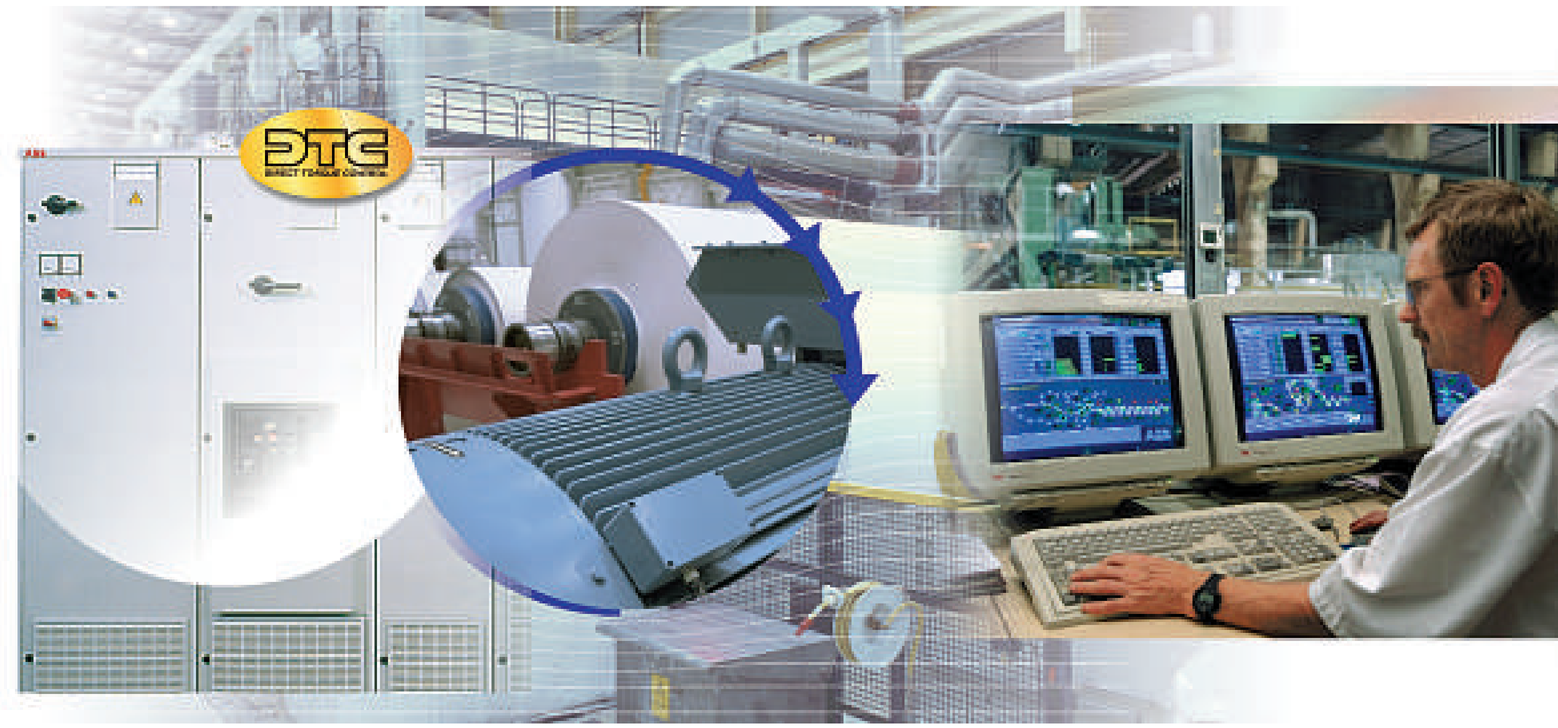


Permanent magnet motors eliminate gearboxes

Jouni Ikäheimo

Used for decades in smaller-scale applications, for example in the computer industry, where its favorable weight-to-performance ratio is an advantage, the permanent magnet motor has now been further developed by ABB to provide high accuracy and reliability for industrial applications requiring high torque at low speed. This new permanent magnet technology is helping to eliminate gearboxes across a wide range of industries. Initially, the paper industry will be targeted, as paper machines require large numbers of high-accuracy, low-speed drives.

The permanent magnet motor is the heart of a system known as the DriveIT Direct Drive Solution. This consists of a DriveIT permanent magnet motor, controlled by a DriveIT low-voltage AC drive based on the ACS 600 frequency converter, connected directly to the paper machine, without gearboxes or pulse encoders.

ABB's permanent magnet motor is a synchronous motor, which, as there is no rotor slip, provides better accuracy than standard, asynchronous, motors (see panel on page 25). 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.

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 new 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.

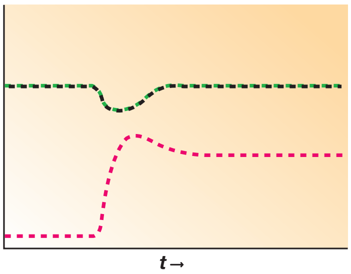
The synchronous motor can also deliver more power from a smaller unit. To power the in-drives of a paper machine directly at 220 to 600 rpm with a conventional asynchronous motor would require a motor frame substantially larger than that of a 1500-rpm motor. The new motor type has, in most cases, the 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 at room temperature available, with high values of flux density at very high values of magnetization. It is also extremely resistant to demagnetization. And NdFeB is less costly and brittle than samarium cobalt, another rare earth material, that was used widely in the 1980s.

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.

The permanent magnet motor is synchronous so there is no rotor slip, eliminating the need for slip compensation. Motor control is better as a result.

The graph shows measured/estimated speed (black/green) and torque (red).



Higher efficiency and less maintenance

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.

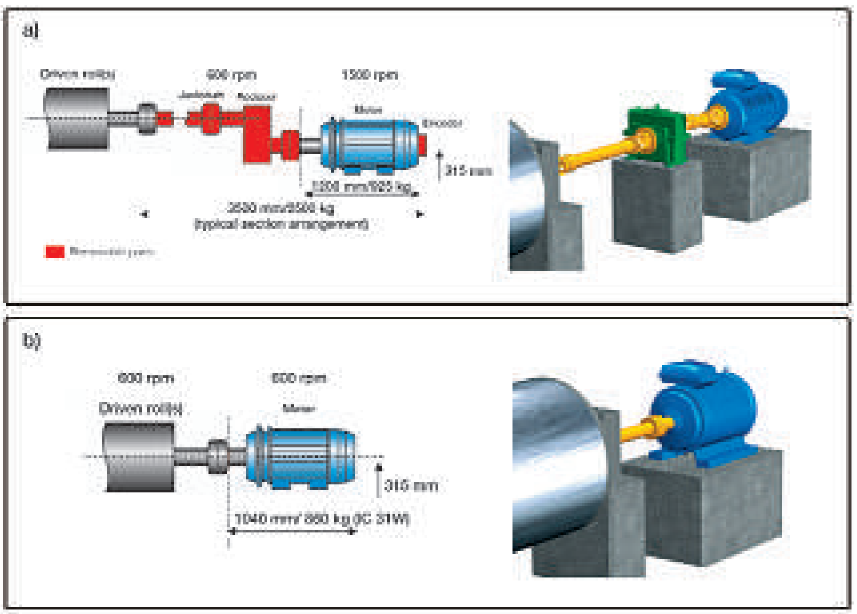
This is normally overcome by using a gearbox. However, the gearbox is a complicated piece of machinery that takes up space and needs maintenance as well as considerable quantities of oil.

The new 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.

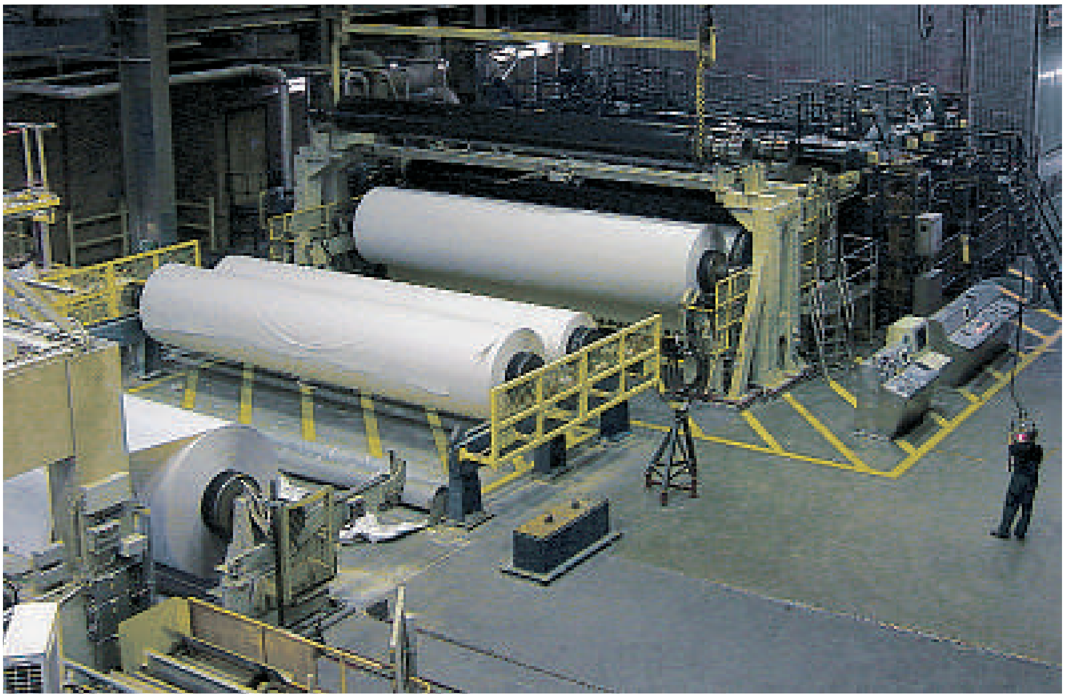
High performance at low speed is sometimes achieved by using a DC drive. Compared to this, the new ABB solution will save on motor maintenance as the permanent magnet motor is very robust and the maintenance it requires is similar to that for standard AC induction motors.

The combination of fewer compo-

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



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



nents 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 and repair work can also be carried out faster.

Drive IT 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.

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

Familiar motor type in new role

The permanent magnet motor has been around for decades, 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. Powers range from 27 to 1800 kW and the motor voltage is typically 400/690 VAC. The temperature of the permanent magnet rotor remains naturally low, allowing higher power densities.

Like all synchronous motors, the new 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 method has been further developed to achieve this.

The Direct Drive system is based on ABB's ACS 600 frequency converters. The motor control can use the same inverter hardware as the induction motor control and be cooled by air or water.

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.

Used in Azipod technology

The Drive IT Direct Drive Solution is initially being targeted at the paper industry, as this sector is particularly dependent on high accuracy and high reliability in low-speed applications. However, permanent magnet motor solutions have existed for some time, finding early applications in servomotors and traction motors. Permanent magnet motors are already well known today for being used in the Azipod marine propulsion system. The Direct Drive is the first 'standard' solution for low-speed industrial applications.

Thanks to the permanent magnet motor, the Azipod solution is more compact, making it viable for use in smaller ships. The experience of permanent magnet motors gained with Azipod was also put to good use during development of the Direct Drive for the pulp and paper industry.

Wind turbine generators represent a growing application area for the permanent magnet motor. Being slow running, these could benefit from the removal of gearboxes. Ski lifts and elevators are among other possible application areas.

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 would save energy through better efficiency, as losses are considerably reduced.

At the moment, the investment cost for the Direct Drive, due to the high cost of the materials, is comparable with that of a traditional drive installation with gearbox. As outlined, the benefits lie in reduced maintenance, the smaller space it requires, improved energy efficiency and better reliability. This will initially restrict use of the technology to specialist applications such as paper machines and Azipod. In the years to come, however, there is no reason why the permanent magnet motor should not become a common sight on factory floors.

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%.

Some frequency converters feature slip compensation to reduce this. The speed drop can then be reduced to about 10% 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.

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