

# New Direct Drive system opens a new era for paper machines

## SUMMARY

The development of electrical drives has reduced the need for mechanical drive components for paper machines. This reduction has been driven by bigger and faster paper machines with higher requirements on powers, control accuracy, system availability and functionality,

and lower life cycle cost. ABB introduced a new Direct Drive system at the PulPaper 2001 trade show in Helsinki in June. This new technology significantly improves the overall efficiency of paper machines.

## TIIVISTELMÄ

ABB on kehittänyt uuden sähkökäyttöteknologian Drive<sup>IT</sup> Direct Drive, jolla voidaan parantaa paperikoneen kokonaistehokkuutta toteuttamalla käytön mekaaninen laitteisto aivan uudella tavalla: ilman vaihteita sekä pulssiantureita. Direct Drive -ratkaisun merkittävimpiä etuja ovat:

- Parempi paperikoneen ajettavuus ilman akselien ja vaihdevälysten aiheuttamia resonanssi-ilmiöitä
- Alhaisemmat suunnittelu-, asennus-, ja ylläpitokustannukset vähentyneen komponenttimäärän vaikutuksesta

- Pienemmät energiakustannukset vähentyneiden kokonaishäviöiden vuoksi
- Uusi ratkaisu pohjautuu radiaalivuo-moottoriin, joka on varustettu kestopagneettimoottorilla. Lisäksi invertterissä on toteutettu synkronimoottorin säätöohjelmisto, muuttamatta nykyistä invertterilaitteistoa. Sekä moottorit, että invertterit ovat suunniteltu joko vesi- tai ilmajäähdytteisiksi. Synkronimoottori ohjattuna ABB:n Direct Torque Control (DTC) -säätötekniikalla sallii paperikoneen ajon kokonaan ilman pulssiantureiden käyttöä.

## Introduction

ABB has been delivering drive systems for paper machines for 100 years. The first system, the line shaft drive, was replaced by the DC sectional drive in the sixties. In 1983 ABB (Stromberg) was the first company to introduce the AC sectional drive for the paper industry. Today practically all new machines and most rebuilt machines are equipped with AC sectional drives.

To further increase reliability and decrease life cycle cost, ABB started to develop a new paper machine drive system in the mid 90s. The target was for a high torque

drive directly coupled to the indrive of the paper machine section, thus limiting the mechanical drive, in most cases, to the coupling between the drive motor and the paper machine section.

The first drive of this new generation was installed in a paper machine in Finland in mid 1999. The machine has been running successfully since then. The drive power is 90 kW at 234 rpm. ABB is currently replacing the mechanical gearbox with a 'virtual digital' gearbox.

January 2001 saw the second start-up using this technology for two paper ma-

chines in another Finnish mill. The start-up was trouble-free and the drives are running very well. The section powers are 37 kW and 99 kW and the corresponding speeds 600 rpm and 425 rpm.

## Customer benefits with the Direct Drive

The main benefits deriving from Direct Drive are:

- ◆ Lower plant engineering and installation costs due to fewer mechanical drive components.
- ◆ Better paper machine runnability due to the synchronous drive with minimal shaft resonance and no gear play.
- ◆ Higher availability of the paper machine due to fewer mechanical components and no pulse encoders.
- ◆ Lower maintenance costs as a result of a simpler system with fewer components and spares.
- ◆ Lower energy costs due to lower over-all losses.

With the Direct Drive, the vision for a very simple paper machine drive is now a reality.

The rebuild of a conventional ABB AC paper machine drive to a Direct Drive is very simple. The mill will need new motors for the direct driven sections. The conventional ABB ACS600 converters need to be uploaded with PM-DTC software. The new Direct Drive runs very well in parallel with existing AC or DC drives.

## The Direct Drive

In the Direct Drive the motor is directly coupled to the paper machine section with a conventional low speed coupling. The motor is a radial flux design with a permanent magnet rotor. ABB offers a series of motors of this kind for paper machines. Fig. 2 shows the powers and indrive speeds gen-



**Fig 1. Metsä-Serla, Kirkniemi Direct Drive running in a PM1 dryer section since July 1999, replaced old DC motor and gear in front.**

erally needed in a paper machine.

The drive panels consist of ABB ACS 600 converters. The hardware of the converters is the same as for conventional AC-drives and both air-cooled and water-cooled designs are available. The converter control software is designed for permanent magnet motor, which is one type of synchronous motor. Synchronous motors enable tachless operation in paper machines. The drive control system, application software and man-machine control is similar for all ABB drive solutions for paper machines. The new Direct Drive can therefore be used in parallel with other ABB drive solutions and old ACS 600 converters can easily be upgraded to the new Direct Drive.

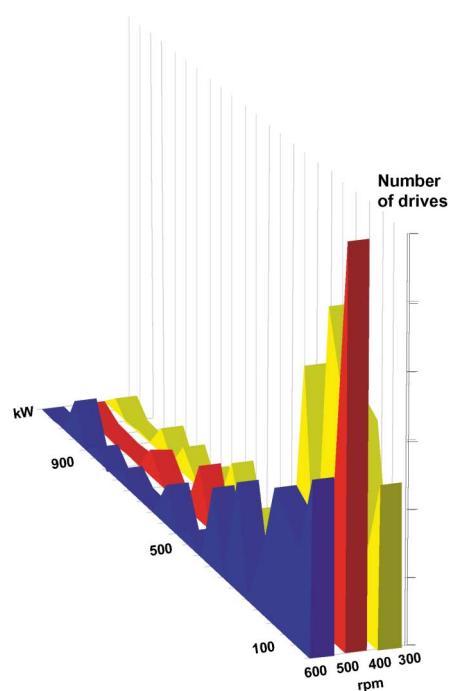
## New motor design

The geared motor speeds are normally about 1500 rpm to 1800 rpm on a conventional paper machine drive. The indrive speeds needed for the paper machine are set by selecting an appropriate gear ratio. The corresponding motor speeds with a direct drive would vary from 300 rpm to 600 rpm. Using a conventional induction motor for these speeds the motor frame would need to be at least twice the size as that for a 1500 rpm motor. This is clearly neither practical nor cost efficient, and this is one reason why the new type of motor has been developed. In this motor permanent magnets in re-shaped slots replace the squirrel cage conductors of an induction motor.

In the rotor design special attention has been paid to minimizing torque harmonics to obtain the smooth running characteristics needed in paper machine applications. Since the rotor is practically lossless, the motor can be designed for higher output power and even higher stator loss dissipation can be allowed. The active, torque producing part of the stator current can also be

increased since almost no magnetizing current component is needed as the magnetizing flux is produced by the permanent magnets in the rotor. A further increase in loadability can be achieved by using water cooling for the stator where almost all losses are produced.

The stator winding is basically the same as the winding for an induction motor, but as already stated the current loading can be considerably higher. This enables the new reduced-size motor to meet the requirements of a direct drive. Fig. 3 shows the size and weight of a conventional drive including gear and shafting and the new Direct Drive. Guards for rotating parts and other auxiliary equipment are not shown. The improvements of the new motor include almost unity power factor and high efficiency, especially when output and speed are reduced. This is of interest in paper machines where motors for many sections are sized according to the starting power re-

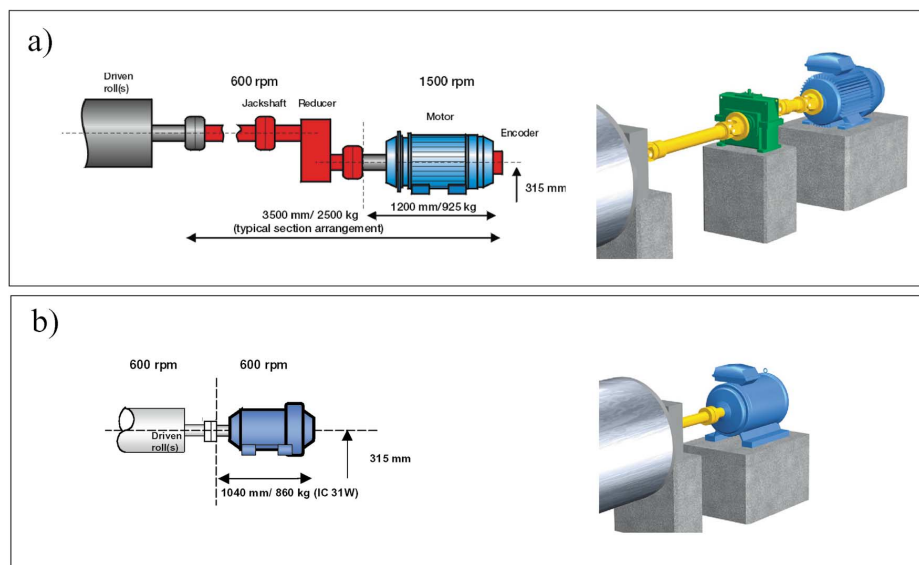


**Fig 2. Generally needed powers at low indrive speeds (300-600 rpm) in paper machine.**

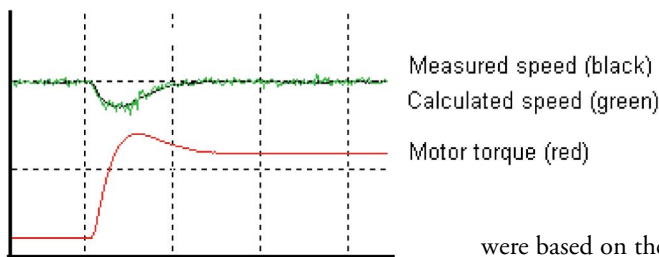
quirements and the design speed is achieved only after years of operation.

## Tachless operation

Tachos for motor speed feedback have proved to be generally reliable. However, they need regular preventive maintenance because of their permanently greased bearings. On a 50-section paper machine all tachos need replacing at certain intervals in order to prevent unexpected shutdowns, tachless operation was therefore one target in the development of the Direct Drive.



**Fig 3. Drive configurations with; a) conventional induction motor drive, gear and jackshaft, b) remarkable weight reduction with the Direct Drive.**



**Fig 4. Test of calculated speed in a dynamic load change situation.**

The real motor speed is needed both for feedback and monitoring. A method to calculate motor speed has been developed and included in the DTC motor control. Fig. 4 shows an oscillogram taken in the ABB Pulp & Paper R&D Center for a 37 kW drive. The two upper traces show the speed on the motor shaft measured with a tacho and the speed calculated by the drive. It can be seen that the two traces are identical with no deviations even during dynamic disturbances. The third trace shows the motor torque change caused by a load step. The load change is one third of the nominal load representing a big change in the motor operating conditions.

Fig. 5 shows the R&D Center equipment used for the test. High inertia is used to monitor the drive conditions on a paper machine and the tacho is of the same type normally used on paper machines.

### Evaluation of the life cycle cost savings by replacing conventional geared drives with Direct Drives

In 1996 ABB collaborated with the consulting company Ramse-Synton Oy, at that time a J. Pöyry owned enterprise, to study the savings potential from replacing a geared paper machine drive with Direct Drive. The main parts of this study are presented here. A modern, high-capacity paper machine was selected as the target for the study. The breakdown of life cycle cost savings from the customer perspective includes acquisition and ownership cost elements. The estimates

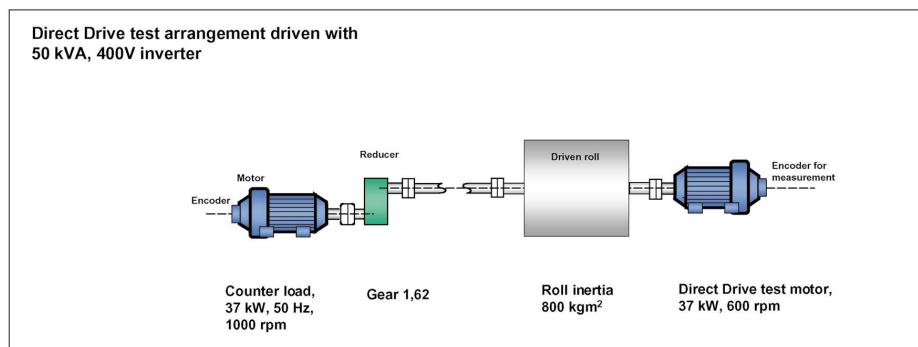
were based on the available experience and expertise of the paper industry.

The acquisition cost comprises investments in gears, couplings, accessories and spares, and accessory systems for the gears. Investments in building structures and foundations, as well as the related engineering work, also need to be taken into account. Ownership costs can be divided into operational costs, maintenance costs and costs resulting from non-availability of production capacity.

The elimination of the gear units and the dimensions of the new drives may result in savings through having smaller paper mill buildings and drive foundations. The impact on the paper machine side bay needs to be taken into account at the planning stage on a case-by-case basis. In rebuilds the removal of gears provides additional space for new equipment.

Factors affecting the side bay are the ground floor equipment arrangements, the placing of electrical rooms and other electrical and mechanical equipment, as well as the maintenance routes between them on the operating floor, and the ventilation equipment on the heat recovery floor. The indirect benefit of a more spacious working environment can be of great significance.

The outcome of the study was that the total cost savings were of the same magnitude as the cost of a new paper machine drive. About 20% of the cost savings were related to acquisition costs and 80% to ownership costs. The study also included a sensitivity analysis showing the impacts of the changes of different costs, and the components of the total life cycle cost savings. Energy costs were one of the main issues in ownership costs.



**Fig 5. Direct Drive test facility with 7 ton roll.**



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