas.

What are the technological challenges in extracting oil and gas?

The main challenge is getting at the molecules. It has often been said that the easy oil has already been found. It wasn't always that easy to find the oil, but it was easy to produce once we found it – it came out of high-permeability rocks. Today we have far better engineering and better understanding of geology but the exploration environment is more difficult. For example, we are drilling in water depths over 8,000 feet (2,500 m) and working in the arctic or in the oil sands of Canada. These regions are not just more challenging geographically, but also technologically. And thus they are expensive.

Let us look at shale gas for example. Natural gas exists across the vast geographical extent of the shale basin. Basin's are heterogeneous and rock-fluid conditions will vary. Every basin is different. Companies have to be intelligent about where they drill and how they access reserves from a surface disruption (environmental) perspective. Instead of having a well every ten acres, multiple long-reach laterals are being drilled from a single surface location.

Water is another challenge. The operation has to access the formation, produce methane and water, separate the methane and re-inject the water. A tremendous amount of fresh water goes into hydraulic fracturing, and things like proppants have to be put into the water to hold the fractures open. Formation waters are produced, and either need to be cleaned up at the surface or re-injected; both of which cost money.

Many older fields have been producing for decades and are now in decline. What can be done to prolong their economic lives?

Many older oil fields are indeed in decline. But often the production tails are longer than we thought as we are finder better ways to coax that next barrel out. However, despite the best technology, we are still leaving a lot of oil behind. If you spill oil on your shirt or the garage floor, you see how tough it is to get out. Rocks are like that as well. Depending on the field the amount left in the ground can be less than half, 60 percent or even 80 percent or more.

Methods used to extract additional oil include water flooding, and chemical, thermal and even microbial processes. These are all costly. We often know we can make more oil but if we can't recover the costs then we don't do it. Energy is a strongly cost-driven sector and if you don't know if the oil price next year will be \$150 or \$50, it is difficult to convince your stockholders to support such an investment.

Non-OECD countries such as China and India are seeing unprecedented economic growth. What effect is this having on oil and gas?

There are 600 million people in India that don't have access to modern energy. That is almost twice the population of the United States. China has a similar number. That's not considering the combined billion people in those countries that already have access to energy; and this number is growing rapidly. In 2005, the number of automobiles sold in China was about a third that of the United States. Six years on, China has already surpassed the US figure and is approaching 20 million cars a year. This growth is going to continue – and rightly so. There is a clear correlation between access to energy and economic health.

The challenge is to not industrialize in the same way that the OECD countries did the last century. We industrialized in the best way that we could, given the technology of the time. But that was an experience that cannot be repeated. Trying to repeat that would stretch the energy supply enormously while impacting the economy and the environment. Non-OECD and OECD countries must work together to deploy energy-efficient, economically-efficient and environmentally sound technologies. Many of these technologies are already available. The great opportunity is that it is easier to create state-of-the-art systems from scratch than it is to retrofit old facilities to bring them up to the same standard.

What is the potential for energy efficiency?

Energy efficiency is certainly the low-hanging fruit if not the fruit on the ground. The United States consumes about 100 quads (or 100 EJ, or 100 TCF of natural gas equivalent) of energy per year. Less that half of that, so about 45 quads, is turned into useful energy. Most of the rest ends up as wasted heat, be it heat from industrial stacks, from commercial buildings, tailpipes or heat lost in homes. Increasing energy efficiency is about reducing the energy lost as heat. Again, this is easier to do in new builds than to retrofit. As an example, in my own home I put in new fluorescent bulbs, improved the insulation and sealing of the structure, put in an energy-efficient water heater and other such measures. The sad truth is that the investment will never pay back economically. It is good to save energy, but it is more philosophical; we feel good about it. Had we implemented those features from the beginning and actually built the house with them, I think they would have paid for themselves.

> One significant difference between oil and natural gas is that natural gas is really not a physical global commodity yet. We don't move it around as we move oil.

Energy decisions are mostly based on price. We see this in industry and also in personal choices. For energy efficiency to become more attractive it has got to become economically attractive.

How can that be achieved?

Companies can develop products that are designed to be more efficient and affordable. Individuals can play a part through their personal choices. Economies of scale will kick in. Governments can also make energy efficiency more attractive.

To what extent should governments get involved?

They can lead through broad incentives that encourage industries and individuals to become more efficient. But they should avoid the temptation of picking winners. One of many negative examples here in the United States is corn ethanol. Corn ethanol is not energy policy, it is agricultural policy. It needs water and fertilizer and soil and is in competition with food production while its net energy balance is pretty low. It would have been better for government to create broad goals (emissions, efficiency, low energy, low cost, whatever . . .) and allow industry, academia and others to compete in developing the best solutions. Take CO_2 emissions. If coal or natural gas can meet targets and be as affordable as wind, solar and others, then we should allow for that. But there are often other

Statoil's LNG plant on the Norwegian island of Melkoya (part of the Snovhit gas field). ABB delivered a range of power and automation products to the plant.

Technology and price are inextricably linked. When the price is right, a technology becomes viable.

interests driving policy that go beyond the stated goals. That is when governments get in trouble

Talking about CO_2, what part can carbon capture and sequestration (CCS) play?

The Bureau of Economic Geology, where I work, is one of the leading carbon sequestration research groups in the United States. We were the first to put over a million tons into the Earth. It is fascinating science and technology.

Looking at the bigger picture, I think we should be asking three framing questions: is it possible, is it doable and is it sensible?

Is it possible? In the Bureau we are looking at the geology and studying how we can put it into the Earth at volume and rate. Others are studying how to capture CO_2 from stacks. As research progresses the answer looks more and more like it is possible in some areas, driven largely by geology.

Is it doable? Can it be accomplished in terms of policy and regulation? Will people accept carbon being sequestrated under their back yard? This is more of an aboveground challenge. Again, I think it could be doable, but there is a lot of work to be done, and it won't be doable everywhere. And finally, is it sensible? What is it going to cost and what will the environmental benefit be? The world currently produces between 25 and 30 Gt (gigatons, billions of tons) of CO_2 annually from anthropogenic sources. To capture 1 Gt annually we would have to realize 1,000 projects of one megaton (million tons) annual injection each. A megaton project is a big project. We have to find suitable locations and to be able to afford to do them. The capture part is expensive (billons of dollars per major facility). The compression and injection part is less expensive, but there is still a lot of money involved. Add to that the regulatory and legal aspects and the overall costs are going to be very high, adding substantially to the kWh price of power from coal. And will it make a difference in terms of climate change? The infrastructure will take time to ramp up. And this total of 1 Gt/y, ambitious as it may seem, represents only about one thirtieth of total emissions. Huge challenges are involved in being able to accomplish that at the pace required. And all the time while we're doing this research, the clock is ticking. Although most who are invested in CCS or climate research won't say it, I worry if CCS is sensible. Time will tell.

CO_2 is not the only environmental issue surrounding the oil and gas industry. Another area of concern is hydraulic fracturing.

The process of hydraulic fracturing has been going on for many decades. It has also been used in conventional drilling. When the liquid is contained in very small pores (tight rocks), the only way to get at it is to induce the rock to crack so that the liquid can flow. These cracks are kept open by introducing proppants. This typically happens between 3,000 and 10,000 feet (1,000 and 3,000 meters) below the surface of the earth. The energy used in the hydraulic fracturing process presents a natural limit to how far from the wellbore fractures can extend.. We have done close to one million frac stages in the United States. Some well bores have over 30 different frac stages along the horizontal well path. The fracturing itself has, to my knowledge, never created fissures that went all the way to the surface. It would require a far more powerful process to do that and some laws of physics would have to bend a bit . . .

That said, the process of drilling wells and of moving fracturing fluids in by truck and handling them on the surface is associated with a certain risk. Leaks and spills can occur, as they can in any other industry. We should work to improve those processes: The target should be zero spills. But we usually know when a leak has occurred. The damage tends to be locally constrained and the leakage can be stopped and damage contained and mitigated. Such an incident is bad, but it's not going to contaminate a very large geographic region.

What other tendencies are going on in unconventionals?

Technology and price are inextricably linked. When the price is right, a technology becomes viable. One area with a lot of potential is the Arctic: Very little of the basin's vast oil reserves have been extracted. We are going to have to work there in a way that is environmentally sound.

The same is true of the oil sands in Alberta, for example. Oil sands have been mined at the surface. That's a not a particularly environmentally friendly thing to do – in fact it's quite ugly. But technology has progressed and now we're seeing what is called steam-assisted gravity drainage (SAGD) in which water is boiled, using natural gas, to make steam. The steam is sent down into well bores to heat the oil (which has about the density of a hockey puck) and liquefy it. The surface impact of this is minimal. When finished, the well head is moved and once the trees have grown back there will be few signs that anything happened there.

These SAGD operations are expensive, but with demand for liquid hydrocarbons still strong, and with the price of hydrocarbons continuing to rise and technology also progressing, more and more reserves will become viable. Some people say (and have said for decades) that oil and gas production is peaking: They are thinking in today's economic and technology paradigm. Supply will eventually peak, especially as we stop exploring and moving into new areas (geographically and geologically). As fossil energy prices rise, other energy sources will become more viable and gradually replace oil and gas. One day we may look back and ask, "why did we ever burn oil in our cars?!"

So if oil peaks it's not going to be because we are running out, because we have found something else?

Something else more affordable, or even better! There is a silly saying that the Stone Age didn't end for lack of stones. And the oil age will not end for lack of oil. At the right price, there remains a tremendous global oil resource. Consider that there was a time that we used whale oil for lighting. I may get hate mail for saying this, but because petroleum came along, we no longer needed to hunt whales for oil. In a perverse way, oil saved the whales.

How many hydrocarbons are still out there?

The world has consumed just over a trillion barrels of oil, and about 1,000 TCF (trillion cubic feet) of natural gas. There are anywhere from five to 10 trillion barrels of oil remaining and probably 5,000 to 10,000 TCF or more of natural gas – at the right price. The challenge is that you cannot get to most of that economically. As the oil price continues to climb – and we can argue whether or not the present development is a spike that will come back down, it probably is – but it may be a price point now that sustains opening up quite a bit of those expensive to reach oil molecules.

Scott Tinker

Scott W. Tinker is Director of the Bureau of Economic Geology, the State Geologist of Texas, Director of the Advanced Energy Consortium, a Professor holding the Allday Endowed Chair and acting Associate Dean of Research in the Jackson School of Geosciences at the University of Texas at Austin. Scott spent 17 years in the oil and gas industry prior to coming to UT in 2000. Scott is past President of the American Association of Petroleum Geologists (2008–2009) and the Association of American State Geologists (2006–2007). Tinker was a Distinguished Lecturer for the AAPG (1997), Society of Petroleum Engineers (2002), and Distinguished Ethics Lecturer for the AAPG (2006–2007) and won best paper awards in two major journals. Tinker holds appointments on the National Petroleum Council, the Interstate Oil and Gas Compact Commission and serves on several private, professional, and academic boards. Tinker's passion is building bridges between academia, industry and government and he has given over 400 invited and keynote lectures and visited over 45 countries towards this end. Tinker's degrees are from the University of Colorado (Ph.D.), the University of Michigan (MS), and Trinity University (BS).

Hydrocarbons are not just a source of energy. What about the other uses?

With energy types such as solar, wind, geothermal and biofuels expanding, we will eventually see fewer hydrocarbons being burnt for energy. This means that more will be available for other valuable uses such as plastics, lubricants, and fertilizers. Hydrocarbons are truly amazing, and very difficult to replace.

Thank you for this interview

The interview was conducted by
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In the depths of the desert

The challenges of building oil and gas infrastructure in a remote and inhospitable part of the Sahara Desert

SERGIO CASATI – Over the past 45 years ABB has successfully completed more than 300 engineering, procurement and construction (EPC) projects in the oil and gas, power generation and water industries. Many of these projects have been carried out in remote and demanding environments where the logistical constraints of deploying equipment, materials and labor across multiple work fronts were a major challenge. One such ongoing project is the El Merk oil and gas development in Algeria for which ABB is designing, procuring, constructing and commissioning a significant part of the field infrastructure. Located in the remote south-east corner of the country, El Merk is a vast and searing desert land of towering, intermeshing sand dunes that stretches across an area of some 5,000 square kilometers. The sheer expanse and complexity of the El Merk development demands a unique set of EPC skills and tools to ensure that the project is implemented and completed on time and on budget.

The El Merk oil and gas fields are situated in the Berkine Basin, the second largest hydrocarbons basin in Algeria and one of the most prolific in the country in terms of output and the frequency of new discoveries. Located in the depths of the Sahara Desert, El Merk is characterized by its harsh and inhospitable environment: Temperatures frequently reach 50 °C, rainfall is negligible and the terrain is largely composed of huge interlocking sand dunes, which tower to a height of 300 meters and whose contours are constantly shifting in the burning dry wind. It is also a remote area with no previous infrastructure – situated some 1,000 kilometers from the cities and ports of the northern coastal belt where 90 percent of Algeria's 35 million inhabitants live ➔ 1.

The El Merk development comprises four fields within two blocks (Blocks 405 and 208). The four oil and gas fields (known as EKT, EMN, EME and EMK) are being developed by a consortium of six partners (Sonatrach, Anadarko, Eni, Maersk, ConocoPhillips and Talisman) and the development is managed by the Sonatrach-Anadarko Association[1] joint venture, Groupement Berkine. At full capacity the El Merk facility will process 160,000 barrels of oil equivalent a day from nearly 140 wells. The wells will be linked by a system of field pipelines to ten field gathering stations (FGS), from where the product will be piped to a central processing facility for separation, stabilization, gas compression, natural gas liquid extraction and storage. The gas will then be re-injected via six gas distribution manifolds (GDM) distributed throughout the four fields. In 2012, it is planned to have approximately 80 wells in production.

ABB's EPC responsibility

Groupement Berkine has awarded several EPC contracts for El Merk for the construction of the central processing facility, offsite facilities, camp accommodation (base de vie) and industrial base, and for the export pipelines, power lines and substation. The ABB-led consortium, com-

The El Merk oil and gas fields are situated in the Berkine Basin, the second largest hydrocarbons basin in Algeria.

Title picture
Located in the remote south-east corner of the country, El Merk is a vast and searing desert land of towering, intermeshing sand dunes that stretches across an area of some 5,000 square kilometers.

Footnote

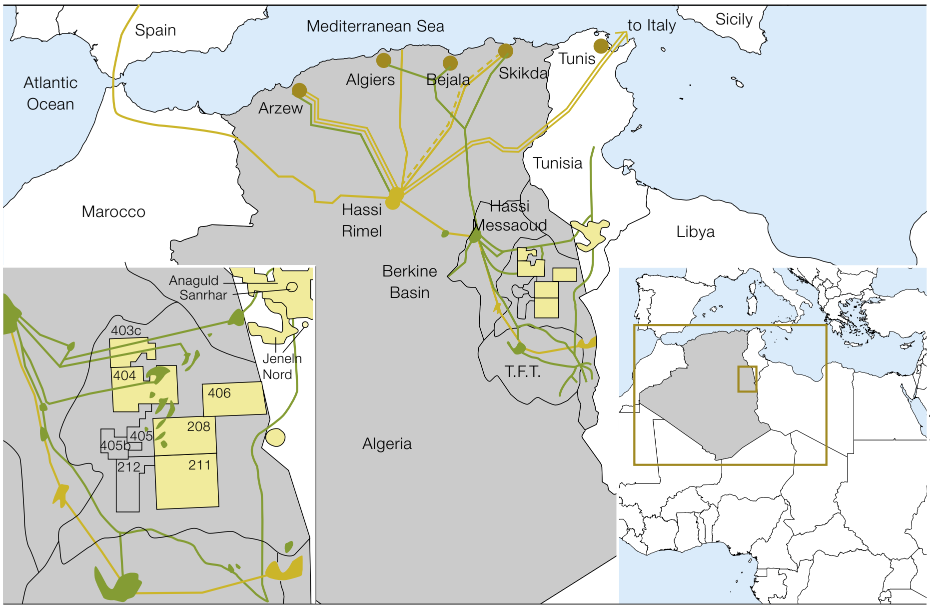
1 The Sonatrach-Anadarko Association is jointly owned by Sonatrach (the Algerian state-owned oil and gas company), Anadarko (the US-based independent oil and gas company), Eni (the Italian national oil company) and Maersk (the Danish privately-owned oil and gas company).

prising ABB, Sarpi of Algeria and PetroJet of Egypt, is responsible for the offsite facilities. The contract, worth $650 million, is one of the largest EPC contracts in ABB's history. It states that the company is responsible for the design, procurement, transportation, construction, commissioning and startup of:

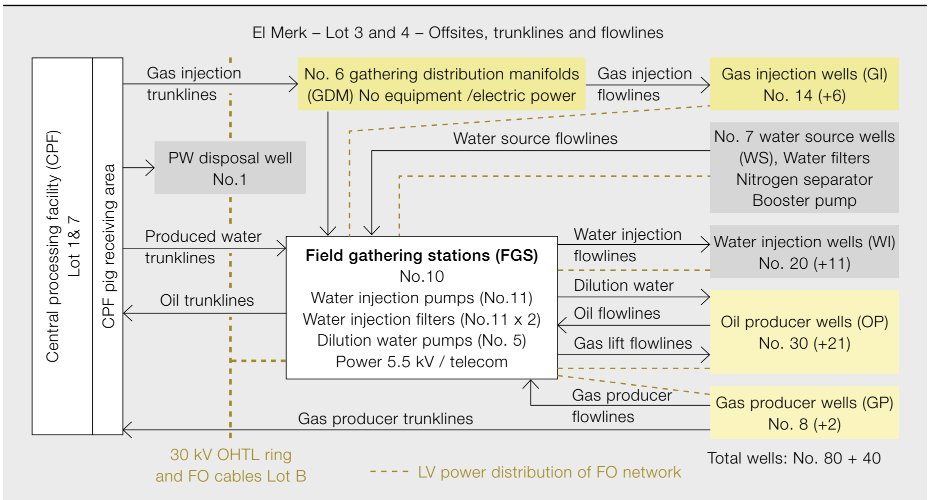
- The ten field gathering stations
- Six gas distribution manifolds
- The complete material supply for 120 wells as well as the hooking up of the first 80 for production
- The 719 km of pipelines and process piping across all four fields of block 208

ABB's scope of supply → 2 includes the water systems for injection; the flowlines for production, gas lift, dilution water and water supply; the trunk lines for oil and gas condensate, gas injection and water injection; and the process piping. In terms of equipment and products, ABB will supply water injection pumps, source water booster pumps, dilution water pumps, water filters, recycle coolers and nitrogen separators. On the electrical side it includes medium- and low-voltage switchboards and power transformers; and in instrumentation it comprises the metering system, multi-phase flowmeters, wellhead valves and field instruments. The chemical injection skids, pipeline pig launcher and receiver stations, and cathodic protection systems will also be supplied by ABB.

1 The location of the Berkine Basin and El Merk in Algeria.



2 ABB project highlights as presented at the El Merk field kick-off meeting



GIS precision and efficiency

Another key ABB deliverable is the geographic information system (GIS) for the entire El Merk project. The GIS is a geospatial-based infrastructure management system that enables all the field infrastructure and production assets to be designed, constructed, maintained and managed at the highest level of efficiency and precision. It provides all participants in El Merk with an accurate and up-to-date view of the progress of the project in real time. It integrates data coming from many different sources and performs precise calculations of the amount of material needed for construction. It assesses all possible interferences along the pipeline corridors, such as differences in elevation, the angle of dune slopes, and so on. And it automatically generates alignment sheets and documents, including all information needed in the field. The solution supports the pipeline open data standard (PODS) model, the most widely used pipeline data model in the oil and gas industry.

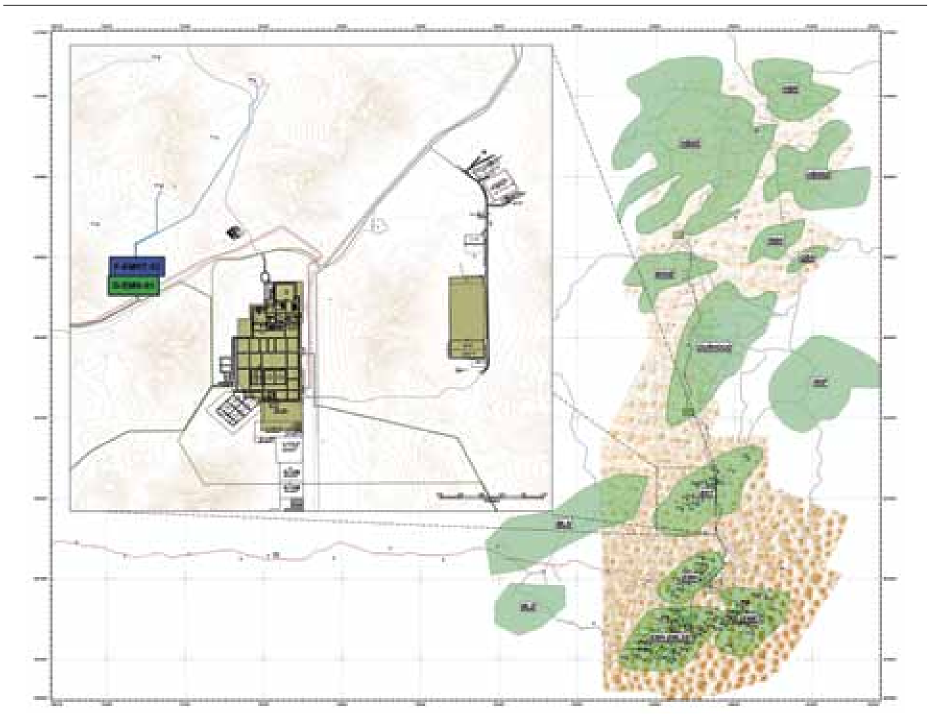
The GIS is a major contributor to the success of a major infrastructure project like El Merk, where there are numerous EPCs and subcontractors and thousands of workers involved at any one time → 3. Without it, the ASP consortium has estimated that the development of El Merk would likely take an additional 12 months, with all the added costs and revenue loss that such a delay entails. For instance, in a project of this scale it is not unusual for the location of wells or the route of pipelines to change as reservoir development progresses. Because subcontractors tend to interpret geodetic data differently, disagreements as to the correct positioning of production assets are common. The ABB GIS solution not only prevents any possible misunderstanding (and thus potential sources of delays), but it also brings precision and efficiency to the field.

ABB selected Intergraph as its partner in the GIS project, with Intergraph supplying the geospatial platform and ABB managing the project information and interfacing the data from all EPCs and contractors → 4. The system monitors the construction of every single site asset – from the wells and pipelines to the workshops, offices and housing on the base, and the power lines, utilities and communication cables that link the assets into a national network.

Meeting the challenges of complexity

El Merk is not just a highly complex and challenging project but it is all this in a remote and very harsh environment. From an engineering point of view, the

3 Panoramic views of part of the El Merk site.



fields are spread over a wide area and work such as well drilling, the laying of the pipelines and construction of the facilities will be carried out in parallel. On the logistical side, this means ordering huge volumes of equipment and materials [2] from suppliers and factories across the globe and transporting it the 1,000 km from Algeria's ports to the desert site. This all has to be executed in an efficient and cost-effective manner to ensure everything arrives according to schedule.

GIS is a geospatial-based infrastructure management system that enables the design, construction, and management of field infrastructure and production assets.

Up to 6,000 local and foreign personnel will be working on the project at its peak. Language barriers and cultural differences in a community of this size are common and have to be planned for and managed. Security is another aspect that has to be considered. From an ABB point of view, the facts and figures of its contribution to the project are outlined in ➔ 5.

Health and safety

With a workforce of 1,500 people working several million man hours, the need to excel in health, safety and environment (HSE) is a crucial aspect of ABB's responsibility [3]. ABB's HSE targets for the El Merk project are:

- To instill a zero-incident culture throughout the workforce

Footnotes

2 All equipment and material should be capable of operating in temperatures of 55 °C.

3 ABB's overall HSE objective is: no harm to people; no damage to the environment; no damage to property; no loss or damage to data and documents.

4 GIS presentation on the El Merk scope of supply, which shows the extent of the infrastructure and facilities

5 El Merk project – ABB facts and figures

To implement the project, ABB estimates that it will spend:
– 150,000 man-hours on procurement and project management
– A further 200,000 man-hours on engineering.

ABB's electrical scope includes:
– 300 km of high-voltage cables
– 200 km of low-voltage cables
– More than 150 high-, medium- and low-voltage switchboards
– 140 transformers
– 3,000 field instruments (control valves, transmitters, pressure gauges, flowmeters, etc)
– 400 km of instrument cables
– 400 km of fiber-optic cables

With regard to hardware, the ABB consortium is responsible for designing, delivering, installing and commissioning some 700 km of pipeline, which will be fitted with almost 10,000 manual valves.

ABB is also responsible for five telecom towers, and the heat, ventilation and air conditioning (HVAC) and fire fighting systems at the ten field gathering stations.

An ABB team will supervise the field activities of the almost 2,000 people employed by Sarpi and PetroJet on site. This workforce is expected to spend five million man-hours building and installing the El Merk off-site facilities over the course of some 42 months.

– To design HSE into all consortium facilities and worksites
– To develop and implement an HSE management system and risk management process
– To implement site-specific HSE plans and programs for contractors
– To have in place operational readiness for a seamless handover of HSE procedures and systems upon project completion

The expanse and complexity of the El Merk development demands a unique set of skills and tools to ensure that the project is implemented and completed on time and on budget.

EPC center of excellence

ABB is directing its part of the project, which is currently on schedule, from its EPC center of excellence in Milan. The completion of more than 300 EPC projects in the oil and gas, power generation and water industries, many of which were carried out in remote and environmentally hostile regions, makes ABB one of the most experienced and successful EPC contractors in the business. This is not the only factor that determined ABB's suitability as a contractor for the El Merk project: The company has had a strong local presence in Algeria since the 1970s and its involvement in the growth of the country's oil and gas industry, which led to the formation in 1993 of Sarpi, a joint venture with Sonatrach, were also contributing factors.

Other EPC projects in Algeria that ABB is currently implementing include a gas flaring elimination project at Haoud Berkaoui on behalf of Sonatrach (the contract is valued at $225 million and covers gas compression trains and re-instrumentation at three sites); and the delivery of utilities, storage and export facilities for the central processing plant at MLE in the Berkine Basin (a contract worth $245 million).

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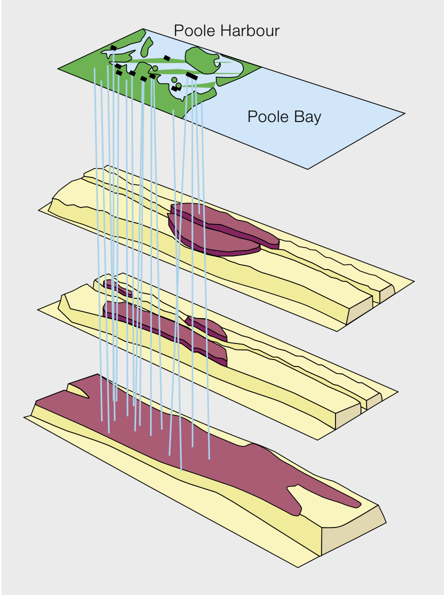
Fuel from integration

Integrated solutions for coal bed methane projects

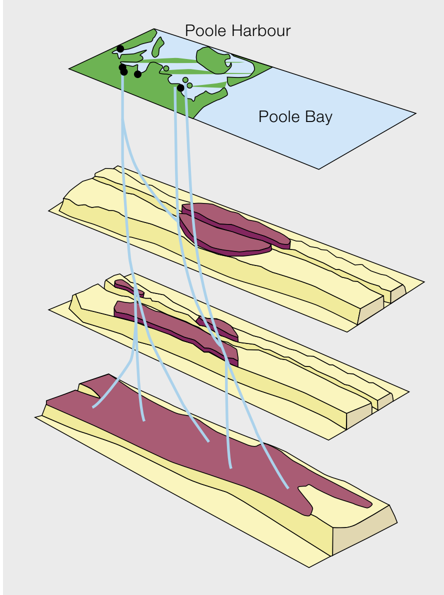
COLIN PEARSON – In an ever intensifying search for new energy sources, interest is growing in the methane gas contained in relatively shallow coal seams. Methane gas was and is a major source of hazard for mines and miners. In the past, such practices as placing canaries in the mine warned of its presence. Today technology exists to extract this gas in its liquefied form. Extracting this methane from coal seams not only provides commercial benefits but helps in preventing this gas naturally venting to the atmosphere.

ABB's contribution to coal bed methane (CBM) projects lies in its ability to provide total integrated solutions – combining automation, safety, electrical distribution, water management and telecommunications systems. This integration provides total visibility of the whole system (often distributed over a large and inaccessible geographical area) for operations, maintenance and asset and alarm management – stretching from the field to the business systems, regardless of where these may reside.

1 Single well solution versus directional well solution



1a Single Well Solution



1b Directional Well Solution

CBM is a naturally occurring component of solid hydrocarbons. Methane is "absorbed" into the coal seam over the geological timescale of its production and can be formed by either biological or thermal processes. During the earliest stage of coalification (the process that turns vegetable matter into coal), methane is generated as a by-product of microbial action. This methane remains locked in the coal until extraction (or venting) processes allow the gas to "desorb" from the seam at low pressures (1–4 bars). The technology required to enable this desorbsion and extraction is relatively low-tech and often portable.

Methane gas is the single largest cause of mining deaths around the world (accounting for 5000, or 80 percent of all annual mining deaths in China alone). Methane is also the biggest contributor to greenhouse gases, having a 21 percent greater affect on the environment than CO_2. By extracting this gas prior to excavating the coal, methane wastage is reduced by up to 70 or 80 percent – not to mention the improved safety for miners.

The typical coal seams where extraction is viable are relatively shallow and flooded. The initial phase of a well's life thus involves a period of "dewatering". This can take in the range of months to years depending on the seam conditions. Once the coal seam is sufficiently exposed, the gas desorbs and can be extracted for transport to LNG plants and onward sale.

The rate of gas desorbsion from the coal seam (desorbsion rate) depends on the quantity of exposed (ie, not submerged) coal. Water extraction can therefore be used to regulate the pressure and flow of methane. Managing this flow is extremely important as the low-pressure side often uses standard PVC piping. It is often not cost effective to add steel piping or expensive pressure relieving devices due to the high number of wells required to make these solutions viable (well numbers are typically in the order of thousands). Higher flow rates can furthermore lead to the premature depletion of a well.

In today's global and competitive market place, systems are required to be more high-tech than ever before.

The large volumes of water removed are an important factor in the extraction process and often require water-treatment plants and large reservoir facilities to manage the cleaning and safe disposal of this brackish bi-product.

The upstream desalination and compression systems inevitably require large amounts of power which can exceed the requirements of the midstream (LNG plant) by a factor of 10.

The upstream systems can be classified as large scale power distribution and water management systems with methane gas as bi-product.

Extraction technology

CBM is extracted by drilling wells into various areas of the relatively shallow coal seam (100's rather than 1000's of meters). Hydraulic fracturing of the coal seam is performed by pumping large volumes of water and sand at high pressure into the coal seam. The sand deposits itself in the fractures that open up and prevents them closing when the pumping pressure ceases. The gas then moves through the sand-filled fractures to the wellhead → 1.

Wells generally have two phases during their lifecycle, a "dewatering phase" and a "free flowing phase". In the initial dewatering phase, a well is comprised of a downhole pumping unit. This can be removed once the well becomes free-flowing. The remaining components are a water separation rig, instrumentation, solar panel with battery units and remote terminal devices (RTU's). The RTU passes the wellhead information back to a central recording and controlling system via wireless networks. In ABB's case the host system can either be a SCADA or 800xA system installation for a fully integrated solution.

Viable CBM projects can require many thousands of wellheads where several drilling solutions can be used. Regional topology and environmental impact studies will often be the deciding factor when selecting the solution to be used. This can include direct vertical drilling – one well/ one RTU or directional drilling solutions where one RTU can manage the production from up to ten wells and has a much lower environmental impact.

ABB TotalFlow is the US market leader in CBM wellhead solutions. Of the 30,000 to 35,000 wellheads in the US, 20,000 to 25,000 contain ABB equipment → 2.

Technical challenges

From the point of view of these large distributed systems, CBM projects can provide many technical, operational and maintenance challenges that either require personnel at each field facility (compression stations), or require an infrastructure that provides communications and field personnel to react to failures, fault or configuration issues.

Integration ensures information and facilities are made available for operational, maintenance and business purposes and even to package-vendors – remotely from a central control and engineering facility. This provides the opportunity to minimize staff requirements in the field, making these systems more efficient to operate as well as improving safety.

ABB is observing a clear drive towards these integrated solutions. The emphasis on integration is leading end-users and owner-operators to work much closer with EPC's (engineering, procurement and construction suppliers) early on in the project's design phase to ensure long term operational benefits are part of the initial design criteria. Without this, end-user input the goals of the EPC can often conflict with the processes required for long term operational benefits.

ABB's "operational excellence" focused thinking and "integrated operations" products and services combined with existing technologies are providing an extremely effective solution for such projects and end-user thinking. Several key factors that are attracting end-users to this approach are: → 3.

ABB's customers

Forward thinking owner/ operators are already preparing for changes to their automation strategies to accommodate these future challenges and necessities for integration (as recently seen on Australian CBM projects). The concept of "integrated solutions" ideally suits the current System 800xA topology as well as its future direction which will ensure our clients can better utilize their long term assets as well as maximize their available personnel whilst providing them a safe environment to work in.

> As the markets for LNG are already committed, it is more important than ever that it is efficiently and reliably extracted and distributed.

With ABB's ability to integrate its automation, telecoms and electrical systems (IEC 61850 and Profinet) into the System 800xA environment, ABB is able to provide end-users with unprecedented visibility of their assets and so permit more efficient operations.

In a recent ARC study, it was estimated that by providing visibility of the system drive's health from a central control facility, it is possible to prevent over 44 percent of drive failures which will obviously increase production and minimize downtime.

The advantages of a fully integrated solution for process automation, safety, electrical control, power management and telecommunications using a common system and protocols can be numerous. Some of these are listed in → 4.

Centralized control of CBM projects

With such large distributed systems it is imperative that the system users have access to the relevant information without regard for location or system type. By offering a single harmonized and con-

2 ABB and CBM projects

ABB has been supplying systems to coal bed methane projects in the US and Canada for many years through its ABB TotalFlow organization. The company has delivered more than 30,000 remote terminal units (RTUs) for CBM wellheads in these countries. ABB has also recently won a $58 million (and increasing) CBM order in Australia, with BG (UK), for a fully integrated solution using System 800xA and third party RTU devices.

Several major gas companies now consider CBM as a viable business and are investing billions of dollars in exploration, mining and infrastructure. China is one of the largest areas for CBM development.

Although historically this extracted gas has generally been supplied directly to "consumers", it is now becoming viable to sell it to the open market in its liquefied state.

CBM projects are made up of several relatively low tech sections: wellheads, compression, distribution and accumulation, liquefaction plant and loading facilities. The wellheads discharge the water they produce into large holding facilities for later disposal. Low pressure compressors are used to transfer the "wet gas" to a drying facility and then on through high pressure compression units to a distribution and accumulation pipeline network which is also used for accumulation and storage during specific plant conditions. Downstream of these pipeline systems are standard LNG facilities and ship distribution systems.

Due to their often vast topographical nature, it is imperative that integration is maximized. This reduces the need to send maintenance crews and engineers into the field (often in very difficult terrain) for troubleshooting and configuration purposes.

Drawing on its extensive know-how and portfolio, ABB is able to meet the requirements of these vast projects by providing fully integrated solutions, combining automation, safety, electrical distribution, water management and telecommunications. Without the level of integration offered by ABB, the end user cannot maximize the level of diagnostic data available at the host system (800xA) and as such is forced to send people into the field which furthermore increases the potential for health and safety issues when problems do occur.

3 Key factors favoring integrated operations in CBM

- The shrinking engineering pool and, as a consequence, the difficulty of getting the right people in front of the systems to ensure that all important production uptime. This will be particularly important in places such as Australia with their expected engineering resource issues.
- Capabilities now available with remote operations and access to global technical support. This gives system users access to expertise from ABB and third party suppliers without the expense and issues associated with global travel.
- CBM projects are often in extremely remote or (environmentally) hostile locations. The number and complexity of onsite service agreements can therefore be minimized.
- Ever present demand to drive down capital and operational expenditure by being able to improve and optimize the systems remotely.
- In the near future EPC's and end-users will have to integrate their automation, IT and electrical engineering resources due to cost/ skill availability issues. This is being made easier due to the integrated nature of automation systems and engineering database tools such as Intergraph's SmartPlant and Comos PT.
- Ever tighter project execution schedules, disparate systems mean more risk to schedules.
- Operational excellence policies are themselves being developed by end-users within their own groups as this is being seen by them as the key to successful long term profitability.
- Business decisions need to be made with real-time information and in a timely fashion to take full advantage of process variants and market conditions.
- Often on CBM projects several stake-holders may "own" wells or groups of wells making the management of production complex and will require decisions based on data from several sources and at various levels of the infrastructure (field to enterprise layer).
- The shifting experience and expectations of the IT savvy "operator" generation. Future training will begin to encompass all aspects of automation systems including electrical, telecommunications and IT systems.
- Requirements for central production operational staff to have visibility of multiple process plants in order to harmonize company-wide operational and maintenance procedures.

These issues are very real and very relevant for the extremely large scale and long term CBM projects.

4 Benefits of full integration

- Operators are able to have a consistent look and feel across the whole platform and therefore all plant assets. This includes common alarm lists, audit trails and asset management reporting for automation, electrical and telecoms.
- Common engineering tools are possible for configuration and maintenance.
- The use of IEC 61850 as a standard for the integration of intelligent electrical devices (IED's) reduces risks and cost as well as providing a large amount of diagnostic data to the integrated alarm/ event and asset management systems.
- Computerized maintenance management systems (CMMS) can manage all assets, whether it is a SMART field instrument, an IED or a telecom asset.
- Asset and production reporting can be generated from live data from all connected assets at the enterprise level. Business managers are able to make more accurate decisions if they have access to real-time information from across the whole plant. This leads to improvements in both fiscal and production decision making.

ABB can offer this from one single harmonized system making our 800xA system an industry leader for such large distributed CBM projects.

5 The ABB 800xA Extended Operator Workstation

sistent environment, ABB is able to supply its clients with systems and solutions that allow them to comply with the latest EEMUA (191 and 201) and the more stringent ISO 11064 guidelines. These guidelines indicate the "how" these systems should be used.

By planning systems to take into account the "how" clients operate, ABB is driven to provide integrated offerings with common user interfaces regardless of the provider of the "field-level systems". This serves the long term interests of clients and gives ABB an advantage over other system suppliers as the 800xA system is designed around this very concept.

Having the necessary operational or maintenance information at hand guarantees that users have the information available to make the right decisions at the right time and ensures a speedy response to any urgent upset condition → 5.

This has obvious benefits when time to repair is critical.

System 800xA, through its HMI[1] and EOW[2] systems are allowing CBM system users (operators, maintainers and managers) to carry out their business much more efficiently than ever before.

Potential Barriers

To some extent, barriers to long term operational excellence can be created at the procurement stage. Often procurement strategies dictate that, for cost comparison purposes, various sections of a solution must be held up for cost comparison across multiple suppliers. Although there is a very good reason for this, it does often lead to procurement teams "cherry-picking" a cheaper component with little regard for integration or associated costs for long term operation.

With its recent Australian CBM projects, ABB was able to bring together all its products and services to enable clients to get the absolute maximum from their systems. Customers are thus receiving a globally leading solution, which will put them at the forefront of CBM production.

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Footnotes

1 HMI: Human machine interface
2 EOW: Extended operator workplace

A new housing trend

Customized electrical houses are now being delivered with fully integrated electrical and automation systems

ANDREAS RENULF, J. PAUL SINGH – Traditionally oil and gas and engineering, procurement and construction (EPC) companies received their switchgear, drives, periphery distribution equipment and automation systems from multiple electrical equipment suppliers and obtained the electrical house from a fabricator. But the need to reduce risk, costs and delivery time has steered the industry away from this practice. Today, there is a clear trend toward delivering an integrated, installed and precommissioned electrical and automation system together with the complete electrical house. ABB has just the right portfolio to meet this demand and has already delivered many such installations.

1 ABB's UniGear type ZS1 switchgear in an electrical house

For many companies, it is no question that there is a great advantage to using one supplier for multiple products. In the oil and gas industry, electrical equipment – including switchgear → 1, drives, distribution equipment and automation systems – has traditionally been supplied by multiple vendors. What's more, the protective electrical house in which all of this equipment must reside has typically been provided by yet another vendor. Inherent in this setup is the potential for increased risk of integration errors, higher costs and longer commissioning times.

A single vendor capable of engineering, designing, assembling, packaging, testing and delivering the equipment, as well as managing the fabrication of the electrical house, is the key to reducing these risks, costs and commissioning times, and improving project capex (capital expenditures).

Reducing risk

With conventional supply of equipment to an EPC or oil and gas company, multiple suppliers are involved. This means that, even with any minor change to the electrical loads, there will be a ripple effect of changes to, eg, the switchgear, drive torque, number of I/Os, electrical housing layout and air conditioning requirements, requiring the company to communicate the change with each supplier, as well as with the electrical house fabricator, who must then make the appropriate changes. The risk of errors associated with this type of setup is high. Contracting a single vendor to supply the equipment and manage the electrical house can mitigate this risk.

Reducing costs

Costs can be incurred in any number of ways. And when it comes to the supply of electrical and automation systems, one of the quickest ways to incur them is by using multiple suppliers who must then install the equipment at quite often remote locations.

With a single-vendor setup, the complete system is shipped fully functional and ready to go; once the equipment arrives on-site, it has already been built and tested and must only be "plugged in." Further, the prefabricated enclosures or electrical houses → 2, 3 can be shipped as modules, requiring only a small amount of on-site assembly. If there are changes in the electrical loads during engineering, the inherent subsequent changes must not mean additional financial burden since this is handled centrally by one supplier. In addition, the reduction in on-site work results in significant financial savings.

Reducing delivery time

The traditional multivendor approach to equipment delivery demands that the electrical house must be complete before the products can be delivered, installed, cabled and commissioned. With prefabricated electrical houses, this can be done in parallel and the working system can be delivered to the site in one package, reducing the amount of time required for the delivery and installation process.

For an electrical products and systems supplier, managing the electrical house fabricator is a relatively new area that involves further expertise.

Weight and size are key factors when the electrical house is installed on an offshore platform or as a module on top of a floating, production, storage and offloading (FPSO) vessel. This makes the interaction between the switchgear man-

Title picture
Offshore electrical house (foreground)

ufacturer and the electrical house fabricator even more crucial since there is no room in the electrical house to accommodate changes to the switchgear.

Single suppliers across industries

Some large EPC companies in Japan in particular have lost a significant amount of money as a result of overruns in on-site work. Consequently, these companies have recently begun to use the single-supplier approach where one supplier also oversees the fabrication of the electrical house. Other industries are using this approach as well. The minerals industry is also motivated to reduce the need for on-site work since the mines are often located in remote areas where qualified personnel can be hard to recruit. The power generation industry is also turning toward a single-supplier approach for the same reason – power plants also are often located in remote areas.

Almost all the equipment required inside an electrical house can be supplied by ABB, who installs and tests the products in the house prior to shipping. When all the different products are supplied by one vendor, the EPC or oil company has only one point of contact and one vendor who accepts full responsibility for the delivery, which reduces the risks for delay and cost overruns.

Taking on new challenges

Supplying highly efficient switchgear, drives, automation systems and the like is second nature to ABB. But for an electrical products and systems supplier, managing the electrical house fabricator is a relatively new area that involves further expertise in fields like structural engineering, HVAC engineering, fire and gas system engineering, cable scheduling and, most importantly, project management. Taking responsibility for the fabricator and accepting the added inherent risks requires all of these capabilities and more. Changes to the electrical house are inevitable and must be carefully managed. For example, if the location of the switchboards changes, so too must the length of the cable.

EPCs and oil companies are capable of managing electrical house fabrication. But turning this responsibility over to a supplier such as ABB can be a great advantage. To guarantee a successful outcome, it is essential that the electrical house fabricator's capabilities are known. In addition, since the cost for the electrical house can be as much as 50 percent of the complete delivery, attention is also paid to the fabricator's pricing structure. To achieve the best cost for the electrical house, ABB consolidates its purchasing powers from a global perspective.

2 Fabrication of an offshore electrical house

The final, essential component following delivery is of course service. With one supplier, eg, ABB, the EPC or oil company can be assured one point of contact for any service required on all ABB products, as well as on the electrical house.

Successful electrical house delivery

Each electrical house project is a customized, engineered solution with unique requirements. Marine warranty surveys and feasibility studies for factors such as heavy lifting, preservation, sea fastening, and load-out procedures are carried out for every offshore project. ABB also has qualified, capable fabricators within Southeast Asia and China.

Experienced project proposal team

An important element for success in ABB's electrical house projects is a technically sound proposal. As stated earlier, fabrication contributes to up to 50 percent of the total contract value of an electrical house project. Including engineers with expertise in electrical houses during the proposal phase reduces both the risk in project management and the chances of variation in orders from the fabricator. These engineers can then review features such as the structure's

> With a single-vendor setup, the complete system is shipped fully functional and ready to go; once the equipment arrives on-site, it has already been built and tested and must only be "plugged in."

3 Offshore electrical house close to completion

weight, required HVAC, cabling (including interconnecting cabling), ladders, trays and fire and gas (F&G) systems according to specification. This approach ensures that ABB's proposal is accurate.

Effective project management team

Because successful electrical house deliveries are to a great extent a result of good project and fabricator management, and because the most affected industry is the oil and gas industry, there are strict project-management certification and appropriate risk-review procedures in place. An effective project management team must have experience in electrical house projects. ABB has demonstrated its strong project management capabilities in delivering large orders.

> With one supplier, eg, ABB, the EPC or oil company can be assured one point of contact for any service required on all ABB products, as well as on the electrical house.

Occupational health and safety

ABB is committed to health and safety, not only out of concern for its staff and business colleagues, but also to ensure its products and engineered solutions comply with the highest standards. Comprehensive risk assessments are carried out prior to any work commencing on fabrication or customer sites. Safety standards are applied to the technical design and project planning stages to ensure compliance throughout the complete plant life cycle.

Quality

At ABB, quality is an essential component of its products and services. ABB's advanced quality management systems span the entire business process, from responding to initial customer inquiries to delivering the final product to commissioning and after-sales service. For example, qualified quality control (QC) personnel are deployed full-time on-site during the construction phase. In-house quality assurance personnel develop and review all quality procedures.

Document control

Document control is an important service function implemented in all ABB projects, managing the transmission, flow and storage of all project-related documents. A document controller is assigned to manage all documents. Documentation tools such as the EDMS (electronic document management system) add value to the project and reduce the time needed for transmittal during execution.

Supply chain management

An integral member of the project team is the procurement manager, whose responsibilities include managing the supply chain, quotations, supplier evaluations and associated documentation and certification. The project manager's role includes the coordination of this procurement function to ensure effective management of project-specific materials.

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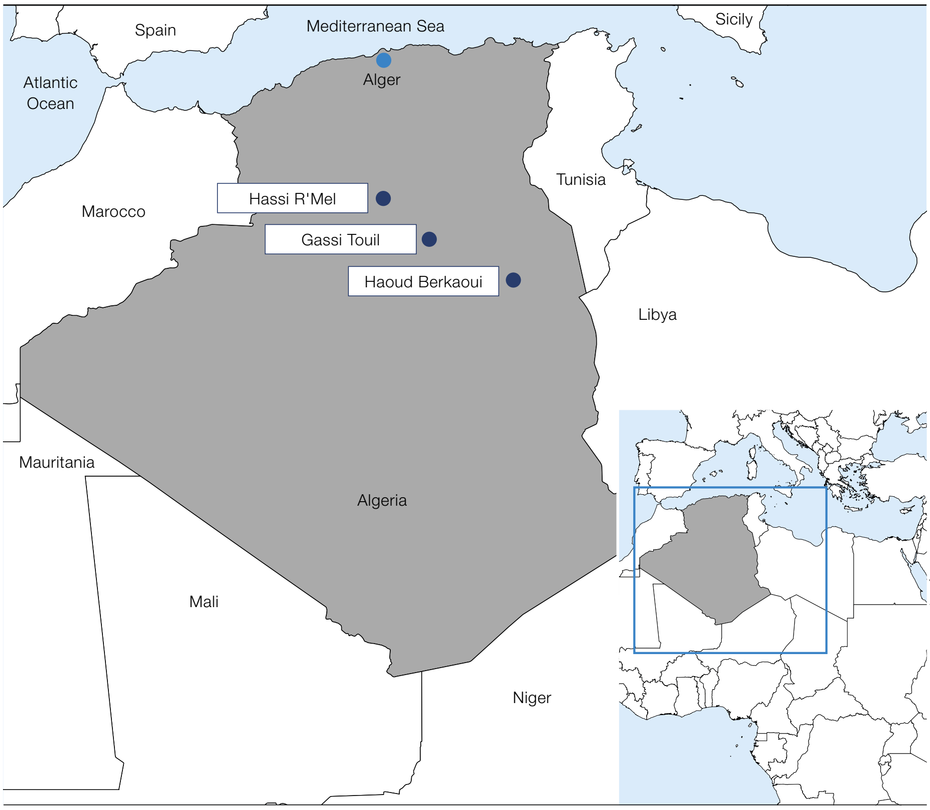
Untroubled waters

A flexible, compact and efficient solution for oil and water separation technology

MARCO APICELLA, NUNZIO BONAVITA, PAOLO CAPELLI, RAIMONDO CIANFRUGLIA – Produced water is oily wastewater that is co-produced during oil and gas production and whose management constitutes a major challenge in environmental terms due to its highly saline nature. Produced water is essentially water trapped in underground formations that is brought to the surface along with oil or gas. It is by far the largest volume byproduct or waste stream associated with oil and gas production. Management of this produced water presents considerable challenges and costs to operators [1] and disposal of produced water can be problematic in environmental terms due to its highly saline nature.

1 Locations of the water de-oiling plants



Oily wastewaters constitute a major environmental problem in many industries [2]. Metal, textile, automotive, petrochemical and aeronautical industries are affected by this problem. Conventional treatment of process effluents typically involves a combination of physical, chemical and biological processes. In addition to formation water, produced water from gas operations also includes condensed water and has a higher content of low molecular-weight aromatic hydrocarbons such as benzene, toluene, ethylbenzene and xylene (BTEX) than those from oil operations; hence they are relatively more toxic than produced waters from oil production. Studies indicate that the produced waters discharged from gas/condensate platforms are about 10 times more toxic than the produced waters discharged from oil platforms [3].

Standard oily wastewater remediation relied for decades on API 650 for oily wastewater separation (OWS) treatment. OWS uses gravimetric lagoon separation, then reprocesses the recovered floatable oil portion and uses holding-pond clarification of the wastewater portion before "land-farming" discharge, which led to substantial groundwater and air pollution. OWS certainly can't be expected to meet the more stringent requirements of modern environmental regulations, or be deployed for remote sites as a package treatment plant option.

Various new configurations of separation technology have expanded oily wastewater treatment options; everything from hydro cyclones to coalescing plate filters, and even the use of ultra filtration to separate and concentrate the individual waste streams. Oily wastewaters can be generally separated into oil and aqueous phases by gravity separation, using either the API separator, or a parallel-plate separator. The surface oil can then be skimmed off by various devices. Air flotation can also be used for the more difficult separations, or where better performance, or more rapid recovery is required. Chemical additives may be used in air flotation to improve separation. Ultrafiltration is an important technology employed to clean up the wastewater to make it suitable for discharge into municipal sewers and provide an oily concentrate rich enough to support combustion.

While these methods offer a good process response through a wide range of flows, and can meet typical 100 mg/l total hydrocarbon cleanup regulations, they are incapable of meeting proposed European environmental protection legislation, and also risk non-compliance with the ATEX Directive for processes operating in explosive environments [4].

Moreover, none of these filtration methods are capable of treating the produced wastewater for removal of heavy metals, COD, nitrogen and phosphorus without more advanced treatment processes, such as chemical precipitation, air strip-

The management of oily wastewater constitutes a major challenge in environmental terms due to its highly saline nature and the often demanding environments where it is produced and processed.

ping, chemical oxidation, or activated carbon adsorption. Again, these advanced processes generally cannot be deployed for remote sites as a package treatment plant option and all produce a toxic concentrate or sludge requiring further treatment or disposal as special waste.

Water de-oiling plants

From 2000 to 2006 ABB has built and studied in North Africa water de-oiling plants in three different locations ➔ 1:

- Three plants in the Hassi R'Mel region (total of 3,400 m^3/day).
- Three plants in the Haoud Berkaoui region (total of 4,800 m^3/day).
- One plant in the Gassi Touil region (total of 2,400 m^3/day).

Construction of these seven plants has been performed by ABB in partnership with SARPI (joint-venture ABB/Sonatrach).

After handover, the plants were operated and maintained locally until 2007 when, because of a change in policy, it was decided to outsource the related services.

ABB and SARPI were selected to perform both operation and full service activities for a period of five years on the following four water de-oiling plants:

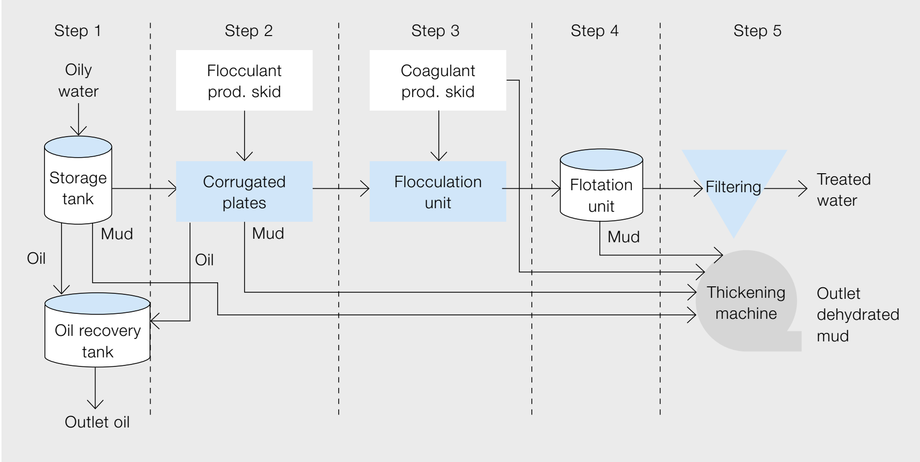
- Three plants in the Hassi R'Mel region since March 2009.
- One plant in the Gassi Touil region since February 2009.

The three water de-oiling plants located in the Hassi R'Mel region are named "North," "Central" and "South" based on their relative geographical location.

The largest is the Central plant with a daily treatment capacity of 2,400 m^3/day, while the other two are significantly smaller with a treatment capacity of just 500 m^3/day.

The plant in Gassi Touil has the same capability as the Central plant in Hassi R'Mel and was built in the same period (start-up in 2001) while the two smaller units, North and South, had their start-up in 2006. Both the Gassi Touil and the Hassi R'Mel Central plant underwent a major revamp in 2008 as part of the present project, in order to improve both their effectiveness and efficiency.

2 Oily water treatment schematic



Process technology

Schematically it is possible to distinguish three separate treatment cycles:

- Water: Water coming from existing oil & gas production plant, which contains hydrocarbons and solid particles in suspension, is collected in a storage tank. The water is passed through a corrugated plate interceptor (CPI) and then to a flocculation unit, where specific chemicals (flocculant and coagulant) are added. Water is transferred to a flotation unit and the cleaned water is passed through a filter unit before underground injection.
- Oil: Floating hydrocarbons on the surface inside the storage tank and the CPI are recovered by oil skimmers (disc-oil) and collected in a recovered oil tank before being sent to the client's oil production unit.
- Mud: Flocculant masses (flocs) developed inside the CPI and the flocculation unit are sent to the flotation unit. Flocs grow until they become mud, which is recovered by the scraper inside the flotation unit and sent to the thickening machine. Mud collected at the bottom of storage tank, flotation unit and flocculation unit are also sent to the thickening machine.

The water treatment process is similar for Hassi R'Mel, Gassi Touil and Haoud Berkaoui plants and it consists of five main phases shown in figure ➔ 2:

During the storage phase, lighter hydrocarbons collect on the surface of the water in tank S-101 and are recovered by oil skimmer (disk-oil) before being sent to recovering oil tank S-108. The

Traditional mechanical filtration is enhanced by chemical filtration where sand grains become coated with the chemical additives.

3 Hangar H-101 (Hassi R'Mel)

The solution utilizes easily available cheap base ingredients, a feature which is highly advantageous in desert areas.

water is transferred to the CPI S-102 in order to perform the physical separation of water and hydrocarbons. Specific flocculant is added to water inside the CPI in order to produce flocs that grow until they become mud, so facilitating the recovery of hydrocarbons and solid particles. The third phase happens in the flocculation unit S-103 where a specific coagulant is added to water inside S-103, in order to remove colloidal material.

From flocculation unit S-103 water is transferred to flotation unit S-104, where compressed air is injected, causing very fine air bubbles to collect on the flocs and raise them to the surface of the water. The floating solids are recovered by scraper and sent to thickening machine S-105. The treated water then follows different paths depending on the plant:

- At the Gassi Touil and Haoud Berkaoui plants, treated water is transferred to an external basin where it evaporates.
- At the Hassi R'Mel plant, treated water passes through a filtering unit before being injected underground.

The fifth and last phase is solid thickening and drying where collected solids from flotation unit S-104, mud from storage tank S-101, and solids from the CPI and from flocculation unit S-103, are agglomerated and centrifuged. The resulting centrifuged mud is stored in an external area.

Challenges

Tackling water treatment in these specific cases has been particularly challenging. The authors went through extensive research and testing activities, with trials of a large number of commercial products commonly used for oily and industrial waters, but without reaching fully acceptable results.

However a novel stoicheiometric formulation of traditional products achieved surprisingly good results and gave indications about the best directions to be followed. Additional experiments resulted in the design and realization of a skid-mounted device, which is able to automatically process and prepare the additive in the optimal doses, starting from raw materials that are also available in these developing regions.

The filtration phase has also been improved because water entering the filters is mixed with the same additive. This way the traditional mechanical filtration is enhanced by chemical filtration where sand grains become coated with the chemical additives.

Finally the process is flexible enough to allow further tailoring to the specific plant features and/or needs. In our experi-

4 Operational activities at the plants

- Periodical process parameters checks (on site and in control room).
- Recording and analysis of process parameter values and trends.
- Plant management according to process parameter trends, ie, opening/closing control valves adding/reducing chemical additives, etc.
- Visual checks of equipment and instruments.
- Preliminary diagnosis of incorrect running, ie, abnormal noise, abnormal vibration, abnormal temperature, etc.
- Recoding consumption and refilling of chemical additives.
- Putting equipment into a safe condition before starting maintenance activity.
- Planned equipment shutdowns and startups.
- Coordination with maintenance personnel and laboratory technician.

5 Water quality results for Hassi R'Mel Center de-oiling plant

	Units	Inlet water	Outlet water	Acceptable values after treatment
Hydrocarbon concentration	mg/kg	278.90	0.70	5
Suspended solids concentration	mg/kg	11.05	0.34	20 (SiO_2)
Filtration degree	µm	>> 5	< 5	5

ence, the capability to understand and adapt to water and environment specific challenges is no less important than the underlying technology.

Advantages

The innovative approach and equipment are currently patent-pending and present the additional advantage of being relatively cheap and potentially able to significantly remove heavy metals through an ionic exchange-like procedure.

The water treatment process has been selected because of some striking advantages inherent in its implementation.

In fact the proposed approach:
- Can be adapted to treat oily water with high salinity.
- Is not dependent on the pH of the wastewater.
- Is not dependent on the temperature of the wastewater.
- Has full flexibility of flow (0 to 100 percent of maximum inlet water flow).
- Improves energy efficiency by minimizing the number of pumps through the use of gravity flow.

The approach is also characterized by a reduced footprint, it is housed in an indoor area just 35 meters wide and 80 meters long ➔ 3. The solution allows easy management by local operators and utilizes chemicals which can be produced on site starting from easily available cheap base ingredients, a feature which is highly advantageous in desert areas like the locations discussed here. Lastly, it should be noted that because of the design, the de-oiling plants can be built on skids (in factories or workshops) and then hauled to site for final installation and commissioning.

Operation and results

Gassi Touil and Hassi R'Mel Central plants were commissioned after revamping in the first quarter of 2009.

For each water de-oiling plant, three groups have been set-up in order to assure continuous and efficient operation:
- Plant operation team, composed of one site manager and four operators (two on day shift and two on night shift).
- Plant maintenance team. Composed of one mechanical technician, one electrical technician, one instrument technician, and one helper.
- One laboratory technician.

Maintenance activities are based on a detailed maintenance plan which has been prepared, starting with equipment maintenance manuals and an analysis of equipment criticality. The plan was developed in order to ensure plant availability and reliability and to guarantee full compliance with health, safety and environmental requirements. Planning has reduced corrective maintenance and has maximized planned and preventive maintenance activities including:
- Major overhauls.
- Mechanical and static equipment inspections.
- Instrumentation and electrical component checks.
- Spare parts replacement.
- Lubrication refilling.
- General cleaning.

In order to ensure the correct operation of the water de-oiling plants, laboratory analyses are regularly performed by a laboratory technician who is in charge of water analysis for all the water de-oiling plants in the same region. Correct operation requires the following quality analyses to be carried out daily on water samples:
- Hydrocarbon concentration (HC).
- Suspended solids concentration (TSS) or turbidity.
- Filtration degree (only for Hassi R'Mel Region).
- pH (only for flocculant preparation).

After the plant's startups and first operational experiences, laboratory analysis provided consistently excellent results ➔ 5. Note that hydrocarbon content and suspended solid concentration values in the outlet water are respectively seven and 55 times smaller than the client's contract specifications ➔ 6.

> The process is flexible enough to allow further tailoring to the specific plant's features and needs and the innovative approach and equipment have a significantly reduced physical footprint.

The plant uses standard equipment (pumps, motors, air compressors, etc.) and instruments (indicators, transmitters, etc) for which the operators don't need specific know-how or experience. Operation of the water de-oiling plants is relatively simple and the whole process

6 Visual evaluation of the water purification process results

is controlled and regulated by a DCS located in the control room. The plant layout and hydraulic profile are designed to maximize the use of gravity flow and to reduce the number of pumps. Electrical and instrument components are ATEX Directive compliant and the plant is protected by a fire fighting system which uses water, foam and CO_2 as appropriate. The plant construction and setup took approximately two years, including six weeks for pre-commissioning and commissioning.

Hydrocarbon content and suspended solid concentration values in the outlet water are respectively seven and 55 times smaller than the client's contract specifications.

Options for the future

The oily-water treatment strategy and implementation described above is proving a remarkable success in a number of respects. First it has reached and exceeded performance targets in terms of the quality of the treated and released waters. Secondly this performance has been obtained in a reasonably short period of time and with a clever and careful procedure which has proved to be sustainable over time. Last but not least, this design is energy efficient, and enables the operator to minimize operating costs.

Because of its inherent features, the described approach (presently patent-pending) is suitable for the treatment of highly saline wastewaters, making it an excellent fit for the treatment of wastewater from oil and gas production plants.

The methodology promises to be easily and successfully extended to water treatment units in such diverse environments as oil refineries and pulp and paper plants, not to mention the potentially large market of oil production from oil sands in regions like Alberta, Canada, where the extraction process demands huge volumes of water.

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Further reading
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Testing large ASDSs

Testing adjustable speed drive systems which are bringing new levels of efficiency to oil and gas customers

DANIELE BUZZINI, MAURIZIO ZAGO – Driving a compressor by means of an adjustable speed drive system (ASDS), which is the ensemble of transformer, converter and motor, assures higher flexibility, higher efficiency, lower maintenance costs and a lower impact on the environment. For these reasons the extensive use of ASDS driven compressors and pumps is increasing in oil and gas applications, specifically for transportation, gas liquefaction and injection. This article goes behind the scenes to look at the testing of large ASDSs and how customers are given the evidence that the system meets the performance of the design stage before its delivery to site [1].

ASDS performance testing

In 2009, ABB's Process Automation division for oil and gas won two contracts which include two ASDSs rated at 18.2 MW which will drive centrifugal compressors for gas lift facilities and two ASDSs rated 13.5 MW that will drive centrifugal compressors for gas injection facilities in the UAE. The ASDSs selected for this project are all based on load commutated inverter (LCI) technology, each one composed by a four winding transformer, a 12-pulse LCI, a synchronous motor and a power factor compensation and harmonic filter ➔ 1. The four windings transformer has one primary and three secondary windings. Two secondary windings feed the 12-pulse converter rectifier, which is line commutated, while the third feeds the power factor compensation and harmonic filter. The windings dedicated to the converter are 30 degree phase shifted thus creating the 12-pulse reaction line side which contributes to eliminate the non characteristic harmonic currents such as the 5th, 7th, 17th, 19th.

The LCI converter is one of the most reliable drives available on the market. The LCI is based on thyristor technology and it consists of two six-pulse input thyristor rectifiers, a DC-Link reactor, two six-pulse thyristor inverters, the control system and a synchronous motor excitation unit and cooling unit. The LCI acts as a current source for the motor, the controlled rectifiers are line commutated while the inverters are load commutated. The thyristors are selected in N+1 configuration so that, even in case of single failure, the converter is still capable of providing full power, therefore maintaining the system's availability. The DC reactor serves to smooth the DC current as well as to reduce fault currents in the DC link.

The four-pole, solid rotor, synchronous machine has two 30° phase shifted windings, suitable for 12-pulse inverter connection. The current fed in each of the three phase windings remains a six-pulse current, but the resulting magnetic field in the air gap presents only 12-pulse characteristic harmonics. This reduces the shaft torque ripple as well as the rotor temperature rise caused by the losses of induced current harmonics in the rotor.

The autotransformer is the perfect choice to keep a high short circuit level at supply side.

The motor excitation is brushless with a tri-phase stator winding (exciter machine), fed by a static excitation unit mounted within the LCI excitation cabinet. The exciter winding itself, generating the rotating field, is fed via the exciter machine and the rotating diode bridge.

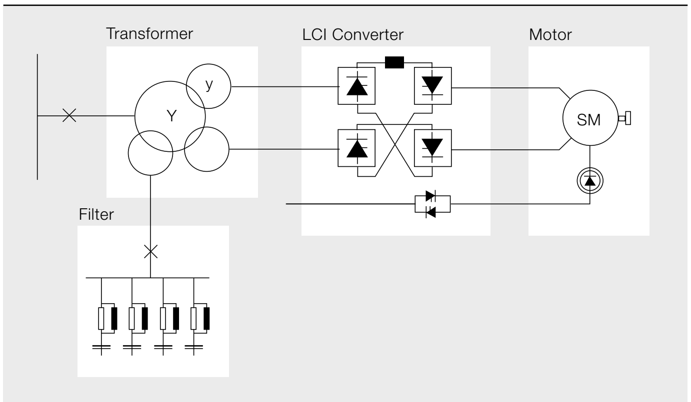
The power factor compensation and harmonic filter (PFCHF) has the primary function of compensating the LCI reactive power consumption. The choice of the filter composition (ie, the number of branches, tuning etc.) has been done in such a way to reduce as far as possible the injection of current harmonics by ASDS into the grid.

The back to back test

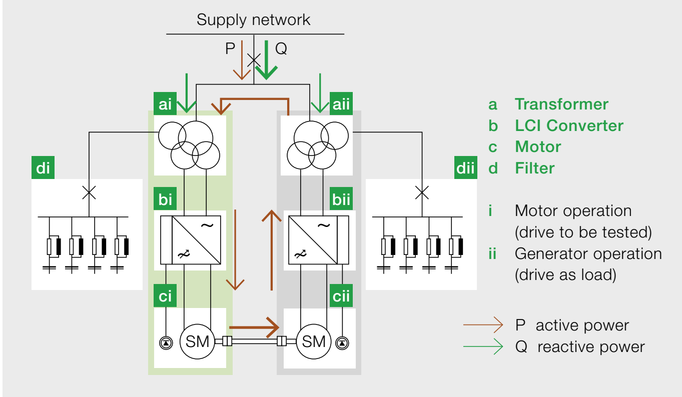
For this specific project, the end user requested a performance test of the whole ASDS according to the Shell Design and Engineering Practice. The LCI converter is an inherent four-quadrant converter, meaning it can be operated in motor and braking mode, which is well suited to the back to back test configuration. In the back to back test arrangement, two ASDS were lined up: one working as motor (driver) and one acting as generator (braker) ➔ 2. The active power adsorbed by the motor is generated by the braker and recycled in the motor again. On the other hand the reactive power is adsorbed by both the converter (driver and breaker). As a consequence, most of the power remains in the process and only the losses of the two VSDSs, and the excess reactive power which is not compensated by the two filter systems, consume energy fed from the test bay supply network. The absorbed power was 8 MVA of which 1.7 MW was active power and 7.8 Mvar was reactive power.

The back to back test arrangement makes it possible to run the ASDSs at their rated power, a condition not otherwise possible during either the compressor string test nor during site test. In fact, with these two test configurations, the load applied to the motor shaft corresponds to the compressor rating, in this

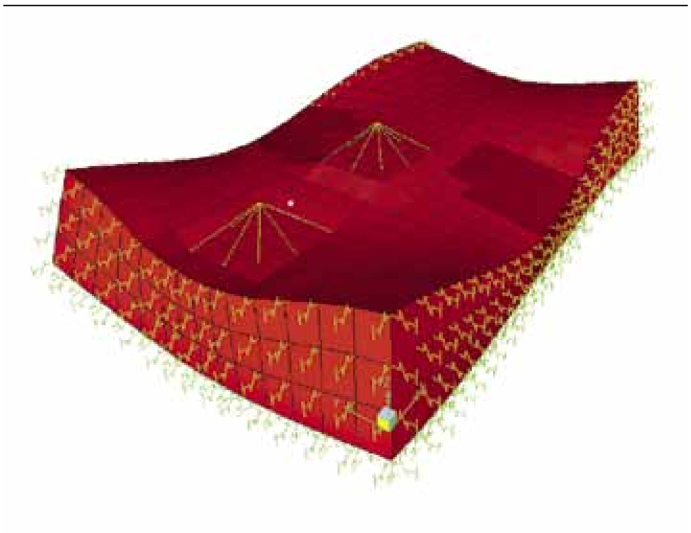
1 ASDS overview



2 Back to back test setup



3 FE flexible model of the foundation



4 Construction of the foundation

case 10.6 MW and 15 MW for the gas injection and gas lift respectively, while the rated power of the synchronous machines are 13.5 MW and 18.2 MW. Such a test requires available power, adequate facilities and experienced know how. The cooperation between ABB's Process Automation experts and the team from CESI was the key to success.

Test-field power figures

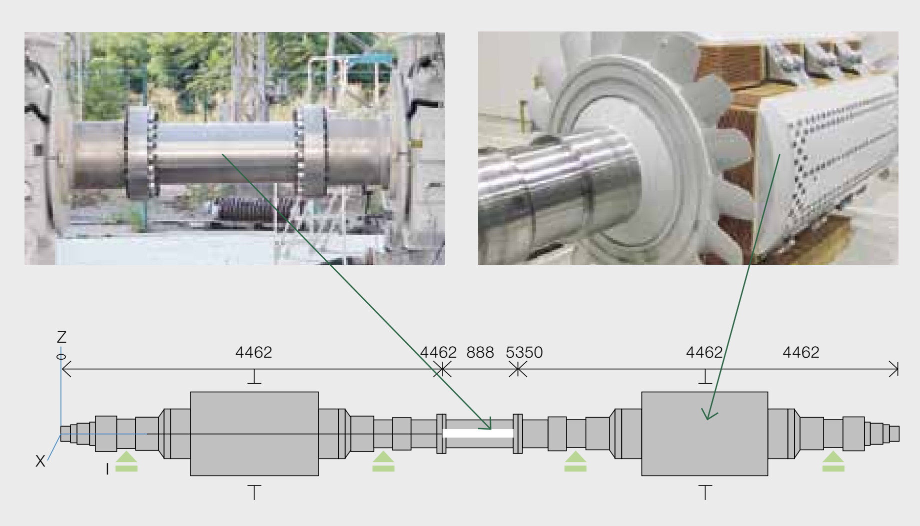
The test bay is fed by a devoted 70 MVA, 220/24 kV transformer, directly connected to the Italian high voltage power transmission grid. This ensures a reliable and stable power supply as well as a high short circuit power at the point of coupling (PCC) 600 MVA. The high short circuit power at PCC means a lower voltage drop at equal load conditions and a higher harmonic current injection to the utility system. This made it possible to make the design of the harmonic filter easier and more cost effective. A 20/25 MVA autotransformer is used to step up the voltage to the ASDS transformer primary winding voltage: 33 kV. The autotransformer, with its inherent low short circuit impedance, is the perfect choice to keep a high short circuit level at supply side. The short circuit power at 33 kV is in fact 350 MVA, in a ratio larger than 20 compared to the absorbed power, hence no dynamic issues were faced.

The importance of a stiff foundation

Special care has been taken to design the foundation for the rotating machines. The foundation must ensure a rigid mounting for the rotating machine (IEC 60034-14). A foundation of 20 × 13 × 3 m was designed and built from scratch in the test bay. A finite element (FEM) model of the foundation resting on the Winkler spring bed was set up to compute flexible eigenvalues and eigenvectors → 3. Since flexible modes can be excided by unbalanced forces, a dynamic analysis was carried out with the FEM model to evaluate the foundation vibration at the motor fixing point. The maximum vertical vibration of the motor fixing point was calculated around

The LCI converter is an inherent four-quadrant converter and is well suited to the back to back test configuration.

5 Back to back shafting construction



The back to back test arrangement makes it possible to run the ASDSs at their rated power, a condition not otherwise possible during either the compressor string test nor during site test.

10^{-3} mm/s, below the lowest threshold values listed in the IEC 60034-14 for class B vibration limits (25 percent of 1.5 mm/s for motor with shafts height greater than 280 mm) → 4.

Rotor dynamic analysis and pulsating torque in the air gap

The coupling between the two synchronous machines was designed to withstand short circuit torques and to avoid possible resonances due to the pulsating torque in the air gap of the rotating machines generated by the converter operation → 5.

The power converter driven machines are subject to pulsating torque in the air gap → 6. The pulsating torque components are due to the current harmonics which are impressed on the motor by the converters. These pulsating torque components can be classified as follows (f_M = motor frequency; f_N = line frequency):

– integer pulsating torques with the frequencies n f_M, (n = 6, 12, 18, 24)
– non-integer pulsating torques with the frequencies k f_N (k= 6, 12)
– non-integer pulsating torques depending on both the network frequency and the motor frequency according to: $f = |n f_M \pm k f_N|$ (n = 6,16; k = 6, 12).

Although the amplitudes of the pulsating torque are small compared to the driving torque, they can excite resonances when their frequencies coincide with a natural frequency (modes) of the shafting. The coupling was designed in order to guarantee a separation margin between the intersections (resonances) of the inclined lines and the modes.

Harmonic filter and reactive power compensation

To compensate reactive power and harmonics a filter system was designed and commissioned for this test → 7. The filter used during the test was built up in three branches and tuned to the, 5th, 11th and 23rd harmonic order, to reduce the current harmonics injected by the LCI converter into the network. The capacitors of the harmonic filter are also used to compensate the reactive power adsorbed by the converter.

The characteristic current harmonics are absorbed by the filter branches for the 11th and 23rd. The non-characteristic harmonics N=5 are absorbed by the 5th harmonic filter → 8. The reactive power of all three filter branches (per drive) adds up to 11.5 MVAr for the gas lift system and 6.5 MVAr for the gas injection system (only 5th and 11th filter branches were switched on). The measured voltage THD was 0.85 percent, far below the recommended IEC prescriptions (<5 percent IEC 61000-2-4, class 1).

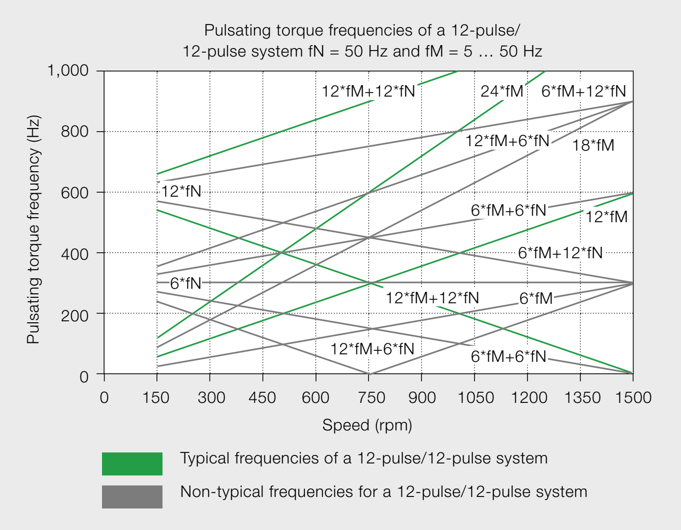
Test schedule and results

The ASDS has been subjected to the entire test sequence listed in the Shell Design and Engineering Practice for AC electrical VSDs. Heat run, load, no load, functional and fault condition tests have been carried out → 9. A network analyzer installed in the test bay shows the voltage and current at the primary and secondary side of the transformer when the filter is switched on → 10.

To compensate reactive power and harmonics a filter system was designed and commissioned for this test.

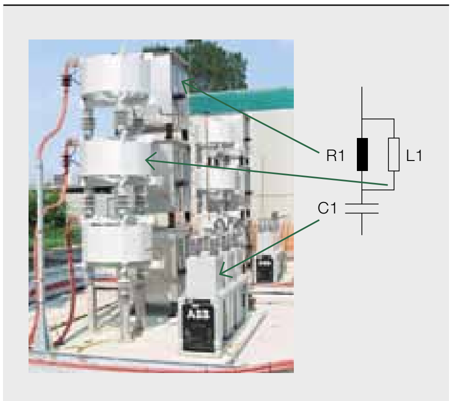
The efficiency of the adjustable speed drive system is determined by summation of the losses of the drive system equipment that are measured or calculated (segregated losses method) [2]. The test has shown that the efficiency of the

6 Pulsating torques

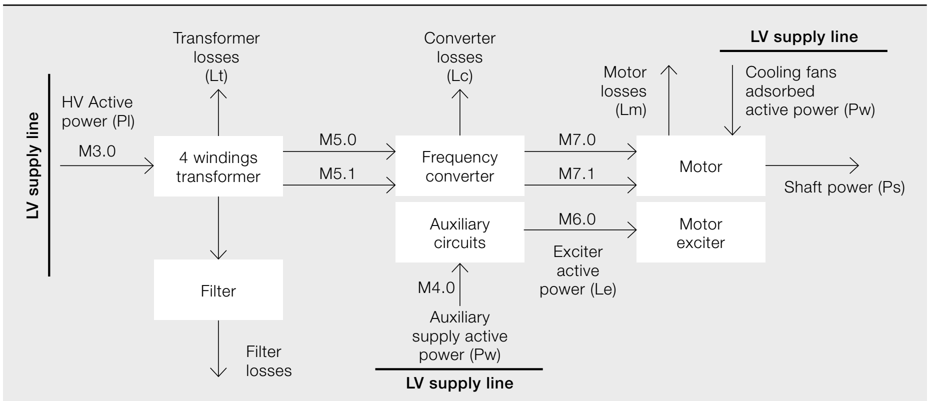


7 Reactive power and harmonics filter

8 5th harmonic filter branch



9 Active power flow during tests



ASDS is 95.76 percent. This value complies with the anticipated figure.

A proper measurement strategy has to be adopted for measuring the electrical variables in the case of a distorted load like a frequency converter.

Active power is defined as:

$$P = \frac{1}{k \cdot T} \cdot \int_{\tau}^{\tau + k \cdot T} p \cdot dt$$

(p is the instantaneous power: $p = v \cdot i$)

Applying Fourier analysis to voltage and current, the active power results as the sum of two terms: P_1 and P_H, the fundamental active power and the harmonic active power respectively.

$$P = P_1 + P_H$$

Fundamental active power (W)

$$P_1 = V_1 \cdot I_1 \cdot \cos\delta_1$$

Harmonic active power (non fundamental active power, W)

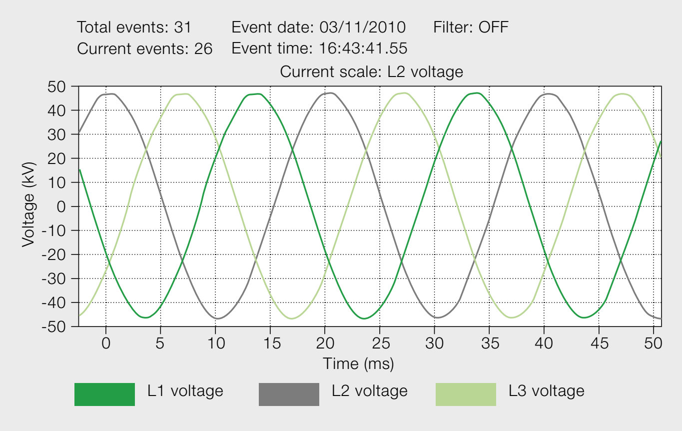
$$P_H = V_0 \cdot I_0 + \sum_{h \neq 1} V_h \cdot I_h \cdot \cos\delta_h$$

For the electrical machine the harmonic active power is not a useful power, that is, it does not contribute to the positive sequence torque. Consequently, it is meaningful to separate the fundamental active power P_1 from the harmonic active power P_H.

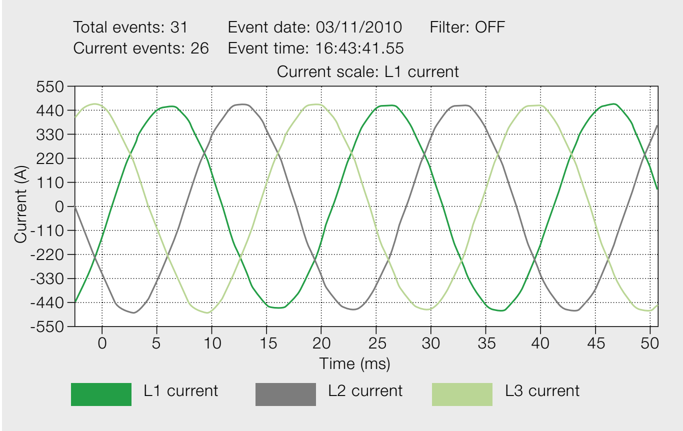
The measurement of P_H itself is not an effective way to evaluate harmonic power flow, because some harmonic orders may generate power while others dissipate power in the observed load, leading to mutual cancellation in the P_H term. Only a complete listing of the harmonic voltage and current phasors (magnitude and phase) can lead to a clear understanding of the contributions made by each harmonic to the electric energy flow [3].

The test experience gained in this field is used to give customers the confidence that their drive system meets their efficiency requirements.

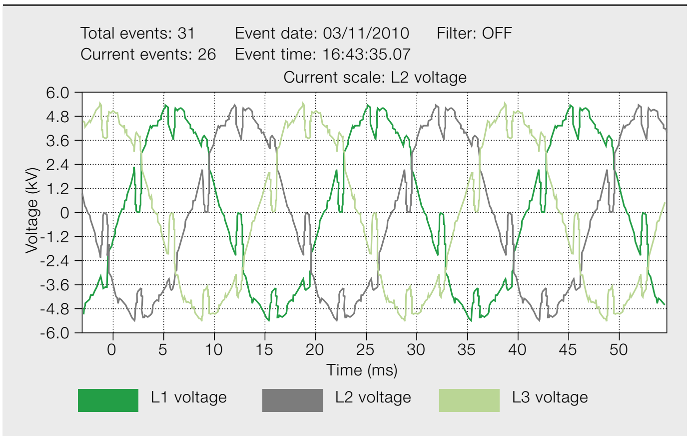
10 Voltage and current at primary and secondary side of four windings transformer



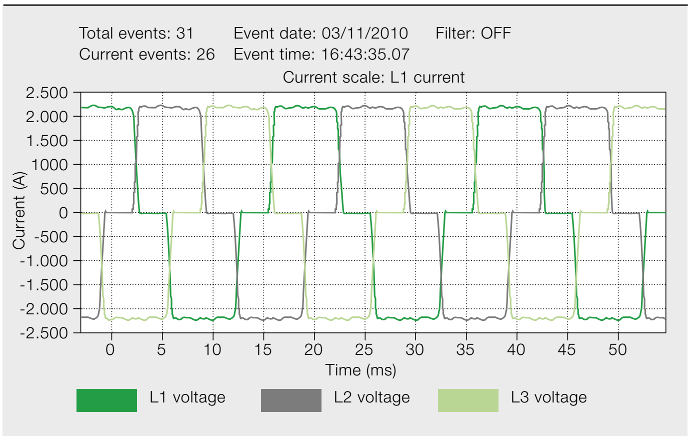
10a Voltage at primary side



10b Current at primary side



10c Voltage at secondary side



10d Current at secondary side

Valuable outcomes

Two 13.5 MW and two 18.2 MW ASDSs have been successfully tested by ABB's Process Automation division for oil and gas in its test facilities at CESI Milan, Italy. The test set up is ready to accommodate machines of up to 40 MW and more.

The test experience gained in this field is used to give customers the confidence that their drive system meets their efficiency requirements and that the system will deliver the nominal power it is designed to. Furthermore the full load performance test can prove that the equipment is compliant for the project specification according to the standards of the oil and gas industry.

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Further reading

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[2] Burmeister, P. (2009, November). Torque Pulsation in the Air Gaps of both Motor and Generator. ATDAD
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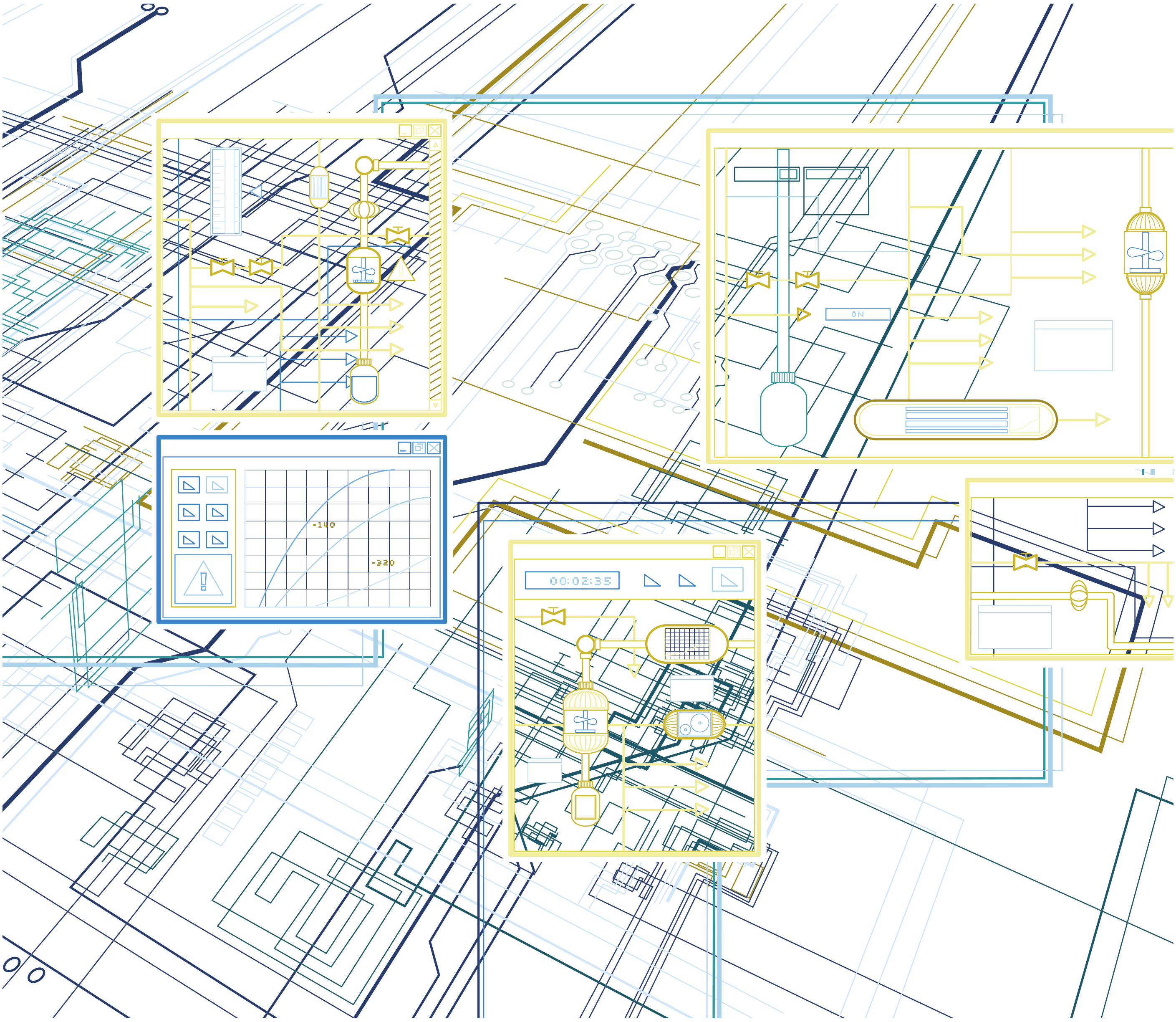


Wise warnings

Providing useful business insight by turning process data into early problem detection warnings

GEOFF ARTLEY – The refining industry today is under extreme financial pressure. Margins are being whittled away, the use of high sulphur, high metals heavy oil is becoming the norm as clean light oil prices increase. The industry is losing knowledge through retirees. However there are solutions to help tackle these challenges. Refining processes can be operated at their operational optimum at a relatively low capital cost, using the experience that is tied up in the process history within the automation system.

Modern distributed control systems (DCS) can store vast amounts of historical data which in turn contains vast amounts of information about the process. Using that data and converting it to information enables the process to be operated closer to the optimum. The key thing to remember here is that this can be achieved with a relatively low capital outlay.

Modern DCSs generate terabytes of data which are often just stored in the control system historian for regulatory and compliance reasons. This data remains unanalyzed and is discarded once the regulatory storage date has passed. Yet within this data there is a goldmine of information that, if interpreted correctly, can be transformed into information and knowledge and used to improve the profitability of the enterprise.

The challenge for many processes is maintaining tight control of the process by taking timely corrective action. Early recognition that the process is moving away from the normal operational envelope reduces process variability and allows the process to be operated closer to its optimal limits. A data mining application enables early recognition by determining when the process is moving away from "normal". This is achieved by using the historical data to benchmark the process for "normal operation", comparing the current operation to the data-mined normal, and then detecting when the operation is moving away from the required normal.

Process alarms are currently used for two purposes: protecting the equipment and the process from damage and protecting the process from straying outside normal operation. Process alarms that are used to protect equipment and the process are often invoked too late for the operator to take controlled corrective action, except to shutdown or take other extreme evasive action. By using an online data mining application, abnormal operation can be detected before such a process alarm is activated.

These applications exist and are in use in some industries today. ABB is able to offer Early Detection of Abnormal Operation (EDAO) [1] based on AJMC's MS2 online application [1] and is also developing another early fault detection (EFD) application [2] in partnership with Shell/Statoil. The EFD solution is a sophisticated asset monitoring application that builds on knowledge of multivariate changes. Rather than considering a single variable, multivariate means that variables are correlated and this correlation should be taken into account when considering the response of the measurement of interest. Most processes are multivariate in nature. The applications use principal component analysis (PCA) to capture the variability within the data, related to multivariate changes.

By using an online data mining application, abnormal operation can be detected before process alarms are activated.

The basic principle is that data that is representative of normal operation is used as the operating benchmark and this data is used to create the benchmark model. Current process variable values are compared to this benchmark model to determine whether the current data is within or outside of this normal operation.

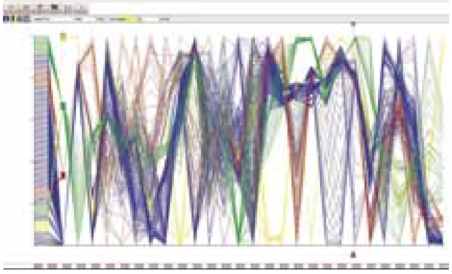
To assess whether the data is within or outside of the benchmark model, a measurement is required. In the case of MS2, this is the square of the errors between the current data and the benchmark model data. If this value goes high this would indicate that the current operation is very different to the benchmark model and is abnormal.

When the application recognizes changes that are outside the normal variability of the process it advises the operator that a potential issue is occurring. These change issues can be detected before a process alarm has been invoked, giving the operator time to take corrective action. For large rotating machinery, similar applications have provided early warnings days, or even weeks, in advance of a machine failure allowing planning time to correct the fault before a catastrophic failure.

To apply the solution universally, the application needs to be DCS independent. Hence data should be transferred using

1 Parallel coordination visualization (PCV) plot

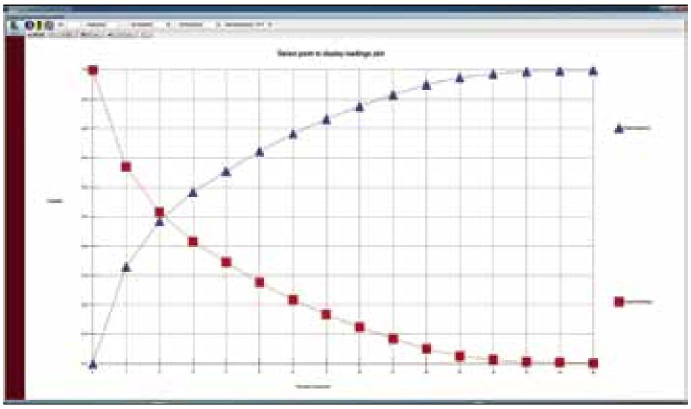
This technique provides a view of relationships between many diverse process variables, for instance quality parameters such as pH and viscosity, process parameters such as maximum pressure or temperature and calculated values such as operation duration or shift identity. Results of further analysis, such as principal components, can be viewed on the same plot as primary variables.



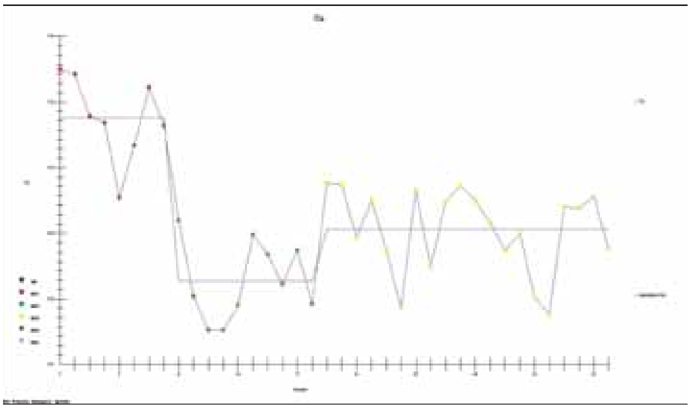
Footnote

1 ABB's EDAO system incorporates the MS2 process diagnostics system, developed by AJM Consulting with assistance from the Centre for Process Analytics and Control Technology at Newcastle University. MS2 has been successfully applied to a range of process sectors including petrochemical, chemical, pharmaceuticals, nuclear and advanced materials.

2 Example of a scree plot



3 Manhattan plot showing temperature



OPC, which is a standard which specifies the communication standard for real-time plant data between control devices from different manufacturers, and offline data imported using csv and xls data files.

Process operators and engineers often prefer to look at graphical views of the operation and, in the case of MS2 and EDAO, this can be provided in scores plots. Scores plots are the principal components plotted against each other (three principal components produces three graphs, four principle components produces six graphs, and so on) and they are able to depict the "normal" or "required" representation of the benchmark data in ellipses of confidence limits that include all of the data. The current data is plotted alongside this benchmark data and if the current data is within the confidence limit ellipse then the representation of the operation is classified as "normal and required". Once the data point moves outside the confidence limit ellipse it is classified as "abnormal". If it is later decided that this data is not abnormal then it can be included in the model for normal data to improve the model and to eliminate false alarms arising. The ability to re-classify outlying data is an important concept in preventing false alarms.

If a particular abnormal situation has been seen previously and analyzed to determine a cause and corrective action, for ABB's system 800xA, a text string message can be sent to the operator screen providing advice as to what action can be taken to remedy the situation. This builds operator confidence in using the application; otherwise the apparent black-box nature of the application may discourage operator use. The mathematics within the application is relatively complicated and determining an ultimate reason for an abnormal situation would involve somewhat complex analysis to decide on an action to be taken. Any new analysis in this respect would normally be undertaken by an engineer or expert.

Applying EDAO

There are four simple steps for deploying EDAO applications online. ABB personnel are able to support clients in all of these steps:

1 Decide on the measurement of interest.
2 Create the benchmark model.
3 Set up the communication link.
4 Configure the interface.

The first task is to decide on the measurement of interest. This is the most important step and it is vital that this variable represents an overall target for the process, particular process area, or item of equipment. The measurement of interest would normally be a high level measurement such as an intermediate or final quality or throughput or impurity. It may be necessary to create a derived tag to act as the measurement of interest, for example, in the case of rotating equipment it may be an efficiency or throughput measurement.

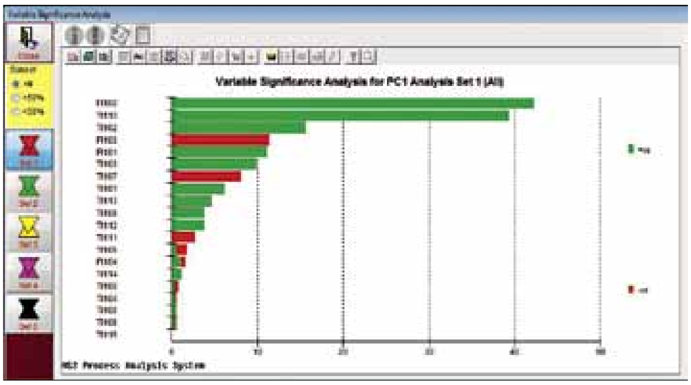
The user then analyzes which measured variables relate to or affect the chosen measurement of interest, and could highlight abnormal operation. Any data used for this analysis needs to be screened and either corrected or discarded due to bad values, high data compression, zeros, and so on. At this stage, any reasons for the abnormal operation are also determined with the intention of passing this information to the operator for situations that have been seen before.

The second step is to create the "normal required" benchmark model of the process for both the measurement of interest and the variables affecting the measurement of interest. Determining the contributing variables for periods of operation where the measurement of interest is within the required range or normal is done offline and uses historical data.

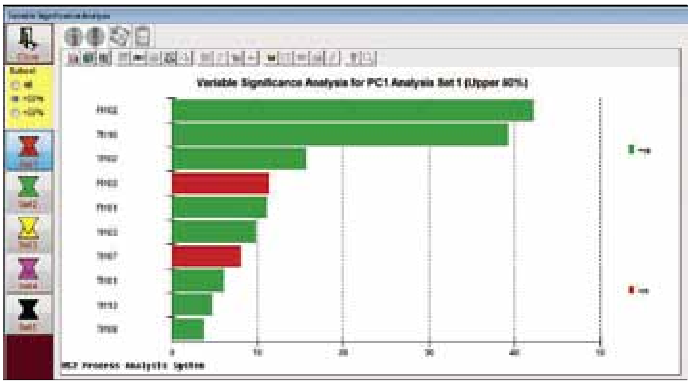
For viewing the data a parallel coordinates (PCV) plot is very useful and will determine any univariate reasons for abnormal operation → 1. A PCV plot shows all of the data, with each variable along the Y-axis joined to the equivalent (normally on a sample time basis) value of another variable along the x-axis. A PCV plot is one of the main viewing

For large rotating machinery, early warnings have been provided days, or even weeks, in advance of a machine failure allowing planning time to correct the fault before a catastrophic failure.

4 Variable significance analysis showing which variables contribute to the cluster set



5 Example of a variable significance analysis



Early fault detection applications are set to become the expected way of informing the operators that the important process variables are trending away from good control.

tools used by the MS2 and EDAO application.

A PCV plot is univariate but is a useful tool for seeing all of the data. It is unlikely that univariate analysis will completely determine the reason for abnormal operation; also any univariate reason is likely to have been found through other data viewing and analysis methods, such as, time domain plots of the variables. For multivariate analysis, which is the likely required analysis, principal component analysis (PCA) is used to find the variables contributing to abnormal operation.

The user or expert needs to choose the number of principal components (PCs) that represent the variability of the process and the contributions to the measurement of interest. This is also carried out offline. Choosing the number of PCs is a significant factor in obtaining good data analysis. The analysis can be affected by choosing too many PCs, which could slow down the analysis, as well as too few PCs, which could mean missing vital information. There are several means of choosing the optimum number of PCs, for example, perhaps only those PCs with eigenvalues that are greater than one are relevant. This is based on the Kaiser-Guttman rule for significant PCs. Often this provides a sufficiently representative model of the variability.

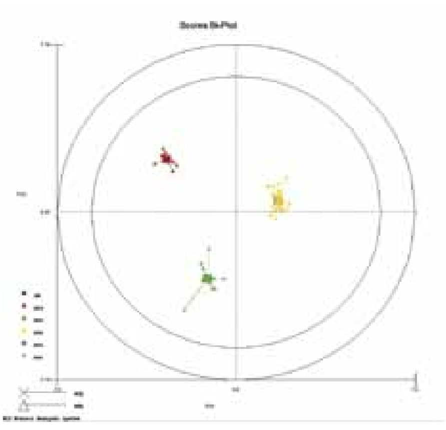
Between 75 to 90 percent of the variability should be represented by the number of PCs chosen. If the automatic choice method does not provide a good solution analysis for the measurement of interest then the number of PCs can be chosen manually to represent more of the variability. A scree plot shows graphically and numerically how much of the variability is represented by the number of PCs chosen → 2.

As part of the offline analysis other graphical views could be used to finalize the reasons for abnormal operation; such as; Manhattan trends → 3, CUSUM trends → 3, variable significance plots → 4 and → 5, scores plots → 6 and → 7 and so on. The Manhattan plot shows the time series variable value (in blue) the CUSUM plot (in green) and the Manhattan plot (in black) showing the points of significant change. The sensitivity of the Manhattan analysis can be chosen, to assess the significant change points and compare them to the measurement of interest change points. The Manhattan analysis is a powerful tool in assessing the areas of significant change and determining the contributing variables. This plot is only available as part of the MS2 and EDAO tools.

For online analysis the current process values that have been determined to contribute to the measurement of interest are compared to the benchmarked model to determine whether the current values of the variables are within this benchmark model range.

The next step is to set up the communications link to allow current on line data to be used by the application for analysis. Real-time data would be generally passed over to the application at some specified frequent interval using OPC. The user needs to allow time for the application to run its algorithms on the current dataset then, where the application detects operation outside the benchmarked operation, an alert can be sent to the operator workstation screen as a warning that the process is heading off in an undesired direction. Operation that is

6 Scores plot showing how different analysis sets form clusters



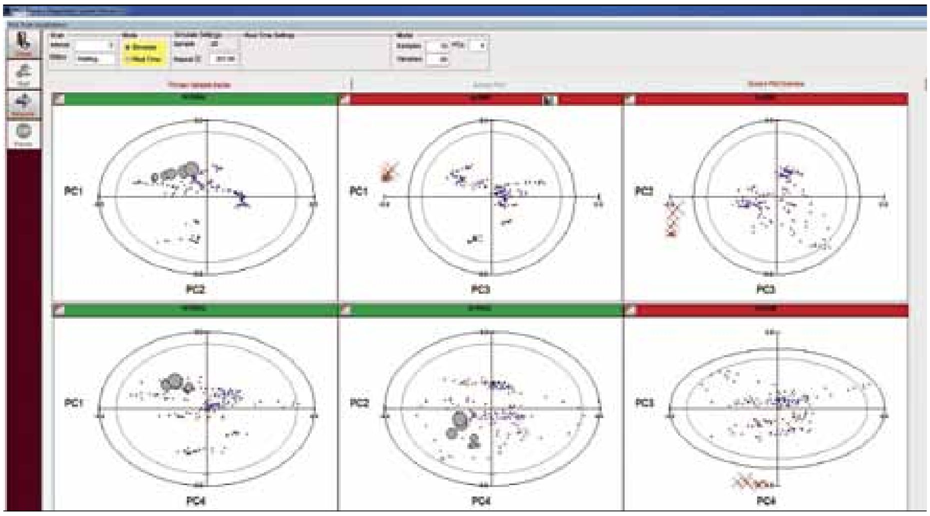
subsequently assessed as being desirable is easily incorporated into the benchmark model to prevent future unnecessary notifications.

Once the communications link is established the user needs to consider how the operator will be alerted. ABB is conscious that creating an alarm is relatively easy therefore it's possible to have too many operator alarm alerts. However, abnormal operation alerts could be created in many ways for example; via mobile telephone SMS messaging to the engineer responsible for the process area, or to the responsible engineer's computer or by a text message on the operator workstation. When the process

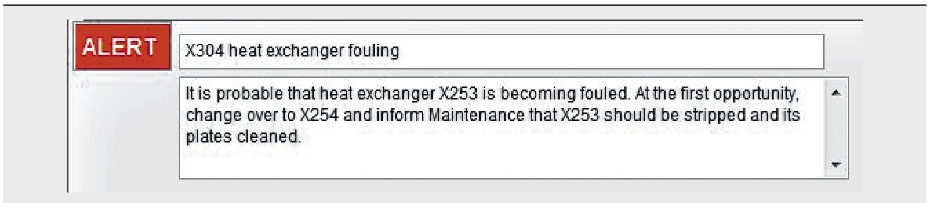
> Operation that is subsequently assessed as being desirable is easily incorporated into the benchmark model to prevent future unnecessary notifications.

operation moves outside the benchmark range, operator alerts can be created (either through an alarm or simple graphical color change on the operator workstation, and so on) to inform the operator that the measurement of interest is moving away from its desirable value. This detection would be observed before any

7 PCA score plot providing a fault signature



8 Operators diagnostic message



process alarm is invoked therefore leading to early detection of an abnormal situation. This could be achieved, for example, by displaying the square of the differences (for MS2) as a bar graph with limits that invoke a color change when the value goes high. The operator is then able to investigate the various graphics for confirmation. Also, as previously mentioned, if the excursion pattern has been seen before and analyzed and a reason found and configured on the DCS (for example, a fouling heat exchanger or a blocking filter) then a text string message can be displayed on the HMI to suggest actions that the operator can take to alleviate the issue → 8.

Outcomes

These early fault detection applications are set to become the expected way of informing the operators that the important process variables are trending away from good control. The current process alarms are then able to be used for real emergency situations only rather than the current practice of trying to cover poor operation as well as protection. These applications involve complex mathematics but are normally black-box applications as far as the operator is concerned and do require engineer or expert intervention for full understanding.

When assessing the benefits, the cost of investing in such an application is offset against the massive cost of loss of production or critical equipment replacement.

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References

[1] Offline MS2 is marketed through AJMC, http://www.ajm.co.uk. Online MS2, called EDAO, is currently marketed through ABB UK at St Neots
[2] ProcessInsights – refer to Knut Hovda or Hans Petter Bieker ABB Norway

Remote inspection and intervention

Remote robotics at work in harsh oil and gas environments

CHARLOTTE SKOURUP, JOHN PRETLOVE – The global demand for oil and gas remains high and will do for the foreseeable future. However, the industry is facing a number of challenges, including the struggle to retain production levels and access reserves that are often in extremely demanding environments. These challenges have led to calls to boost the level of automation in the oil and gas industry while maintaining the focus on health, safety and the environment. Many oil and gas facilities are already remotely operated during normal operation, but highly skilled people are still needed to perform specialized work, such as maintenance and repair tasks during operation and planned shutdowns. To benefit from an increased level of automation in this area, which would protect humans from hazardous environments and potentially dangerous tasks, a combination of remote operations combined with telerobotics is required. In answer to this demand, ABB has developed a robotics-based remote automation system prototype that is capable of performing inspection and maintenance of an oil and gas process module. This compliments existing automation system and work practices and enables the operators to perform the same job but from a safer location.

The level of automation in different industries can vary quite dramatically. Within the manufacturing industry, for example, tasks that lend themselves well to being automated are those that are repetitive and repeatable; require high accuracy; are routine and often heavy; and dirty and dangerous to workers. In the oil and gas industry, the degree of automation varies between the different phases of oil exploration, extraction and production, and between the various disciplines and regions. Levels of automation range from almost non-existent (field operators reading in-field analogue measurements) to advanced process and safety control systems that have automated large, complex and dynamic processes. In general, however, most oil and gas facilities operate with hybrid or mixed levels of automation.

Challenges within the industry, such as lower recovery rates, the difficulty in accessing fields and the exploration of


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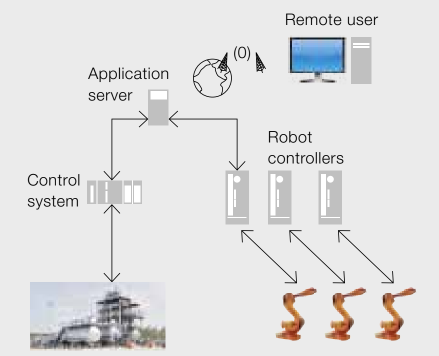
1 Physical and cognitive tasks

The mechanical or physical level of automation (LoAphys) concerns the physical work content, which is still relatively low for all tasks in the field of oil and gas installations. Teams of operators and various specialists execute the various physical tasks using their hands and tools. Some tools, such as infrared cameras that take temperature images from the outside of the process and equipment, are rather advanced.

Levels of cognitive task automation (LoAcogn) vary across the entire spectrum depending on the task. For example, when unforeseen situations occur, operators have to use their cognitive capabilities to understand the current situation, predict future states and make decisions concerning further actions. At the other end of the scale, the automation system automatically handles the immediate shutdown of the process or parts of the process without human intervention when an emergency situation occurs. Human intervention is necessary after the shutdown to access the problem and restart the process.

3 The outdoor robot test facility in Oslo

2 The robotics system architecture



ABB's robotics-based remote automation system prototype is capable of performing inspection and maintenance of an oil and gas process module.

unconventional reserves have put the need for raising the level of automation high on the agenda. Remote operation during normal operation is already a reality for many facilities. However, highly skilled people are still needed to perform critical equipment inspection including verification, maintenance and repair tasks during operation and planned shutdowns in what are often considered hazardous environments. To increase the level of automation in this area requires a combination of remote operation and telerobotics.

The introduction of robotics technology will influence roles, responsibilities and work tasks. For a start, the presence of robotics does not mean humans become redundant: They will remain a vital and irreplaceable part of the process with the main focus on cognitive rather than physical tasks → 1. Therefore, it is crucial to decide on the roles, task allocation and levels of automation between the human and the automation system incorporating the robot. An adaptive, variable, approach to automation has been suggested as a way to trade off the various benefits and costs associated with automation and manual control. In any case the main design principle of the human/robot system is to enable the operator to focus on the tasks that need to be performed and to perceive all controllable robots as physical enablers in the field to execute these tasks. This correlates with the relationships between control room operators and field operators in today's process plants. In the robotized system, the human operator remains responsible for the process and its operation while the robot performs the physical tasks with sensors and tools in the field.

Remote inspection and intervention of process infrastructure

As part of its strategy for exploring and developing new concepts for extended remote operation, ABB has already developed a robotics-based remote automation system prototype that can perform inspection and maintenance of an oil and gas process module. The system is capable of remote visual inspection, remote verification, remote automatic pig handling, and remote testing and calibration of process components. The philosophy behind this remotely operated robotics system is that the robots are integrated in the field and seen as assets in the control system. They serve as the physical tools and the operators' extended "eyes, ears and hands" within a hazardous process environment. Within the control system, the remote operator interacts with the robot using a human-robot interface (HRI) through which the different tasks the robototics system is expected to flawlessly complete can be defined and initiated. The results are then returned and presented by the control system to the operator.

4 On-site customer installation of the robotics system

Test facilities

Indoor and outdoor test facilities exist to simulate, test and verify new on-site test configurations. The indoor test facility housing the prototype is a unique lab environment used to demonstrate, test and evaluate concepts and solutions that could be of interest for future oil and gas facilities. The prototype setup comprises three ABB robots, one gantry-mounted IRB 2400 and two rail-mounted IRB 4400, as well as a full-scale separator process module (see title picture). All robots have access to multiple tools that can be changed automatically using pneumatic tool changers. Some of the sensors are carried on the robot arm, such as cameras for monitoring the work, whereas application specific sensors are mounted on the tools. In the lab setup, one robot is typically used for inspection and two for maintenance tasks.

The robots are controlled by robot controllers – all of which are accessible from an application server – while a control system controls the process. The application server runs path-planning algorithms and handles communication with the users ➔ 2. One of its main tasks is to translate the commands given by the users to instructions for the controllers and vice versa.

Computer vision and optimization algorithms have also been implemented to cope with the uncertainties of moving instruments and apparatus in harsh environments. Because these objects can move or become temporarily or permanently mechanically deformed, their position and orientation are not fixed and constitute an uncertainty that needs to be taken into account when the robots interact with the process.

Three main aspects of telerobotics are tested in the lab: autonomous control, semi-autonomous control and manual remote control. Autonomous control is ambiguous and could be described as a continuum from fully manual control to fully autonomous control. In other words at the lowest extreme, humans make all the decisions and perform the necessary activities without any assistance from the control system; at the other extreme the control system makes all the decisions and executes actions without any human involvement. An example of fully autonomous control is the frequent inspection rounds that follow a pre-defined schedule. As well as being fully capable of performing this, the control system can also decide which robot is available for each task, select the proper sensor, move the robot with the sensor safely to the various inspection points and take the measurement. The operator is only notified when deviations from "normal" values are detected. Otherwise the measurements are stored in databases and the necessary reports generated. Manual control is necessary, for example, to remove ice that has formed on a valve. During semi-autonomous control, the control system or the operator initiates tasks for the robots. The (remotely-located) operator utilizes a 3-D process model as the interface to the process to define and initiate tasks for the robots and retrieve the results from such tasks. This has been tested by operating the test facility remotely from various locations, including Houston in the United States and Stavanger in Norway. The tests have proven that the technology works consistently over several days, even over a public network with limited bandwidth.

The outdoor test facility is used to further simulate, test and verify concepts that are developed and commissioned in the indoor lab to suit real on-site test configurations before delivery ➔ 3.

A practical application – scraper handling

Based on the specialised lab facilities and experience gained within this novel field, Shell Global Solutions and ABB, in a collaborative project, have recently developed, tested and verified an automated solution for on-site scraper handling.

In the robotized system, the human operator remains responsible for the process and its operation while the robot performs the physical tasks with sensors and tools.

The purpose of the project is to demonstrate the use of robotics technology for handling scrapers in a real process environment.

5 The ATEX certified ABB IRB 5500 robot at the scraper station on a cold day during the demonstration period

The ABB and Shell demonstrator has shown that robots can be used in oil and gas facilities to perform high precision operations in all kinds of weather.

A scraper, or pig, is a device that is sent through a pipeline to inspect or clean the inside of the pipe. Each scraper consists of elastic, over-dimensioned disks that seal the pipe, while pressure from the transported product (oil or gas) pushes it forward. Typically, scrapers are manually inserted and extracted at special stations along oil and gas pipelines; extracting a scraper is particularly risky for the human operator.

A scraper will accumulate debris as it travels through the pipeline, which itself widens into a barrel form at the receiving end so that the scraper can be extracted. This barrel needs to be depressurized and drained before the door can be opened. The accumulated debris sometimes causes the depressurization process to fail, causing the scraper to be ejected with great force, as has happened on several occasions. In addition, in facilities with a high degree of poisonous gas in the reservoir, such as H2S, scraper-handling operations have to follow very strict procedures, making these operations undesirable from a cost, and in particular, from a health, safety and the environment (HSE) perspective.

The ABB/Shell solution consists of an ATEX certified industrial ABB robot (IRB 5500), which has been equipped with a tool specifically designed for scraper handling. The tool's sensors, together with the robot's built-in sensors, guide the robot and verify that operations can be safely performed. The demonstration used a standard and unmodified scraper barrel and door. With safety as a priority, an operator interface was installed next to the robot, enabling a trained operator to acknowledge each step of the process before the robot was allowed to execute the subsequent step.

The entire demonstrator concept was first installed, commissioned, tested and verified (ie, the robot was used to launch scrapers into the barrel and receive them upon arrival) at the outdoor test facility in Oslo. Before being shipped to the demonstrator site, the Nederlandse Aardolie Maatschappij (NAM) BV Schiedam's Gaag facility outside Rotterdam in the Netherlands, it passed a pre-delivery acceptance test with participants from both ABB and Shell → 4. The on-site tests (ie, extraction of the scrapers only) were performed during winter, in snow, rain and sunshine and in temperatures that fell to minus 10 °C → 5.

During a typical test → 6, the robot first verifies that initial safety critical preparation steps have been executed by ensuring that the door lock and handle are in the expected locations (ie, locked and closed). A proximity switch integrated into the tool is used for this purpose. The robot then unlocks and slightly opens the barrel door to allow debris and residual oil to pour onto a drain table in front of the barrel before fully opening the door. It inserts the tool into the barrel and begins to search for the scraper. Inbuilt functionality in the robot controller halts robot movement on state change of an input signal. When the scraper is found, the robot extracts the scraper and places it on the table. The door is then closed and locked before the robot returns to its home position.

Some simplifications were imposed on this demonstrator to fulfil the requirements. To begin with, the number of robotized tasks related to the scraper operation made up a subset of the complete operation of scraper extraction. Some of the subtasks outside the scope of this project included the opening and closing of valves, running drain pumps and removing vent plugs (after which the scraper extraction task starts). All these steps can, however, be automated with existing technology. The robotics demonstrator was also restricted to retrieving scrapers located relatively close to the door (ie, less than 0.5 away). In reality, scrapers may be located up to two

6 The robot performing its scraper handling task on site

the technology in increasingly demanding and realistic settings.

This is the approach adapted by ABB during the development of its remote automation system prototype. The initial results of this novel robotics concept are very promising. As well as increased safety, another long-term aim is that it will enable more consistent and reliable operation, which in turn will contribute to higher uptime and increased profitability of the facility.

meters from the door. Finally, the demonstrator was powered with a stand-alone diesel generator and produced its own instrumented air to avoid major modifications to the plant drawings.

With this demonstrator, ABB and Shell have shown that robots can be used in oil and gas facilities to perform high precision operations in all kinds of weather. More importantly, however, this demonstrator has enormous potential to reduce the HSE risks that these operations represent.

The challenge ahead

Future extraction and production of oil and gas are facing a number of challenges, such as lower recovery rates, fields that are difficult to access and the exploration of unconventional reserves in combination with more challenging reservoirs. These challenges indicate that an increase in the level of automation at an installation – maybe to the point that oil and gas facilities are unmanned – is all but inevitable, especially if the continuous demands for improved safety are to be properly addressed. If this is the case, then the inspection and maintenance tasks, verification, tests and calibrations currently carried out by field operators and maintenance staff will eventually have to be done by robotics integrated into the control system. While this has the potential to improve safety, it will also need to be efficient to secure added value and optimal production within a distant and harsh environment.

Satisfying the criteria of safety, efficiency and cost effectiveness in a solution is not an easy task and may require novel technical solutions, new working practices and business models. There are, however, a few fundamental factors that influence a successful outcome. To begin with, close collaboration with end-users and customers within the oil and gas market allows the projects to focus on real problems and challenges faced by the industry. This helps to provide well-defined customer requirements. The next step is deciding if these can be met using existing or emerging technologies or a combination of both. To meet the various challenges of such a complex robotics system, a step-by-step approach is necessary during the development phases, which also involves validating

As well as increased safety, ABB's remote automation system prototype has the potential to help contribute to higher uptime and increased profitability of a facility.

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Title picture

The prototype setup shown is used to simulate, test and verify concepts and new test configurations. It generally comprises three ABB robots (one for inspection and two for maintenance operations).

A mine of efficiency

ABB is helping extend the life of the massive Aitik copper mine by making it more efficient

LENA NYBERG, GERD EISENHUTH, KJELL SVAHN, PER ASTROM, SARAH STOETER
– Some 1,000 km north of Stockholm, Sweden, past the Arctic Circle, lies an impressive open-pit copper mine, known as Aitik. Although the proportion of metal found at the Aitik copper mine is low – less than 0.3 percent – it is a highly profitable mine because it is run so efficiently. In fact, operations have recently become even more efficient – a $790 million modernization of the entire mining operation has enabled the mine operator Boliden to double its production capacity and extending the life of the mine to 2030. ABB has contributed to this success by supplying a range of products and systems to power and operate the entire site.

ABB delivered the world's first gearless mill drive to Lafarge cement company in France in 1969, and the 6.4 MW machine is still operating today.

Located near Gällivare, in the arctic Lapland region of Sweden, the copper deposit at Aitik was discovered in the 1930s. However, mining there began only in 1968 when technology was sufficiently advanced to profitably extract the metal. Although the ore grading is low – 0.25 percent copper, 0.1 g gold per ton ore, and 2 g silver per ton ore – these metals are nevertheless worth digging for. In 2006, Boliden made its largest investment decision to increase output at the mine in the form of a three-year, $790 million upgrade.

Among the products and systems supplied by ABB are 650 motors, 230 drives and variable-speed drives, two 22.5 MW gearless mill drives, two 2 × 5 MW dual-pinion drive systems, four 1.4 MW permanent-magnet motors, 23 distribution transformers, gas-insulated switchgear, a harmonic filter system, the Extended Automation System 800xA process control system and of course a comprehensive service contract ➔ 1.

Mining at ABB

ABB has a long history in mining solutions. The company delivered the first drives and controls for a mine hoist at the Kolningsberget iron mine in Norberg, Sweden, in 1891 – 120 years ago! It has also delivered more than 600 new hoists and modernized hundreds of existing plants. A mine hoist delivered around 1930 by ASEA, a predecessor company of ABB, to the Zinkgruvan zinc mine in Sweden is still in operation today. ABB has several other firsts in mining history – a predecessor company, VEM, delivered the first bucket chain excavator and conveyor bridge in 1949 as well as the first conveyor belt in 1960.

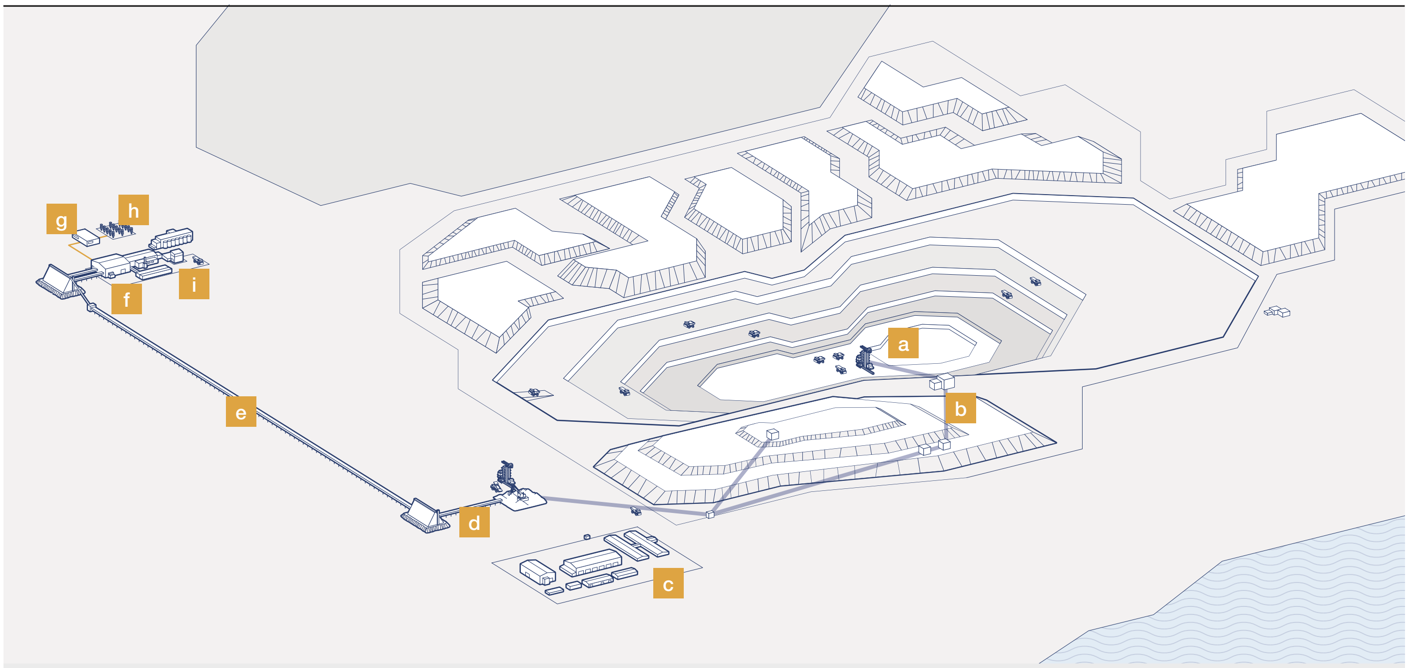
ABB has also pioneered the development of gearless mill drive (GMD) systems – giant motor and drive systems that power ore mills.[1] They are more reliable and energy efficient than traditional mill drive systems, and increase mill productivity. ABB delivered the world's first gearless mill drive to Lafarge cement company in France in 1969, and the 6.4 MW machine is still operating today.

The first ABB GMD system for mineral processing was for a copper concentrator at the Bourgainville mine in Papua New Guinea in 1985. Since 1969, ABB has delivered or has on order more than 100 GMD systems around the world. Over the years, the systems have become larger and more powerful; in 2010, ABB delivered one 28 MW GMD for a 12.2 m semi-autogenous grinding (SAG) mill and two 22 MW GMDs for the 8.5 m ball mills, for the world's largest and highest altitude GMD systems, which were to operate at 4,600 m above sea

Title picture
Aerial view of the Aitik copper mine in Gällivare, Sweden. The open-pit mine is 3 km long and 405 m deep. Photo copyright Boliden/Lars Devall.

Footnote
1 See also "Driving value" in *ABB Review* 1/2011 and "Smooth operation" on page 74 of this issue of *ABB Review*.

1 Overview of ABB's delivery to the Aitik mine



[a] **In-pit crusher**
- Motors
- Drives

[b] **Underground conveyor**
- Motors
- Drives
- Distribution transformers

[c] **Truck workshop**
- Low-voltage switchgear

[d] **Intermediate storage**
- Low-voltage switchgear

[e] **Overland conveyor**
- Motors
- Drives
- Distribution transformers

[f] **Concentrator plant**
- Gearless mill drives
- Dual-pinion drive systems
- Permanent magnet motors
- Distribution transformers
- Low-voltage switchgear
- Motors
- Drives

[g] **Substation**
- Gas-insulated switchgear
- Transformers
- Medium-voltage switchgear

[h] **Harmonic filter system**

[i] **Control room**
- Extended Automation System 800xA

level in the copper concentrator at Minera Chinalco's Toromocho mine in Peru. In 2010, ABB received an order to supply a 28 MW GMD for the world's first 12.8 m diameter SAG mill. But the most powerful GMD systems currently in operation – 22.5 MW – are those used in Boliden's concentrator plant in Sweden; they drive the huge 11.6 m autogenous (AG) mills. In terms of volume, the Aitik mills are the largest in the world with their astonishing length of 13.7 m.

Ensuring reliable and stable power through the delivery of electrical infrastructure and related equipment is also a cornerstone of ABB's contribution to mining. Automation has been a key component as well, providing the means to precisely control processes and equipment, optimize production throughput, improve worker safety, and operate with the most efficient use of materials and energy resources. Since 1883, ABB's predecessor company ASEA has been delivering electrical power and control systems to major mining operations throughout the world. Some of ABB's high-profile projects are highlighted in → 2.

Operations at the Aitik mine

A weekly blast at the Aitik mine produces enough ore for Boliden to process 106,000 tons each day. This is enough to keep the massive, 100 ton trucks – with wheels 3.4 m high – filled, hour after hour → 3. Each of the trucks delivers about 200 tons of ore to a crusher located inside the 405 m deep pit, where it is reduced to 30 cm boulders and transported via underground conveyors to an above-ground storage area. At a speed of 4 m/s, another conveyor carries the ore to the concentrator plant. ABB motors and drives power the conveyors, which

> ABB has delivered some 650 electric motors and drives for the new installations at Aitik.

2 Some of ABB's high-profile mining projects

- Supply of two bauxite transport and storage plants to the Bauxiven Los Pijigaos bauxite mine in Venezuela in 1992. The installation included the entire electrical infrastructure and electrical equipment such as switchgear, transformers, motor control centers, variable-speed drives and an ABB Master control system.
- Modernization of Cajamarquilla's zinc smelter in Peru in 1998. ABB's delivery included transformer rectifiers, an induction furnace and a process control system, which helped double the plant's capacity.
- Construction of Vale's new Moatize coal plant in Mozambique beginning in 2009. The delivery includes ABB's Extended Automation System 800xA, all medium- and low-voltage power distribution systems, drives, motors and other auxiliary equipment.

3 Massive, 100 ton trucks with wheels 3.4 m high are used to carry 200 ton loads to the crusher inside the pit at Aitik. Photo by Peter Tubaas.

4 ABB drives are installed in the 7 km of conveyors that transport the ore to the concentrator plant at Aitik.

total 7 km in length. At the concentrator plant, two 22.5 MW gearless mill drives – the most powerful in operation today – grind the ore down to sand, crushing a total of 4,400 tons of ore per hour. The sand is put into flotation tanks filled with reagents, foaming agents, compressed air and chalk, and some 500,000 liters of water are added each hour. This chemical treatment allows the metal to float to the top for easy separation. The resulting concentrate, chalcopyrite, containing 25 percent copper, is transported by rail to Boliden's smelter in Rönnskär, some 400 km southeast of Gällivare.

ABB technologies throughout the mine

Efficiency is truly the key to productivity at the Aitik mine. And ABB has provided the technologies that are making it possible for Boliden to double its production capacity to 36 million tons of ore per year.

Conveyor drives

An impressive 7 km of conveyors transport the large chunks of ore to the concentrator plant where they are ground further ➔ 4. The use of such long conveyors means that there are more demands placed on the mechanical devices and power supply. Controlled soft starting, and controlled operation and protection of the equipment, are thus important. Consequently, choosing the optimal drive solution for the conveyor is critical.

ABB has developed technology specifically to meet overland conveyor requirements. ABB's overland conveyor (OLC) drive solutions, used throughout Aitik, provide OLC-specific functionality such as load sharing, soft start under all load conditions, various braking and stop functions, and more. These solutions take into account performance, efficiency, capital costs, flexibility and optimization of operation, reliability and aging of the conveyor equipment, the number of parts subject to wear and tear, compactness of the motor, and a motor design that allows easy and rapid change of pulleys and pulley bearings.

Motor and drive systems

ABB has delivered some 650 electric motors and drives for the new installations at Aitik. The motors range in power from 4 kW to 5 MW and are used at almost every stage of the mining process. They drive the crushers in the mining pit, the conveyors carrying the crushed rock to the concentrator, the grinding mills, the pumps supplying water to the mills and removing the muddy waste left after the concentration process, as well as the fans regulating air quality.

> An impressive 7 km of conveyors transport large chunks of ore to the concentrator plant where they are ground further.

Many of the motors used at Aitik must operate 24 hours a day, 365 days a year – like the mine itself – and often in very dusty conditions. What's more, any outdoor equipment at the site must be able to withstand temperatures that can drop as low as – 45 °C in the winter. These factors make reliability one of the most important requirements of the motors and drive systems.

Substation and harmonic filter

Mining is an energy-intensive activity, and the Aitik expansion project has required the construction of two additional power lines to the site. A new, higher-capacity substation was also required to manage the additional incoming power.

ABB has delivered a 170 kV substation based on gas-insulated switchgear technology, which has reduced the size of the installation by 80 percent ➔ 5. The substation has two incoming power lines from the utility, ensuring delivery of electricity even if one line fails. Three 80 MVA transformers lower the voltage of the incoming power for use in the mine. These transformers can handle the same amount of power required by a city of 100,000 people.

Electricity is distributed throughout the mine via 24 kV switchgear from ABB's UniGear family of equipment. The substation and the two power lines are monitored and protected by ABB's Relion® relay protection. The power equipment ensures the highest possible reliability of the power supply, keeping the mine running night and day.

5 ABB's 170 kV gas-insulated switchgear distributes electric power to the mine.

6 ABB's gearless mill drives power two massive grinding mills, which are the world's largest at 13.7 m long and 11.6 m in diameter.

ABB has delivered a 170 kV substation based on gas-insulated switchgear technology, which has reduced the size of the installation by 80 percent.

ABB has also supplied a harmonic filter system, which enables Boliden to avoid damage to its own equipment as well as disturbance to the local power supply, which could lead to fines from the utility. The harmonic distortions in the grid are kept below the limits given by the IEC (International Electrotechnical Commission) and local standards, and the installed filter and power-factor correction system ensure the power factor is equal to or higher than 0.99.

Gearless mill drives

Mill drives are a critical component in ore and mineral processing. They combine huge capacity and brute strength with energy-efficient operation to grind ore into smaller pieces for further processing. Gearless mill drives (GMDs) are the largest variety, and the absence of a gearbox and other mechanical components increases their efficiency while reducing the need for maintenance.

The main component of a GMD is a colossal motor integrated into a drum-like mill in which the ore is ground. The motor is equipped with a drive, which starts the mill smoothly without any mechanical stress. The GMDs at Aitik have a rating of 22.5 MW, making them the world's most powerful in operation today → 6. The mills they power are 13.7 m long and 11.6 m in diameter – the world's largest by volume – and each has a grinding capacity of 2,200 tons of ore per hour. ABB gearless mill drives provide the huge capacity needed while keeping energy consumption low, and without reducing power quality.

Energy consumed in grinding can be 50 to 70 percent of the total energy used to recover ore. Drives are an energy-efficient way to match mill speed to the needs of the grinding process. With no moving parts between the motor and the drum, a gearless mill is also extremely strong and can reliably process vast quantities of ore.

Control system

The entire mining process at Aitik – including the concentrator plant, conveyor systems, pumping stations and even the mine's own sewage plant – is controlled by ABB's Extended Automation System 800xA → 7. System 800xA integrates a diverse assortment of equipment, systems and applications to provide a common visual interface.

At Aitik, the mine's IBM Maximo maintenance system is integrated with System 800xA, enabling creation of fault reports directly in the operator interface. This integrated solution makes it easier for the operators to report problems to the maintenance department. Now the operators simply click on the object they want to report, choose "create fault report", input the problem and submit the report, which then becomes available in Maximo. Since integrating the maintenance system, there has been a five-fold increase in fault reports, which are attributed to a reduction in unplanned downtime and process disturbances.

7 The control room at the Aitik copper mine

ABB's Extended Automation System 800xA controls the entire plant and each piece of equipment throughout the mine.

8 HTC smartphones are being used as handheld units on which to run System 800xA

Soon, engineers, operators, supervisors and the like will each have their own HTC smartphones to supervise and control the plant.

Aitik is the world's first installation to integrate not only the maintenance system but also the document management system with System 800xA. This gives operators fast and easy access to correct instructions, drawings, etc., and enables quick and accurate decisions and actions. In March 2011, Aitik also began using System 800xA asset monitors as a means to achieve predictive maintenance, focusing on three critical parts of the operation that are essential for availability and profitability at the mine. One of these is the gearbox for the large mills. Asset monitors signal the need for maintenance and help proactively detect equipment anomalies and take corrective actions before operations are affected. Boliden plans to implement the ABB Asset Optimization solution at all of its mines when upgrading their System 800xA control systems.

Aitik is the world's first installation to integrate not only maintenance systems but also document management systems with System 800xA.

Another first achieved at Aitik is the ability to run the complete System 800xA for the concentrator plant on HTC smartphones ➔ 8. This enables immense flexibility in supervising and controlling the plant.

Aitik is also one of the first industrial sites in the world to use the new international standard, IEC 61850, that defines communication within and between electrical components. This means that System 800xA provides a single environment by which to control and supervise process automation equipment, power automation equipment, as well as protection, switchgear, transmission and distribution equipment. The integration of the electrical control system with the process control system at the plant increases productivity and reduces stoppages by permitting a single strategy in the areas of engineering, maintenance and operations. Furthermore, the adoption of a global standard based on the latest technology enables lower installation and operational costs, as well as enhanced visibility of power usage and consumption.

A reliable and dependable energy supply is vital for the functioning of any industry. Managing and controlling this supply is thus as important as managing and controlling any other significant process parameter. At Aitik this means that the incoming power is visible in System 800xA. The operators have a complete overview of the entire plant and can immediately make adjustments if there are disturbances to the incoming power.

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Harmonizing drives

The driving force behind ABB's all-compatible drives architecture

MIKKO LÖNNBERG, PETER LINDGREN – ABB's drive product range extends from low- to medium-voltage AC drives to DC industrial drives. They contribute to increasing the efficiency, reliability and flexibility of industrial processes while at the same time the use of variable-speed drives contribute to significant energy savings. Now ABB has created its first low voltage AC drives portfolio built on the same, all-compatible architecture. In other words low-voltage AC drives use the same control panel, the same parameter menu structure, universal accessories and the same engineering tools. Initially the new architecture is being applied to ABB industrial and standard drives up to 250 kW with plans to extend it to higher powers in the future. The latest ABB industrial drives in the ACS880 series are one of the first to be based on the architecture. They are powerful drives capable of tackling any application and any challenge in any industry.

ABB is the world's largest drives manufacturer. Its variable-speed drives are used to regulate the torque and speed of an electric motor by controlling the power fed to it. This in turn results in: substantial energy savings (compared to constant power loads); optimal process control; a reduced need for maintenance; and functional safety as most drives offer safety features that comply with the requirements of the European Union Machinery Directive 2006/42/EC.

ABB has further enhanced its drives business by creating an all-compatible low-voltage AC drive portfolio that is built on a common architecture. The drives portfolio is specifically designed to simplify operation, optimize energy efficiency and maximize output. The new architecture enables the new ABB drives to control virtually any type of AC motor and interface across all major fieldbus protocols as well as remote monitoring solutions. Compatibility is the key with users enjoying many more convenient functions for easy selection, installation, fast set up and maintenance with integrated safety features. The first drive available for ordering will be the wall-mounted ABB industrial drive.

The benefits of having unified architecture include:

- "Learn it once, use it everywhere" – The same control panel, common engineering tools and parameter menus reduce the time needed to learn and operate the new drives
- Universal accessories provide low-spares cost and easy stocking
- Integrated safety features increase personnel safety and lower installation costs
- Reduced energy use from energy saving features, such as the energy optimizer
- Built-in energy-efficiency information to help analyze and dimension the application. The information is provided by a load profile and energy efficiency calculators, which determine used and saved energy, CO_2 reduction and money saved

The smooth transition from the old to the new generation of drives has resulted in dimensions that are either the same or, in many cases, considerably smaller. This is in part due to the fact that the power

Title picture
ABB's drive product range extends from low-voltage to medium-voltage AC drives to DC industrial drives and is applied across many industries.

1 The new high-contrast, high-resolution control panel

2 Unified control-panel features

- It offers soft keys and an intuitive four-direction navigation to help users quickly locate parameters or functions.
- Information can be displayed in basic formats or in more advanced views, offering visual trend graphs and histograms, bar graphs or numerical data that make it easier and faster to interpret process variations and faults.
- Panel assistants save commissioning time by simplifying the set up of essential parameters for different functions so the user does not need to know all the parameters for the function. For example a fieldbus assistant helps the user set up the drive and fieldbus adapter for communication.
- The menus and messages can be customized to use terminology appropriate to the application so that the drives can be configured using familiar words.
- The panel's text editor lets the user add information and customize text.

3 Built-in safety features help achieve the highest machine safety.

ABB's new all-compatible architecture enables new drives to control virtually any type of AC motor, and interface across all major fieldbus protocols as well as remote monitoring solutions.

density of the new generation of drives has increased significantly to the point that the new ABB industrial drive in particular has a volume that is up to three and a half times smaller than its predecessor! As well as size, many of the best features from the existing drives, such as functional safety and energy-efficiency calculators have successfully made the transition to the new architecture.

A control panel and PC tool with a difference

The new high-resolution control panel ➔ 1 is based on modern interface techniques with features that are outlined in ➔ 2. Importantly, it enables quick drives set up and allows one control panel to control several drives by simply daisy chaining the drives with the help of built-in terminals. The control panel enables parameters to be copied from one drive to another, saving time and providing flexibility especially when several drives need to be configured.

The drive composer PC tool, for all drive types, offers fast start-up, commissioning and monitoring. An entry version provides start-up and maintenance capability while the professional version of the tool provides additional features, such as custom parameter windows, control diagrams of the drive's configuration and safety settings. The control diagrams save users from browsing a long list of parameters and help to set the drive's logic quickly and easily. The PC tool can be connected to drives using a standard USB connection or an Ethernet connection. With one mouse click on the PC tool, all drive information such as parameter lists, faults, back-ups and event lists, are gathered into a file, which can be e-mailed to maintenance personnel or ABB for further analysis. This provides faster fault tracking, shortens downtime and minimizes operational and maintenance costs.

Advanced safety functions

The drives' functional safety complies with the requirements of the European Union Machinery Directive 2006/42/EC. Built-in safety features, such as safe torque-off (STO), which enables emergency stopping and prevents unexpected start-ups and other safety-related functions achieve the highest machine maintenance and operation safety. Integrated safety functions reduce the need for external safety components, which simplifies the configuration and reduces installation space ➔ 3. ABB's industrial drives offer integrated safety options that include safe stop 1 (SS1), safe stop emergency (SSE), safely-limited speed (SLS), safe brake control (SBC) and safe maximum speed (SMS).

Low energy consumption

While drives inherently save energy, details of just how much is used and saved (in kWh and MWh) and the amount of CO_2 reduction are available through

4 The new wall-mounted ABB industrial drives, ACS880-01 series

built-in calculators. The information provided by these calculators helps to fine tune the process to ensure optimum energy use. The energy consumption optimizer control mode ensures maximum torque per ampere and reduces energy drawn from the supply.

Minimal training

Thanks to the "Learn it once, use it everywhere" approach, the time needed for machine builders, system integrators and end users – including maintenance personnel – to optimally configure, operate and maintain the new drives is reduced significantly. This is possible because the drives use the same control panel, the same engineering tools and universal accessories across the drives architecture. In addition all parameters are harmonized (ie, they use the same structure and naming) right across the platform, and as with the different functionalities, the naming used is consistent in all drives.

The ABB industrial drive ACS880-01

Of the new generation of AC drives that will be based on the all-compatible architecture, the first to be launched is the industrial drives ACS880 series. The first drive available in this series will be the wall-mounted single drive [1] ACS880-01 → 4, which is initially available with a power range of 0.55 to 250 kW and voltage range of 380 to 500 V, with plans to extend the voltage range. It is designed for a wide range of applications including extruders, cranes, winches, winders, conveyors, mixers, compressors, pumps and fans, and is targeted at industries, such as marine, mining, cement, oil, gas, metals, chemical, material handling, pulp and paper. The different ACS880 drives versions are built-to-order to satisfy customers' requirements and come with an array of options, such as a wide selection of fieldbuses, EMC filters, resolvers, encoders, du/dt filters, sine filters, chokes and brake resistors, as well as application-specific software.

Through the highly accurate and proven motor control platform, direct torque control (DTC), the ACS880 industrial drives can be used for open- or closed-loop control of almost any type of AC motor, including synchronous and permanent magnet machines, as well as induction servomotors. In order to maximize productivity, the DTC technology has been further enhanced for the new drive families to ensure highly accurate motor control and quick responses to process changes without needing a feedback device. The drives can also control permanent magnet motors without extra software.

The drive offers two enclosure ratings, IP21 and IP55 for dusty and wet environments. Both versions come with varnished boards, which improve durability in harsh environments. In addition, the air inlet temperature is constantly monitored and a warning is issued when critical temperatures are reached.

The new industrial drives support the CoDeSys [2] programming environment, allowing easy integration with ABB's AC500 programmable logic controller (PLC), which is also programmed and configured using the same CoDeSys-based engineering tool. Some control logic can even be transferred from the PLC to the drive. ABB's industrial drives can also interface with most popular fieldbus protocols as well as remote monitoring solutions.

A real driving force

The past 20 years or so has seen some remarkable advances in AC drives technology and ABB has been leading the way. While miniaturization is one of the most striking developments, drives have also become more intelligent, have better communications, and are easier to install and control. ABB continues to remarkably increase the power density of its drives, and to illustrate this point, its new ACS880 industrial drive has a volume that is up to three and a half times smaller than its predecessor.

The creation of a drives portfolio built on the same, all-compatible architecture will bring huge benefits to customers. As well as enabling the control of virtually any time of AC motor, fast commissioning, an even greater reduction in energy consumption and higher productivity mean customers can expect the lowest total cost of ownership for ABB LV AC drives used in industrial, commercial, public sector and residential applications.

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Footnotes

1 Single drives are complete AC drives that can be installed without any additional cabinet or enclosure. They are available as wall-mounted and cabinet-built constructions.

2 CoDeSys, an acronym for Controller Development System, is a development environment for programming controller applications according to the industrial standard IEC 61131-3.

Substation retrofit

Retrofitting Sils substation with IEC 61850 technology

MARCEL LENZIN – The introduction of the IEC 61850 standard marked an unprecedented revolution for the integration and communication needs of substations. Utilities across the world were quick to adopt this standard, enabling high levels of interoperability between devices (even from different manufacturers) and providing an advanced means of communication. Besides its relevance for new installations, many utilities are seeking to introduce the standard to existing substations as part of retrofit work.

The Swiss utility KHR (Kraftwerke Hinterrhein) operates a 380/220 kV air-insulated substation in Sils. This substation is an important node in the Swiss transmission network (itself part of the European UCTE network).

The retrofit in the Sils substation was initiated because the entire secondary infrastructure and parts of the primary equipment of the 380 kV voltage level had reached the end of their lifecycle. KHR decided to replace most of the secondary part, while retaining most of the primary equipment. As the lifecycle of secondary equipment is typically half that of primary devices, such a retrofit scenario is quite common in industrialized countries. To ensure the investment would serve the needs of the next 10 to 15 years, KHR chose to make the secondary system compliant with the new IEC 61850 standard.

The retrofit challenge

Retrofit projects are, by their nature, more challenging than projects in which everything is built from scratch. The old and new parts must be compatible and the continuity of the substation's operation must be assured during the transition →1. Outages must be used only where no other possibility exists; and their duration must be as short as possible. The operation of the overall transmission network must be unaffected by the work. Project teams must therefore carefully analyze and gain a detailed understanding of the existing system.

1 The continuity of the substation's operation must be assured during the retrofit

2 Substation control room at Sils

Retrofit projects are, by their nature, more challenging than projects in which everything is built from scratch. The old and new parts must be compatible and the continuity of the substation's operation must be assured during the transition.

The solution based on IEC61850

The secondary part of a substation has two main purposes: It controls the primary equipment and protects it from damage by electrical faults. These functions are provided by so-called IEDs (intelligent electronic devices). An IED has an I/O (input / output) connection to the system's primary equipment and controls either a bay or part of a bay. The protection functions are specific to the type of bay (transformer, line, coupler, etc).

In their control role, IEDs are responsible for control and interlocking functions. They ensure that a primary device can be operated only if certain prerequisites are fulfilled. In their protection role, they constantly monitor the electrical behavior of the substation (on the basis of voltage and current measurements). Should a fault that could lead to damage of primary equipment be detected, the necessary parts of the station must be shut down and the faulty equipment isolated. Alarms to inform the central control system are transmitted via the IEC61850 bus.

The communication bus connects the IEDs to the substation control system, from which the complete system can be operated and monitored. A substation is just one node in a complete electrical network, therefore consolidated substation information must be reported to a network control center, typically located many kilometers away → 2. Depending on the network operation authority concept, it may also be possible to control primary equipment from the network control center. The interface to a remote control center is provided by a gateway.

In the Sils substation, ABB's Relion® 670 series IEDs were adopted for control and protection functions. Utilities often require that devices from different suppliers are installed in parallel to provide backup. In Sils, the protection devices for this purpose were supplied by a third party and fully integrated using the IEC 61850 standard. This integration capability is one of the main strengths of IEC 61850.

The functionality of the IEDs was engineered to serve the needs of the existing equipment, but also to take advantage of newer technology such as the bay-to-bay communication protocol GOOSE[1] for example.

All IEDs are connected to the IEC 61850 communication bus → 3 The bus is divided into several physical rings, one as station LAN[2] and the others for communication between station-level and bay-level devices. The ring configuration was chosen to increase the availability of the network. The control system uses ABB's MicroSCADA Pro and runs on a high-end server, equipped with redundant power supply and RAID[3] storage system. For backup software functionality, a separate storage server is connected to the station's LAN.

Ensuring a redundant gateway as the interface to the network control center, two independent IEC 61850 clients are

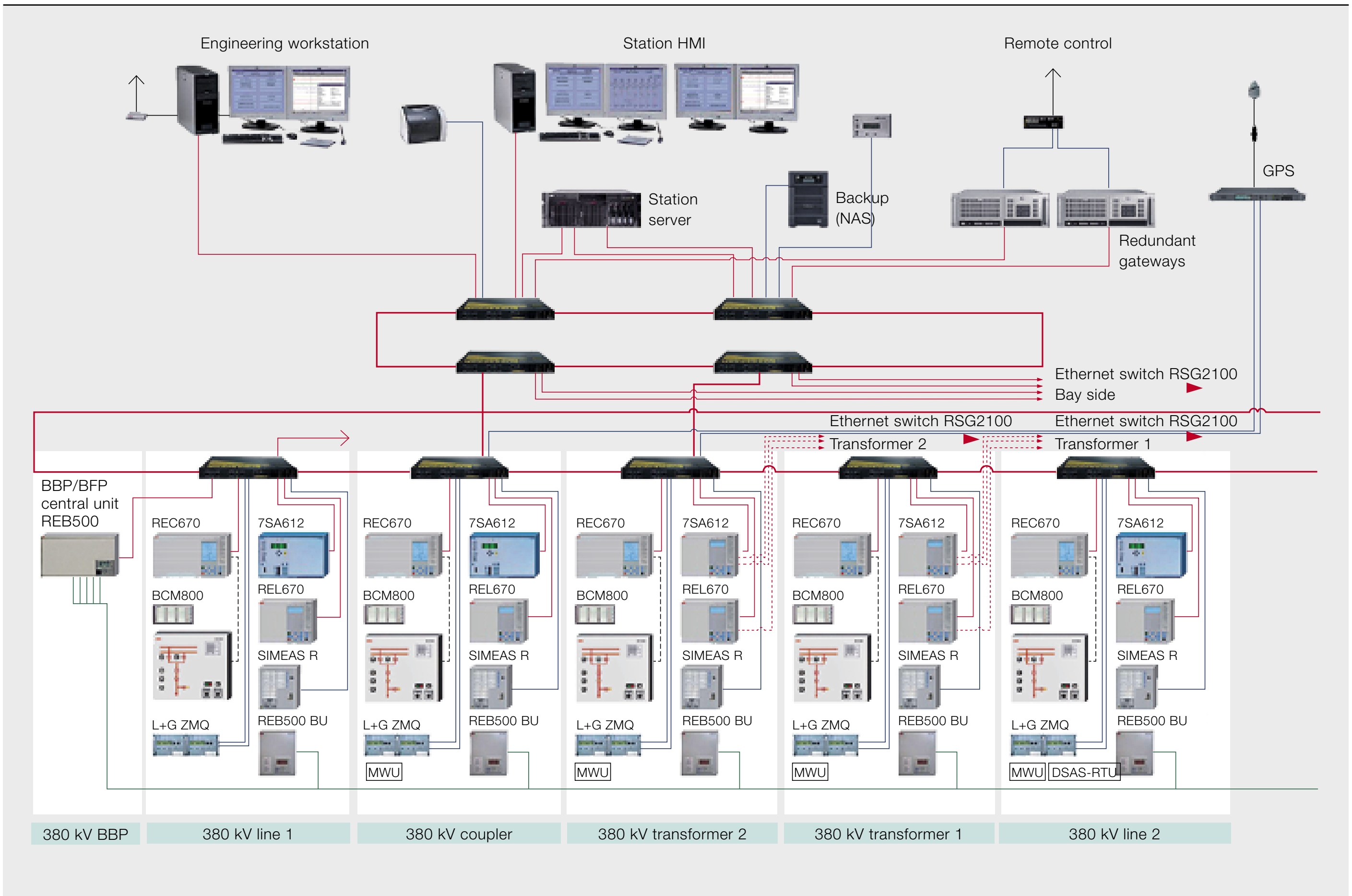
Footnotes

1 GOOSE: generic object oriented substation event.

2 LAN: local area network.

3 RAID: redundant array of independent disks.

3 IEC 61850 based substation automation system in Sils



connected directly to the bus. This allows the station to be remotely controlled, even if both substation control computers are shut down.

KHR gained numerous advantages by basing the new secondary part of the substation on the IEC 61850 standard. The standard defines the SCD-file[4]. It contains all relevant information, from the topology of the primary equipment down to the complete data flown of the secondary equipment. The availability of this information supports later extensions, replacements or upgrades of the substation automation system or parts thereof, and so supports long-term reusability. Besides this, it also ensures data consistency of the complete system for current engineering. Since IEC 61850 also specifies the horizontal and vertical communication on the bus, the system can be built using IEC 61850 compliant products from different suppliers.

Furthermore, to reduce the copper wiring between bays, KHR decided to implement horizontal, bay-to-bay communication with the GOOSE protocol. All communication relating to the interlocking between bays is exchanged via GOOSE messaging between IEDs using the IEC 61850 bus.

Project phases

All projects start with a design phase, with focus being on interfaces to existing equipment and the additional functionality to be introduced to the system. The design phase must clarify how new parts are to be commissioned without jeopardizing the commercial operation of the substation. At Sils, ABB's engineers had to understand the functionality of the current system in detail inn order design the new system appropriately. In future, this phase will be supported by the availability of the SCD files.

The next project phase is implementation and production. The IEC 61850 standard also defines the engineering processes. It is therefore essential to use a system engineering tool that fully supports IEC 61850, keeping data and data flow consistent across the entire substation and correctly documenting changes in the SCD file.

In the Sils project, special attention was given to the factory testing phase – the last project phase before the new equipment was delivered to site. This served to shorten the subsequent commissioning phase compared to on-site testing. Various simulators were used to test in-

In the Sils project, special attention was given to the factory testing phase. Various simulators were used to test interactions with existing equipment.

Footnote

4 SCD: substation configuration description.

4 Installed breakers waiting to be connected

teractions with existing equipment. Testing was split into two phases: individual tests for each bay, and a test for the entire system. IEDs of each typical bay type were connected at station level and the functionality of the complete system was tested in ABB's test field. To test the bay interlocking, GOOSE messages from all devices that were not physically present in the test field were simulated.

The commissioning phase is probably the most challenging phase of a retrofit project. An entire substation cannot be shut down for commissioning. The outage times of individual feeders need to be kept to an absolute minimum and must be planned and approved by the grid operator (in this case, Swissgrid) months in advance. At Sils, commissioning had to be executed stepwise, feeder by feeder, following a detailed schedule.

Bay-by-bay commissioning involves complete systems being delivered to site. The complete bay level system, including the station level components, is installed on site with only the AIS (air-insulated switchgear) interfaces being omitted → 4. This omission permits extensive testing (including complete IEC 61850 communication) of the installation without affecting commercial operation. Once this is complete, all that remains to be done is swapping the connection to the primary equipment from the old to the new IEDs. This approach shortens commissioning time and ensures that the outage time of the bay can run to plan.

An additional advantage of bay-to-bay commissioning is that when the complete system is connected to the IEC 61850 bus, whether it is already connected to the AIS or not, all GOOSE messages are already working for bay-to-bay interlocking. No configuration changes are needed at system level or in the already commissioned bay-level systems.

As an alternative to having all IEDs sending GOOSE messages via the bus, IEDs can also be simulated.

During the transition phase (which can be a period of several months) the substation must operate with equipment that is going to be replaced and equipment that has already been replaced running side by side. In planning this phase, special attention must be given to system-wide functions, such as busbar protection. In the Sils project, the switch over to new busbar protection was performed at the end of commissioning, with the old system continuing to operate throughout the transition.

The project demonstrated the aptness of the IEC 61850 standard for retrofit projects.

Integration of the 220 kV substation to the control system

Following the successful retrofit of the 380 kV substation, the 220 kV part was integrated with the newly delivered substation control system. On the 220 kV level, the complete bay level was still up to date and there was no need for replacement. The existing IEDs were equipped with new IEC 61850 communication interfaces. These enable communication with the new MicroSCADA Pro control system via IEC 61850 and ensure that both the 380 kV and 220 kV switch yards can be operated and monitored from the central control system. Furthermore, the MicroSCADA Pro system was extended to a hot standby system, in which the complete control and monitoring functionality runs on one computer, and while a second computer, running the same application in parallel, is ready to take over the complete operation immediately in case of faulty operation of the first computer.

A successful project

The Retrofit of KHR's Substation was performed successfully and the renewed system is up and running. Thanks to close and constructive collaboration between ABB and KHR, and the extensive respective experience of both partners, the complex project was completed with minimal inconvenience.

The project demonstrated the aptness of the IEC 61850 standard for retrofit projects. The standard enabled the straightforward combination of ABB and third-party protection IEDs and thus fulfilled the requirement of the customer. The use of GOOSE messages for bay-to-bay interlocking considerably reduced the need for copper wiring. The complete substation is now documented in an SCD-file in a standardized way, which is an advantage for future maintenance and extension projects. The 220 kV part of the project was integrated using ABB's 61850 SPA/IEC 61850 gateway to ensure that the complete 380/220 kV substation can be monitored and operated from new MicroSCADA Pro central control system.

As a result of exemplary teamwork and the high-quality project execution, the secondary part of KHR's 380 kV Sils Substation is now equipped with state-of-the-art technology and ready for another 10 to 15 years of operation.

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Speedy protection

ABB surge arresters for rail applications at formula-one speed and beyond

STEPHAN HOFFARTH – The market for high-speed rail is rapidly expanding. According to the International Union of Railways (UIC), the world's high-speed network is expected to grow from currently 13,000 km to well above 30,000 km within the next 10 years [1] – and with it the demand for trains and their components. Equipment mounted on the outside of such rolling stock must be designed to withstand faster air flow. This is especially true for surge arresters, which are generally installed on the train roof, immediately adjacent to the pantograph, as they must protect all downstream electrical equipment against incoming overvoltages. Despite the fact that surge arresters perform very well in the high-speed train market, concern regarding this function has increased. Therefore a more differentiated consideration of this application is necessary.

Overvoltages in electrical railway networks result from the effects of lightning strikes and switching actions and cannot be avoided. They endanger the electrical equipment because, due to economical considerations, the voltage withstand capability of insulation cannot be designed for all possible cases. An economical and reliable service therefore calls for a comprehensive protection of the electrical equipment against unacceptable overvoltages.

The greatest threat comes from lightning strikes. Appropriate protection is used to reduce the overvoltage resulting from such a strike to a safe level. Metal-oxide surge arresters without spark gaps provide outstanding protection in this situation.

In general, the demands on the arresters for rolling stock applications depend on the operational conditions and the type of the electrical equipment to be protected. In modern electrical trains the high voltage of the pantograph is brought inside the locomotive by means of a bushing or a cable. For maximum overvoltage protection, ABB recommends a co-ordinated concept consisting of two different types of arresters [2]:

1 A premium arrester with a line discharge class of 3 or 4 installed on the roof close to the current collector.
2 A standard arrester with a slightly higher continuous operating voltage mounted inside the locomotive in front of the main power breaker.

In order to meet the requirements of reliability, availability, maintainability and safety (RAMS) the surge arresters have to fulfil the international standard IEC 60099-4 "Metal-oxide surge arresters without gaps for a.c. systems."

Furthermore both types of arresters have to withstand the mechanical loads caused by the train operation. These demands are covered by IEC 61373 "Railway applications – Rolling stock equipment – Shock and vibration tests."

In addition, the surge arrester mounted on the roof should be able to withstand the corresponding operating conditions such as weather influences and mechanical stress due to the airstream.

IEC 60099-4 defines the requirements for conventional applications (for example protection of distribution transformers) but wind speeds above 34 m/s (122 km/h) are considered abnormal service conditions and are therefore not covered.

Despite this lack of standardization and the related absence of an appropriate qualification procedure, surge arresters have been used successfully for many years on high-speed railways. Nevertheless, operators and potential customers are increasingly expressing interest concerning the impact of head wind. Therefore ABB decided to verify the airflow performance of the arresters it supplies for installation on the roof of rolling stock.

Verification of airflow performance

It was decided to carry out the tests in a wind tunnel of the German Aerospace Center, DLR [3]. In the course of the ensuing tests, AC surge arresters of types POLIM-H..N and POLIM-S..N and DC surge arrester of type POLIM-H..ND were exposed to wind speeds up to 100 m/s (360 km/h) → 1.

The test sequence was divided into five parts. Speeds started at a moderate 20 m/s and increased in steps of 20 m/s up to 100 m/s. They thus reflect a wide range of operating conditions ranging from slow freight trains to high-speed trains. To achieve realistic test conditions, all arresters were equipped with the accessories typical to railway applications. Furthermore the devices under test were mounted on a load cell equipped wit a strain gauge to permit the quantification of the bending stress at different wind speeds. The behaviour of the arresters was recorded by means of a high speed camera during the verification.

Results

None of the tested samples showed damage or lasting deflection from the wind exposure. The measured forces during the tests were well below the maximum specified continuous bending moments of the corresponding arrester designs. The sheds of the silicone housings did not display oscillations under the maximum applied wind speed of

The greatest threat comes from lightning strikes. Appropriate protection is used to reduce the overvoltage resulting from such a strike to a safe level.

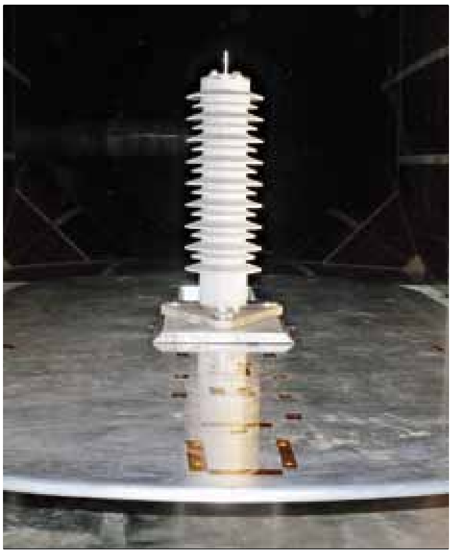
Footnotes

1 International Union of Railways UIC, High speed rail – Fast track to sustainable mobility, November 2010, ISBN 978-2-7461-1887-4
2 ABB Switzerland Ltd – High Voltage Products, Application guidelines for overvoltage protection – Dimensioning, testing and application of metal-oxide surge arresters in railway facilities, PTHA/SA3020EN_01.09.07
3 German Aerospace Center DLR (Deutsches Zentrum fuer Luft- und Raumfahrt), www.dlr.de

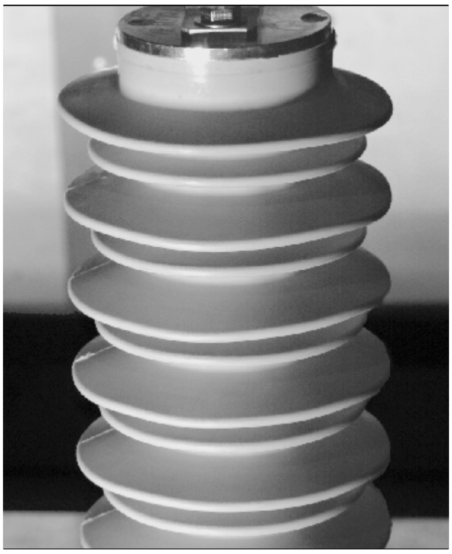
Title illustration

Roof-mounted equipment is exposed to considerable aerodynamic forces. The title photograph shows AVE trains of Spanish operator RENFE, capable of travelling at 350 km/h.

1 Test setup of surge arrester type POLIM-H 33N in one of the wind tunnels of the German Aerospace Center DLR



2 Silicone housing of surge arrester type POLIM-H 33 during the test with 100 m/s (360 km/h) airflow



100 m/s. The danger of a significant reduction of the creepage distance caused by deformation of the arrester housing can therefore be ruled out.

Ready for speed

These tests clearly show that ABB surge arresters of type POLIM-H..N, POLIM-H..ND and POLIM-S..N are well suited for applications on high speed trains. These arresters are not only an ideal

> Arresters have to withstand the mechanical loads caused by the train operation, including Formula 1 speed headwinds.

option for the overvoltage protection of fixed installations but also appropriate for all kind of rolling stock applications up to a maximum speed of 100 m/s or 360 km/h.

Looking further, it should be taken into consideration that the high speed rail industry is intensifying its focus on energy efficiency. At the last international trade fair for transport technology, Innotrans [4], several manufacturers of high speed trains showed optimized aerodynamics on their products, for example by masking roof-mounted equipment.

Such modifications are primarily aimed at cutting the energy consumption of the vehicle, but do also reduce the wind load on the arresters by reducing their exposure to the airflow.

In this respect ABB will permanently assess its railway arrester portfolio in order to meet the future demands.

ABB railway surge arresters are certified according to the International Railway Industry Standard IRIS Revision 02 [5]

For more information on ABB and railways, please see *ABB Review* 2/2010, “Railways and transportation” or visit www.abb.com/railway.

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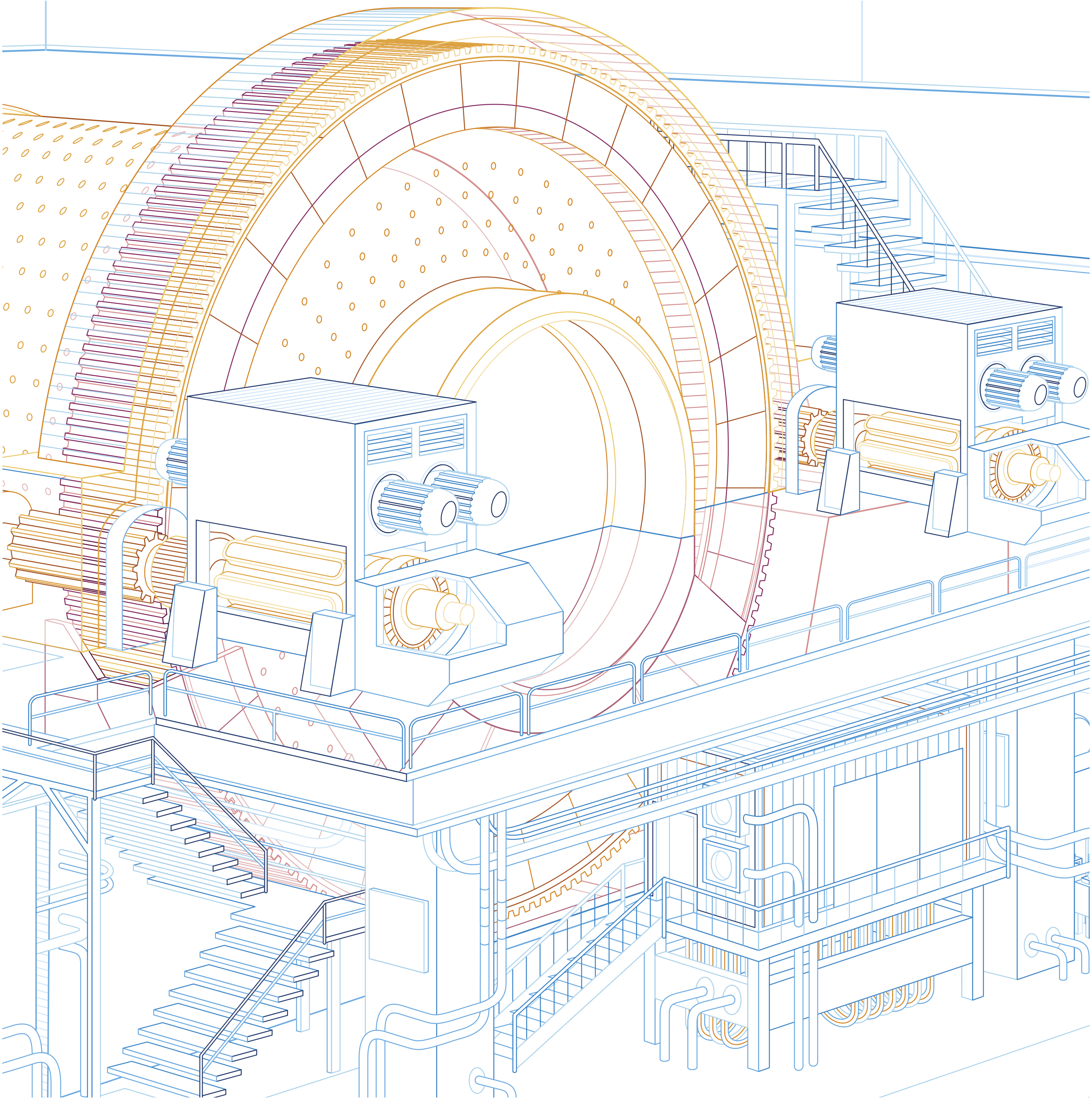
Footnotes

4 International trade fair for transport technology Innotrans 2010, www.innotrans.com

5 International Railway Industry Standard IRIS Revision 02, www.iris-rail.org



Smooth operation

Sophisticated ring-geared mill drives from ABB (Part 2)

MARCO RUFLI, MAARTEN VAN DE VIJFEIJKEN – The development of several dedicated and advanced operational and maintenance functions for ABB's latest generation of medium-voltage frequency converter drives ensures smooth, safe and reliable operation in the ring-geared grinding mills used in the minerals industry. Part one of this two-part series, which was published in *ABB Review* 1/2011, described in detail the functions and the effectiveness of implementing them. Part two focuses on the amazing accuracy achieved with an installed and commissioned 2 × 5 MW dual-pinion mill-drive system.

1 An installed and commissioned 2 × 5 MW dual-pinion ring-geared pebble mill

In ring-geared mill drives (RMDs) and especially dual-pinion systems, the mechanical stress added by the motors can be significant. Therefore the control concept between the two motors must be fast and accurate to avoid any additional stress to the pinions and ring gear.

Thanks to the addition of an extra controller, ABB's latest generation of medium-voltage (MV) frequency converter drives not only includes several new application-related functions for the safe and smooth operation of the mill, but it also simplifies the interface between the mill drive system and the customer's distributed control system (DCS). On the operation side, these functions help improve the start, normal grinding operation and stop sequences, while dedicated maintenance and protection functions, such as creeping (turning the mill at very low speeds for inspection), automatic positioning sequencing, deformation protection and frozen-charge remover ensure fast, easy and safe servicing of the mill.

In part one of this two-part series [1], the drive-system performance during start, operation and stop sequences for a configuration consisting of a converter transformer, an ABB ACS 6000 multidrive MV frequency converter and one ABB AMI630 four-pole squirrel-cage asynchronous motor was illustrated. Part two focuses on field measurements taken from the drive system of an installed and commissioned 2 × 5 MW dual-pinion ring-geared pebble mill → 1. The mine in which the drive system is installed is described in "A mine of efficiency" on page 56 of this issue of *ABB Review*. In this set up, the two motors are mechanically connected via the mill ring gear and operate together to turn the mill. This mechanism requires very accurate load sharing between the two motors during the start, normal operation and stop sequences.

In dual-pinion mills,the system is driven by more than one motor, which are mechanically coupled to each other to ensure load sharing.

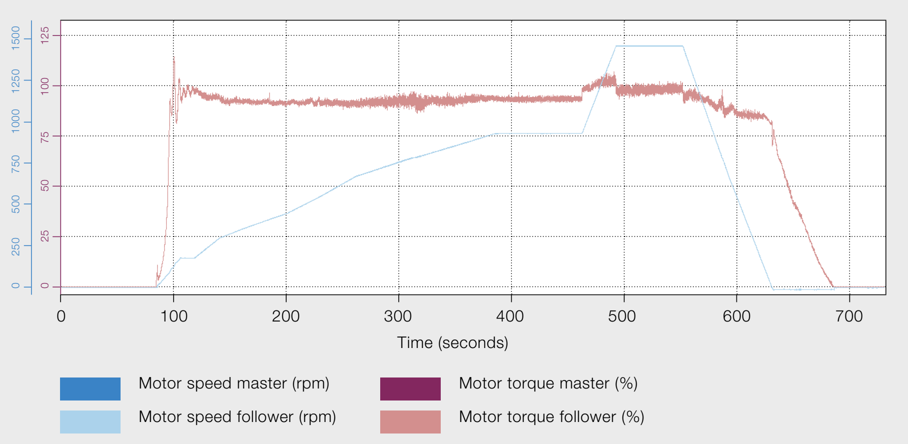
A dual-pinion system with a master/slave drive configuration

In dual-pinion mills, the system is driven by more than one motor, which are mechanically coupled to each other to ensure load sharing. Load sharing – or the ability to maintain equal load distribution between the two motors – is necessary to minimize mechanical stresses and backlash. In the dual-pinion mill applications, the two motor shafts are relatively hard coupled via the ring gear. In larger dual-pinion ring-geared mills where the length of the pinions and ring-gear teeth is gradually becoming longer, the perfect alignment of pinion and ring gear (and gearbox in some cases) is pivotal. However, experience has shown that this can be difficult to achieve let alone maintain. But if rough starts, torque spikes and load oscillations between the two motors in large mills are to be avoided, a mechanical friendly system that ensures smooth, fast and accurate load sharing during all operating conditions is required. ABB drives feature direct torque control (DTC), which ensures fast and accurate load sharing. With DTC technology load sharing can be established in different ways and the most suitable algorithm for this specific application has been selected. On the hardware side, the link between the two main drive-control boards is established using a fast fiber-optic connection.

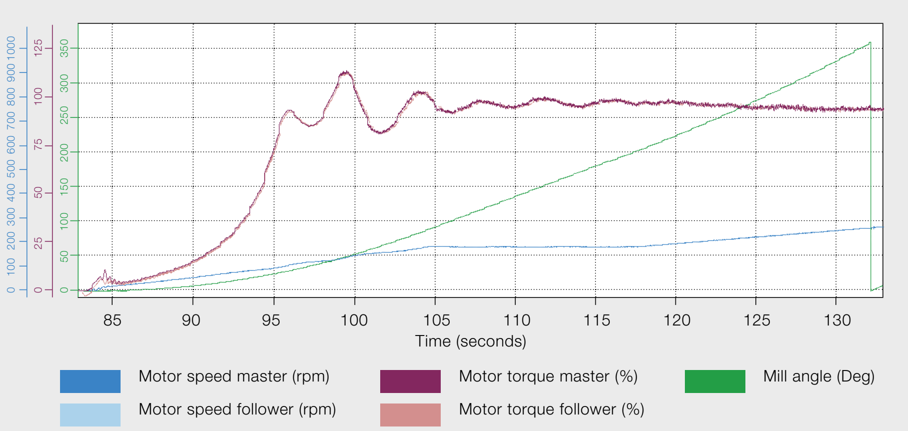
Title picture
A $790 million modernization at the Aitik copper mine near Gällivare in Sweden has extended its life to 2030. ABB has contributed to this success by supplying a range of products and systems to power and operate the entire site.

In the 2 × 5 MW dual-pinion ring-geared pebble mill example, one of the inverter units in the ACS 6000 drive is configured to be the “master” and receives the speed reference via the mill controller from the DCS. The other inverter unit is known as the slave and it follows the master drive’s speed and torque reference. The control accuracy of this master/slave configuration during start, normal operation and stop sequences is illustrated in the following sections.

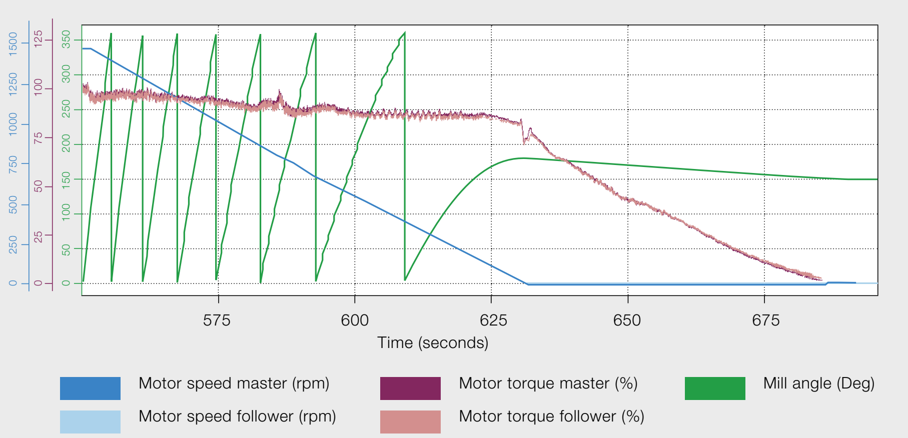
2 Master/slave drive start and stop sequence



3 A close up of the start sequence



4 A complete stop sequence using the master/slave drive system



Start/stop sequence

A complete start/stop sequence of a master/slave drive-system set up is shown in ➔ 2. The measurements show the individual speed and torque signals for both asynchronous motors. The graph looks practically identical to ➔ 3 in [1], which showed speed and torque measurements for one motor only. ➔ 3 and ➔ 4 show a close-up view of the start and stop (with controlled rollback) [1] sequences respectively. Again, the individual speed and torque signals for both motors are almost identical to ➔ 4 and ➔ 6 in [1]. This clearly illustrates how accurately and smoothly the torque of one motor (slave) follows that of the other motor (master). In fact the torque difference between the two motors is well below 1 percent of nominal torque ➔ 5! The biggest deviations, shown by the peaks in ➔ 5 and which amount to much less than 3 percent of nominal torque, occur at the beginning of a sequence and when controlled rollback is started (at around 630 seconds), and last well under a second.

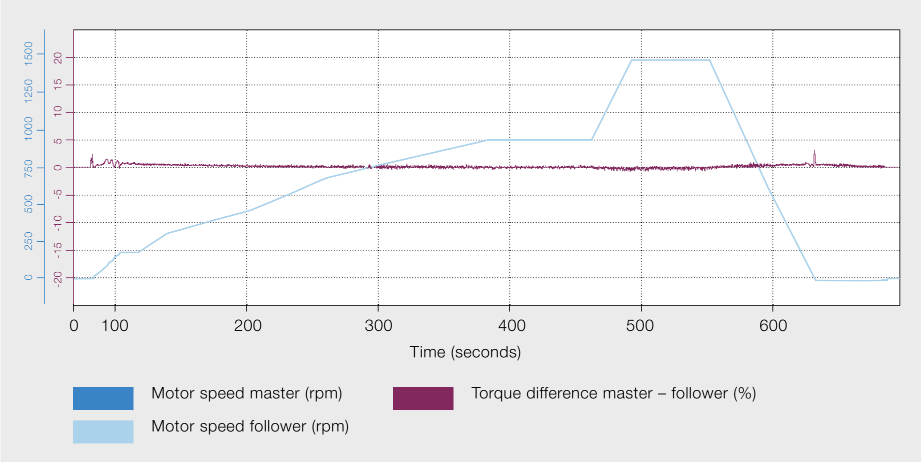
ABB’s DTC technology in mill-drive solutions enables fast and accurate load sharing, which minimizes stress and prevents backlash.

During the stop sequence with controlled rollback, the mill is ramped down until it comes to a standstill. Both motors then generate just enough positive torque to hold the mill with the charge unbalanced. By slightly reducing the torque, the mill rolls gently back until the charge is balanced. Because the torque is always positive, even when the direction of rotation of the mill changes and during controlled rollback, contact is always maintained between the teeth of the two pinions and the ring gear, thereby ensuring no backlash can occur.

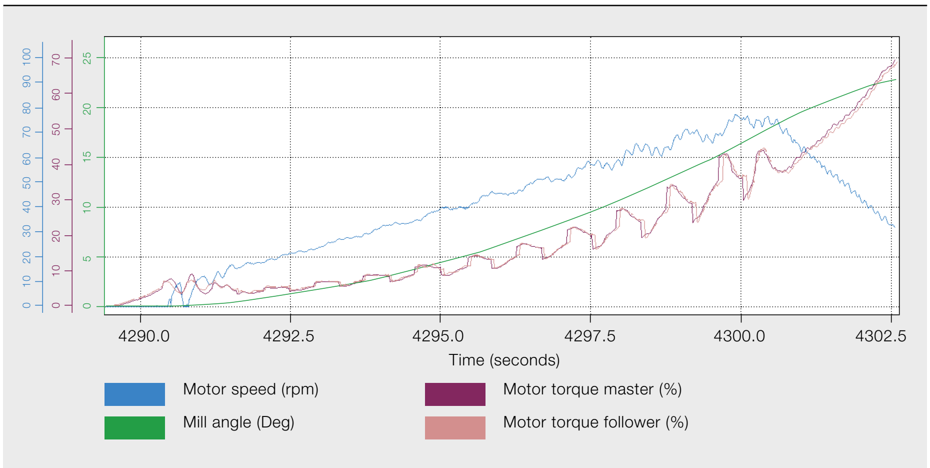
Footnote

1 To avoid the unnecessary and long backward and forward rocking of the mill caused by a coast stop, ABB has implemented a function called “controlled rollback,” which quickly brings the mill into a torque-free position in a controlled way.

5 The difference in torque between master and slave motors is negligible



6 Frozen charge remover function in action using the master/slave drive system



Even during the frozen-charge remover function sequence, in which torque steps are applied to the system to loosen frozen material in the mill, the torque of the slave perfectly matches that of the master drive system with no obvious signs of oscillations or backlash → 6. Backlash would be seen by a drop in torque to zero or even negative values, but since torque and speed are always positive, backlash does not occur.

This type of drive system with a diode rectifier bridge cannot feed braking energy back to the network and therefore the generative power is limited by the losses of the drive system. This then results into a relatively low negative speed to roll back the mill. To feed back energy to the network, which then enables a significant reduction in the rollback time of the mill, an optional four-quadrant ACS6000 drive system with an active rectifier unit is available from ABB; this means that the drive system, as the largest consumer in the plant, could also be used for power factor correction.

Inherent features

The measurements shown in both articles clearly illustrate the power of ABB's DTC technology in a flexible mill drive system. Not only does it enable fast and accurate load sharing, which minimizes stresses and prevents backlash, but it also ensures mechanical- and electrical-friendly solutions. In addition, as an inherent feature, the mill speed can be smoothly varied. Variable-speed is a well accepted advantage of semi auto geneous (SAG) [2] mill drives, but not necessarily for ball and pebble mills. A significant number of large SAG and ball mills are installed in South America with so-called gearless mill drives (GMDs), which also have the ability to vary the mill speed. And it has been recorded that the variable-speed feature is indeed used in reality, not only in SAG mills but also in ball mills. The flexibility introduced by the variable-speed drive system significantly impacts the overall grinding efficiency and mill availability by having the possibility to minimize both re-circulating loads and over-grinding.

Theory and practice

There is no doubt that ABB's new dedicated mill functions contribute significantly to the efficient operation and maintenance of grinding mills. The measurements in this article show that these functions, as part of ABB's master/slave drive system concept, are not only nice in theory – as shown in [1] – but they work with amazing accuracy in an installed and commissioned dual-pinion mill. The customer benefits not only from greater grinding flexibility but this leads to lower maintenance requirements, reduced operating costs and extended equipment lifetime.

ABB's new dedicated mill functions contribute significantly to the efficient operation and maintenance of grinding mills.

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Footnote

2 Compared to a ball mill, a semi auto generous (SAG) mill utilizes less steel balls for grinding in addition to the ore (pieces of rock), and it is generally used as a primary or first-stage grinding solution before ball mills.

Reference

[1] Rufli, M., van de Vijfeijken, M. Driving value: Sophisticated ring-geared mill drives from ABB (Part 1). *ABB Review* 1/2011, 29–35.

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

ABB Technology Ltd.
ABB Review
Affolternstrasse 44
CH-8050 Zürich
Switzerland

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Printer
Vorarlberger Verlagsanstalt GmbH
AT-6850 Dornbirn/Austria

Layout
DAVILLA AG
Zürich/Switzerland

ISSN: 1013-3119

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Technology matters

We live in a technological society. Technology affects almost every aspect of our life. *ABB Review* 3/2011 will present technologies from across the board of ABB's portfolio. An advanced plant-wide automation system can provide up-to-date and actionable data to operators and maintenance personnel, and so create entirely new and more resource effective ways to operate the plant. A small converter attached to the solar panel mounted on the roof of a house can reduce the carbon footprint of the household and even permit electricity to be sold to the utility, reversing a traditional supplier-consumer relationship.

These and other technologies will be discussed in *ABB Review* 3/2011.