

Smooth operation

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

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



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

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

In part one of this two-part series [1], the drive-system performance during start, operation and stop sequences for a configuration consisting of a converter transformer, an ABB ACS 6000 multi-drive MV frequency converter and one

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

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

In dual-pinion mills, the system is driven by more than one motor, which are mechanically coupled to each other to ensure load sharing. Load sharing – or the ability to maintain equal load distribution between the two motors – is necessary to minimize mechanical stresses and backlash. In the dual-pinion mill applications, the two motor shafts are relatively hard coupled via the ring gear. In larger dual-pinion ring-gear mills where the length of the pinions and ring-gear teeth is gradually becoming longer,

the perfect alignment of pinion and ring gear (and gearbox in some cases) is pivotal. However, experience has shown that this can be difficult to achieve let alone maintain. But if rough starts, torque spikes and load oscillations between the

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two motors in large mills are to be avoided, a mechanical friendly system that ensures smooth, fast and accurate load sharing during all operating conditions is required. ABB drives feature direct torque control (DTC), which ensures fast and accurate load sharing. With DTC technology load sharing can be established in different ways and the most suitable algorithm for this specific application has been selected. On the hardware side, the link between the two main drive-control boards is established using a fast fiber-optic connection.

Title picture

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

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

Start/stop sequence

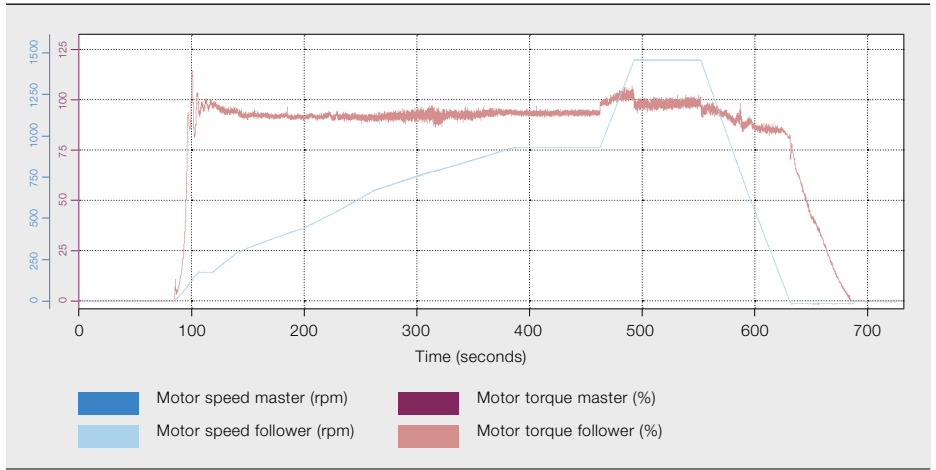
A complete start/stop sequence of a master/slave drive-system set up is shown in → 2. The measurements show the individual speed and torque signals for both asynchronous motors. The graph looks practically identical to → 3 in [1], which showed speed and torque measurements for one motor only. → 3 and → 4 show a close-up view of the start and stop (with controlled rollback) ¹ sequences respectively. Again, the indi-

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

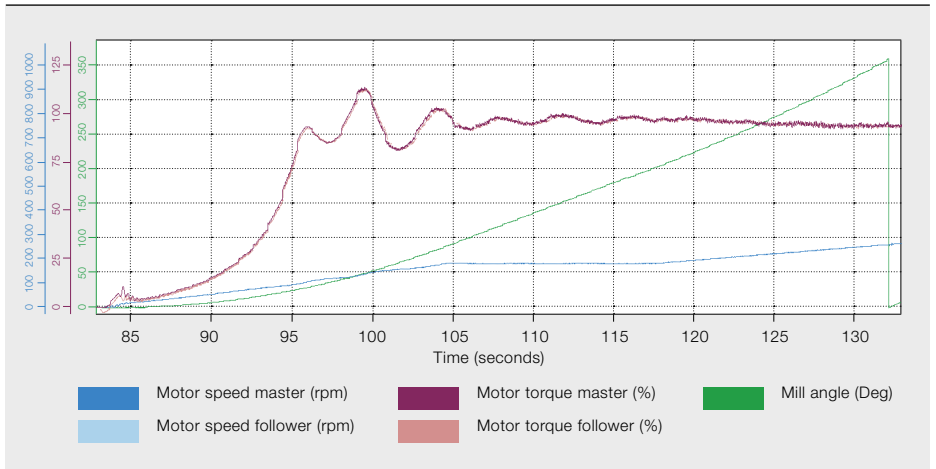
vidual speed and torque signals for both motors are almost identical to → 4 and → 6 in [1]. This clearly illustrates how accurately and smoothly the torque of one motor (slave) follows that of the other motor (master). In fact the torque difference between the two motors is well below 1 percent of nominal torque → 5! The biggest deviations, shown by the peaks in → 5 and which amount to much less than 3 percent of nominal torque, occur at the beginning of a sequence and when controlled rollback is started (at around 630 seconds), and last well under a second.

During the stop sequence with controlled rollback, the mill is ramped down until it comes to a standstill. Both motors then generate just enough positive torque to

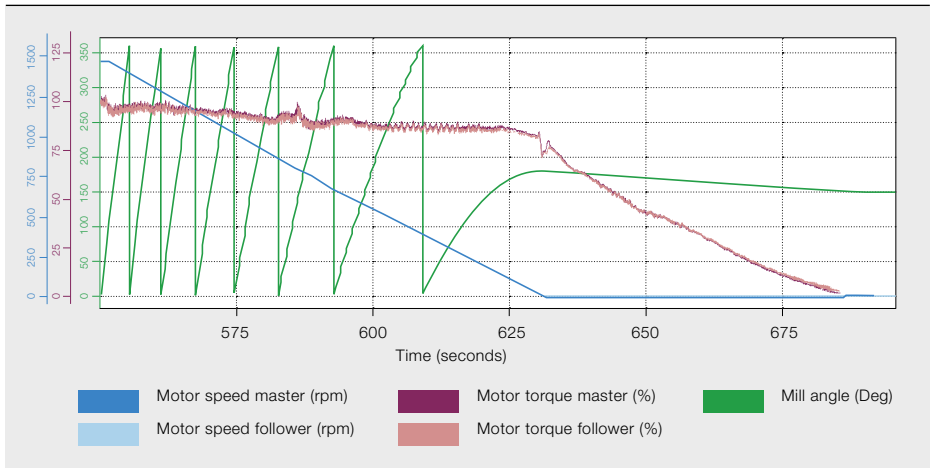
2 Master/slave drive start and stop sequence



3 A close up of the start sequence



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

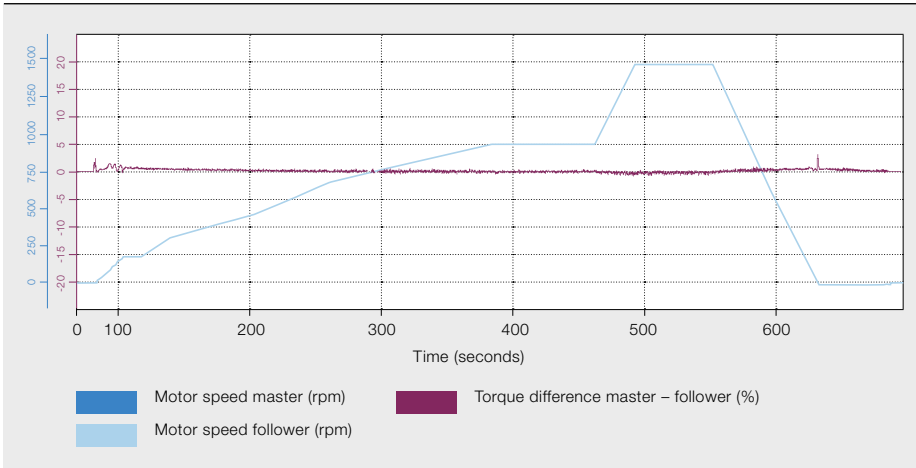


hold the mill with the charge unbalanced. By slightly reducing the torque, the mill rolls gently back until the charge is balanced. Because the torque is always positive, even when the direction of rotation of the mill changes and during controlled rollback, contact is always maintained between the teeth of the two pinions and the ring gear, thereby ensuring no backlash can occur.

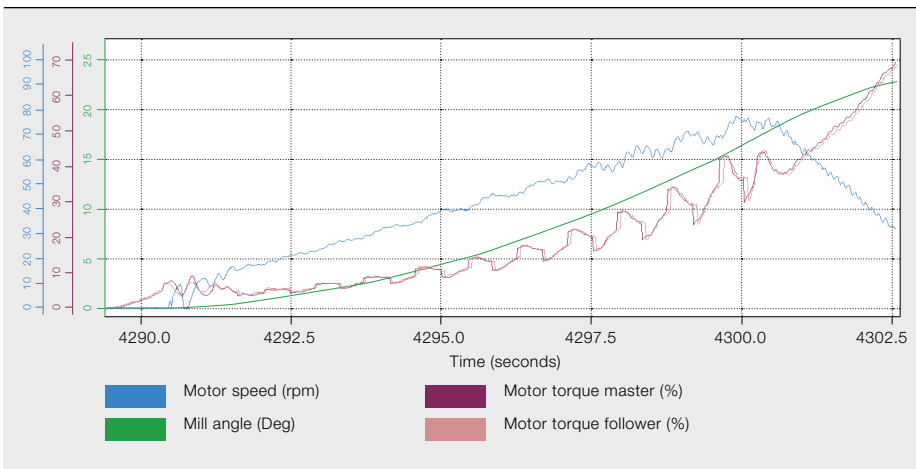
Footnote

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

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



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



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

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

Inherent features

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

Theory and practice

There is no doubt that ABB's new dedicated mill functions contribute significantly to the efficient operation and

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maintenance of grinding mills. The measurements in this article show that these functions, as part of ABB's master/slave drive system concept, are not only nice in theory – as shown in [1] – but they work with amazing accuracy in an installed and commissioned dual-pinion mill. The customer benefits not only from greater grinding flexibility but this leads to lower maintenance requirements, reduced operating costs and extended equipment lifetime.

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Footnote

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

Reference

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