












# ABB Review

Special Report

Motors  
and drives



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## ABB at the wheel of electrical drive technology



Electrical drives are, quite literally, the driving force behind all automation systems used in industry, commerce and buildings. They are used in a wide range of applications in many industries such as cement, chemical, pulp and paper, metal and oil and gas, and contribute enormously to increasing the efficiency and reliability of these processes while at the same time improving safety and energy savings.

Since entering this market in the early 1970's, ABB has become the world's leading manufacturer of AC variable-speed drives. With an estimated 16 percent market share, we have a product range which is considered the widest and most complete in the industry. Our most recent innovation, the ACS50 component drive, is considered a 'small revolution' in terms of size and simplicity, with 'gigantic' performance and overall functionality. Its core platform has enabled us to target new markets like the consumer industry.

A modern electrical drive consists of a controller, a static converter and an electrical motor. Technologies such as

microelectronics, software, sensors, industrial communication and materials science are making these individual units smaller and smarter. The overall result is a more complex, technologically advanced, not to mention cost effective drive family with a broad range of industrial and consumer applications.

The use of advanced semiconductor switches or intelligent power modules enable the application of control techniques that, a decade ago, seemed only a vision. In the last decade the motors themselves have improved in efficiency by an average of 3 percent. And the journey doesn't end here. Motor and drive technologies such as high-energy permanent magnets, semiconductor switched reluctance motors, silicon micro-motor technology and soft magnetic materials are developing at a record pace. In fact, ABB engineers have further developed permanent magnet and very high voltage motor technology to satisfy various customer requirements.

In industry, motors and drives powering mechanical equipment account for about 65 percent of the total electrical energy consumed. Reducing this figure is therefore of prime importance when it comes to energy savings. The longer drives and motors are in operation, the higher the savings. Over the total running time, more than 97 percent of the total cost of a drive system is accounted for by its power consumption and only 3 percent by the capital investment, hence the vital importance of high motor efficiency.

With years of experience and know-how, ABB is leading the way in the development of drive technology. One such development has been a radical

new control technique known as Direct Torque Control (DTC). DTC contributes directly to energy efficiency by motor flux optimization.

Another striking development affecting drives is miniaturization. Increasing component integration means circuit boards are becoming smaller, which in turn leads to more cost- and energy-efficient manufacturing. On top of this, environmentally friendly and energy-efficient technologies combined with sound manufacturing processes and increased recycling of resources contributes enormously to the environmental health of our planet.

The use of ABB AC drives in the speed control of pumps and fans has, in the past ten years, allowed a worldwide average of 81,000 GWh of energy to be saved each year!

Drives technology is a field that inspires engineers to develop better systems with cutting edge technology. In addition, it contributes to the efficient use of energy, which in turn improves the economy of our customers. Last but not least, drives technology supports a sustainable development for all of us.

In this special report, let ABB 'drive' you through the fascinating world of drives and motors. We wish you an interesting journey.

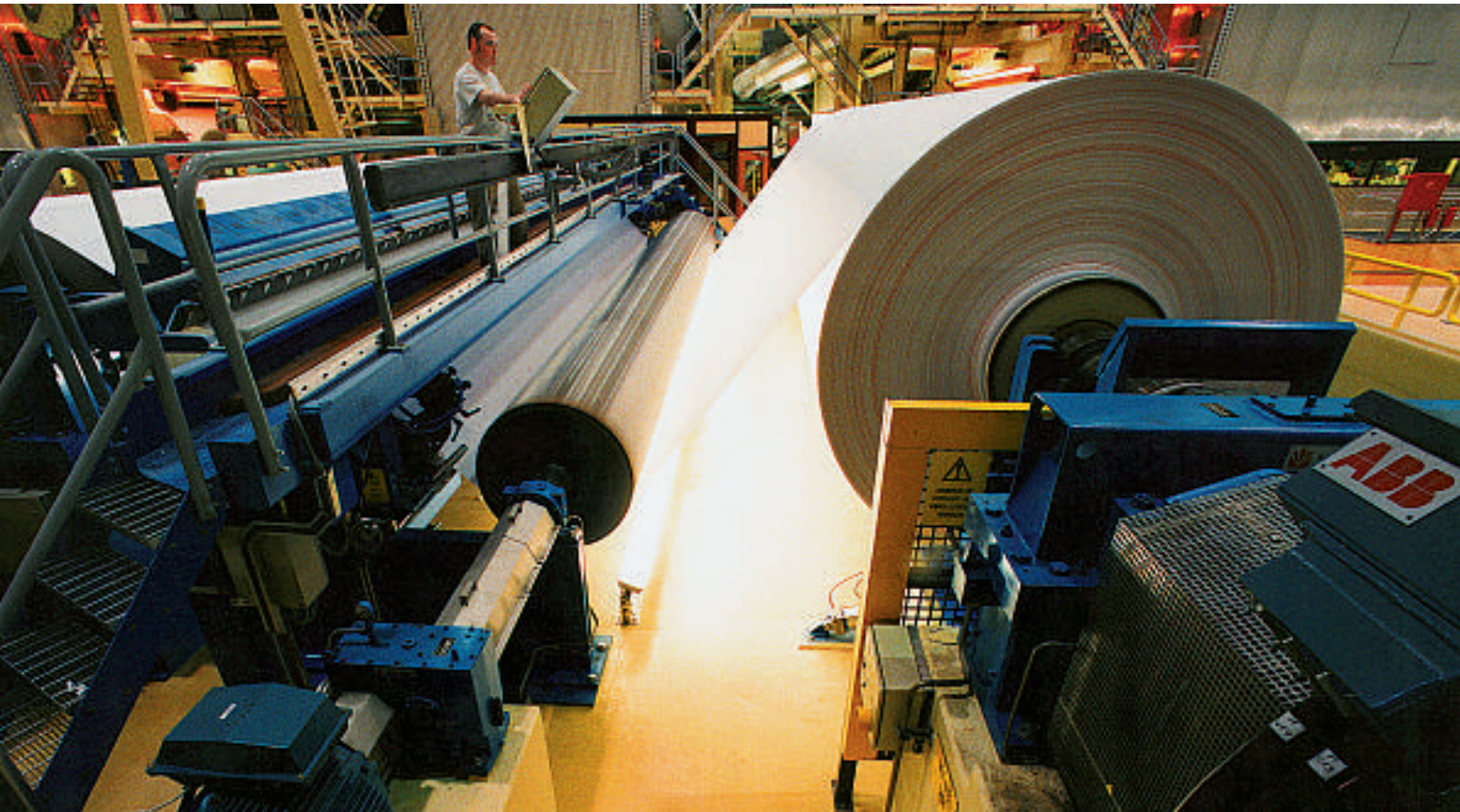
H. Markus Bayegan  
Chief Technology Officer  
ABB Ltd



# A winning formula

Factors that make ABB the number one supplier of variable-speed drives

Pekka Tiitinen



With an estimated 16 percent of the global market, ABB is the number one supplier of variable-speed drives. The company has a product range that is considered the widest available from any vendor, and a reputation for manufacturing products that are reliable, simple and flexible.

But it takes more than just good products to be a leading player and maintain that position in today's variable-speed drives market. It takes creativity and hard work. Customers no longer look just at the product, but also at the company supplying it. Key factors considered by customers when selecting a drives company include service levels, total lifecycle costs, availability and expertise.

ABB is meeting customer demands in a variety of different ways, from setting up networks of specialists to educating customers on how to get the most from their drives.

In 2002, Europe and North America experienced an overall decrease in the sales of variable-speed drives. In fact, it was reportedly the worst year ever in both regions for these products. IMS Research reveals that the North American market for motor drives suffered most, contracting by 4.2 percent. The European market fared slightly better, but also encountered negative growth during 2002, with an estimated decline of 1 percent.

Even with this depression in the market, ABB went on to sell more drives that year than in 2001! In addition, 2003 turned out to be a bumper year with the company growing more than twice as fast as the market. Similar growth is expected during 2004 ■. So, what factors have enabled ABB to grow in the face of a troubled market?

### Increasing competition

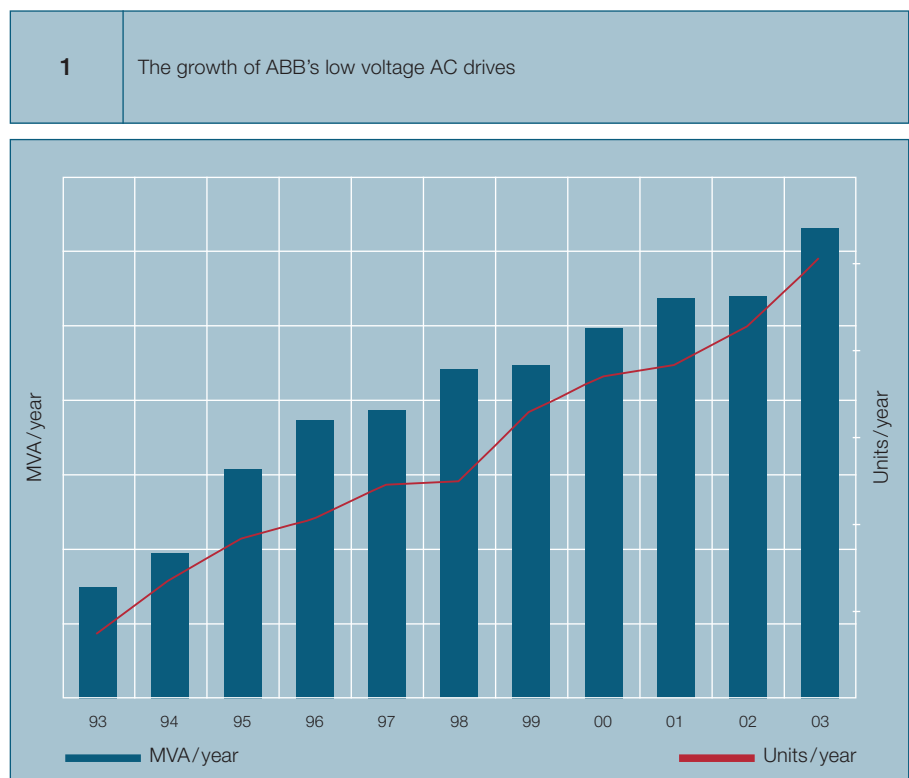
The variable-speed drives market is very fragmented. Many companies now specialize in one or another area of drives, and some of these have proved to be very competitive.

So what effect do these specialist companies have on larger ones like ABB? There are those who say that specialist drives companies are better at capitalizing on the competitive difficulties of the global marketplace. They do this by meeting the needs of the market more accurately and by being more flexible and adaptable.

ABB believes it can easily match the know-how of so-called specialist companies. Employing many people does not imply know-how goes down, but rather the opposite is true. ABB is a big employer with many specialists throughout the organization.

It is widely thought that specialist drives manufacturers allow original equipment manufacturers (OEMs) to shop around, enabling them to meet their application demands more precisely. This in turn avoids any dependency on a single supplier.

However, ABB strives to make all it's offering, not just drives, competi-



tive. The company believes that if the products more than satisfactorily meet the requirements, why not buy them from one company. In addition, one-stop shopping has many benefits, including time savings, clear responsibilities and reduced purchasing costs.

### Channel partner networks

ABB drives' product portfolio is huge and continues to grow as new products are released. As this portfolio expands, so too must the company. Many of ABB's customers are more willing than ever to go one-stop shopping, but they demand a local presence and faster response times. With an ever-growing international customer base, this presents an enormous challenge to ABB.

That is why large organizations, like ABB, are very interested in companies in other countries that are able to offer similar services at the same professional level. In other words, a first-class channel partner network, one with the same look, feel and level of professionalism is essential to meet the challenges mentioned previously.

ABB now has an alliance of channel partners that allow the company to mix high levels of expertise with proximity to the customer. To further support these partners, the company has established logistics centers as well as a variety of e-tools. In addition, products designed specifically for sale by its channel partners have been added to ABB's drives portfolio.

ABB's channel partners are further supported by networks of specialists that look after specific market sectors, such as HVAC, food and beverages, water and cement. As well as dedicated products and services for the end users, these networks bring specialist knowledge of their particular industry.

### Lack of information – the biggest rival

ABB is aware that some of its competitors are very strong, and that a combination of creativity and hard work is essential to keep the company ahead. To maintain its leading market position, ABB knows it must invest in product development, manufacturing technologies and service capabilities. This together with a focus on minimizing the

total lifecycle cost of drives is, many believe, a winning formula. But there are those who believe that one of ABB's biggest challenges is ensuring that potential customers are well informed about the benefits of ABB drives.

More and more people are concerned about saving energy. Variable-speed drives reduce energy consumption while increasing productivity, something ABB believes many potential customers are completely unaware of. If this is the case, then it is highly likely these customers have no idea that a variable-speed drive can, depending on the application, pay for itself within a few months simply through the energy saved. There are other benefits of drives that remain relatively unknown, including the use of a soft start-up that reduces maintenance costs over the drive's service life.

Proof of this lack of information is reflected in the fact that for many years, it was widely quoted that only 3 percent of motors were fitted with variable-speed drives. Today, ABB believes this has risen to only 5 percent. As such, the cost of the drive needs to be compared with the actual energy saving that can be achieved. However, there are more small motors in the world than large motors, and the smaller the motor, the less favorable are the energy savings.

Because many customers are concerned about saving energy, it is absolutely essential for all drive manufacturers to communicate the benefits variable-speed drives can bring. For those manufacturers that do, like ABB, customers clearly see these benefits, and none are more convincing than the translation of energy savings into cost savings.

### Is technology alone enough?

Technological developments have, until now, helped lower the price of variable-speed drives, making them an economical alternative to mechanical methods of speed control, and that includes hydraulic and pneumatic solutions. In addition, these developments have contributed to the continuous expansion of the variable-speed drives market. By using its know-how, ABB has been confident enough to enter the microdrive market, and lately the sub-microdrive market.

One notable technological development is ABB's motor control platform called Direct Torque Control (DTC). Launched about 10 years ago, DTC continues to be the main control platform for ABB

Because variable-speed drives reduce energy consumption while increasing productivity, they can, depending on the application, pay for themselves within a few months simply through the energy saved.

drives, and it has helped the company increase its market share from about 11 percent in 1995 to 16 percent today, nearly twice that of its nearest rival. Competitors have not embraced DTC mainly because it is the result of a major R&D effort which

many companies cannot afford, and is protected by several patents.

ABB continues to invest heavily in product development for which it has earmarked some 1200 man-years over the next 5 years.

Over the past number of years, however, it has become evident that technology alone will not keep companies ahead of the competition. Because customer requirements have changed,

global suppliers must now offer custom software, improved interface packages, specialty application hardware, equipment installation, project commissioning, product training and maintenance services.

### Customer demands

When selecting drives, customers no longer look just at a company's product, but also at service levels, total lifecycle costs, availability and productivity. When it carried out its own research, the ABB Drives unit identified five prerequisites that customers are looking for: reliability, ease of use, drives integration, backup and standardization.

### Reliability of a company and its products

Drive reliability, measured as the mean time between





failure (MTBF), has increased five-fold since the 1980s. The MTBF is better than 1 in 50 years for ABB drives!

Such high reliability is the result of years of know-how combined with stringent testing methods. All drives coming off the assembly line in Helsinki are individually tested with a fully loaded motor. After a specific length of time, the test is repeated. Drives that fail during testing or in the field are sent back to quality control for analysis, so that corrective action can be taken.

Research engineers are also contributing to the increase in reliability by continuing to explore ways of reducing the component count within a drive. Since the 1980s the size of drives, measured in volume, has decreased by 70 to 80 percent, while the number of components has come down by 60 to 70 percent.

Even though product reliability is very important, customers are just as concerned about the reliability of their suppliers and the channel partners they choose. This type of reliability is measured as the ability to deliver what has been promised, on time.

In the past two years ABB has invested heavily to have the most advanced trio of drives assembly plants on the planet. These factories are situated in Helsinki, New Berlin in America and Beijing, and produce the latest ABB standard drive to identical specifications with unsurpassed reliability.

All too often companies fail to stock enough products locally, or product delivery times are simply too long. ABB's aim is to provide 'next day delivery' for all its drives. But currently in many countries, the company can deliver low-power drives in 90 minutes.

**Intelligent drives that sell themselves – almost**

There was a time when the development of variable-speed drives was quite a specialist activity. As technology has advanced over the years, drive manu-



facturers, including ABB, have been able to add attractive features to, and increase the functionality of their products. This in turn has resulted in drives that can be tuned for a wide range of applications. Unfortunately, there is a downside to this and it comes in the form of complex interfaces and thicker instruction manuals.

One thing has happened that have forced manufacturers, like ABB, to change their approach to drive design. The role of indirect sales has increased,

especially for low-power drive, and because of this, it is necessary to make drives technology accessible for non-specialists. By adopting the 'let technology do the job' message and rethinking its design strategy, ABB has been able to develop intelligent drives with simple interfaces.

A good example of this is ABB's latest standard drive. It illustrates how far the company has come since the early days of variable-speed drive technology, some 30 years ago.



## To standardize or not to standardize

Over the past years, there has been a push towards standardization in the drive market. While this is possible in certain areas of drive technology, it is extremely difficult in other areas with the result that despite the ongoing standardization, the number of different drive types continues to grow.

A classic example of technology acceptance and standardization comes in the form of EMC filters. A few years ago, when the EMC directives were prevalent, there was much debate in Europe about whether EMC filters for drives should be fitted internally or externally, or if they should be integrated in a product or sold as options. Today, many drive manufacturers have EMC filtering built-in.

Nevertheless, because variable-speed drives are finding their way into various industrial applications, for example wind power generation and in the marine industry, the result is ever widening product portfolios ranging from decentralized drives to large multi-drive systems. From this perspective, it is this rapid increase in the choice of drives that characterizes the market. For that reason, ABB found it necessary to introduce some new terminology to help customers make the right selection (see glossary on page 62). So, what is seen as standardization in some areas is proliferation in others. More importantly, understanding these dynamics will separate the winners from the losers.

### The power of customer support

Many people recognize that service is very important, and one of ABB's major objectives is to keep its customers happy long after they have bought a drive and are using it in their production process.

This means working together with the customer to minimize the total cost over the lifetime of the product, while at the same maintaining high levels of availability.

Even though ABB accepts its drives are not the cheapest on the market, the company knows that by adopting the above philosophy it has, in the medium- to long-term view of things,

One of ABB's major objectives is to keep its customers happy long after they have bought a drive and are using it in their production process.

become a low-cost player. Customers with a long-term perspective, who are in the majority, appreciate this.

While ABB charges for most of its services, it stresses that charging is not necessary to support declining hardware prices. Several surveys have put ABB as the global leader for drive hardware, software and services, but in

pure product sales, the company has featured outside the top three. Service revenues make up about 20 percent of ABB business. If the company's market share is 16 percent and the nearest competitor about 10 percent, then it is clear that even if hardware alone is counted, ABB remains number one.

**Pekka Tiitinen**

ABB Oy

Helsinki, Finland.

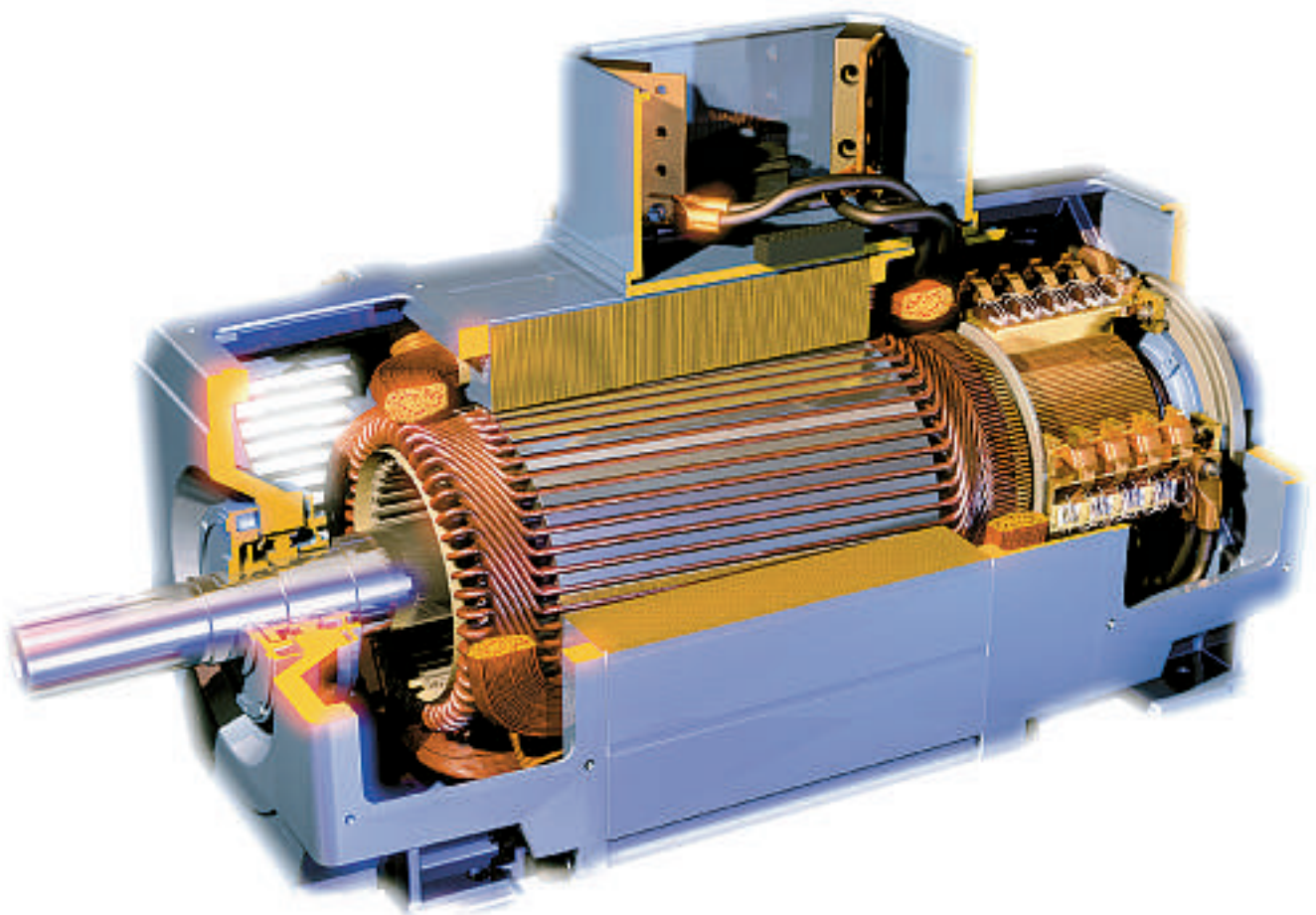
pekka.tiitinen@fi.abb.com



# DMI – a milestone in the development of DC motors

Christer Söderberg

ABB's medium-sized (IEC frame sizes 180-400) DC motor offers good performance in a number of important areas. Many of the motor's key attributes were previously considered mutually exclusive, ie, it was not possible to combine them in the same machine. Thanks to the motor range known as DMI, customers have been taking advantage of high power, a wide speed range, high torque, small dimensions, and high overload capacity or low moment of inertia simultaneously for some years. The improvements were important enough to justify calling DMI the beginning of a new era in DC motor technology.



DC motors have existed for more than a century, and at least twice during that period they have been popularly regarded as doomed to extinction. The first time this happened was when three-phase AC supply came onto

Performance in terms of output power, torque and speed has increased in DC motors over the years at the expense of the electrical margins and speed range at rated output power.

the scene around the turn of the century. Thanks to their good regulatory properties DC motors nevertheless survived and, during the last few decades, have become more popular than ever, largely due to thyristor converters making it easy to capitalize on the advantages of DC technology. However, in the mid to late 1990s, the doomsayers came knocking again, this time predicting the demise of the DC drive because it was possible to approach its precision and responsiveness with frequency converters and standard squirrel-cage AC motors. Once more, the prophecy did not materialize; sales of ABB DC motors in recent years have remained stable;

**1** Even though DC motor performance has improved over the last few decades, it has come at a cost. ABB's new motor eliminates this cost.



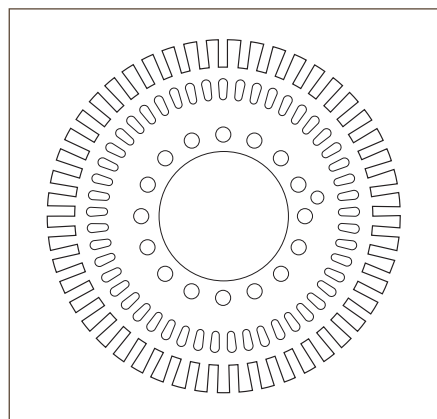
and what is more, thanks to the introduction of the DMI motor, ABB experienced significant growth in this sector.

### DC motor development

The stiff competition in the field of DC motors has led to ever more 'stressed' designs. While performance in terms of

output power, torque and maximum speed has increased over the years, it has been at the expense of the electrical margins and speed range at rated output power. This in turn has led to a greater need for maintenance of brushes and commutators and to a reduction in lifetime **1**.

**2** Armature laminations of the new motor.



**3** Symmetrical positioning of the armature cooling channels in relation to the winding slots.



The challenge for the DMI project team was therefore to turn the development of DC motors back towards ideal characteristics, including a wide speed range at constant output power, low electrical stress levels and, as a result, less need for maintenance.

### ABB's approach

Some time ago, sales of the DMI's forerunner, the DMG motor, gave ABB reason to contemplate the future of their involvement in DC machines. The company decided it wanted to reverse the market trend towards increasingly restrictive designs and, based on its broad know-how, experience and state-of-the-art design tools, develop an ideal motor



with respect to its mechanical and electrical properties. Specifically, this meant higher output power, higher torque, higher speed, a wider speed range, lower moment of inertia, better low-speed properties and lower electrical and mechanical stresses.

Two possible avenues were open: start with the current motor series and improve it, or design an entirely new machine. The first was less risky and less costly, but also less promising; the second, although it obviously entailed more risk and higher costs, held more promise. After careful analysis, ABB chose the second path and laid plans to design an entirely new series of motors. This was done because its potential by far outweighed the greater risks and higher development costs. The result – the DMI motor – proved to be the right choice. Compared with the forerunner, this motor exhibits approximately:

- 50 percent higher output power
- 90 percent higher torque
- 30 percent higher maximum speed
- 30 percent wider speed range

4 The armature coils are skewed for smoother running at low speeds and less noise.



ably better. In addition, the magnetic balance of the armature is improved by the fact that the cooling channels are located symmetrically in relation to the winding slots **2**. The symmetry of the magnetic flux in the armature circuit, which ensures that no armature coil is subjected to higher electrical stress than any other, was one of the aspects examined during the computerized optimization of the magnetic circuit.

**3** shows an example of the way the results of flux calculations were presented.

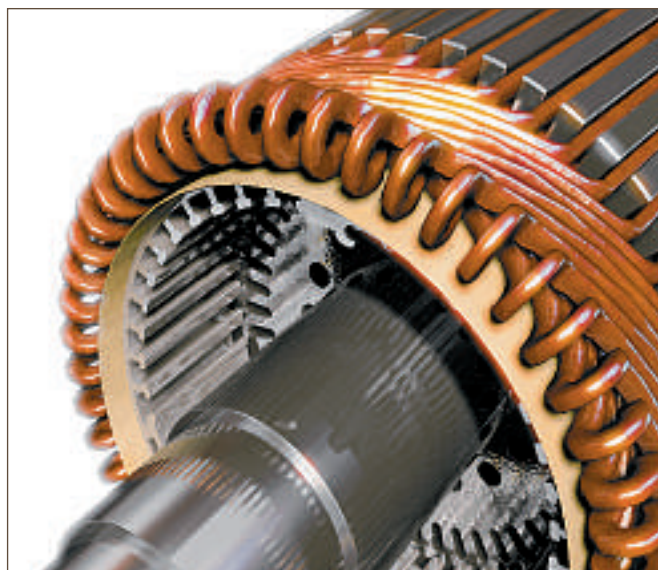
#### New solutions

The development project spawned a number of novel technical solutions, for which several patent applications were made. The most important development was a new principle for cooling the armature windings. In this principle, the cooling channels are moved through the armature laminations closer to the winding slots, while at the same time significantly widening the overall cooling area. Because of this, the cooling capacity is consider-

Other improvements to the armature were:

- The manufacturing process for core laminations was refined to reduce the variations in magnetic polarization of the electrical steel used. This measure has resulted in smoother running at low speeds.
- The armature coils are skewed, resulting not only in smoother running at low speeds but also in lower noise levels **4**.

5 The coil ends of the armature are mounted on sturdy support rings made of aluminium.



6 Improvements in the motor stator include more space for the windings, and better magnetic balance and temperature distribution.



- The coil ends of the armature are mounted on rigid support rings made of aluminium, thus reducing vibrations and contributing to the high speed limit of the motor. The arrangement also improves the cooling of the coil ends, a weakness in many older designs which directly affects the durability of the insulation **5**.
- The motor shaft is overdimensioned to further reduce vibrations and contribute to the high speed capability of the motor.

The stator was also improved. More space was created for the windings. The magnetic balance is now better, as is the temperature distribution. All of this was made possible by computerized optimization of the magnetic circuit, more compact coils and improved manufacturing methods **6**.

The commutator was also redesigned: Its diameter was reduced and made sturdier. Consequently, it too contributes to the motor's high speed capability and wide commutation margin (ie, its capacity to conduct current without sparking) **7**.

### Dramatically improved performance

The above-mentioned improvements

were introduced to boost the output power of the motor without compromising the commutation margin. However, the results far exceeded the expecta-

**An extremely wide commutation margin in DMI ensures high operational reliability and minimal maintenance for the motor.**

tions. Despite a boost in power of up to 70 percent, the commutation stress level fell significantly.

The performance boost, compared with conventional DC motors on the market, is evident from **8**. The horizontal section of each diagram represents the 'shunting range' giving a good indication of the commutation margin of each motor at rated load.

### Commutation margin: the key to high reliability

The commutation margin is a measure of the ability of DC motors to conduct currents between the brushes and the

commutator without sparking. Consequently, it is one of the most important properties governing operational reliability and maintenance requirements. The commutation margin is affected by factors such as current ripple, vibration, temperature, load and contaminants in the cooling air – all factors which, in different ways, have been attended to in the motor. The commutation ability of the DMI has been verified with converter supply, which is significantly more demanding than a smoothed DC supply. An extremely wide commutation margin ensures high operational reliability and minimal maintenance for the motor **9**. In reasonably stable operating environments, the commutator and the brushes do not need servicing more often than the bearings. Suddenly the DC motor is on par with squirrel-cage AC motors in terms of maintenance intervals.

### Insulation: the key to long life

Different materials are used for the insulation of the DMI motor to extend its life for as long as possible. For example, materials with high temperature indices – far higher than Class H – are used where the temperature is high, and mechanically stronger materials

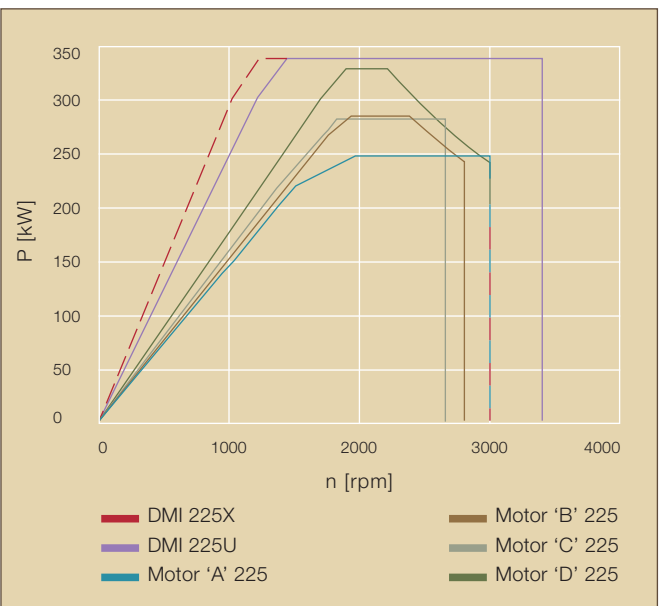
**7**

The commutator has a small diameter and therefore a low peripheral speed, ensuring that it will run properly even at high speeds.



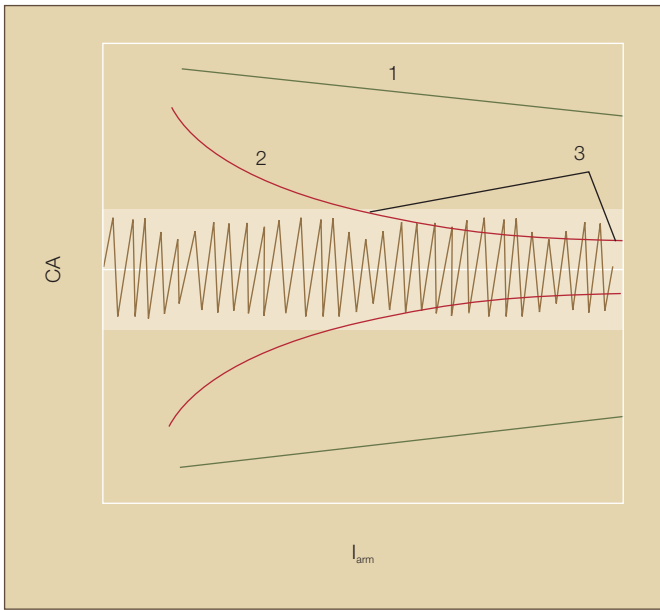
**8**

Power (P) and speed range (n) of the DMI motor compared with some well-known conventional DC motors on the market



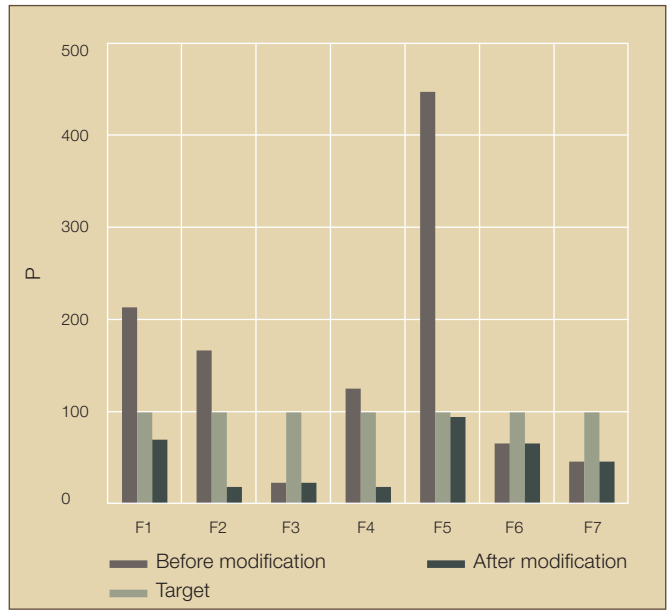


**9** Commutation ability (CA) vs armature current ( $I_{am}$ ). The center area represents disturbances during normal operation that affect the commutation margin.



- 1 DMI motors
- 2 Other motors
- 3 Insufficient commutation

**10** FMEA was used throughout the design and production engineering phases to ensure that the set quality and reliability objectives were reached.



P Probability index  
F1-F7 Failure modes

where temperatures are lower. In this context it is important to point out that ABB calculates temperature margins for the DMI on the basis of the actual temperature during operation, not the temperature some time after shut-down, which the IEC 34-1 standard permits. ABB temperature tests are also based on the more demanding converter supply.

At the same time, the risk of hot spots developing is eliminated thanks to near-ideal electromagnetic dimensioning and improved cooling.

### FMEA – a systematic approach to achieving high quality

A systematic approach to identifying the measures required to reach the set quality objectives is offered by ‘Failure Mode and Effect Analysis’ (FMEA). This method was therefore used throughout

the development and production engineering phases of the new motor <sup>10</sup>.

### Long-term viability foreseen for DC technology

Designing electric motors, like so many other design assignments, is largely a matter of finding the best balance between desirable, but conflicting, properties. In the case of DC motors, the desirable properties include high output power, high torque, high speed, a wide speed range, small dimensions, low weight and minimal maintenance. Different motors, not least from different manufacturers, have traditionally been good at different things; none has been good at all of them. Thanks to unique human resources in its design department, up to date computer-based design tools and a good measure of innovative thinking, ABB has, with the DMI motor, a product which is significantly better

on all counts. This is good news for all involved, and for the ability of DC technology to remain viable in the long term.

**Christer Söderberg**  
ABB Motors  
Västerås, Sweden  
christer.lj.soderberg@se.abb.com

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New markets targeted with  
ABB's variable-speed microdrive

Mika Paakkonen

# ACS50

## sizing up the consumer industry



Advances in AC drive technology have brought about a 'small revolution', and at the same time presented ABB with a whole host of new market opportunities for its variable-speed drives. The revolution is the newly launched ABB component drive ACS50, while the new opportunities are to be found in the vast consumer industry. Here, applications for very small, affordable drives abound, for example in home and medical appliances.

ABB is a market leader in the design and supply of electrical drive equipment for industrial, commercial and building applications. The company offers one of the largest portfolios of variable-speed drives and backs it up with in-depth application know-how. ABB drives are used, for example, in the cement, chemical, metal, oil and gas, and pulp and paper industries, in marine applications, in food and beverage production, and in power plants.

To hold on to this number one market position, ABB follows a strategy of increasing market share through sustainable innovation and of breaking into new markets with smaller and easy-to-use products.

To increase market share, ABB continues to enhance its portfolio by making drives:

- Easier to use by implementing advanced software

- More cost-effective, and therefore more competitive
- Smarter

Some remarkable advances in AC drive technology over the past 20 years have also made it possible for ABB to enter new markets. Advanced technology, plus understanding the customers' needs and the markets in which they operate, is the key to everything. With an eye on the domestic appliance mar-



ket, ABB conducted customer surveys to discover what the most desirable features are when it comes to variable-speed drives. In order of popularity, these are:

- Simple controls and setups
- A user-friendly operator interface
- Programmability
- Price

From these findings, ABB knew that it could cleverly use simple adaptations of known technologies and provide products that are technologically straightforward to target these customers and markets. But the company additionally knew that not just simpler, but also smaller drives were needed to fit the required applications.

Here, ABB had the advantage that miniaturization has been one of the most striking successes of its AC drive development efforts. What is more, making drives even smaller continues to be a key goal of the company's R&D teams. Miniaturization is possible in the first place thanks to the continuous development of power semiconductors and use of advanced cooling techniques. Advanced flow modeling, in particular, is steadily improving heat sink design and performance.

Among other things, miniaturization keeps costs down and facilitates new applications. Smaller drives mean less material, so manufacturing costs are reduced and the cost of the end product is lower.

Component integration is another important factor; reducing the number of parts not only contributes to lower costs but also improves reliability.

The fruit of all this labor is the ACS50 component drive. Rated from 0.18 kW to 0.75 kW, the ACS50 is small and compact (in fact it is currently the smallest 370-W drive on the market) as well as easy to install and use. Its core platform puts the company in a position to tailor drives for a wide range of home appliances, such as washing machines, refrigerators and freezers

#### The ABB component drive ACS50

The ABB component drive ACS50 belongs to the Drive<sup>IT</sup> Low Voltage

The new drive's core platform enables ABB to tailor the ACS50 for a wide range of home appliances, such as washing machines, refrigerators and freezers.

AC Drives family, with powers from 0.12 kW to 4500 kW. The drive is available for either 100–120 V AC, or

200–240 V AC single-phase systems. It is also suitable for three-phase motors with ratings from 0.12 kW to

0.75 kW and 230 V. In addition to being the smallest on the market, it is by far the easiest drive in its class. No special knowledge of drives is required prior to setup.

Installation and manual configuration require just a few minutes; there is no need for any programming! Also, since there is no control panel, there are no hidden functions. What you see is what you get.

The ACS50 can be used with domestic networks due to its good electromagnetic compatibility (EMC) even without an external filter. It is in fact available with a built-in EMC filter for first environment applications (see 1st panel) and is protected to the IP20 standard. An optional EMC filter is available for long motor cables, with unrestricted sales distribution up to 75 meters in the second environment and restricted sales distribution up to 30 meters in the first environment (see 2nd panel). It comes equipped with a choice of silent or standard noise control.

The user interface features three control potentiometers and eight dual in-line package (DIP) switches located on the front panel. The potentiometers control the motor thermal protection, acceleration/deceleration time (variable between 0.1 and 30 seconds), and the maximum frequency. The ACS50 drive is configured via the DIP switches, which are used to set functions such as:

- Nominal frequency of the motor
- Motor noise control
- Minimum analog input
- Drive auto reset for faults

#### First and second environments

Drive systems can be connected to either industrial or public distribution networks. The environment class (of which there are two, known as the first and second environment) depends on how the system is connected to the power supply.

The first environment includes domestic and other premises directly connected to a low-voltage power supply network supplying residential buildings without an immediate transformer.

The second environment includes all establishments other than those directly connected to a low-voltage power supply network supplying residential buildings.

#### Restricted and unrestricted classes

A drive's route to market is divided into unrestricted and restricted sales distribution classes.

Unrestricted distribution is a mode of sales distribution in which the supply of equipment is not dependent on the EMC competence of the customer or user with regard to drive applications.

Restricted distribution is a mode of sales distribution in which the manufacturer restricts the supply of equipment to suppliers, customers or users who separately or jointly have the required EMC competence with regard to drive applications.

Standard input/output functionality is provided via a control terminal on the front of the unit.

**Applications: from the usual to the unusual**

Aimed at simple applications in industries like heating, ventilation and air-conditioning (HVAC), or food and beverages, the ACS50 is seen as a substitute for existing products such as contactors, soft starters, multispeed motors, tri-acs and regulating transformers.

Aimed at simple applications in various industries, the ACS50 is seen as a substitute for contactors, soft starters, multispeed motors, tri-acs and regulating transformers.



ACS50 component drive models

ABB expects the ACS50 to open up new markets with unusual applications as diverse as automated gate control, medical scanners and pizza ovens. In fact, customers have already tested the drive in some of these areas, and all have commented that it could be quickly installed – usually in less than five minutes! – and was extremely easy to use. Other foreseeable applications include packaging machines, scanners, and pumps and fans.

Here, likely purchasers will be small- to medium-size OEMs who demand simple, easy-to-use products. It is anticipated that these OEMs will account for 90 percent of sales.

The drive can be either DIN-rail or wall mounted and comes in two frame sizes. The smaller model is 45 mm wide by 146.5 mm high and 128 mm deep while the larger version is 67 mm wide with the other dimensions the same. These dimensions make it the thinnest drive available on the market today.

**Application-specific intelligence**

ABB knows that each customer application is unique. Designers at the company therefore created a core platform that ensures an extremely fast design cycle for special product variants of the AC component drive offered to larger OEMs.

This means that, depending on the application, specific functionality, such as unbalance control in washing machines, can be added to suit customer requirements. Besides providing products with better control, this also increases ABB's competitiveness in the high-volume design area.

The component drive ACS50 is the latest product of the 'small revolution' under way in AC drives at ABB. The company has taken the 'simple is best'

approach and developed a compact, easy-to-use drive that will make the life of system designers easier as well as improve the performance of many consumer electrical products.

**Mika Paakkonen**  
ABB Automation Technologies  
Helsinki, Finland  
mika.paakkonen@fi.abb.com



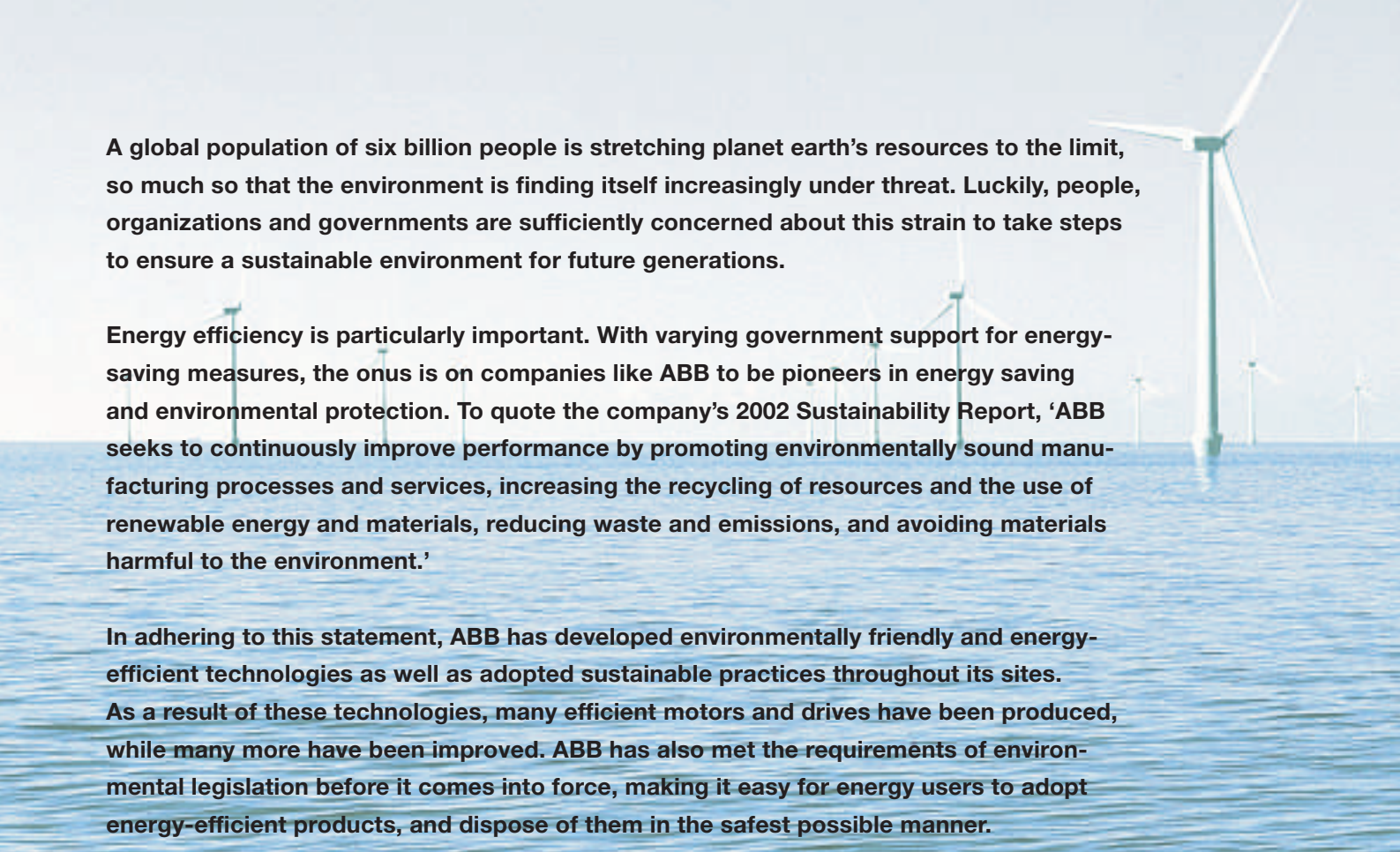
# Protecting the environment

Increasing the energy efficiency of ABB drives and ensuring their safe disposal

Akseli Savolainen







**A global population of six billion people is stretching planet earth's resources to the limit, so much so that the environment is finding itself increasingly under threat. Luckily, people, organizations and governments are sufficiently concerned about this strain to take steps to ensure a sustainable environment for future generations.**

**Energy efficiency is particularly important. With varying government support for energy-saving measures, the onus is on companies like ABB to be pioneers in energy saving and environmental protection. To quote the company's 2002 Sustainability Report, 'ABB seeks to continuously improve performance by promoting environmentally sound manufacturing processes and services, increasing the recycling of resources and the use of renewable energy and materials, reducing waste and emissions, and avoiding materials harmful to the environment.'**

**In adhering to this statement, ABB has developed environmentally friendly and energy-efficient technologies as well as adopted sustainable practices throughout its sites. As a result of these technologies, many efficient motors and drives have been produced, while many more have been improved. ABB has also met the requirements of environmental legislation before it comes into force, making it easy for energy users to adopt energy-efficient products, and dispose of them in the safest possible manner.**

**A**BB has always taken environmental issues seriously **■**. The company is a signatory to the International Chamber of Commerce Business Charter for Sustainable Development, and in 1992 it adopted the 16 principles of the Charter as its group-wide environmental policy. In adhering to this charter, products and services designed to improve the performance of utility and industry customers are also designed to ensure that any environmental impact is minimized.

Currently, ABB has around 2,000 environmental improvement projects in progress, and 46 percent of these are concerned with reducing global warming. Many energy-efficient motor and drive products have been produced as a result of the development of new technologies, a large number of which focus on significantly reducing CO<sub>2</sub> emissions. By replacing an average 1980s motor and frequency converter with an ABB high-efficiency motor and a modern ABB drive, not only are CO<sub>2</sub> emissions curbed, but a payback time of a few years is predicted due to lower energy consumption. Naturally, this prediction

depends on annual operating hours and energy prices.

ABB ensures that its manufacturing facilities, processes and workshops operate in accordance with the highest environmental standards, and this is especially true of the manufacture of eco-efficient products such as high efficiency motors and variable-speed drives. One of ABB's corporate objectives is to implement the international environmental management standard, ISO 14001 at all its manufacturing sites. Currently, about 97 percent of all sites designing and/or manufacturing products, or providing services, are certified to this standard. In 2002, ABB extended its environmental management program to all remaining non-manufacturing facilities, beginning with the Group's Zurich headquarters.

As well as providing environmentally sound manufacturing processes, the company is continuously working to improve existing products. In particular, the design of products such as drives and motors is aided by *Design for Environment* toolboxes. These toolboxes,

developed by ABB, consist of guidelines, web-based tools and databases of information, all of which help engineers and scientists design for low environmental impact.

One of the most useful management tools in this area is Life Cycle Assessment (LCA). LCA evaluates the total environmental impact of products during their entire lifecycle, from the production of raw materials to the recycling of material when the products are taken out of service. The information obtained from these LCAs form the basis of Environmental Product Declarations (EPDs). EPDs describe and quantify the environmental performance of all ABB's core products, including drives and motors.

#### **ABB – ahead of legislation**

The disposal of failed or redundant products has become a very important subject for companies, especially those operating within the EU. Two new EU directives, the Waste Electrical and Electronic Equipment (WEEE) and Restriction of certain Hazardous Substances (RoHS) are currently being incorporated into na-

tional legislation in member countries, and must be implemented by 2006. Manufacturers will need to ensure that their products - and their components - comply with both these directives.

The WEEE directive aims at minimizing the impact of electrical and electronic equipment on the environment during their lifetimes and when they become waste. The RoHS directive will ban the placing on the EU market of new electrical and electronic equipment containing more than agreed levels of certain substances like lead, cadmium, and mercury.

ABB anticipated the introduction of these directives and, in accordance with RoHS, it has abolished the use of hazardous materials such as cadmium in its products. In the UK and Finland, ABB has already piloted product take-back schemes for obsolete variable-speed drives and electrical motors, complying with the requirements of WEEE.

Up to 90 percent, by weight, of ABB's drives can be reused or recycled. Where

recycling is not possible, ABB and its channel partners will dispose of redundant products and components according to local legislation.

As well as WEEE and RoHS, the EU is drafting a new 'Eco-design requirements for Energy using Products' directive. The directive is designed to encourage manufacturers, when designing products, to take environmental impacts into consideration throughout the entire product lifecycle. It is generally believed that over 80 percent of all product-related environmental impacts are determined during the product design phase. Integrating environmental considerations as early as possible into the product development process is seen as the most effective way of introducing changes and improvements to products. This in turn would accelerate the move towards improving the environmental performance of energy-using products.

Working with the Technical University of Tampere in Finland, ABB has prepared a study of how well today's AC drives fulfil the requirements of this

draft legislation. It concludes that ABB's current products have already meet almost all the future needs of the directive.

### Getting the message across

With directives soon in place and reports, articles, papers and documents in abundance all relaying the same basic message: saving energy contributes enormously to protecting the environment as well as saving money, it may be surprising to learn that many companies still do not have a strategy that deals with environmental issues.

In Germany, for example, many big companies are very committed to saving energy, while many others have yet to adopt it as part of their thinking. Even a government 'Eco Tax' imposed on electricity used by the manufacturing industry failed to get some companies into the energy-saving mindset.

### Working together

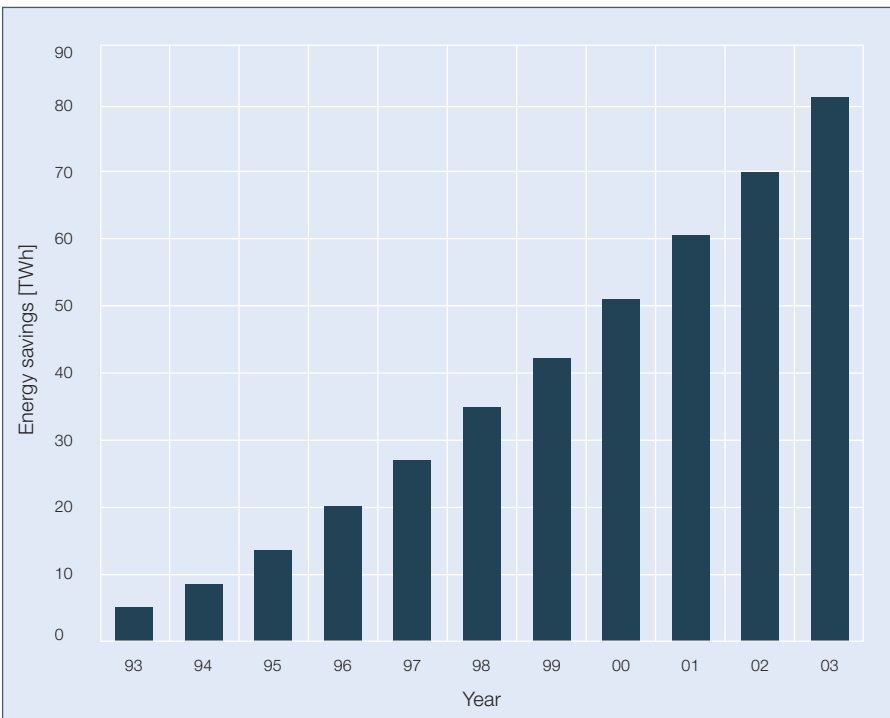
Together with ZVEI, the German Electrical and Electronic Manufacturers' Association, ABB is doing its bit to try and promote this message. As part of its environmental commitment, ABB Germany plays an active role in Global Compact, a UN organization that promotes sustainability.

ABB in Finland is working in much the same way by co-operating with the national energy offices to promote energy saving in motor-driven systems.

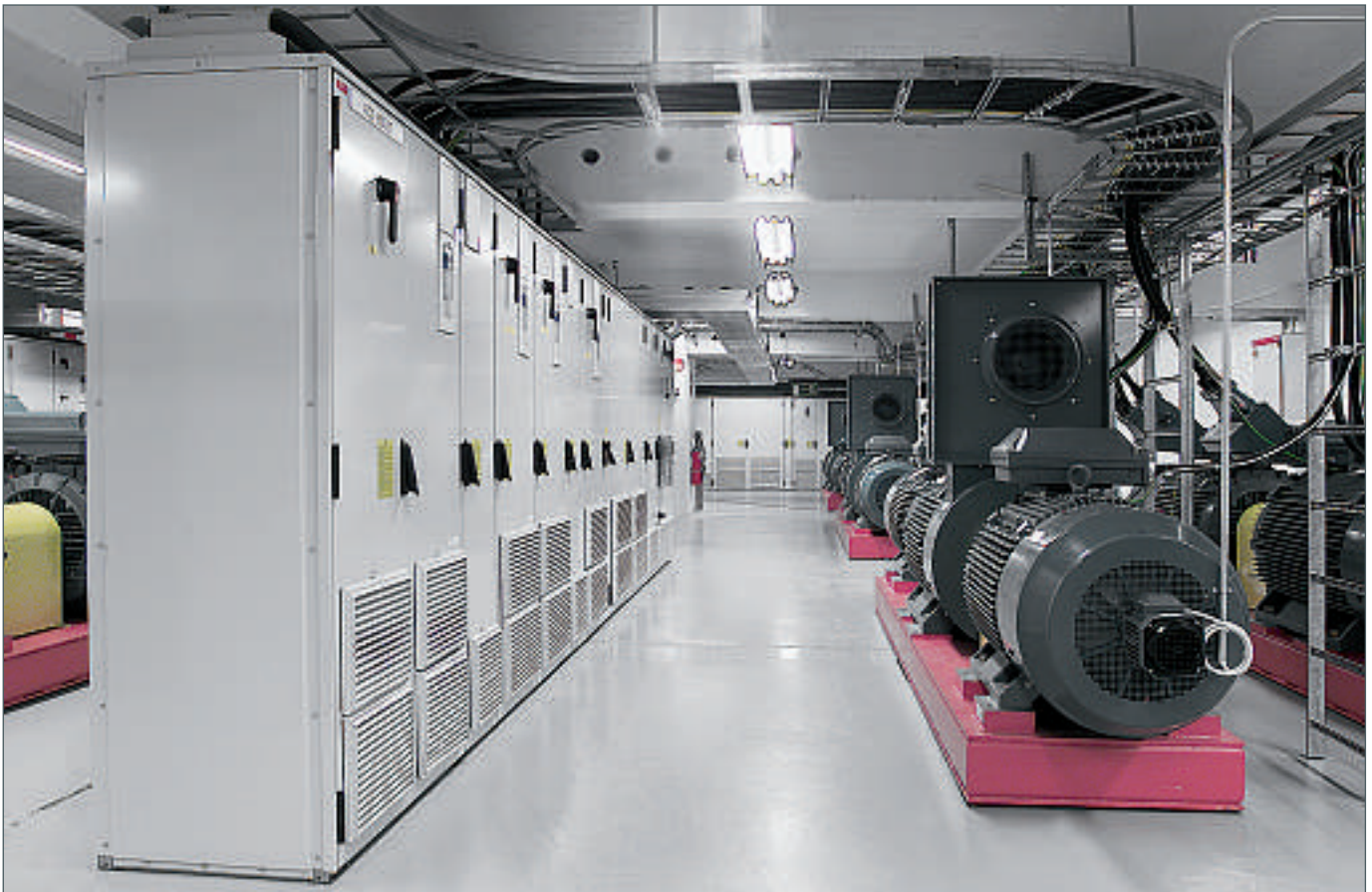
ABB in Italy was rewarded at EcoAmbiente Laigneglia, the first national Italian event devoted entirely to environmental communication, for its efforts in promoting EPDs. By promoting EPDs, the company is helping managers make environmentally responsible purchases.

In 2003, Pirelli held a conference for its global energy managers, and ABB was invited to host a seminar about energy-saving techniques and technologies. Using case studies of real contracts, the company showed Pirelli what it could achieve. As a result of the seminar, ABB was invited to a Pirelli factory in Turin to investigate its energy usage and advise on the installation of variable-speed drives.

**1** The amount of energy saved with over one million ABB drives, delivered during the last 10 years, is considerable.







The Italian government is working hard to promote energy saving by introducing a scheme to encourage the installation of energy-saving plants. It has set up an organization to study installations proposed by companies. If the proposal is approved, the company is awarded a certificate showing how many tons of oil equivalent the plant will save. This certificate, when presented to the electricity supplier, entitles the company to a reduction in its electricity bill.

Together with the trade organization UCIREV, ABB has proposed an alternative scheme, similar to that adopted in the UK. Products would have an energy saving certificate, and companies buying the products would qualify for reductions on energy tax.

Recently, ABB has become an official endorser of the European Commission's

Motor Challenge Programme (MCP). MCP [1] is the Commission's voluntary scheme to encourage the use of high-efficiency motor-driven systems throughout the industry. MCP endorser are approved equipment suppliers and other organisations that are committed to helping end users reach their energy efficiency targets.

#### Energy saving in practice

ABB is working extremely hard to help customers reduce their energy consumption. For example, ABB Italy has sent a CD containing an energy-saving calculation tool to thousands of energy users around Italy. This energy saving calculation tool uses information about a company's pumps and fans as input, and calculates the payback time if variable-speed drives were installed.

Another example is ABB's six-step energy-saving plan [2] designed to help customers find their energy 'glutton' applications. Launched by ABB in the UK to coincide with the introduction of the UK Government's climate change levy, the six-step energy-saving plan has won industry awards for its innovative approach to helping customers save on their energy costs.

ABB is looking after its own future and that of its customers, while at the same time ensuring that people everywhere have a future to look forward to.

**Akseli Savolainen**

ABB Oy

Helsinki, Finland.

akseli.savolainen@fi.abb.com

#### References

[1] <http://energyefficiency.jrc.cec.eu.int/motorchallenge>

[2]: <http://www.abb.co.uk/global/gbabb/gbabb903.nsf/0/d235c048a8898394c1256c5d0055b00b?OpenDocument>

# Improving motor efficiency

Steve Ruddell

Energy efficiency has never been higher on the agenda as it is today. Fossil fuels are diminishing, demand is growing and environmental aspects are setting new standards. This means that energy prices are under a lot of pressure. The same problem applies to electricity. In fact, emission trading legislation within the European Union could raise the price of electricity by up to a third.





The cost of energy is concerning major energy users in industry, who increasingly see energy use reduction as a key to improving their profitability in an increasingly competitive world.

An estimated 65 percent of industrial energy is used by electric motors, and so they are an obvious target for attention. Energy consumption by electric motors can be reduced in two main ways – efficient control of the speed at which they run, and making the motors themselves more efficient. Design and production of motors and the drives that control them are both areas of expertise for ABB, and we clearly have a responsibility to bring this expertise to bear in an effort to reduce the environmental impact that motors have.

### Optimum motor speed brings best efficiency

By far the most effective method of controlling a motor's speed is through the use of variable speed drives **1**. However, much control is still performed with throttling valves in pump systems or vanes in fan applications, while the demands for rotating machinery are solved by gears or belt drives. Speed control with belt drives, gearboxes and hydraulic couplings all add to the inefficiency of the system to varying degrees, and require the motor to run at full speed all of the time. In addition, mechanical drives can be noisy as well as difficult to service, situated as they are between the motor and the driven machinery. These arrangements often seem cost-effective at first sight, but they are energy wasters.

Imagine trying to regulate the speed of your car by keeping one foot on the accelerator and the other on the brake. Running a motor at full speed while throttling the output has the same effect; a part of the produced output immediately goes to waste. Of that estimated 65 percent of energy used by electric motors, some 20 percent is lost by wasteful throttling mechanisms.

In fact, so much energy is wasted by inefficient constant speed and mechanical control mechanisms that every in-

dustrialized nation around the world could make several power stations redundant simply by using variable speed drives instead. In the right applications, variable speed drives can make a huge difference.

Of the estimated 65 percent of industrial energy used by electric motors, some 20 percent is lost by wasteful throttling mechanisms.

In pump and fan applications **2**, using variable-speed drives can cut the energy bill by as much as 60 percent. A pump or fan running at half speed consumes only one-eighth of the energy compared to one running at full speed. Or, put differently: the power required to run a pump or a fan is proportional to the cube of the speed. This means that if 100 percent flow requires full power, 75 percent requires  $(0.75)^3 = 42$  percent

of full power, and 50 percent flow requires  $(0.5)^3 = 12.5$  percent of the power.

As a small reduction in speed can make a big difference in the energy consumption, and as many fan and pump systems run at less than full capacity a lot of the time, a variable speed drive can produce huge savings. This is particularly so when compared to a motor that is continuously running at full speed.

The efficiency of motors and drives has improved considerably over the years. Motors have improved in efficiency by an average of 3 percent over the last decade, while ABB AC drives delivered in the past ten years for the speed control of pumps and fans are estimated to reduce electricity consumption by about 81,000 GWh per year worldwide. This means that ABB AC drives now in use reduce global CO<sub>2</sub> emissions by over 68 million tonnes every year, equivalent to the emissions of a country the size of Finland, with a population of over five million people.

If we replace an average 1980s motor and frequency converter with an ABB high-efficiency motor and an ABB drive,

**1** Variable-speed drives offer the most effective method of controlling a motor's speed, thereby contributing significantly to energy saving.





the payback time due to lower energy consumption is a few years, depending on annual operating hours and energy price. This points to a great potential replacement market as users seek to improve their energy consumption.

And when an 11-kW motor drive is replaced, annual CO<sub>2</sub> emissions are reduced by six tonnes! To this end, ABB has been selling standard motors from 11 kW upward only in the best efficiency class defined by the EU.

Regulating the motor speed has the added benefit that it easily accommodates production rises without extra investment, as speed increases of 5–20 percent are not a problem with an AC variable speed drive. By matching the performance of the motor to the needs of the process, variable speed drives can give major savings, compared to the wasteful practice of running the motor at full speed against a restriction to modulate output. In an ideal world, we would be approaching the point where energy was applied with pinpoint accuracy when and where needed, and never wasted.

Despite these obvious energy saving advantages, 97 percent of all motors in applications under 2.2 kW have no form of speed control at all, equating to some 37 million industrial motors sold annually worldwide.

In the past, this might have been understandable, as a small drive cost in the region of US\$500 per kW. But over the past few years, drives across the range have become smaller and cheaper, and now start at around US\$ 150 per kW. This can make investment in a variable-speed drive a viable proposition on energy grounds alone.

The new generation of drives is smaller and so installation might be possible in places where a space constraint was an issue in the past. They are also more energy efficient than their predecessors.

2 In pump and fan applications, variable speed drives contribute to large energy savings, which in turn impacts the environment.



An example of these smaller, cheaper drives is the range of ABB component drives; these are being used in new, small-scale operations where no one would have thought of employing a variable-speed drive in the past, such as potter's wheels, spa baths and oven hobs. It is estimated that 40 percent of the value (and 90 percent in units) of all drives shipped are rated at less than 40 kW.

ABB is leading the way in developing drive technology, with radical new control techniques such as Direct Torque Control (DTC). A feature of DTC which contributes directly to energy efficiency is motor flux optimization, which greatly improves the efficiency of the total drive, the controller and the motor in pump and fan applications. The drives themselves are becoming leaner too, not only smaller in size but more energy efficient to manufacture, with smaller circuit boards and enclosures made of recyclable plastic.

**ABB drives in use**

A case in point is the German company Stadtwerke Strausberg, which operates the district heating scheme in the town

of Strausberg, 30 km east of Berlin. Its 86-MW power plant produces 190,000 MWh of heating energy, distributed through a 32-km distribution network with seven substations, to most official buildings and 50 percent of the private households in the town. The company decided to upgrade its control system, which was using throttling valves, to one with variable speed drives.

Using the throttling valves to reduce flow increased the head, making the system less efficient as the pump worked harder to overcome the extra

head. Temperature changes were too large and fast, and high pressure through the control valves caused loss and noise.

The system is now equipped with variable speed drives, and works on the principle of keeping constant pressure in the network. When temperatures drop, the thermostat valves open, causing the pressure to fall and the pressure transmitter output signal to decrease. This increases the pump speed and the higher flow rate increases the water pressure until a control loop balance is reached.

The annual pumping energy consumption was about 550 MWh using throttling valves, but that was reduced to 230 MWh when variable speed controlled pumps were used throughout the year. The payback period of the variable-speed control system was 12 months.

Because variable-speed drives across the range are smaller and cheaper than ever before, investing in them is a viable proposition on energy grounds alone.

**The next step – motor efficiency**

The other major energy efficiency strategy is to make the motors themselves more energy efficient and encourage companies to use them.

The Danish Energy Agency is one of the leading organizations in this field. It has published a list of high efficiency motors and offers subsidies for motors purchased from this list: US\$ 10 per kilowatt for both new plant and for replacements. It promotes this scheme direct to the 4000 largest end users of motors.

The USA and Canada have introduced the Energy Policy and Conservation Act (EPAAct). Among other legislation to improve the environment, it specifically targets motors from 0.75 to 150 kW as prime candidates for improvement. It has adopted a scheme similar to the Danish

one, with a list of high-efficiency motors published and reduced electricity tariffs for users of these motors.

The US Department of Energy also requires the efficiency rating to be indicated on the motor nameplate, the energy efficiency to be displayed prominently in all literature and marketing material, and the inclusion of other

markings to facilitate the enforcement of energy efficiency standards. Failure to comply with these requirements carries severe penalties.

The European Union has continued its energy efficiency policies under the EIE's SAVE subprogram. SAVE focuses on industrial facilities and buildings, especially where energy intensive processes play an important role. This includes voluntary agreements with branches of industry and companies to reduce energy consumption and CO<sub>2</sub> emissions.

The EU is also working with CEMEP, the European Committee of Manufacturers of Electrical Machines and

Power Electronics, to improve the efficiency of motors. In 1996, the EU Commission unveiled its plans to expand the use of high-efficiency motors, and CEMEP was instructed to work towards making these motors standard. 1999 saw agreement between the EU and CEMEP on efficiency levels for motors. There are three class levels of efficiency, known as Eff1, Eff2 and Eff3, applying to low

voltage two- and four-pole motors with ratings between 1.1 and 90 kW <sup>3</sup>.

The scheme requires motor manufacturers' literature to indicate the Class Level at three-quarter and full load. The motor nameplate also needs to carry confirmation of the Class Level. The intention is to reduce the manufacture of motors in the lowest efficiency Class Level, Eff3, by 50 percent within three years and to zero soon afterwards, at the same time increasing the numbers of motors made in levels Eff1 and Eff2. The scheme will also encourage motor users to use high-efficiency motors exclusively.

The European Commission has also introduced a voluntary program known as 'The Motor Challenge Program' in which industrial companies are given help to improve the energy efficiency of their motor-driven systems. Companies can participate as partners or endorsers. Partners are typically manufacturing companies that use motor-driven systems. Endorsers are manufacturers of motor driven system components. ABB has endorser status.

### Motor rewinds – a false economy

Many motor users, faced with a failed motor, will opt to have it rewound rather than purchase another one, believing this to be the cheaper of the two options. Although this is the case in a straight comparison between rewind cost and new purchase cost, the resulting loss of efficiency wipes out any initial cost advantage.

This was illustrated in the Ontario Hydro experiment. Ontario Hydro purchased ten new 15-kW motors, which were then independently tested. The motors were then purposefully damaged and sent to nine different repair companies. They were retested after winding, with the results shown in *Table 1*.

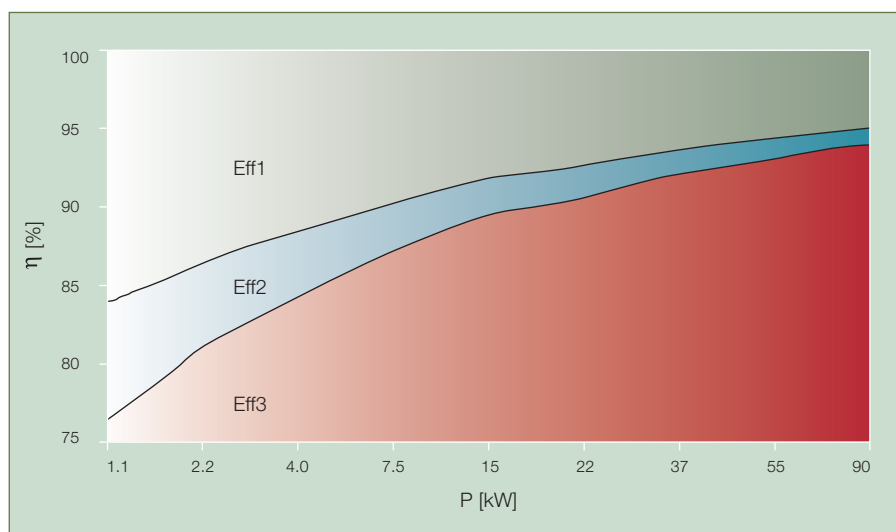
Ontario Hydro concluded that, in many cases, failed standard efficiency motors should be scrapped and replaced by high-efficiency models.

Efficiency is lost in rewinds for several reasons: core losses increase due to the

## The European Commission's 'Motor Challenge Program' helps industrial companies to improve the energy efficiency of their motor-driven systems.

3

The EU has published energy efficiency categories for motors. There are three class levels: Eff1, Eff2 and Eff3, applying to LV two- and four-pole motors rated from 1.1 to 90 kW. The aim is to phase out production of the less energy efficient machines.



Results of tests carried out on 15-kW motors rewound at nine different repair companies	
Motor	Efficiency change %
1	- 3.4
2	- 0.9
3	- 0.6
4	- 0.3
5	- 1.0
6	- 0.7
7	- 0.4
8	- 0.9
9	- 1.5
Average	- 1.1

high temperatures experienced during failure; stripping the motor for repair also damages the laminations; copper losses increase because of the practice of using smaller conductors, increasing I<sup>2</sup>R losses; finally, fitting of universal cooling fans, which may not be designed for the particular motor, leads to an increase in windage losses.

This decrease in efficiency and the consequent increased running cost makes the rewinding of motors not such an attractive option as it might first appear, as Table 2 illustrates.

As can be seen from the figures, purchasing a new ABB motor results in a saving of US\$ 690 over the first year.

### Improving motor efficiency

What can be done to improve motor efficiency? Designers can minimize losses by improving the design of features that give rise to the main losses in the motor. The greatest losses are the iron losses that occur in the rotor and stator, accounting for 50 percent of the total loss. This can be improved by using low loss steel and thinner laminations. Copper losses account for 20 percent. Using an optimum slot fill design and larger conductors can reduce these. Bearing friction and windage losses total 23 percent and can be reduced by using a smaller cooling fan. Stray losses, which account for 7 percent of the total,

Rewinding a motor versus purchasing a new one	
Example: 75-kW 4-pole motor; continuous running; US\$ 0.063/kWh	
Original motor rewind	New ABB motor
Cost of rewind: US\$ 2226	ABB high-efficiency motor Typical capital cost: US\$ 3585
Increased annual cost with 1.1% efficiency loss: US\$ 613	Annual energy saving with 3% increase in efficiency: US\$ 1435
Actual cost in 1 <sup>st</sup> year: US\$ 2840	Actual cost in 1 <sup>st</sup> year: US\$ 2150

can be reduced by improving the slot geometry <sup>4</sup>.

### Manage your motors

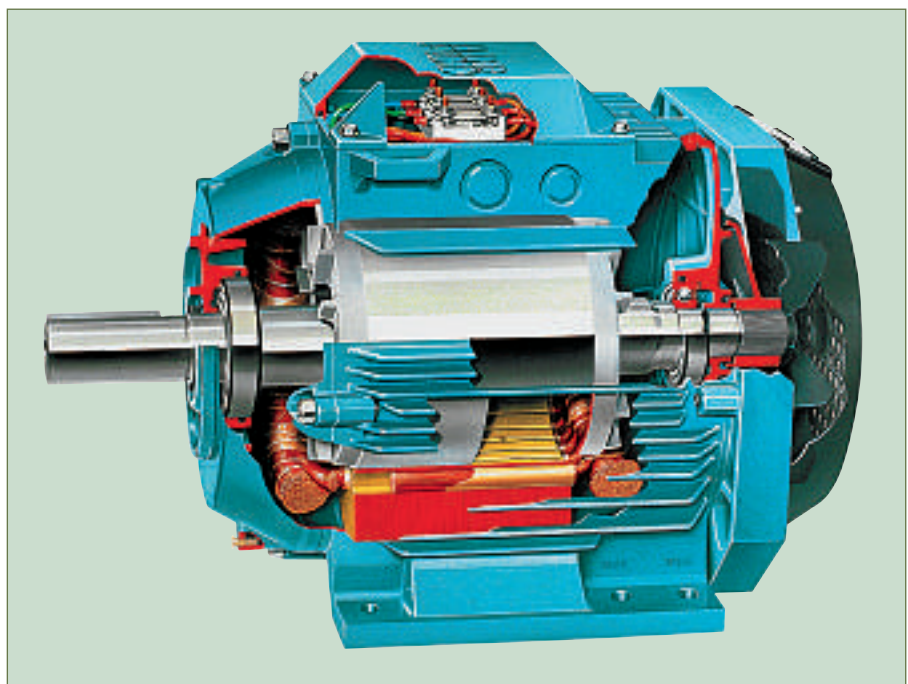
Users can also do a great deal to ensure they are getting the highest efficiency from their motors. A defined motor management policy needs to be in place. One policy decision should be to select high-efficiency motors when purchasing new plant equipment. Users need to specify minimum acceptable efficiency values. A replace

or rewind decision can be made long before failure occurs – there need to be clear guidelines for all responsible personnel.

High efficiency also means improved reliability and less downtime and maintenance. Lower losses give:

- Better tolerance to thermal stresses resulting from stalls or frequent starting.
- Increased ability to handle overload conditions.

4	Motor efficiency can be increased by improving the laminations, slot geometry and slot fill design, and by using smaller cooling fans and larger conductors.
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- Better resistance to abnormal operating conditions, such as undervoltage and overvoltage or phase unbalance.
- Higher tolerance to poorer voltage and current wave shapes.

A motor management policy helps bring together capital, maintenance and revenue budgets, showing the effect they have on each other when different types of motors are selected.

Users benefit from such a policy through reduced energy costs, by upgrading to high-efficiency motors at the most cost-effective time. The forward planning inherent in the practice helps reduce downtime and inventory can also be reduced through a fast track delivery agreement.

### The ABB way

What is ABB doing to reduce the negative impact that its motors and drives have on the environment? As well as constantly developing and promoting the use of high-efficiency motors and variable speed drives, ABB maintains a close watch on the total environmental cost of its products. One of the most useful management tools in this area is Life Cycle Assessment (LCA), which assesses and quantifies the environmental impact of products during their entire lifetime – from supply and manufacture to use by customers and disposal of the products.

ABB's corporate Research Centre in Västerås, Sweden has been working for a number of years to develop methods and capabilities in the field of LCA. ABB, along with several other companies, is supporting efforts to develop objective methods for LCA through participation in the Center for Environmental Assessment of product and Material Systems (CPM) in Gothenburg. CPM's objective is to provide industry with objective

LCA methods and to support the integration of environmental protection into all aspects of products and services.

The CPM now verifies ABB's lifecycle assessment data, adding credibility to our LCA process. LCA helps ABB ensure that manufacturing, use and disposal of our products has the least possible negative impact on the environment.

As a typical example, the environmental impact of an ABB standard drive was studied using LCA with the 'Environmental Priority Strategies in product design' (EPS) method. The product was considered to have a lifetime of ten years, with a usage time of 4000 hours per annum in a 4-kW-pump application in Central Europe. All the categories of environmental impact studied, such as global warming, acidification and toxicity of water, produced negative values for the emissions that contribute to them, showing that using the product reduces the impact of these chemical pollutants (*Table 3*).

<b>Table 3</b>		
<b>Environmental impact of an ABB standard drive, assuming a lifetime of 10 years and 4000 hours of use per year in a 4-kW pump application</b>		
Environmental impact	Amount including energy saved	Equivalent unit
Global warming	-7310.33	Carbon dioxide, kg
Acidification	-45.70	Sulfur dioxide, kg
Abiotic depletion	-25.18	Unit derived from resources use/known resources on Earth ratio
Nutrication	-1.97	Phosphate emission
Ozone depletion	Not available	CFC-11, kg
Photochemical oxidant formation	-1.62	Ethylene, kg
Ecotoxicity	-0.16	Polluted water exposed to toxicologically acceptable limit, m <sup>3</sup>
Human toxicity in air	-64.30	Human body exposed to toxicologically acceptable limit, kg
Human toxicity in water	-0.07	Human body exposed to toxicologically acceptable limit, kg

*Table 4* shows an example of an LCA assessment, a comparison between two standard 15-kW electric motors of different designs running at 12 kW. Motor A is an ABB motor, manufactured at ABB in Västerås. Motor B is made by a competitor. Although motor A requires more copper and iron to manufacture than motor B, this makes motor A more efficient in operation, meaning that it uses less electricity than motor B over its lifetime. With both motors operating 8000 hours per year for 15 years, the following results were obtained.

In motor A, with an efficiency of 91.1 percent, 140,681 kWh will be lost and in motor B, with an efficiency of 89 percent, 177,978 kWh will be lost.

*Table 4* shows the environmental aspects of these two motors based on their losses, manufacture and 98 percent recycling. It has been assumed that the motors will run on an average European mix of electricity. The environmental impact of motor B is greater than that of motor A. Evaluated according to the EPS scheme, motor A puts 21 percent less burden on the environment than motor B.

Motors and their efficient speed control are a major environmental issue. They are clearly a major consumer of the world's energy production and are therefore responsible for a large proportion of the pollutants released to the environment through this production. Reducing the energy they waste, through running them at optimum speed for the load by using variable speed drives and making the motors themselves more efficient, can go a long way to reducing this impact.

Companies such as ABB, with their expertise in both technologies, can have a real beneficial effect. ABB is committed to doing what it can to reduce the negative



**Table 4**

**Environmental impact of two standard 12-kW motors of different designs.  
Motor A is from ABB.**

Environmental aspects over full lifecycle	Motor A: 12 kW 91.1% efficiency	Motor B: 12 kW 89% efficiency
<b>Use of resources</b>		
Coal (kg)	16,370	20,690
Gas (kg)	2,070	2,620
Oil (kg)	3,240	4,090
Steel (kg)	27	24
Copper (kg)	0.9	0.8
Aluminium (kg)	4	4
Silicon (kg)	1.1	1.0
<b>Emissions</b>		
Carbon dioxide (kg)	62.940	79.560
Sulfur dioxide (kg)	495	626
Nitrogen dioxide (kg)	136	172
Hydrochloric acid	8.8	11.1
Metals (g)	538	538
Heavy metals (g)	1.1	1.1
Solid waste (kg)	117	106
Particles (kg)	30.4	38.4
Other (kg)	12	15
Total EPS indices	8.260 ELU of which 99.4% from operation	10.430 of which 99.5% from operation

impact of our products on the environment, demonstrated by our adoption of the environmental standard ISO 14001, which helps companies establish and maintain environmental management systems. The environmental department of the Swedish Standards Institution has recognized ABB as being in the forefront of environmental management systems.

For our customers, of course, energy efficiency is not just an environmental issue. It has a real effect on their costs and therefore their profitability and competitiveness. Environmental pressures and sound business economics are driving forward the development of motors and drives, improving the technology for the benefit of all.

**Steve Ruddell**

ABB Automation Ltd  
Warrington, United Kingdom.  
steve.ruddell@gb.abb.com

# Compact and complete

ABB industrial drive, ACS800

Roelof Timmer

**It is not by chance that ABB dominates the low-voltage AC market. Six generations of drives in three decades, incorporating many successful innovations, testify to a highly market-oriented development program. Now, a new AC drive is making its mark the ACS800 for motors rated 1.1 to 2800 kW. Industrial<sup>IT</sup> enabled allow connection to almost any control system, this extremely compact, energy-saving drive has everything it needs already integrated.**

In March 2002, ABB unveiled a new variable speed drive in its line up of winning drive products. The ABB industrial drive, ACS800, is the sixth generation of drives to be launched by ABB since it entered this market in the early 1970s. ABB has built on the success of each successive generation to become the world's leading manufacturer of AC variable speed drives. Between 1993 and 2003 alone, more than 1,500,000 units were sold, ranging in output from just over a hundred to several million watts.

These installed units have allowed, over that decade, an average of 81 TWh of energy to be saved each year in countless pump and fan applications **1**. The amount is significant when it is considered that the total annual energy consumption of a country like Finland is about 68 TWh. And underscoring its environmental importance is the fact

that the energy saving corresponds to a reduction of some 32 million tons of CO<sub>2</sub> emissions – about the amount produced by country like Austria.

Maintaining this enviable market position is not made any easier by the hundreds of players, all apparently capable of launching 'new' products with innovative features that will change the way customers work.

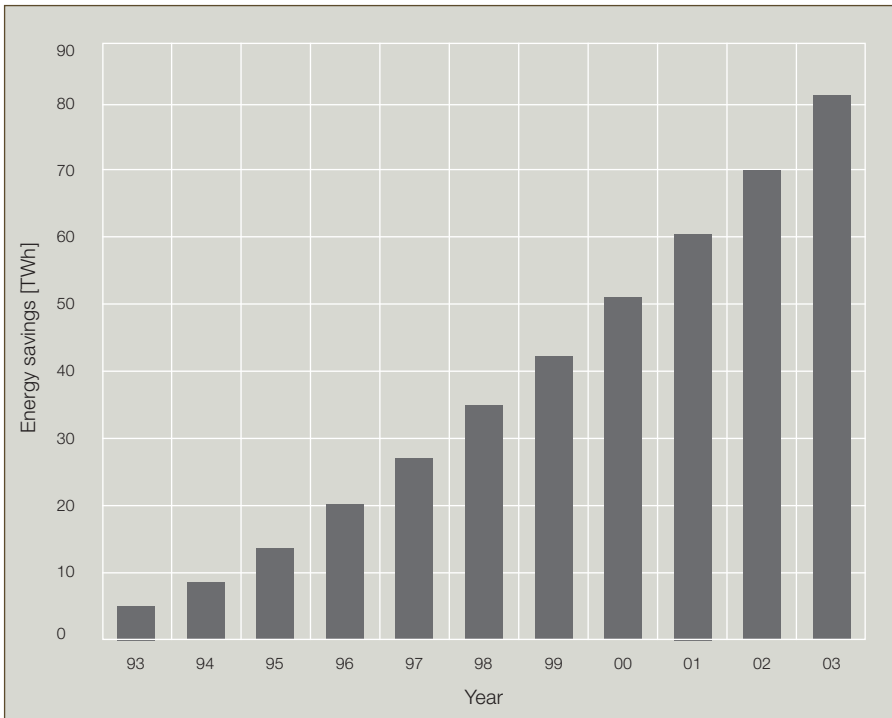
The reason the market is so competitive is that there is a huge potential for saving energy by installing new drives. Industry can significantly reduce its energy bill by replacing its older drives by new ones like the ACS800. This is because a drive varies the speed of its electric motor to make, say a fan or a pump, run faster or slower according to production demand. Huge amounts of energy can be saved when the motor driving the fan or pump is no





1

ABB is the world's leading manufacturer of AC variable-speed drives. More than 1,500,000 units were sold between 1993 and 2003, allowing an average of 81 TWh of energy to be saved each year in countless pump and fan applications.



longer operating at full speed. And with only about 5 percent of the world's motor population presently using variable speed drives, the market potential is vast.

So in such a competitive market, what is the secret of great innovative product design that keeps ABB in the number one slot? And will the new ABB industrial drive be capable of following up on the impressive success of its forerunners?

### Understanding customer needs

Understanding the customers' needs and the markets in which they operate is the key to everything. While many product features may appear good, if they do not make the life of the customer easier or save them money then the product will very quickly be discarded.

It is also important that customers understand that initial acquisition cost is quite different to lifetime ownership cost. Having a product that continues to

save money long after it has been purchased is an important factor that is often overlooked.

Manufacturers, too, have to count costs. Such is the intense competition among them that product price is under constant pressure. Drives are in fact close to reaching their optimum in terms of small size, maximum efficiency and ease of use. Adding valuable features without destroying their affordability is becoming a fine balancing act. As such, all costs in the production chain are now under scrutiny, from manufacturing techniques through to logistics. Each has to be carefully analyzed to ensure a truly competitive product is produced.

Based on customer surveys and building on its large installed base, ABB has come up with a number of product innovations which have been incorporated into the ACS800 drive series.

### Phased product development

At ABB, the development of any new product has to follow a strict code. The complete cycle, from project initiation to market introduction, is broken down into several phases, and progress to the next phase is not possible until all requirements of the current phase have been fulfilled. Checklists exist for each phase to guide project management. Also, each phase needs to be signed off by senior management before the project team can begin work on the next phase. This so-called 'gate model' is an integral part of quality assurance.

A key element of product development's first phase is a detailed market survey to identify what the customers want. Customer interviews are one aspect of this, but ABB's channel partners, such as OEMs, system integrators and technical distributors, are also asked for their feedback.

With variable speed drives the conclusions of many surveys are often the same. In a survey of 279 US readers, for example, the trade magazine *Control Engineering* asked what features were most desired in variable speed drives. Sixty-three percent responded with 'simple controls and setups', 45 percent said 'a convenient operator interface', 45 percent mentioned 'programmability' and 37 percent were concerned about 'pricing.'

Customer surveys conducted over the past five years invariably show these as the four most desired features. But to turn this knowledge into innovative product design, it has to be enhanced by field experience and detailed

knowledge of the way drives are installed and operated. Building on its large installed base, ABB has come up with a number of product innovations

and has incorporated these in the new ACS800 series.

### Ease of use, plus versatility

Something that the surveys also showed was that customers expect ease of use, even though the ACS800 is specifically designed to cope with the demands made on it by extruders, mixers, grinders, ski lifts, cranes, engine test rigs, winders, spinning machines, and so on. These applications are inherently complex and require a certain amount of drive programming by engineers.

It is important, therefore, to clearly understand what customers mean by 'ease of use'. Are they concerned about how easy the drive is to install or is the concern related to how easy the drive is to start-up and commission?

Customers expect 'ease of use' in both cases. The designers of the ACS800 therefore set about addressing all the areas that would ensure this requirement is met.

### Industrial IT

The ABB industrial Drive, ACS800, is a building block in ABB's Industrial IT architecture. As such, it adheres to Industrial IT design standards and has functionality built in that allows multiple products to interact seamlessly as components of real-time automation and information systems. Since it is Industrial IT enabled, the ACS800 can be easily integrated in the Industrial IT architecture in a 'plug and produce' manner.

### Innovative cabling system

Cabling drives can be time-consuming. And where time is money any technique that reduces both is highly desirable.

The dilemma is this: The power output of drives is increasing while the drives themselves are becoming progressively smaller. However, the higher the power rating the bigger the cables need to be. Technicians are finding it increasingly difficult to connect the cabling, which is still done by hand, as the drives become smaller.

The ACS800 overcomes this problem by way of an innovative new cabling principle never before used with AC drives. The power supply and motor cables of the higher-power, bookshelf-style drives are connected into a separate cabling pedestal that is bolted to the floor **2**. Once all the cabling is completed, the drive is wheeled over the pedestal and then locked into position **3**. A big advantage of this method is that the pedestal can be fitted and tested before the drives are delivered. These are simply slotted straight into position, ready for commissioning.

The drive can also be easily removed at any time without having to disconnect the cables. By speeding up maintenance and minimizing any process downtime, this saves time as well as money.

ABB believes that one way of proving you are the technology leader is to create the smallest drive. This raises the stakes in the marketplace, because

having the smallest drive and yet still having all the necessary power electronics inside, means that some clever work has been done.

ABB engineers were able to do this and overcome the problem of thick and heavy cables that do not bend easily, while at the same time ensuring good access to the cabling.

### From bookshelf to flat pack

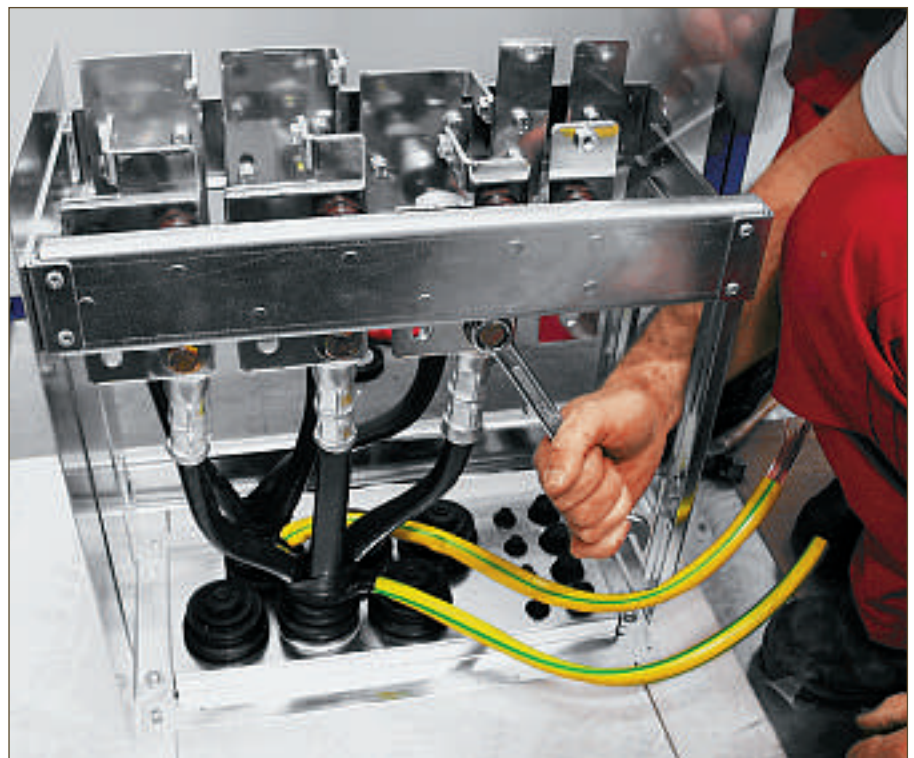
Another innovation is causing quite a stir in the marketplace. It is so simple that the question might well be asked why no one has thought of it before.

Most modern industrial plants have only limited floor space, and the drive industry has responded by introducing so-called 'bookshelf' designs for its higher-rated models. These are narrow enough to sit comfortably between cubicles in a control room.

But while customers in some markets prefer the bookshelf construction be-

2

The ABB industrial drive, ACS800 makes use of an innovative new cabling principle never before used with AC drives. The power supply and motor cables are connected into a separate cabling pedestal that is bolted to the floor.



cause of the need to save floor space, others don't have that need and are more interested in drives with less depth. To satisfy both requirements, ABB's solution is to make the ACS800 bookshelf drive capable of being turned through 90 degrees. The control panel, which is normally on the front of the drive, can then be attached to the side.

The drive can either be installed conventionally – that is, bookshelf – with the control panel on the front of the unit, allowing drives to be placed side by side to save space, or turned 90 degrees and mounted flat against a wall with the control panel moved to what now becomes the front of the drive. There is no need to specify the type of mounting when ordering, because there are slots for the control panel on each side of the module, enabling the panel to be easily moved. No extra hardware or wiring is needed.

**Advanced technology – the key to compactness**

The new drive is narrow even by bookshelf standards. With 90 to 200 kW versions measuring only 250 mm wide and 200–500 kW units only 350 mm wide, for certain powers the ACS800 is only one sixth the width of its competitors. The compactness and optional mounting were made possible by using the latest technologies, such as new-generation trench gate IGBTs and an innovative cooling system. This technology is a product of ABB's heavy investment in R&D, and one of the reasons the company is the leader in the field.

Ever since the launch in 1994 of Direct Torque Control (DTC) – a hugely innovative motor control technique – ABB has been recognized as a key innovator in drive technology. DTC is still the only technology that ensures the fastest

**3** After the cabling has been completed, the drive is wheeled over the pedestal and then locked into position.



torque and speed response for any drive. And it achieves a high level of motor control without the need for an expensive tachometer, which is often required to feed back signals in demanding applications, for example in the pulp and paper industry.

It is not just financial investment in R&D that is needed. To be the best in this market, a company has to set the highest targets imaginable. It must be willing to take the risks and live with the consequences of those risks because not everything works. This is the only way to be number one. It is essential that the design team work in an environment where all ideas are encouraged and are never, ever talked down.

A further example of innovative engineering from ABB is the computer modeling of the airflow around the heat sink. This has resulted in a smaller heat sink with increased airflow capacity for improved cooling.

The reduction in size of many of the parts means that components which would normally be added externally to the drive, can now be fitted inside as standard, thereby speeding up installation. Thus, the drive comes with a large AC choke for drive protection and harmonics filtering built-in as standard. A braking chopper, an RFI filter, a common mode filter for motor protection and up to three plug-in type modules for optional functions can be fitted inside the drive as accessories.

**Enclosure extension**

For applications that require extra components, such as contactors, fuse switches, etc, the ACS800-02 can have an enclosure extension fitted to it.

This gives users the option of adding line-input extras

without having to install the drive in a cabinet. The extension, which comes with a fuse switch and a customer terminal block, features top entry and exit of cables. The enclosure can be supplied with any number of options chosen by the customer.

**Easy commissioning and advanced programming**

In keeping with the 'ease of use' theme, the entire ACS800 series features easier commissioning through an intelligent control panel known as a Start-up Assistant.

This is basically a keypad that guides the user through both start-up and commissioning using plain-language text, rather than complex parameter numbers and codes.

The alphanumeric text is directly connected to the parameter numbers. What is really new is that the user can reach the function he requires without knowing parameter numbers. As with PCs,



many things can now be done without wondering about which numbers to select.

When the drive is first switched on it recognizes whether or not it has been commissioned before, and if not asks the question: "Do you want to use the startup wizard?" From here, it is a logical, step-by-step procedure with plenty of 'help' options along the way.

The ACS800 is the only AC drive that has an intelligent control panel of this kind. No questions are asked that could be irrelevant to the task being undertaken. For example, after the user has selected the application and control mode only questions related to the relevant application macro and motor control technology will be asked.

In conjunction with the easy start-up and commissioning, ABB has introduced adaptive programming, which increases the intelligence of the drive through custom applications or custom drive programming. This shifts the intelligence in the application, traditionally done through PLCs, to the drive.

Adaptive programming consists of a set of blocks that can be programmed to perform any operation from a predefined set of functions.

#### The hidden success factor

There is, however, another interpretation of the words 'ease of use.' Besides expecting products to be easy to use, customers are also demanding that the companies who make the products are easy to work with.

ABB has discovered that this can be the difference between making or breaking sales, and that it is becoming as important as product features in terms of its ability to persuade a customer to buy a drive.

It means providing ever-higher levels of technical customer service. Each customer installation is unique. And while drives are simple to install and use there can still be hurdles to over-



ABB's family of industrial drives. Four wall-mounted units are shown in the foreground.

come within a customer's plant. Such issues include the effect of harmonics, electromagnetic compatibility (EMC), energy saving, application know-how, and the drive's adaptability to customers' specific needs. In each of these areas, and many more, ABB has itself adapted to the challenge, and incorporated in the ACS800 features that will ensure the company's position as the

leading manufacturer of AC variable-speed drives now and in the future.

**Roelof Timmer**

ABB Oy

Finland

roelof.timmer@fi.abb.com





# Smaller and smarter the future of AC drives

Technology is making drives smaller, more intelligent and cheaper

Ilpo Ruohonen

The past 20 years have seen some remarkable advances in AC drives technology. Miniaturization is one of the most striking developments, with a tenfold decrease in volume over the last decade alone.

As many technologies continue to evolve, R&D teams continue to work on making drives even smaller and more affordable. But it is not only size that matters. Engineers and scientists are designing drives that are more intelligent, have better communications and are easier to install and control. Such drives will open the door to many new applications and provide ABB with a whole host of new market opportunities.

Smaller and cheaper drives from ABB are already finding new applications as diverse as running machines and small centrifuges used in honey production. These applications would simply not have been feasible or cost-effective a few years ago.



Modern AC drives are impressively smaller than their counterparts from the early 1990s, meaning that installing them is now easier than ever before. For example, control rooms have become more compact and less costly because panel builders are now able to fit more drives into a standard cubicle. Original equipment manufacturers (OEMs) have also benefited in that it is now much easier for them to fit drives into their equipment.

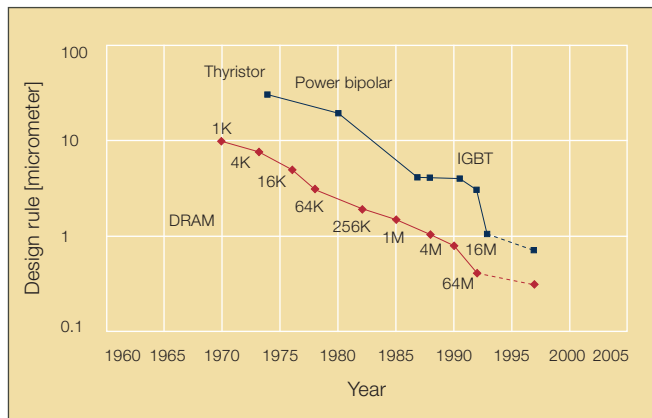
With many R&D teams working to make drives smaller, the question arises as to just how small AC drives can get. ABB believes that there are few restrictions, particularly in the lower power range, and that over the next ten years, drives in this range will shrink by another 60 to 70 percent!

So how is all of this possible? To begin with, there seems to be no end to how small micro-electronics can get, and these developments are rapidly finding their way into the power semiconductor industry **1**. In addition, lower losses are being achieved from the same area of silicon. These two factors combined not only mean smaller semiconductors, but also the amount of heat generated within the drive is reduced, so smaller heat sinks are now possible. There is one limitation though: The cable terminations have to be big enough to accommodate the power-carrying cables.

### Cool!

The development of power semiconductors is an important factor that influences drives miniaturization, but so too is the technology used for cooling. Even though air-cooling is likely to remain the dominant

## 1 Drives are getting smaller



Moore's Law [1] states that the transistor density on integrated circuits doubles every couple of years. This exponential growth and ever-shrinking transistor size result in increased performance and decreased cost.



The ACS800-02 drive, available in the 90 - 150 kW power range, is only one-sixth the size of comparable drives from other manufacturers. The reduction in size has been achieved using new, advanced electronic components in combination with the latest insulation and cooling technologies.

technique, a considerable amount of R&D effort is being invested in developing new cooling techniques as well as in reducing the need for cooling:

- Developments in numerical modeling mean that advanced computer flow modeling techniques are used to design heatsinks that achieve more effective cooling.
- Scientists are looking at: new materials, integrating the heat-sink with the power module for better cooling performance and improving fan performance with variable-speed control.
- Liquid-cooling is finding increasing use in wind power, transportation and marine.

In addition to the ongoing developments mentioned above, new cooling technologies, such as heat pipes and thermosyphons may be applied over the next few years. Thermosyphons use evaporation followed by condensation to transfer heat directly out of the drive. Even though the principles of these devices are well known, cost and performance issues must be solved before they can be commercially applied.

Another area that holds much promise for the future of AC drives is the 'cool chip'. The cool chip is an early application of nanotechnology that uses electrons to transfer heat from one side of a vacuum diode to the other. It uses the principle of electron tunneling in which a voltage bias is applied to make energetic electrons 'jump' across a tiny gap between two surfaces. These electrons transfer heat energy between the two layers, and because of the gap, the heat cannot be conducted back **2**.

Applied to drives technology, the cool chip principle could



be used to carry heat from the semiconductor directly to the heatsink, thereby vastly improving the heatsink's efficiency. This would mean smaller active power devices, generating a lot less heat than would be expected for the rated power. To achieve this, relatively large surface areas with a gap of less than 10 nanometers need to be manufactured. In addition, the manufacturers must ensure no contact between the surfaces at any point.

**Bringing costs down**

Reducing the cost of drives is a goal for all drive manufacturers, and miniaturization contributes enormously in achieving this goal. Smaller and cheaper drives from ABB are finding new applications as diverse as running machines and small centrifuges used in honey production.

In fact, the latest ABB component drive, which was launched in 2003, has opened up a host of new market opportunities for ABB. Not only is it intended for small industrial applications, but also for consumer products such as air conditioners, exercise machines and washing machines.

Component integration also contributes to cheaper drives. ABB predicts that over the next ten years, a combination of tighter semiconductor and mechanical part integration will lead to even fewer parts within a drive. Fewer parts

mean fewer interfaces and fewer mechanical fixings, and this means improved reliability.

Another form of integration, that of the drive and motor with the application, will have its place in the future of AC drives. This is already happening in some specialised applications. One OEM, for example, has developed a fully integrated tubular submersible pump. This form of integration is also seen as being important in the field of robots where true mobility will be obtained with a fully integrated drive.

Naturally, software has a big part to play in the future. As software continues to develop, drives can expect to have increased capability with less hardware.

Manufacturers play a major part in the overall cost-reduction process. They do this by looking at ways of improving every aspect of their products. For example, improvements can be made by:

- Using better components
- Ensuring more integration
- Using up-to-date design techniques
- Using sophisticated and efficient manufacturing processes
- Using improved logistics

As the drive market continues to grow, economies of scale in volume production will be needed to cover the substantial investments needed in R&D to



maintain the steep decline in prices seen in recent years.

**Smarter drives**

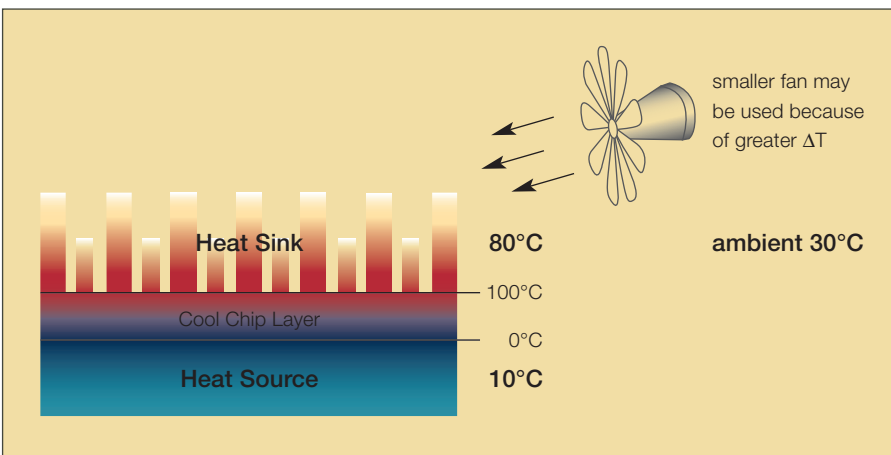
R&D is responsible for making drives smaller and cheaper, and it is also making them more intelligent. As the area of microelectronics continues to advance in leaps and bounds, so too does the ability of microprocessors and the capacity of memory chips. Drives with increased processing power and memory will change the architecture of industrial control systems, and enable configurations that are better suited to an application <sup>3</sup>.

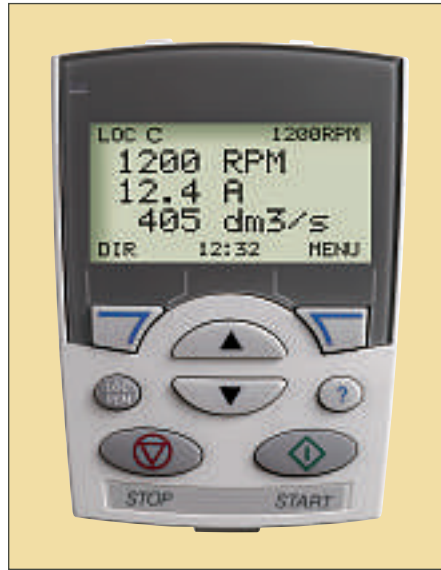
Intelligent drives are certain to benefit from the growth of Ethernet communications by becoming an integral part of control, maintenance and monitoring systems. Decentralized control systems will be created in which multiple drives share control functions, with one taking over in the event of a fault or error in another drive. The advantage of this is that reliance on costly PLCs would be greatly reduced and automation reliability would improve dramatically.

ABB thinks that Ethernet-based drives will become a valuable source of data for preventive maintenance programs. Taking advantage of Ethernet's wide bandwidth, these intelligent drives would be able to communicate greater amounts of monitoring information than would standard web-based systems.

In addition to this type of information, the drive would also collect data that describes the state of the process being controlled. If each drive had its own IP address, it would be easy to gather a log of every drive on a central server via Ethernet, and build up a highly detailed picture of the entire process and

**2** The cool chip principle could be used to carry heat from the semiconductor directly to the heatsink.





Allows easy programming of ABB's standard drive, ACS550. The control panel has various assistants and a built-in help function to guide the user.

its performance. A detailed analysis of this data could be used to adjust the process and improve productivity. It could also be used to increase process availability through proactive fault management and asset optimization. Taking intelligent drives a step further, they could even have the capability of detecting the cause of a fault and providing a course of action for its resolution.

All of this fits nicely with ABB's IndustrialIT concept, in that a drive with advanced communication capabilities can be seamlessly integrated into larger real-time automation and information systems.

### Meeting growing demands

The increase in drive intelligence will meet a growing demand from users for drives that are easier to set up and control. As reliability is now taken for granted, ease of use and ease of commissioning are becoming the most important demands of modern drive users.

ABB's ultimate goal is to have a completely self-commissioning drive, requiring no manual setting of parameters. The company believes it is getting closer to this goal with advanced set-up wizards installed in the latest ABB drives.

### The ultimate in performance

The dynamic performance of AC drives in general has improved dramatically over the years. But with Direct Torque Control (DTC) technology, ABB believes it has reached the ultimate in control performance. Using DTC, applications that were only feasible with other drive technologies, such as DC drives and servo drives, are now routine for AC drives.

For example, the control of new low-speed permanent magnet motors using new developments in DTC technology is likely to find increasing use in a variety of industries. Used for decades in fast-running applications, the permanent magnet motor has been modified to provide high accuracy and reliability at low

speeds without the use of gearboxes. To control the motor, ABB has adapted the control algorithms in its DTC technology to achieve highly accurate control at low speeds without encoder feedback.

### Direct Drive system

Standard induction motors, normally designed to run at 750–3000 rpm, have poor efficiency at low speeds and often cannot deliver sufficiently smooth torque across the speed range. This problem is normally overcome by using a gearbox, but gearboxes are complex and take up valuable space and maintenance resources. ABB's Direct Drive system, using the permanent magnet motor, provides a high torque drive directly coupled to the driven application, thus eliminating the need for a gearbox. This system saves on motor maintenance because the permanent magnet motor is robust, and in maintenance terms, similar to standard AC induction motors.

The Direct Drive system has already been applied in the paper industry, as paper machines require large numbers of high-accuracy, low-speed drives. Another application is in ship propulsion systems. ABB's Compact Azipod, designed to give ships extreme maneuverability, uses a Direct Drive with a fixed-pitch propeller mounted directly onto the motor shaft. The motor's small size enables the outer diameter of the pod to be reduced, thereby improving hydrodynamic efficiency. The system is well suited to smaller vessels.

Overall, the future looks very good for AC drive users. They will be able to buy drives that are smaller, more intelligent, easier to install and suitable for many applications, particularly at low power and low speed. But the best news of all is that these drives will be cheaper than ever before.

**Ilpo Ruohonen**

ABB motors and drives

Finland

ilpo.ruohonen@fi.abb.com

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# New roles

## for permanent magnet technology

Jouni Ikäheimo



For many decades, permanent magnet technology has been used in smaller-scale applications, for example in computer hardware drives and wristwatches, where its favorable weight-to-performance ratio is a distinct advantage. Its use in bigger electrical machines, however, has not been all that common because of the relatively high price of the magnets together with high manufacturing costs. But this is changing.

The increasing demand for new solutions for wind power generators and special motors for industries such as pulp and paper, marine, traction and offshore has created new markets for electrical machines. This in turn has focused attention on the high power density and high efficiency which can be achieved using permanent magnet motors and generators.

ABB has been one of the pioneers in introducing this type of motor in larger sizes, and a good example of its use is seen in marine propulsion. The company has also developed the permanent magnet motor to provide high accuracy and reliability for industrial applications requiring high torque at low speed. Permanent magnet technology has also opened the door for new solutions in wind power generators.



The permanent magnet motor has been around for quite a while, but it is only now that this technology is being applied to large motors. Their small size and high accuracy have, in the past, made permanent magnet motors the preferred type for use in wristwatches and computer hard drives. Today, the largest permanent magnet motor weighs in at seven tons.

The actual motor design is a radial flux construction, air or water-cooled, with a permanent magnet rotor. The temperature of the permanent magnet rotor remains naturally low, allowing higher power densities.

ABB's permanent magnet motor is a synchronous motor, which, as there is no rotor slip (see box), provides better accuracy than standard, asynchronous, motors. In an asynchronous motor, the slip varies according to speed and load. With a synchronous motor, it is simpler to optimize the speed, while the elimination of slip compensation improves the dynamic motor control.

Like all synchronous motors, the speed of this motor can only be controlled with a variable-speed drive. Furthermore, the synchronous motor control must be specifically developed for permanent magnet flux control. ABB's Direct Torque Control (DTC) method has been enhanced to achieve this.

Water-cooling gives higher power density and compact drive cabinets, while the higher protection class enclosures allow more freedom for drive placement by reducing the exposure of the drive components.

### **Simplified synchronous motor construction**

The construction of the traditional synchronous motor is more complicated than that of the asynchronous motor, so it requires more maintenance. However, the permanent magnets in the ABB motor simplify its construction by creating a constant flux in the air gap, thereby eliminating the need for the rotor windings and the brushes normally used for excitation in synchronous motors.

This has resulted in a motor that combines the high-quality performance of the synchronous motor with the robust design of the asynchronous induction motor. The motor is energized directly on the stator by the variable-speed drive.

The synchronous motor can deliver more power from a smaller unit. To power the in-drives, for example, of a paper machine directly at 220 to 600 rpm with a conventional asynchronous motor would require a motor frame substantially larger than that of a 1500-rpm motor. The new motor type has, in most cases, the same size or is even smaller than the existing induction motor.

The permanent magnets are made from neodymium iron boron (NdFeB) – the newest magnetic material on the market. NdFeB is the most powerful magnetic material available at room temperature, with high values of flux density at very high values of magnetization. It is also extremely resistant to demagnetization. Furthermore, NdFeB is less costly and brittle than samarium cobalt, another rare earth material, that was used widely in the 1980s.

### **Higher efficiency, less maintenance and no gearbox!**

Standard induction motors, normally designed to run at 750–3000 rpm, are not

particularly well suited for low-speed operation as their efficiency drops with the reduction in speed. They may also be unable to deliver sufficiently smooth torque across the lower speed range.

This is normally overcome by using a gearbox. However, the gearbox is a complicated piece of machinery that takes up space and needs maintenance as well as considerable quantities of oil. High performance at low speed is sometimes achieved by using a DC drive. Using a permanent magnet motor, ABB has found a solution that completely eliminates the gearbox. This solution will save on motor maintenance as the permanent magnet motor is very robust and the maintenance it requires is similar to that for standard AC induction motors.

The combination of fewer components and simpler configuration reduces plant engineering hours, facilitates installation, allows more efficient use of floor space, and reduces spare part inventories.

Simpler configuration also improves the availability of the production machinery. Less maintenance means fewer production interruptions and start-ups, decreased raw material waste, increased end product quality and reduced wear in the production machinery. Maintenance

#### **Rotor slip**

The main difference between a synchronous motor and an asynchronous induction motor is that the rotor of the former is magnetized and turns at the same speed as the rotating magnetic field.

The synchronous speed of a motor is that speed it would theoretically achieve if speed were only a function of the network frequency and the number of poles in the motor. Ideally, the rotor should exactly follow the rotating magnetic field in the stator. In an induction AC motor, however, the load will cause the rotor to slip in relation to the magnetic field and friction in the motor will add to this slippage. The slip can be in the region of 5 percent.

Some frequency converters feature slip compensation to reduce this. The speed drop can then be reduced to about 10 percent of the nominal slip. If very high control accuracy is required, a speed controller with pulse encoder is used.

The synchronous motor has electromagnets or permanent magnets built into its rotor. These lock the rotor into a certain position when confronted with another magnetic field. The speed of a synchronous motor can therefore be controlled with a high degree of accuracy over a large speed range by supplying it via a frequency converter, without the use of a feedback device.

nance and repair work can also be carried out faster.

### Permanent magnet motors in the pulp and paper industry

Paper machines require large numbers of high-accuracy, low-speed drives. As permanent magnet technology is helping to eliminate gearboxes across a wide range of industries, this particular solution has a ready market in the paper industry.

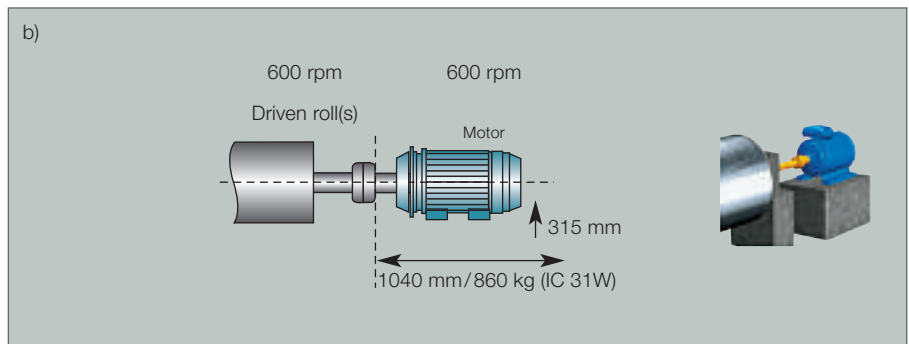
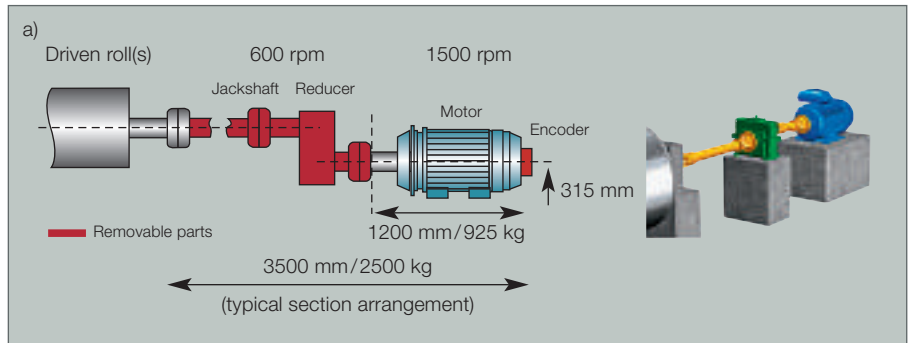
This solution provides a high torque drive directly coupled to the in-drive of the paper machine section. Eliminating the gearbox saves space and installation costs, as the user only has to prepare the foundations for one piece of driving machinery. This also allows more freedom in the design of the mill layout. Getting rid of the gearbox and brushes not only reduces maintenance requirements, it also saves energy.

The permanent magnet motor is the heart of a Direct Drive solution **1**. This consists of the motor, controlled by a low-voltage AC drive based on the ACS600 frequency converter, connected directly to the paper machine, without gearboxes or pulse encoders.

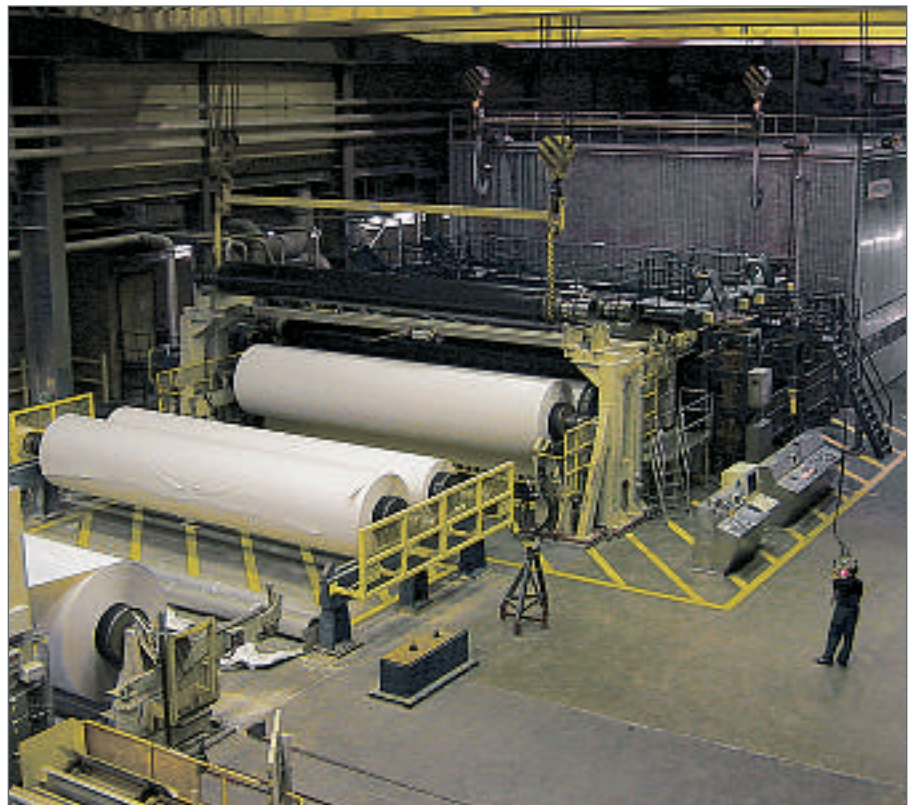
Direct Drive solution technology improves drive controllability, enabling the paper machine drive to run without a pulse encoder, as synchronized motors allow very exact control without feedback. The accuracy is as good as that of an induction motor in variable speed operation with a feedback device. This means the pulse encoder can be eliminated, further reducing the need for maintenance. This is particularly beneficial in the paper industry, where poor reliability of feedback devices contributes to production stoppages. It can also reduce design complexity, as the feedback devices sometimes can be difficult to integrate in the system or have to be positioned in places that are difficult to reach **2**.

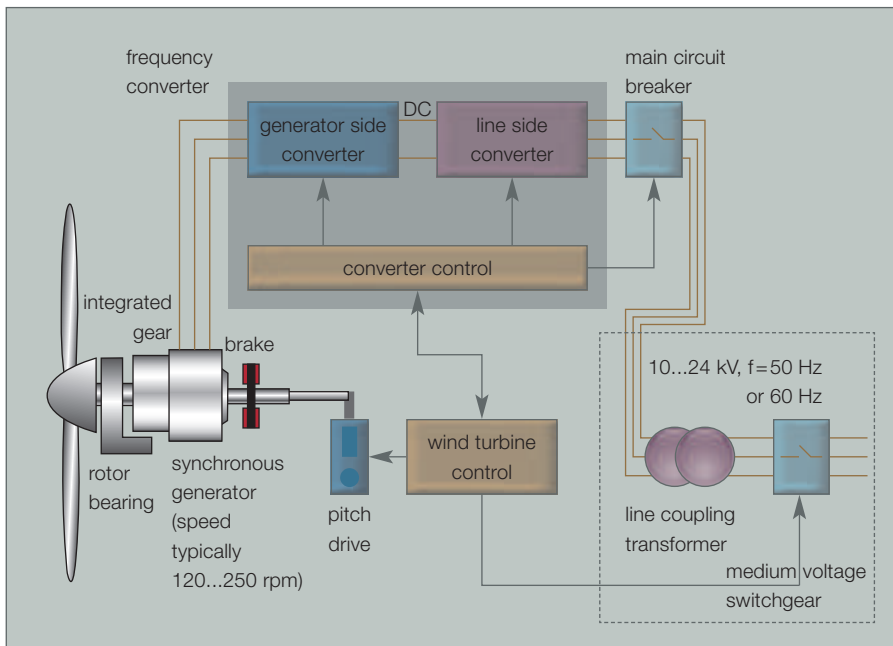
The better electrical efficiency of the new drive has a direct impact on power consumption. Savings increase considerably with further reduced speed.

**1** Drive configuration with a) conventional induction motor drive, gear and jackshaft, and b) the Direct Drive



**2** Besides its energy-saving, maintenance and reliability capabilities, the Direct Drive helps solve the notorious space problems in and around paper machines





Following two successful pilot projects, the first Direct Drive system was installed in August 2002 at the Finnish paper company M-Real, on the line manufacturing packaging materials for the medical and cosmetics industries.

### Permanent magnet technology in propulsion

A new market for electrical machines has been created by the introduction of the podded propulsion concept for ships. The electrical motor is mounted in a bulb, which is attached to the hull of the ship, and these together form the main propulsion system. The speed of the motor is controlled, as is the direction of the propulsion force in relation to the ship.

The typical power range of these motors is 400 kW to 20 MW. One ship is normally equipped with between one and three propulsion units, and rigs equipped with dynamic position systems may use up to 10 units. Known as 'Azipod', this propulsion system was originally developed for ice breakers and ice-going vessels. Compared with conventional mechanical propulsion, Azipod has rapidly

increased the popularity of the system in other types of vessels such as cable layers, dredgers, shuttle tankers, chemical and product tankers, support vessels, motor yachts, drill-ships and semi-submersible rigs. This propulsion system is especially appreciated by owners of big cruise vessels where the total propulsion power is in the region 40 to 60 MW. Azipod allows excellent ship maneuverability, low vibration and noise levels, high efficiency, low emission and passenger comfort.

Permanent magnet motor technology has been used in the development of a highly standardized modular concept known as 'Compact Azipod' which has been designed for a propulsion power range of between 400 to 5000 kW. Permanent magnets and DTC have been the main factors for improving the performance and extending the applicability of Compact Azipod.

The motor module is cooled by the surrounding seawater, allowing high power density for the motor and simple construction with a low number of parts. The pod housing diameter can be

kept small, giving improved propeller hydrodynamic efficiency. This together with the high motor efficiency means high overall efficiency and low fuel consumption.

### Permanent magnet technology in wind power generation

Wind power represents another growing application area for electrical machines. Increased demand presents new challenges for the wind power plant concept in terms of higher output, higher availability, lower noise level and cost-effective solutions.

ABB has three different permanent magnet technologies available for high-, low- and medium speed wind turbine generators. In the low speed (Direct Drive application) version, the turbine and the generator are combined to form a compact and structurally integrated unit. The medium speed unit is a very compact unit with the turbine main bearing and the permanent magnet generator integrated into a single-stage gearbox **3**. The high-speed permanent magnet generator is a compact solution with a maximum output of 3.6 MW from a 500 mm frame.

As permanent magnet motors are used more widely, the price of the magnetic materials, which today are comparatively high, is expected to drop. When this happens, it will be possible to use permanent magnet motors in normal industrial drives where they will save energy through better efficiency, as losses are considerably reduced.


Jouni Ikäheimo

ABB Oy

Vaasa, Finland

jouni.ikaheimo@fi.abb.com





# Synchronous superlatives

Record-breaking electric motors give heavy industry more drive

Johannes Ahlinder, Thomas L. Johansson

**ABB is at the forefront of a world-wide trend towards larger electrical drives. Recent deliveries illustrate this succession of superlatives.**

Historically, mechanical drives such as turbines dominated the high end of the power-drive market, but nowadays their position is challenged by four-pole synchronous motors. Electrical drives are far cleaner, quieter and environmentally friendlier than their mechanical counterparts. They are also more energy efficient and require less maintenance. Drives delivering higher power enable industry to handle production with more flexibility and cost-effectiveness.

As power increases, it becomes even more important to deal with constraints such as voltage drop and inrush current by the selection of an appropriate starting method.

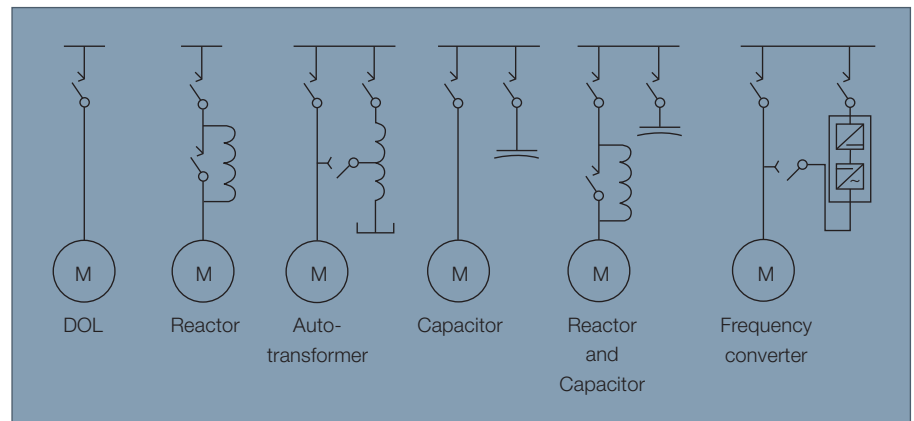
In December 2002, ABB delivered the world's largest four-pole motor. At a rated output of 55 MW, it drives an air compressor at Sasol's synthetic fuels and petrochemicals plant in Secunda, South Africa. One year later, in December 2003, ABB delivered the world's largest refiner motor with a rating of 38 MW. It will power the primary refiner for a new line at Stora Enso, Port Hawkesbury in Canada. Spring 2004 saw ABB deliver two cable wound motors rated at 42 MW and 56 kV to drive compressors at Statoil's Troll-A platform in the North Sea.

These motors form part of a general trend in the industry towards larger electrical drives. Other examples of this trend are the delivery of a 29.5 MW fan motor used in a test rig by Rolls-Royce when developing the Liftfan™ for the Joint Strike Fighter aircraft that will enable short take off and vertical landing, and the order for a 42 MW blower motor to Wuhan Iron & Steel Group Corp. in China.

Large drives have many advantages over smaller ones: Production capacity for a single drive increases and in general system efficiency is improved. In addition, one single drive substituting several smaller units reduces the costs for spare parts, service and maintenance. Larger drives also permit greater flexibility in production: Energy prices often vary according to the time of day, and larger drives, with consumption optimised according to the energy price, can achieve the same daily output as smaller drives, but at a lower cost.

Formerly, the traditional drives for high power applications were mechanical, ie, steam and gas turbines. At first, the only available electric alternative was the large two-pole motor. Electric motors have three main advantages over turbine drives: efficiency, maintenance and environmental benefits. The efficiency of a synchronous motor is normally between 97 and 99 percent, compared to 35 to 40 percent for a gas turbine. A synchronous motor can operate for several years without major overhaul, whereas a gas turbine needs more fre-

**1** Examples of common starting methods for large synchronous motors.



quent attention. An electric motor does not generate hazardous emissions and keeps the audible noise at a relatively low level.

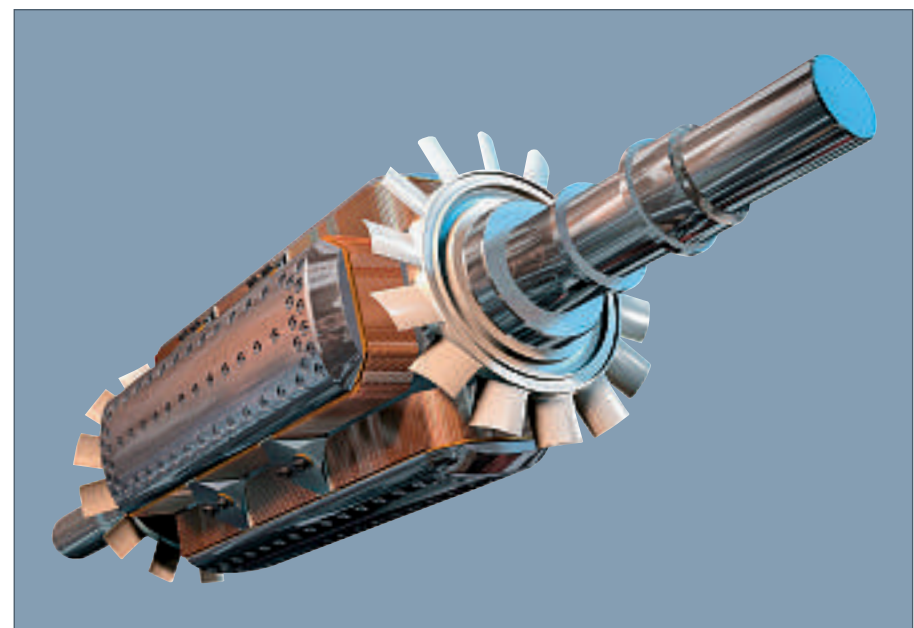
Today, with the improved output of four-pole synchronous motors, an even better alternative is available. Compared to the two-pole solution, four-pole motor technology has several advantages; the most prominent being lower capital investment, and reduced operating costs resulting from higher effi-

ciency. Other benefits of four-pole motors are the reduced overall size and weight and lower noise emissions. This means that the base-plate can be shorter and lighter, that less space is required, and that the need for acoustic counter-measures is reduced.

**Starting methods**

Amongst the most important aspects when dimensioning large electrical motors are the starting requirements. Every electrical motor must be matched,

**2** Salient pole rotor design





both electrically and mechanically, to the power supply, the equipment driven, the protective and control systems and similar constraints. On smaller motors, electrical parameters can often be chosen so that starting currents do not cause a greater voltage drop than permitted<sup>1)</sup>. The simplest and least expensive method for starting a fixed speed motor, Direct On Line starting (DOL), is acceptable. However, voltage drop increases with motor size, and for a very large electric motor even a very stiff electrical network will be subjected to unacceptable voltage drop. This can result in insufficient starting torque or cause problems for other equipment.

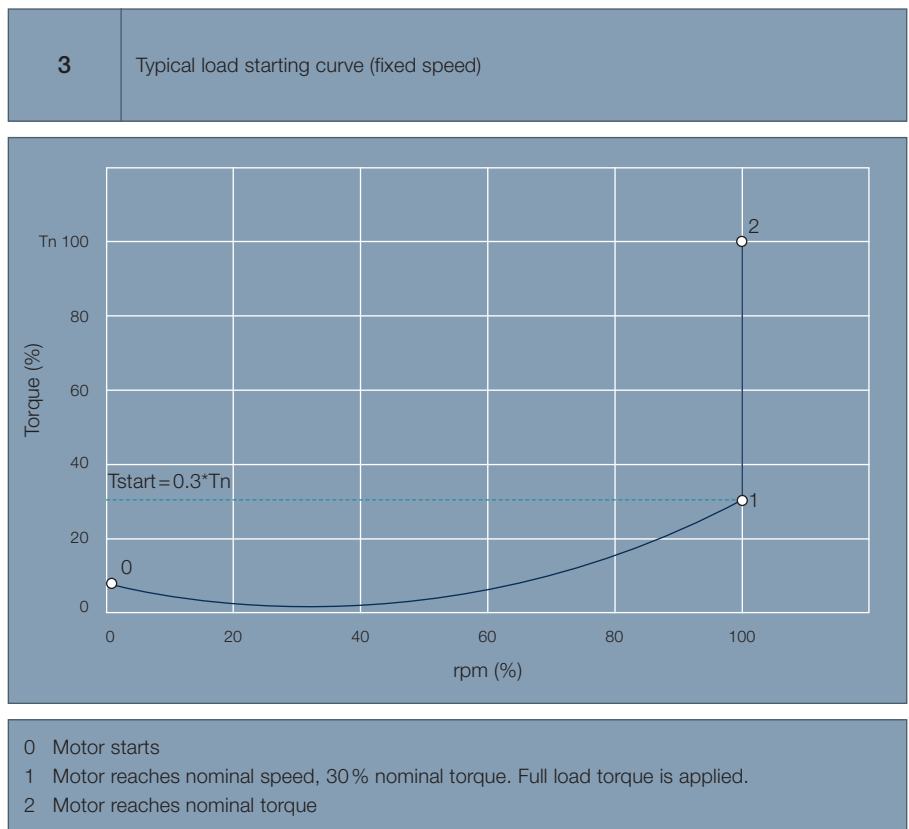
At higher power ratings it is usually necessary to use a starting method other than DOL. The supply network's short-circuit capacity ( $SCC_L$ ) and the maximum permitted voltage drop ( $\Delta U_L$ ) dictate the conditions for starting an electrical motor and pre-empt the design of both the starting equipment and the motor. The grid owner usually specifies maximum allowable voltage drop.

The most economical starting method under the constraints of  $SCC_L$  and the  $\Delta U_L$  is determined through evaluation of the alternatives. The key to good starting characteristics of an electric motor lies in the rotor design. The salient pole design of ABB's four and six pole synchronous machines is designed for high thermal capacity, good overload resilience and the ability to withstand repeated heavy starts. **1** shows some examples of commonly used starting methods.

### Soft start

When a certain motor power output is required, the optimal solution (depending on the power network conditions and requirements) becomes a frequency converter start, also called soft start. It allows the motor to be started at high

<sup>1)</sup> For motors running in island mode networks, for example oil platforms, even smaller motors might require starting methods other than DOL due to the lower short circuit capacity of such networks.



torque without causing any voltage drop on the power network.

The converter brings the motor up to speed. Upon reaching nominal speed and after being synchronized to the network, the circuit breaker between the converter and the power network is opened. The breaker between the motor and the network is then closed. Finally, the breaker between the motor and the converter is opened **1**.

A single frequency converter can be used to start several motors. In such a case, every motor is connected to the converter via a circuit breaker so that no more than one motor is connected to the converter at any time. This method is used at Stora Enso, Port Hawkesbury (described further on).

Using soft starting for fixed speed drives, ie, drives that are not used for speed regulation in the process, means that the cost for the motor and converter can be significantly lower than for a variable-speed drive (VSD). It is possible to design a more cost-efficient motor, since it

will only be subject to the converter supply during the brief starting phase (after the start, the converter is disconnected). Here an additional advantage of ABB's synchronous motors is the salient pole rotor design **2**, which ensures that the solid pole shoes absorb the temporary temperature rise.

Additionally, a converter used for soft starting can be of smaller rating compared to what is needed for a VSD and continuous operation. This is permitted because, relatively speaking, higher losses are acceptable on account of the relatively short start-up phase.

However, the principal reason for the substantially lower cost of the frequency converter relates to the starting curve of the driven equipment. Fixed speed applications are normally started at reduced load, typically 30 percent of the nominal torque **3**. When the nominal speed is reached and the motor is connected directly to the power network, the nominal load torque is applied (usually by opening valves). This implies that the frequency converter is dimen-



sioned for 30 percent load torque, whereas that for VSD must be dimensioned for 100 percent torque since it must be capable of regulating the speed of the motor at full load.

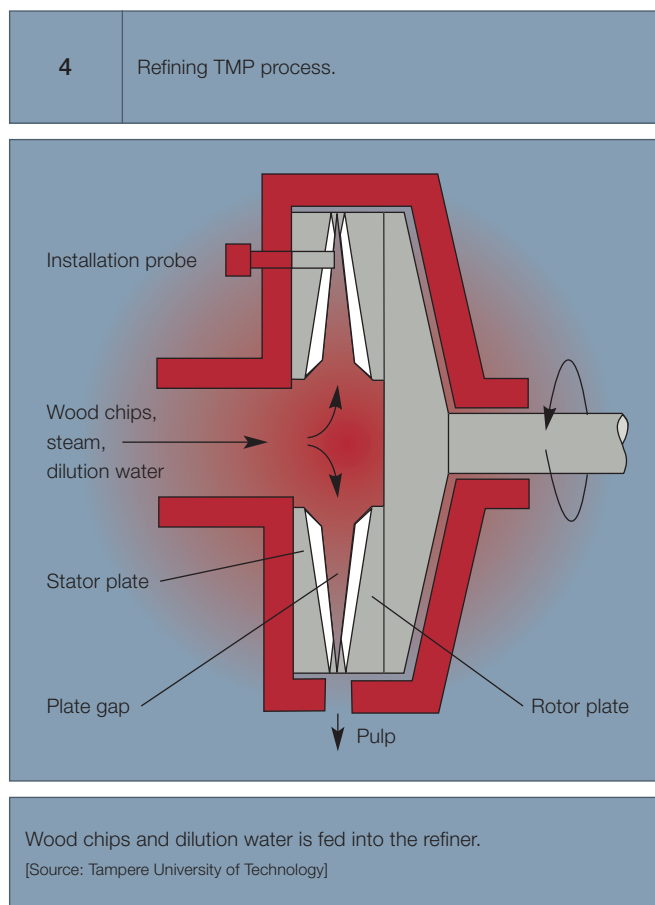
A soft started motor also has advantages over its DOL started equivalent. The former can be dimensioned for better material utilization and thereby higher efficiency, since there is no need to dimension the motor to achieve low inrush current.

### Mechanical and electrical stability for large electric motors

When dimensioning the motor, an important criterion is to minimize different stresses on the complete shaft system of the drive. The stiff rotor and shaft of ABB's synchronous machines contribute to minimizing such stresses by having an operating speed well below the lowest critical bending speed. The complete rotor, including its salient poles and shaft, is machined from a single forging of high-grade steel, enhancing mechanical resilience.

A very important design aspect resulting in mechanical and electrical stability is a reduction of the distance between the bearings. This is achieved by locating the exciter outside the bearing housing, and using a bracket bearing design instead of pedestal bearings. ABB has used bracket bearing design for its largest synchronous machines for more than 15 years. Hundreds of installations later and ABB has amassed considerable experience and knowledge of this design, such that competitors who have recently adopted this concept will need quite some time to catch up.

Air gap adaptation, stator and rotor winding designs, pole shoe design, and dimensioning possibilities of the pole core are further examples of design aspects affecting mechanical and electrical stability. Moreover, ABB's design gives good possibilities for optimizing the



complete shaft train by using different rotor lengths, diameters and masses.

### 55 MW four-pole compressor motor at Sasol, South Africa

In March 2002 ABB received an order from Air Liquide for two four-pole synchronous motors, rated 55 MW and 23 MW respectively. The 55 MW installation is understood to be the world's largest four-pole motor. These two motors drive the main air compressor and the booster air compressor of an Air Liquide oxygen unit. The unit can produce 3,550 tons of gaseous and liquid oxygen per day, making it the world's largest oxygen plant. It is installed at Sasol's synthetic fuels and petrochemicals plant in Secunda, 150 km east of Johannesburg, South Africa.

The oxygen unit forms part of a programme to increase the previous installation's overall oxygen output. The oxygen is used in a process for producing synthetic fuels from coal.

The advantages of the four-pole motors over the two-pole alternatives which were previously installed, were a key issue when Air Liquide and Sasol decided to invest in a four-pole synchronous solution for their expansion rather than staying with the older technology.

The preferred starting method for the 55 MW motor was found to be soft starting using an LCI (load commutated inverter). Compared to other reduced voltage starting methods such as tap-transformer, auto-transformer and reactor, soft starting results in less stress on the motor, the switchgear, the compressor, the grid, and on the complete shaft system with all its components. For very large motors, the soft start method has become the preferred solution.

For optimum motor control, both motors are equipped with rotor telemetry equipment for measuring all important rotor parameters, ie, temperatures in selected locations, current, voltage, and rotor insulation resistance. To ensure maximum availability of the installation, the motors are also equipped with redundant coolers and motor control panels. These are equipped for automatic switch over and follow up.

### 38 MW four-pole refiner motor at Stora Enso, Port Hawkesbury, Canada

In a refiner, wood chips are fibrillated between two rotating metal discs. At least one of the discs rotates at high speed. Centrifugal forces press the chips through a narrow gap causing the fibrillation. The most common refiner-based process is thermo mechanical pulping (TMP). In the TMP process, the refiner is pressurized. The chips are steamed and washed with hot water before entering the refiner. The refining process usually occurs in two stages <sup>4</sup>.

The new 38 MW record-breaking refiner motor at Stora Enso, Port Hawkesbury, Canada is probably the largest refiner motor in the world. The motor will be installed on a primary refiner for the mill's third refining line. ABB has several references for large motors at the mill, including two 32 MW refiner motors installed in 2003. For the original two lines, with 15 and 24 MW motors, the smaller motors are started with DOL and a combination of reactor and VAR support is used for the 24MW motors. In 2003 the two primaries on these lines were replaced by the 32 MW motors mentioned above, using the same type of reactor but with a more complex VAR support scheme. The 38 MW motor at the new Line 3 will use a soft starter of LCI-design to meet the voltage drop prerequisite and flicker limits imposed by the local utility company. The same converter is also used for starting the other refiner motors in the third line.

#### VHV cable wound motors for TROLL A platform, Norway

Voltages have failed to keep pace with the rise in power outputs. As illustrated in 5, only gradual improvements in insulation technology have been made over the years. Briefly explained, it is the squared shaped cross section of the

conventional winding that is the limiting factor in reaching higher voltages.

With the launch of an innovative use of cable technology in rotating electrical machines back in 1998, ABB enabled an increase in machine voltage ratings to radically higher levels by using HV cables in the stator windings. The possibility of connecting a rotating machine directly to the HV grid implies that there is no need for a step-down transformer. A higher system efficiency is thus achieved.

The first VHV cable wound synchronous motor was installed in 2001 at an air separation plant in Sweden. It is connected directly to the 42 kV bus. Rated at 9 MVA it has an active power output of 6.5 MW and can produce reactive power continuously, thus supporting the electrical network during the starting of other large motors in the area.

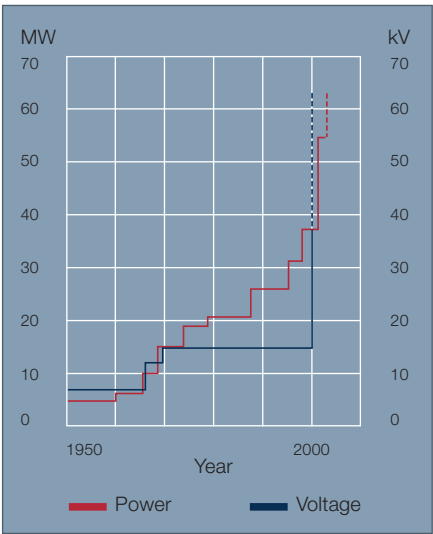
The supply of two VHV cable wound synchronous motors to Statoil's Troll A gas platform in the North Sea follows the success of the first cable wound synchronous motor installation. The two identical units, delivered in Spring 2004, are rated at 40 MW, 56 kV and for variable speed between 1290 and 1890 rpm 6. In early 2005, the motors will be subjected to spin-tests and should start operating later that year. Power will be supplied from shore via four 70 km long underwater DC cables (two per motor). On the platform, the DC will be inverted to AC by an HVDC Light™ in-

6 One of the 40 MW, 56 kV Troll A motors during production



verter station. The alternative would have been to use gas turbine drives, which has been the traditional mechanical drive in the oil and gas industry for many years. However, the trend towards preferring large electrical drives over gas turbines is also affecting the oil and gas sector. For the Troll A project, efficiency, maintenance and environmental benefits were all important aspects when choosing an electrical solution<sup>2)</sup> (see next article).

5 Four-pole motor power and voltage development



<sup>2)</sup> For more information about VHV motors, please see ABB Review Number 1/2001.

Johannes Ahlinder  
 Thomas L. Johansson  
 ABB Automation Technologies  
 Sweden  
 johannes.ahlinder@se.abb.com  
 thomas.l.johansson@se.abb.com



# Powering Troll

## with new technology

Tom F. Nestli, Lars Stendus, Magnus J. Johansson, Arne Abrahamsson, Philip C. Kjaer

With its compressors, motors and electrical systems devouring many tens of megawatts, an offshore installation can be a power-hungry beast indeed. The onboard gas turbines or diesel generators that usually supply this power, however, manage no more than about 25 percent efficiency – way off the dazzling 75–80 percent efficiencies of, say, land-based combined cycle power plants. This inefficiency isn't just costly in terms of excessive fuel consumption, either; high emissions can rack up the cost still further, for example where CO<sub>2</sub> taxation applies.

Technologies from ABB are making it easier than ever before to deliver electrical power to offshore installations, lowering operating costs and reducing environmental impact at the same time. Seventy kilometers off the Norwegian coast, two of these technologies – HVDC Light® and Very high Voltage (VHV) cable wound motor technology – are helping to power 40-MW compressor units on Statoil's Troll A platform without any local power generation.

Troll A platform (Photo: Øyvind Hagen, Statoil)



On most offshore installations, the power generators and large compressors are driven by onboard gas turbines or diesel engines with total efficiencies that can be as low as 20–25 percent even under ideal conditions. As a result, fuel consumption and CO<sub>2</sub> emissions are unnecessarily high. Ever since the Kyoto Protocol, which allows trading of greenhouse gas emissions, high CO<sub>2</sub>

A conventional precompression project, with gas turbines, would have resulted in annual emissions of some 230,000 tons of CO<sub>2</sub> and 230 tons of NO<sub>x</sub>.

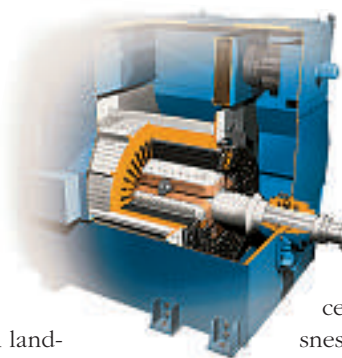
emissions have become a cost factor. On top of this, as on the Norwegian shelf, there may be CO<sub>2</sub> taxation, making emissions costly even without trading.

If the electrical power for all this equipment can be supplied from shore, the CO<sub>2</sub> emissions of offshore installations are eliminated, saving operators a con-

siderable sum of money. But that isn't all; transmitting electrical energy from shore is also more efficient in terms of equipment maintenance, lifetime and availability.

The overall environmental bonus of eliminating low-efficiency offshore power plants is considerable. A land-based combined cycle gas power plant, which utilizes the gas turbine's waste heat, can have an efficiency of as much as 75 to 80 percent. Even if high losses of 10 percent are assumed for a long transmission line to an offshore installation, the saving will still be significant for most installations.

**HVDC Light® and VHV cable wound motor technology join the offshore club**  
Troll A is the largest gas production platform on the Norwegian shelf. Some 40 percent of Norway's total annual gas



production comes from Troll A, which can produce up to 100 million cubic meters of gas per day. Today, the reservoir pressure drives the gas to the onshore processing plant at Kollsnes, where the condensate, water and gas are separated. The gas is then compressed and transported through pipelines to the European continent **1**.

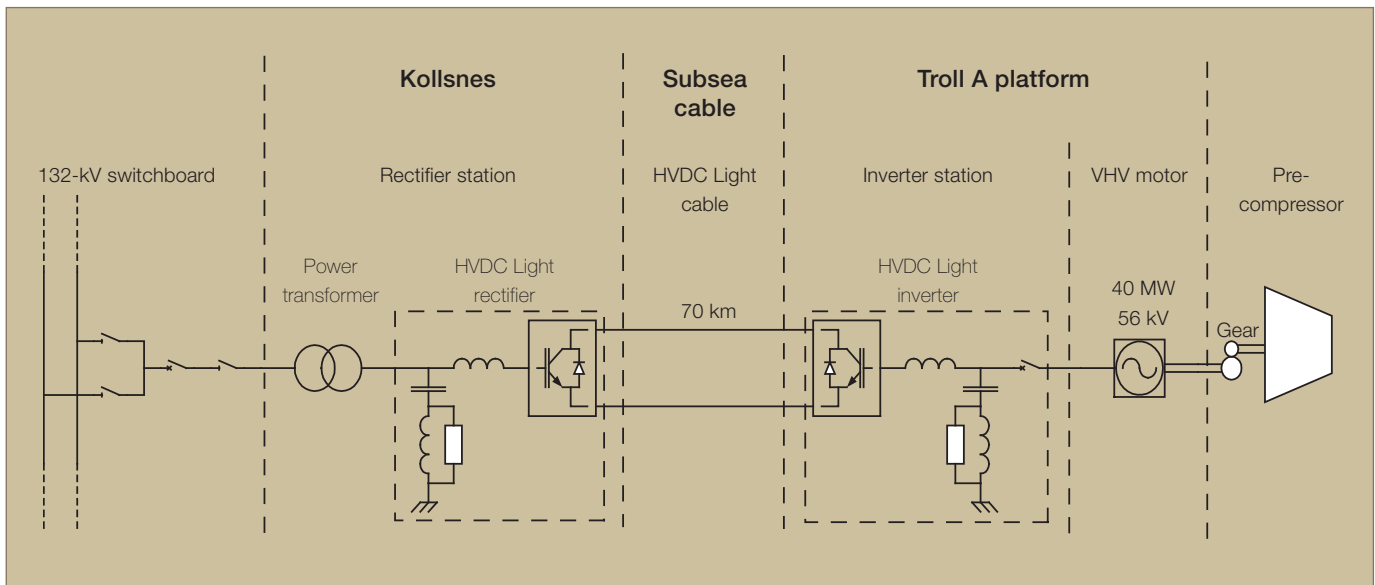
As the gas is taken out of the reservoir, the pressure inevitably decreases. This means that to maintain production capacity, offshore precompression of the gas will eventually become necessary. ABB has been awarded two contracts as part of Statoil's Troll A Precompression Project: a US\$ 185 million contract for the compression equipment and a US\$ 85 million contract for the electric drive systems for compressors. The new installation is due to go into commercial

1

Gas from Troll A is processed at Kollsnes before being transported to the European continent.



From the rectifier station at Kollsnes, subsea HVDC cables transmit power to the Troll A Platform, where the inverter station and VHV cable wound motor are located. Two identical systems are to be installed.



operation in the fall of 2005 as part of a program introduced to maintain and expand the platform's production capacity.

Choosing conventional systems for this project would have meant that gas turbines would drive the compressors. In that case, it is estimated, annual emissions of some 230,000 tons of CO<sub>2</sub> and 230 tons of NO<sub>x</sub> would result. Besides their impact on the environment, the CO<sub>2</sub> taxation in effect on the Norwegian shelf means that such emissions would

also be a significant cost factor. Working with Statoil, ABB developed an alternative system **2** based on two innovative ABB technologies – HVDC Light® and VHV cable wound motors. These have been successfully employed on shore since 1997 and 1998, respectively, but never before on an offshore installation or together as an electric drive system. The system uses power from the onshore electrical grid to drive the compressors on Troll A, thus eliminating greenhouse gas emissions from the platform.

through from zero to maximum speed (at 63 Hz) and from zero to maximum voltage (56 kV), including starting, acceleration and braking. The drive systems perform equally well at each end of the frequency spectrum. Small filters at the converters' outputs keep the motor winding stress at a safe level.

The inverter control software is adapted for both motor speed and torque control. The motor currents and voltages and the rotor position are measured and

### HVDC Light

In the past, high-voltage DC links have been used almost exclusively to transmit very high powers over long distances. HVDC Light [1] is a new transmission technology based on voltage source converters that extends the economical power range of HVDC transmission down to just a few megawatts.

HVDC Light also offers power quality improvements, for example reactive power compensation and harmonic/flicker compensation. Thanks to fast vector control, active and reactive power can be controlled independently, with harmonics kept low, even in weak grids.

### HVDC Light – rectifying, inverting and controlling

HVDC Light [1], by using series-connected power transistors, enables voltage source converters to be connected to networks, at voltage levels higher than ever before, for power transmission, reactive power compensation and harmonic/flicker compensation.

On Troll A, an HVDC Light converter (inverter) feeds the variable-speed synchronous motor driving each compressor with AC power obtained by converting the incoming DC, which is transmitted from shore over submarine cables. As their speed is variable, the compressors are supplied with power at variable frequency and voltage, right

### VHV cable wound motor technology

VHV cable wound motor technology features conventional rotor, exciter, control, and protection technologies. Most of the stator technology is also conventional – the exception is the winding, which is made of XLPE-insulated cable. The stator's cable slots are designed for low electrical losses, high-strength cable clamping, efficient cooling and simple installation. The first VHV cable wound motor to go into commercial operation, at the AGA plant in Sweden, has verified the many benefits of using HV cable technology in large electric motors. VHV cable wound motor technology is suitable for most applications where conventional technology is used today.

3

HVDC Light® extruded submarine cable, with double armoring (80 kV rating)



used together with an advanced model of the machine's electromagnetic parameters to calculate converter switching pulses in much the same way as for smaller industrial variable-speed drives (ACS600/ACS1000/ACS6000). Unity power factor and low harmonics are assured, along with a sufficiently high dynamic response, over the motor's entire operating range. Protection and monitoring of the converters and synchronous machines, as well as control of the excitation converter feeding the latter's field winding, are handled by ABB's well-proven Industrial<sup>IT</sup> HVDC Control, MACH 2.

Overall control of the rectifier station at Kollsnes is also handled by the MACH 2.

There is no need for communication between the rectifier control system on land and the motor control system on the platform; the only quantity that can be detected at each end of the transmission system is the DC link voltage. As the DC

link cannot store much energy, the motor control system is designed to follow even rapid changes in power flow at the opposite end without disturbing motor operation. Nuisance tripping is generally kept to a minimum.

The HVDC Light converter for Troll is based on a two-level bridge with grounded midpoint. Only extremely low ground currents are induced during steady state and dynamic operation, this feature being one of the main reasons for using HVDC for the power supply. No cathode protection of any kind has to be provided for this installation.

#### HVDC Light cable – the power carrier

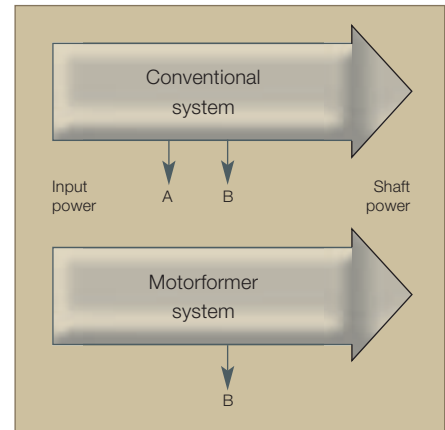
The HVDC Light concept includes a further innovation: the HVDC Light extruded polymer cable. The shift in high-voltage AC technology from paper-insulated to extruded polymer cable was the incentive for ABB to develop and produce an extruded cable offering the same benefits – flexibility and cost-effectiveness – for HVDC transmission.

Troll A's importance as a major gas producer called for an extremely reliable transmission link. The actual cable has a 300-mm<sup>2</sup> copper conductor surrounded



4

Use of VHV cable wound motor technology eliminates transformer losses (A). Only motor losses (B) remain.



by a very strong and robust polymeric insulating material **3**. Water ingress is prevented by a seamless layer of extruded lead, over which there are two layers of armor – steel wire woven in counter helix – to provide the required mechanical properties. This design ensures that the cable has the strength and flexibility necessary for laying in the North Sea. The two electric drive systems require an HVDC Light cable system with two cable pairs (one for each drive), physically separated from each other on the sea floor. The two cables in each pair are operated in bipolar mode, one having a positive and the other a negative polarity.

To make sure that the cables will not be damaged by anchors or trawling, they are laid in trenches on the sea bed formed by water jetting, or covered with rocks where this is not practicable.

#### VHV cable wound motors drive the compressors

Following the introduction in 1998 of new, innovative cable winding technology, ABB's engineers soon began to consider the possibility of using HV cable windings in place of conventional wind-



ings in electrical machines in order to radically increase the voltage rating. Such a machine can then be connected directly to the HV grid, doing away with the need for a costly step-down transformer.

The first product to be based on this principle was an HV cable-wound generator. Shortly afterwards, the same concept was applied to motors, resulting in the development of a synchronous motor, a VHV cable wound motor (see panel on page 48). The first unit was installed in 2001 at an air separation plant in Sweden, where it drives a compressor. This motor is directly connected to a 42-kV bus. In the meantime, ABB offers VHV motors of this kind for voltages up to 70 kV. Work is currently under way to develop units rated at 150 kV.

Apart from eliminating the step-down transformer and related switchgear, a VHV cable wound motor reduces the total system losses by as much as 25 percent <sup>4</sup>. Being epoxy-free, it also has important environmental benefits, including easy recyclability. And fewer components mean higher system reliability and availability, plus reduced costs for service, maintenance and spares.

#### A challenging environment for high-voltage equipment

Offshore equipment design is constrained by the need to keep both footprint and weight to a minimum. HVDC Light and VHV cable wound motors offer important advantages in precisely these areas:

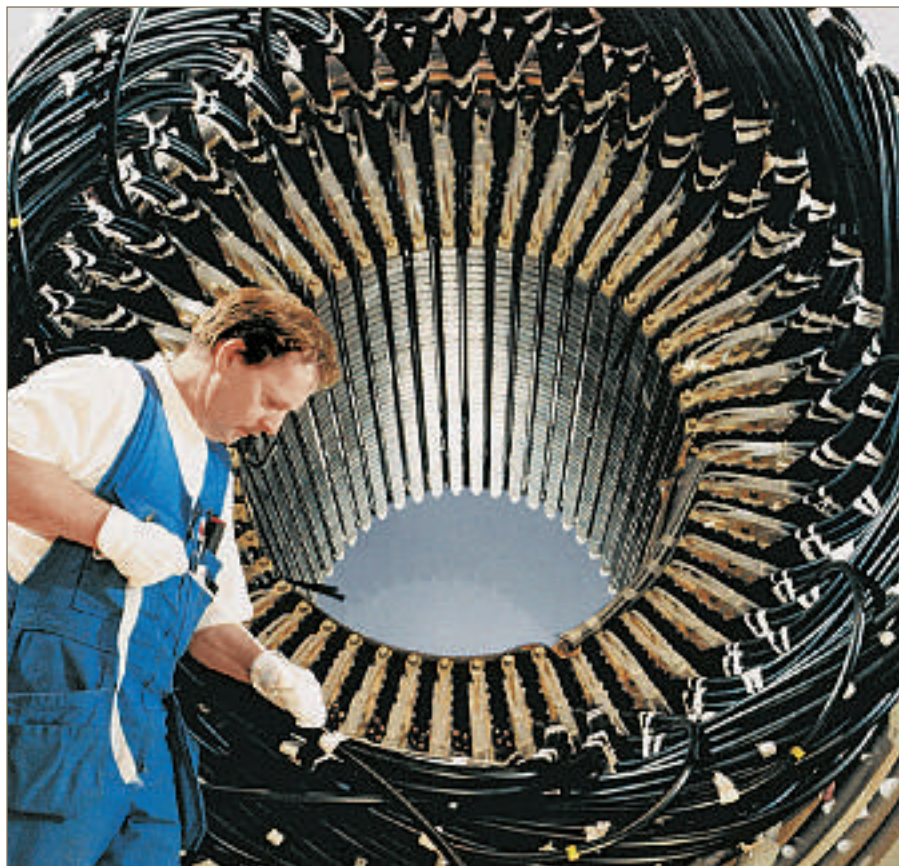
- Smaller filters and the absence of synchronous condensers make HVDC Light more compact and lighter than traditional HVDC systems.

**HVDC Light® and VHV cable wound motors ensure a small footprint and low weight – two essential characteristics for offshore equipment.**

- No large, heavy transformer is required to connect the VHV cable wound motor to the HVDC Light converter.

Other design considerations in connection with this project were:

- Safety: Troll A produces large quantities of hydrocarbon gas, which is not allowed to come into contact with high-voltage equipment.
- Environment: The high-voltage equipment must be protected from the damp, salt-laden sea air.
- Availability: Given the daily production of gas worth US\$ 10–15 million, high equipment availability is essential.



HVDC Light and VHV cable wound motors are innovative technologies with all the qualities needed to power offshore platforms from shore for maximum economical and environmental benefit. Troll A is the first such platform anywhere to be powered in this way, the electric drive system being part of a program to maintain and expand production capacity. The elimination of CO<sub>2</sub> emissions and a smaller equipment footprint are just two of the benefits enjoyed by Statoil as a result.

**Dr. Tom F. Nestli**  
ABB Norway  
tom.f.nestli@no.abb.com

**Lars Stendus**  
**Magnus J. Johansson**  
**Arne Abrahamsson**  
**Dr. Philip C. Kjaer**  
ABB Sweden

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[1] G. Asplund, K. Eriksson, K. Svensson: HVDC Light – DC transmission based on voltage sourced converters. ABB Review 1/1998, 4–9.



# Service is key to unlocking drives potential

Combining service and technology to support drives during their entire lifecycle

Pauli Jarvinen

A combination of technology and service is, ABB believes, necessary to improve end-users' productivity while at the same time lowering total lifecycle costs. But this isn't the only advantage. Drive manufacturers that can deliver high technical competence together with a comprehensive level of service that supports their products during every lifecycle stage will be better positioned in the global market.

End-users benefit from services even before they purchase a drive, and continue to do so until its obsolescence and eventual replacement. Using its Lifecycle management model, ABB provides service products matched to different lifecycle phases, enabling end-users to get the best return on their drive investment.

Through various service offerings, ABB ensures that users service needs are met. An integrated global service network consisting of trained channel partners and ABB personnel provide on-site backup and support when needed.



Advances in technology are making drives more and more reliable, and this means customers have less need for in-house maintenance, thus relying on their vendors for any support that might be needed. These advances, some believe, are making drives from various manufacturers increasingly similar and the only differentiating factor for end-users is the level of service provided.

ABB disagrees with this point of view. Instead, the company believes that service and technology are closely linked when it comes to the development of a product range: feedback from the service organization is important for ABB's product development, while technological innovations in drives allow the company to improve its service offering. In addition, ABB believes a combination of technology and service is necessary to improve an end-user's productivity while at the same time lowering lifecycle costs.

For example, technology now allows service engineers to check and monitor drives remotely, meaning problems can be diagnosed quickly when, or even before, they occur. Combining this with ABB's sophisticated method of storing and retrieving documentation, as well as managing installed base information, these problems can be solved in a fraction of the time taken before, reducing downtime considerably. ABB's use of 'wizards' is another example of how technology is impacting service support. ABB has wizards that ask for input data in the customer's own language rather than code. The advantage of this is that as users do not need drive specialist's knowledge, service and training costs are significantly reduced.

#### Service before, during and after

ABB provides end-users with services even before the drive has been sold and continues to do so until its obsolescence and eventual replacement. Therefore, building a strong relationship with a potential end user is of vital importance, and lifecycle services provide an excellent possibility of doing just that.

ABB works with certified drives engineers from the company and from authorized channel partners. These engineers ensure that customers' needs are specified and that they receive the correct drive for a required application. These channel partners and engineers also provide comprehensive after sales support. This relationship is constantly reviewed to ensure it remains an effective method of support.

To further support an end-user before a purchase is made, ABB carries out an energy audit, harmonics surveys and EMC assessments to identify potential problems and give the user the option of buying add-ons to combat these prob-

lems. Users may also buy their drive equipped with ready-made add-on services including fast start-up, training and extended warranty.

Good after sales service is vital in allowing customers to maximize their productivity, even when it becomes necessary to replace the drives. Therefore, as part

of any lifecycle management, ABB believes its product development strategy should be closely aligned with its service support strategy. This,

the company says, will not only provide optimum support to its customers but will also enable a smooth transition to the next generation of drives at the end of the current drive's service life.

Advances in technology allow service engineers to check and monitor drives remotely, meaning problems can be diagnosed quickly when, or even before, they occur.





## Lifecycle management model

Following on from this idea, ABB has developed a lifecycle management model aimed at proactively providing service products over different phases of the drive's lifecycle **1** to maximize availability and performance.

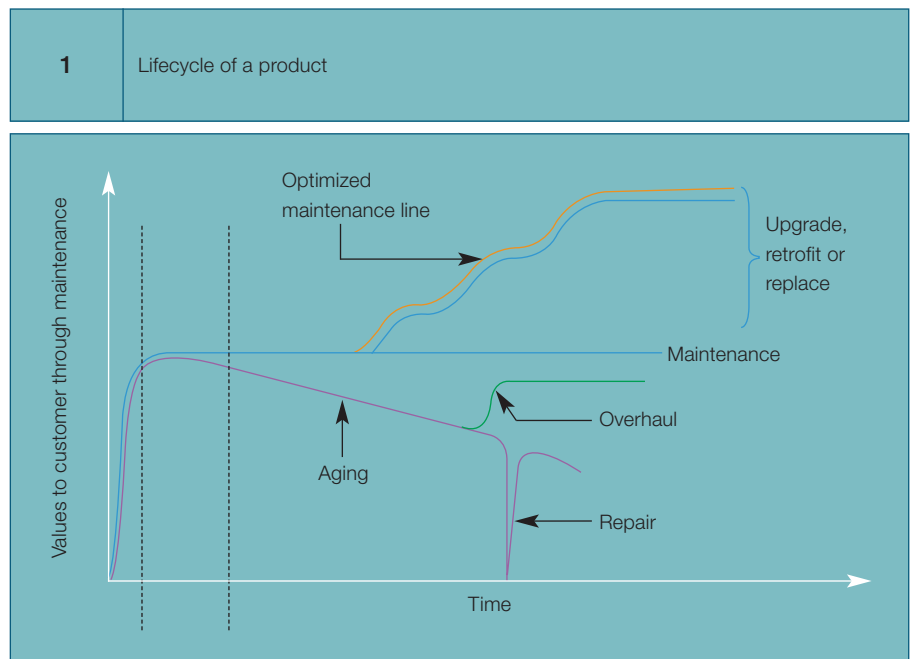
This model divides a product's lifecycle into four parts: active, classic, limited and obsolete. Each phase has different implications for the end-user in terms of the service support provided.

The 'active' phase usually lasts for about ten years, starting from the time the drive was launched. During this phase, the user benefits from warranty options and other services such as initial training and technical support, including drive adjustment for optimum performance. This phase ends when volume production of a particular drive ceases and ABB issues a 'Last buy notice' through its sales and service channels. Users of the drive will continue to benefit from service support throughout the 'classic' phase.

The classic phase, lasting seven to ten years, is closely aligned with research and development undertaken by ABB to provide continued support for its drives while developing future generations. In this phase, new hardware and software developments may be required to provide the maintenance techniques and upgrades needed to guarantee that the drive continues to operate at maximum efficiency.

Even though drive products are no longer marketed during this phase, some units may still be purchased. Complete drive modules for extension and spare part purposes and software upgrades are still available. Throughout the classic phase, ABB issues an annual update on the lifecycle plan of drive products so that users are kept fully informed.

The Lifecycle management model divides a product's lifecycle into four parts: active, classic limited and obsolete.



In the 'limited' phase, product manufacturing is no longer supported by development. However, spare part availability continues as long as components are available. This aspect of lifecycle management means that drive models are becoming increasingly obsolete and when this happens, customers are alerted and suitable replacements are recommended. This ties in nicely with ABB's replacement drive scheme, whereby replacement products from the company's latest portfolio are offered to customers. These replacements usually have more functionality than earlier models, are cheaper and have reduced payback times.

### Services maximize availability while minimizing lifecycle costs

Lifecycle management is one facet of ABB's intention to provide comprehensive service support. But the company also recognizes that service needs vary from customer to customer, and therefore offers optional levels of service to satisfy these needs. For example, customers can choose a standard or an

extended warranty when the drive is initially installed. Typically, support services are an optional cost that has to be considered by the user when deciding on the potential benefits. Lifecycle costs can usually be minimized by following ABB's maintenance recommendations, ie, a maintenance schedule. These recommendations are available for every drive product family and are based on years of experience obtained from the manufacture and maintenance of AC drives.

A maintenance schedule provides a well-structured and scheduled means of maintaining a drive. A maintenance note, on the other hand, contains detailed information of recommended maintenance actions found in the maintenance schedule, and provides a technical explanation as to why each and every action needs to be taken. These two elements are considered the foundation for every proactive drive maintenance program aimed at maximizing availability and minimizing lifecycle costs.

ABB's experience shows that it is of paramount importance to take environmental and operational conditions into consideration when specifying a drive maintenance program. A demanding

environment, such as high ambient temperature or heavy load, can considerably shorten the lifetime of certain components and thus influences the optimal service interval.

In addition to major maintenance actions, including component updates, ABB recommends that an annual drive inspection is carried out to obtain the best possible reliability and optimum performance for AC drives.

A typical service contract will recommend maintenance of the drive, but in general it should match the user's needs. As needs vary, ABB offers different levels of maintenance in its service contracts. These range from highly reactive on-demand services for electronic repairs and spare parts delivery based on agreed response times, to proactive services guaranteeing hardware and software upgrades that ensure optimum performance.

A service contract that includes all the necessary service elements together with asset optimization is given the name *Equipment Performance Management* (EPM). The aim of EPM for drives is to increase the availability of customers' production lines through improved life-cycle management. It does this by applying reliability-centered maintenance to the plant's drive population regardless of the manufacturer. The overall result is financial gain for the customer in terms of lower maintenance costs and greater output.

#### **Efficient and quick service**

To improve its service support, ABB is constantly looking at other developments that would be of help to users.

One interesting example is an Ethernet module that can work with any ABB industrial drive with a fiber optic link. This module enables simple, real time access to the drive via the Internet.



Even though much service support can be provided remotely using modern technology, there are still cases where service engineers need to make on-site visits to troubleshoot a problem. Be-

cause these visits could be anywhere in the world and time critical, ABB has developed an *integrated global service network* consisting of

trained channel partners and ABB service engineers located at key geographical positions. These have access to pre-packed diagnostic equipment allowing them to support users with minimal delay. Global and regional support centers provide additional support to local service organizations.

Databases are helping ABB add value to its support services. One database is used to determine the location of engineers with particular skills so that a suitably qualified person is sent to resolve any issues quickly. Another database collects information about installed bases. To be wholly proactive with its customers ABB must know where each drive is installed and its previous service history. This is information that few manufacturers can provide. ABB also provides users with a comprehensive spare parts database with browsing, ordering and follow-up capabilities on more than 100,000 individual items from ABB automation and power products.

#### **The importance of customer training**

ABB believes that cost effective customer training is an integral part of its service support, and the company has developed both distance learning and modular courses in response to the various forms of training required. These courses are intended to be as flexible as possible, allowing the user to combine in-house web-based learning modules with periods of traditional hands-on training.

Even though ABB has invested heavily in integrating its service support, it believes there is still more it could do to be even more effective. Global, highly productized service offerings, which are created like any physical product, will provide end-users with consistency, quality and efficiency regardless of location. Even services on a very local level are managed globally. ABB believes this to be an essential element for success.

**Pauli Jarvinen**

Product Support & Service  
Low Voltage Drives  
Helsinki, Finland.  
pauli.jarvinen@fi.abb.com



# Simplicity at your fingertips

ACS550 standard drive –  
Sophisticated drive technology made simple

Mika Paakkonen

Motors powering mechanical equipment consume an astounding amount of energy. In the US alone, they account for 60 percent of the total electrical energy consumed, and much of this is wasted by motors running at fixed speed. Such waste is eliminated by the use of variable-speed drives which control motor speed to reflect actual demand, generating end-user savings of up to 70 percent.

When buying a drive, customers want something that is easy to install, configure and use. ABB's new standard drive family, the ACS550, combines simplicity, convenience, fieldbus connectivity, harmonics suppression and programmability to a degree not seen in drives before.

This drive provides high power density to end-users, OEMs, system integrators and panel builders who need a full-featured drive in a small flexible package.

More impressively, the drive has the lowest input current Total Harmonic Distortion (THD) on the market. This has been achieved using ABB's groundbreaking patent-pending swinging choke technology.



To maintain its leading market position, ABB has been working hard in updating its product portfolio with drives that incorporate new technology and evolving customer needs. Previous research and development efforts resulted in a range of intuitive drives designed specifically for off-the-shelf sales. These are known as *standard* drives because they are manufactured in large volumes and are available through local distributors for immediate purchase. In addition, these drives are easy to install, configure and use, thus saving a considerable amount of time. The ACS400 product line, an example of a standard drive, has been a market leader since 1999.

Recent developments have resulted in the launch of the next-generation standard product, the ACS550 low voltage AC drive line. This drive, rated from 0.75 kW to 355 kW, 200 and 400 V, is considered a truly customer driven product because it originates from a needs assessment with Original Equipment Manufacturers (OEMs), distributors, users and system integrators. It is targeted at standard applications such as pumps, fans and constant torque use such as conveyors, and with a range of innovative user support features, it is considered the easiest drive on the market to install, commission and use.

ABB's new standard drive is the result of worldwide expertise, resources and technology used to make drives simple. According to one ABB source, the ACS550 for drive users "is sophisticated technology made simple." The combination of simplicity, convenience, fieldbus connectivity, harmonics suppression and programmability is such that this has never been seen in drives before.

### Nice 'n' easy

The drive is programmed via a control panel that is similar in look, feel and functionality to a mobile phone. A large graphical display and soft keys make it extremely easy to navigate. This detachable, multi-lingual alphanumeric control panel, as shown in **1**, allows access to various 'assistants' and a built-in help function to guide the user during start-up, maintenance and diagnostics. For example, a real time clock assists in rapid fault diagnostics. When a fault is detected, a *diagnostic assistant* will suggest ways to fix the problem. Drive set-

up and configuration data can be copied from one motor controller to another to ensure that in the event of a drive failure, there is no need to start the set-up process from the beginning. This copy feature is also useful when similar parameters are required for other motors.

A *start-up assistant*, together with an on-line information system for additional help, guides users through all essential settings without the need to access complex parameter lists. This assistant prompts users for motor nominal values, and I/O configuration and application specific parameters such as acceleration and deceleration. A total of nine different predefined settings are available, covering the vast majority of industrial applications.

The drive monitors and allows operators to set limits for energy consumption, running hours or motor revolutions, setting off an alarm whenever these limits are reached. A *maintenance assistant* keeps track of the running time, giving a signal when maintenance is required.

### Noise reduction

The ACS550 standard drive has an intuitive noise optimization feature. This feature lowers the noise level by increasing the switching frequency of the drive in response to a reduced motor load. The higher switching frequency of the sensorless vector control platform (for improved motor control performance) further reduces noise. In addition, a controlled cooling fan, used only when necessary, contributes to noise reduction as well as improving energy efficiency.

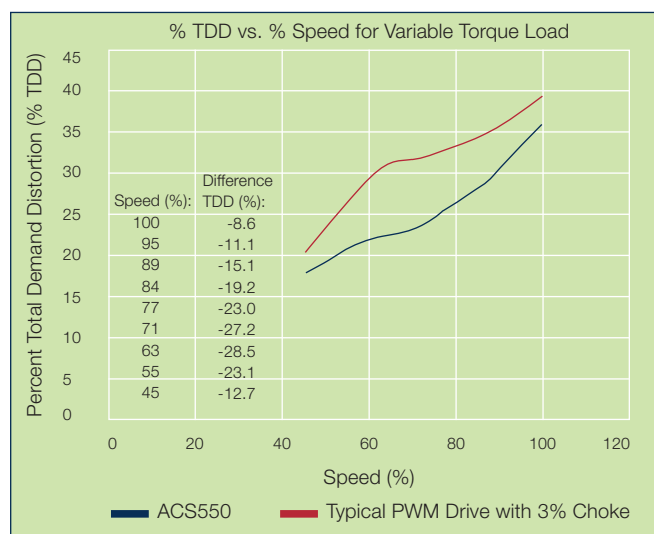
### Fieldbus control giving easier access to automation systems

The standard drive has a flexible Fieldbus system with built-in Modbus as standard. Field-

**1** The detachable control panel on ABB's standard drive, ACS550, has various assistants and a built-in help function to guide the user.



**2** New swinging DC choke design.





bus adaptors and/or a digital interface card, available as options, can be mounted into an available slot inside the drive, allowing connectivity to a wide variety of automation systems. This drive supports high performance protocols such as DeviceNet, LonWorks, Profibus-DP, CANOpen and ControlNet

#### Harmonics suppression

Non-linear loads, such as rectifiers, welders and variable speed drives, generate harmful current harmonics that are potentially dangerous to equipment connected to the same electrical network. Problems caused by excessive harmonic distortion include overheating of: power distribution transformers, cables, induction motors, generators and capacitors. Other problems include flickering lights and electronic displays, tripping of electronically activated circuit breakers and blown fuses. On top of this, utility companies penalize those who introduce harmonics into the supply grid.

To meet existing standards, oversized cabling and standard DC chokes have been used to reduce harmonic distortion levels (by smoothing the current waveform) caused by drive inverters at full loads. But these solutions do nothing to reduce distortion levels at partial loads. In fact, because the impedance of DC chokes is optimized for a specific throughput, normally that used at full load, Total Harmonic Distortion (THD) increases when the load is reduced.

A solution to this problem was found by engineers at ABB and incorporated into the new drive. This solution means that the company now has a drive with the lowest input current THD on the market. ABB's patent pending 'swinging DC choke' reduces harmonics at full and partial loads by up to 30 percent, <sup>2</sup>, when compared with conventional choke designs, thus satisfying all harmonics suppression requirements for industrial applications.

The swinging choke works by providing increased inductance at reduced current, something that has never been done before.

The swinging choke works by providing increased inductance at reduced current, something that has never been done before. It features a variable air gap to give flexible impedance for a range of different loads. This solution can lead to remarkable savings in transformer heat losses. ABB predicts a significant market impact when end-users realize what this means in terms of energy savings, reduced initial costs and increased reliability.

A built-in EMC filter guarantees trouble free operation of surrounding equipment and instrumentation. The drive meets the requirements for the first environment with motor cables up to 30 meters. With longer cables, it meets the requirements for the second environment. This new

standard drive also includes a braking chopper to absorb braking energy, helping to quickly decelerate a load.

Simplicity has also been applied to the documentation. There is a quick guide for initial power-up, an easy to follow user's manual for commissioning and an extensive technical reference manual aimed at designers and technical support.

The ACS550 is a drive that can appeal to a wide engineering community. Because it has been designed in close cooperation with users, it has everything needed in an AC drive to make precise motor control across all industrial applications easier than ever before.

Mika Paakkonen  
ABB Oy

Helsinki Finland  
mika.paakkonen@fi.abb.com





# Tailor made!

Customized drives for any application in record time

Harri Heimonen

In the early days of mass production, Henry Ford famously said that customers could have "any color you like as long as it's black". Customization was a luxury very few could afford. Nowadays of course, Mr. Ford would find it difficult to stay in business. Variety and choice, not only of color, are now essential elements manufacturers need to offer their clients.

Even in large modern-day production facilities, made-to-order products are much costlier than mass-produced ones, but the good news is that this gap is shrinking.

At ABB's drive manufacturing facility in Helsinki, a new advanced production line, nicknamed *Galactica* because of its futuristic manufacturing techniques, can produce customized variable speed drives units in the power range from 50 kVA to 610 kVA. In other words, drives can be customized to any application, no matter how demanding, by tailoring the product as it passes through production.

Using sophisticated software, robots and computers play their part in reducing the cost gap with mass manufactured products.



For some time now, demand for ABB drives has been steadily increasing. While this is good news for the company, regular market research has shown that customer requirements are becoming ever more varied. To maintain its leading market position and meet customer demands, ABB must, and has been adapting its products and services in answer to the changing demands of the market. As a result, the company's product portfolio has expanded to such an extent that it has the widest and most modern product range available on the market, and it has been able to enter market segments that were once considered the domain of niche players.

Much of this has been made possible by investing in flexible production technology for medium and high power drives at ABB's drive manufacturing facility in Helsinki. A new advanced production line, nicknamed *Galactica*, can customize drives just in time within the normal production procedure **1**. Using the company's own precision robots combined with fully automated material flow and testing routines, drives, on average, are now produced three times faster **2**.

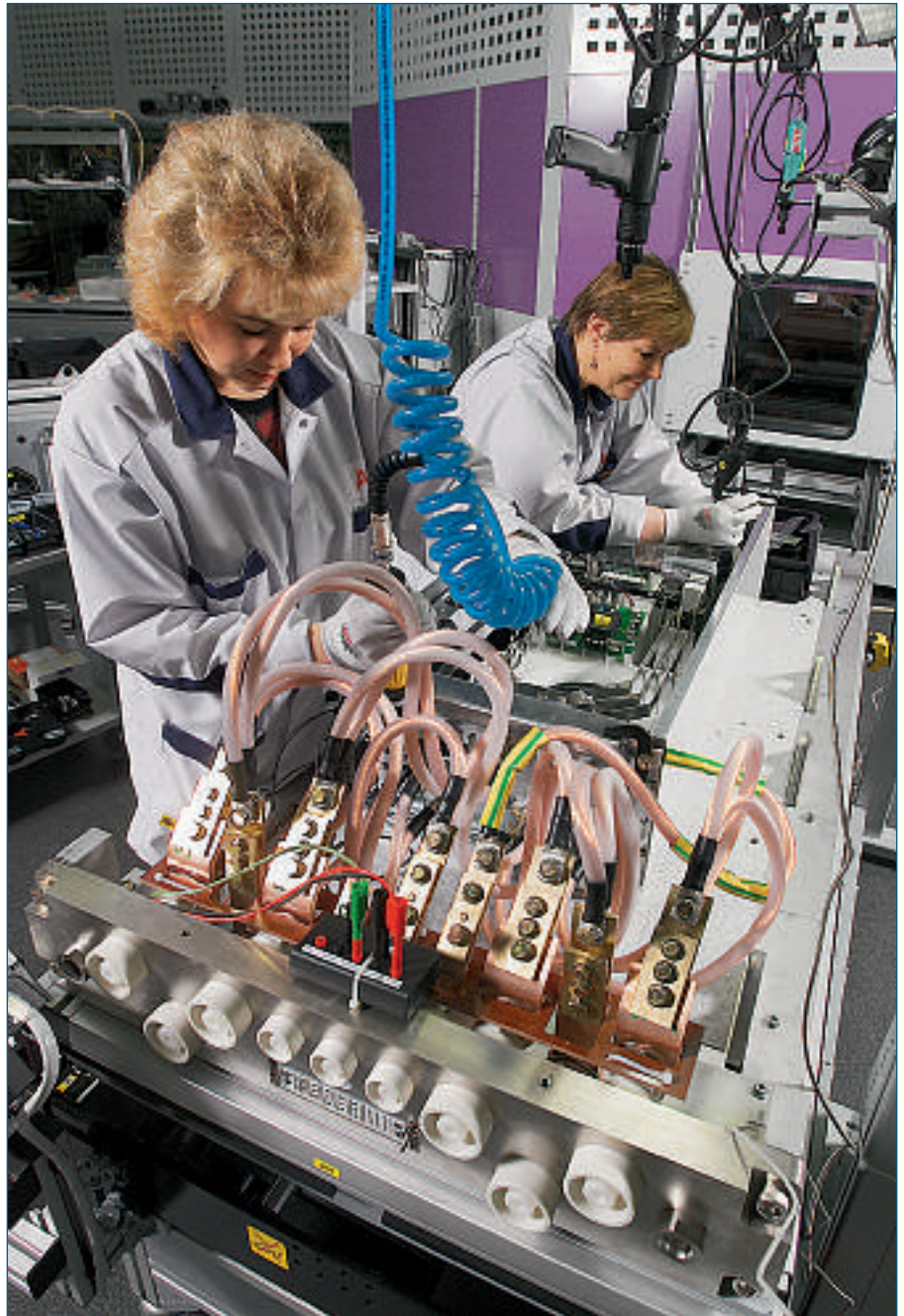
Such an investment means that customers can expect more tailored products with the quality and reliability normally associated with high volume products. In fact, all drives coming off *Galactica* are tested individually. This investment also means ABB can reap the benefits of scale economies. Niche players still have a place in the market, but customization to industry and application specific level is now carried out as a matter of course during manufacturing, intensifying the pressure on small focused manufacturers.

### Drives as components

At what power rating can customers expect to receive customized solutions? In the not so distant past, users would have expected customized solutions to be available only for drives rated above 200 kW. Today, the expectation is somewhat different in that they can expect this service for a 15 kW drive.

1

The *Galactica* production line for the manufacture of customized drives. Alongside the robots, advanced software and latest production techniques, the human touch is needed during final assembly.



In today's market, small drives are now seen as components, much like coils or potentiometers. As customers are more concerned with what these drives can do and not how they do it, together with the fact that they are cheaper than ever before, small drives are finding their way into many and various applications. As a result, ABB's smallest and

newest drive is manufactured in large quantities with no customization. This fist-sized product is manufactured for stock and is specifically designed so that OEMs can fit them into everyday objects such as washing machines.

The same applies to larger drives used mainly for speed control. These are

made for stock so customers can buy them off-the-shelf and fit the drives themselves.

Customization starts to creep in as sizes increase above 15 kW. Drives of this size are frequently used by the heating and ventilation industry and therefore many come equipped with specific macros for airflow control. Other drives are targeted at industries such as pulp and paper, food and beverage or cement. Depending on local demand in export markets, customized drives can be manufactured for stock overseas.

As the drive rating increases, so too does the level of customization. In the higher power ranges, application engineering gets down to the detail of each individual application. This has been made possible because customized features have been designed in from the R&D stage, meaning that each drive variant and components of that variant has its own code. As the drive passes through the manufacturing system, it is tracked using bar codes. The Material Requirements Planning (MRP) system follows the drive and helps select the required component at every stage,

whether this is fitted manually or automatically.

### Software modifications

Advancements in semiconductor technology and software capabilities coupled with developments in manufacturing process technology have helped the drive towards greater customization.

Today, mid-range drives from ABB can store five times the amount of information compared with typical drives from the 1980s. In addition, drives with increased processing power and memory enable configurations that are better suited to an application.

In industry today, software modifications are the most useful and cost effective way of modifying a drive. This is so because developments in software have given drives increased capability with less hardware. For example, a

drive controlling a conveyor belt in a biscuit factory can be programmed to operate in many different ways, such as starting and stopping at certain intervals or advancing a certain distance. The same drive used in a ventilation system can be programmed to maintain con-

stant air pressure in a ventilation duct.

Software developments are also producing drives with adaptive programming. Adaptive pro-

gramming enables the user to freely program the drive with a set of pre-defined software blocks that can be used to perform any operation from a pre-defined set of functions.

### Hardware issues

While software developments have eliminated the need for much internal hardware, external hardware modifications (on the drive enclosure) are sometimes inevitable. The food industry, for example, requires drives that can be hosed down, and ventilation applications sometimes need drives to be installed outdoors. Drives fitted by OEMs inside machinery need no protection from the elements, and can therefore be installed without any enclosure. Various communications options also require the presence of specific hardware, and EMC filters for different environments need separate components.

### No more faxes

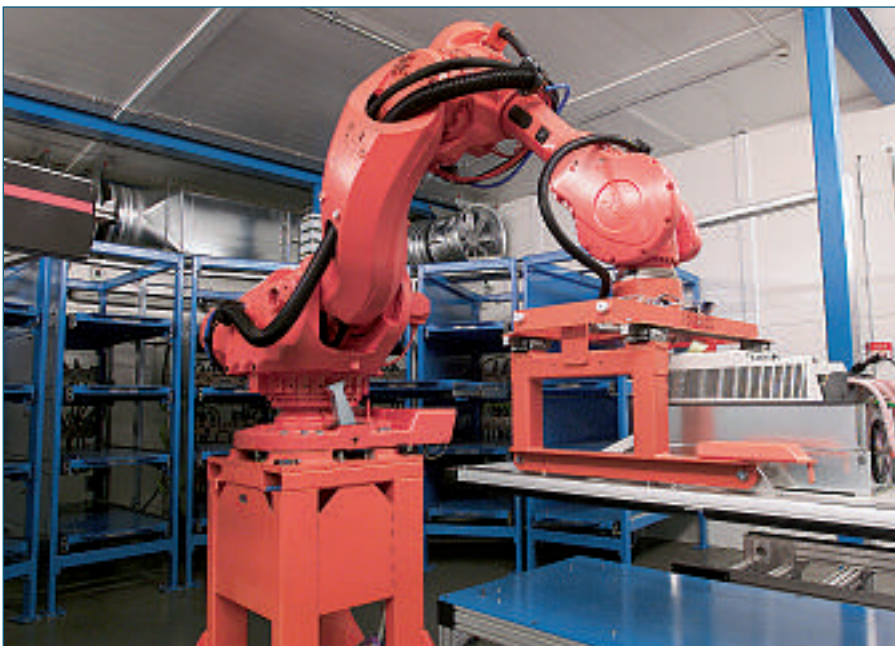
In the past, products such as engineered drives were ordered using an exchange of faxes or letters between the customer and the sales department. For a multinational company like ABB, this meant that the sales department in each country held all the technical information necessary for configuring a drive.

Today, such information is transferred via ABB's web-based electronic ordering system, allowing sales departments to focus more on customer service. Using a built-in configurator tool, which is oper-

ABB's web-based ordering system combined with smart manufacturing for tailor made drives, offers unparalleled customer service at a very affordable price.

2

ABB's high precision robots are used to manipulate drives up to 610 kVA in its new semi-automatic production line.





ated by local sales departments and is the system interface to the outside world, customers can pick from a wide range of product variants to satisfy their application requirements.

Users can choose from a large variety of sizes, types and hardware options, as well as more than 50 types of software for different applications, such as pumps, fans or cranes. Because of the large number of options available, several million different configurations are theoretically possible. On top of this, if further customization is needed for any individual application, factory engineers are available to deal with these special requirements.

As this system interface is web-based, new product features are available to the market almost immediately. In addition, order acknowledgements, something which used to take 3 to 4 days, are now confirmed within 24 hours.

The ordering system is also an integral part of the manufacturing process such that within half an hour of placing an order in Antwerp or Munich, the product can be in the production queue in Helsinki. When an order is placed, production planners at the plant first check to see when the product is required. If the production capacity is available to meet this schedule, the drive is booked into production. The data on available production capacity is updated every half-hour. To reduce the variety of products on any one shift, the planners may rearrange the orders to optimize production capacity.

The delivery time for large and small drives has been reduced by about one-third.

3 Central Stock Europe for motors and drives in Menden, Germany.



**Building blocks**

Essentially, this ordering system is very similar to that used by ABB when placing manufacturing orders for its own stock, and therefore the building blocks of the new system have been tried and tested by ABB for many years.

In the older system, orders from ABB central stock locations are automatically generated and sent to the manufacturing plant so that stock that has just been delivered to customers can be replenished. It is this ordering system that has been updated and expanded to accommodate configured drives and motors. In the future, more ABB prod-

ucts will become available in this way.

**Record delivery times**

ABB has two central stock locations for drives and motors in Europe: Menden in Germany and Sabadell near Barcelona. From these locations, most customers in Western Europe can be reached within 24 hours. When an order is placed, the system checks if the required product is available. If it is in stock, the order is then sent to the relevant stock location so that the item can be dispatched immediately, and if not, it goes to the manufacturing plant in Helsinki.

For small drives, the delivery time from order is now between one and seven days, shaving about one-third off the traditional schedule. The delivery time for large drives, ie, in the range 800 kW, has also been reduced by one-third to approximately four weeks. For customers willing to pay a premium, ABB offers an express delivery service.

ABB's web-based ordering system is an aspect of quality. It enables the company to accurately predict delivery times. Tracking orders is much easier than ever before and the risk of human error is significantly reduced. This smart ordering system, combined with smart manufacturing for tailor made drives, offers unparalleled customer service at a very affordable price.

**Harri Heimonen**  
Product AC drives  
ABB Oy, Helsinki  
harri.heimonen@fi.abb.com

## Product names that simplify AC drive selection

ABB drives has introduced an easy to follow naming protocol to simplify selection from its portfolio of products. The new descriptive names replace the traditional three letter and three digit codes that are now used by ABB for product identification as part of an extended type code for ordering or technical reference.

### Five specific categories define each drive type:

#### ABB component drives:

This is a new category of basic and compact drives aimed at simple low power applications like fans, exercise machines, access barriers, and washing machines. These drives meet the requirements of installation companies and panel builders and can be bought together with other components from an electrical wholesaler. Because they sold in this way, the number of options and variants is kept to an absolute minimum making installation and operation of the component drive very simple.

#### ABB general machinery drives:

These drives are designed to meet the requirements of a wide range of machinery applications. Aimed at OEMs who incorporate drives into machinery, they are easy to install and integrate. In many applications, repeatability of the drive will have an impact on the quality of the machinery and must therefore be high. Many OEMs will buy this type of drive in large quantities, so the product is designed such that logistical costs are kept low.

#### ABB decentralised drives:

Drives in this category are designed so that they can be mounted close to the process; ie either on top of the motor, attached to the motor to create so-called integral motor drives or mounted against the wall. Because of this, they must meet the requirements of relatively harsh environments and have an IP class of typically IP65.

Decentralised drives are characterised by a low power range, 0.55 kW to 2.2 kW, high protection class and fieldbus options for decentralised control. The benefits offered by decentralized drives include a reduction in cabling costs, lower maintenance, space saving (no control cabinet required) and easy installation and commissioning. This type of drive is perhaps best suited to the automotive industry and conveyor machinery.

#### ABB industrial drives:

These highly flexible drives cover a wide power and voltage range, including industrial voltages up to 690 V, and are designed to support order-based customization to meet the requirements of industrial applications. The drives come with a wide range of built-in options, and programmability is a key feature of ABB industrial drives.

#### ABB standard drives:

This category of compact drives is ideally suited for customers who want everything in one package. They are available through ABB's channel partners and, as such, are stocked for instant availability. ABB standard drives have many features that are pre-configured and built-in as standard, and because most of them are sold without direct factory support, the drives include various 'wizards' to simplify commissioning, start-up and operation.



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Motors and Generators

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ABB Ltd

Zurich/Switzerland

**Publisher's office**

ABB Schweiz AG

Corporate Research

ABB Review / RD.REV

CH-5405 Baden-Dättwil

abbreview.abbzh@ch.abb.com

**Printers**

Vorarlberger Verlagsanstalt AG

AT-6850 Dornbirn/Austria

**Design**

DAVILLA Werbeagentur GmbH

AT-6900 Bregenz/Austria

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ISSN: 1013-3119

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# Talented Building Blocks



## Total lifecycle management is a matter of fundamentals.

Installing and managing automation devices is almost elementary when your business is built on Industrial<sup>IT</sup> products from ABB. Anyway you arrange them, these “information enabled” components play a role in building new enterprise value.

We start with the industry’s broadest range of instruments, analyzers, controls, low voltage products, drives, motors, power electronics, robots, and more. Then we enable and certify every device to Industrial<sup>IT</sup> open standards: Asset documentation, configuration and connectivity tools, and lifecycle support resources are bundled into one powerful software shell for “plug and produce” installation and operation.

Whether you deploy them individually or integrated across the plant, ABB automation technologies provide the foundation you need for asset efficiency, transparency, and lowest lifecycle cost. Our customers, with over US\$ 100 billion of installed solutions worldwide, provide the proof.

To start arranging your own compatible enterprise building blocks, visit [www.abb.com/automation](http://www.abb.com/automation).

**Industrial<sup>IT</sup>**  
enabled

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