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REVOLUTIONARY DRIVE CONTROLLER FOR GEARLESS MILLS

L. Bomvisinho, ABB Switzerland Ltd, Baden-Dattwil, Switzerland
P. Meier, ABB Switzerland Ltd, Baden-Dattwil, Switzerland

ABSTRACT

As a result of today's requirements for larger mills with higher power demand, and in order to cope with maximizing throughput, and optimize grinding efficiency, the minerals industry is increasingly relying on the robust Gearless Mill Drive (GMD) solution. This paper describes the new features introduced with the revolutionary ABB drive controller for Gearless Mills, and explains the benefits this can bring to the operation.

Extensive surveys have been performed with GMD users to gather suggestions and understand the market wishes. As a result the new driver controller capabilities and functionalities focus on safety, high availability, operational flexibility and remote diagnostics.

INTRODUCTION

The operation of the main mills is crucial for the production at a mine. Ball and SAG mills are one of the most expensive pieces of equipment designed without redundancy, thus they can quickly become the bottle neck of the whole process, as the productivity of the plant is dependant on the availability of the mills and their motors.

The new Gearless drive controller was developed with the aim to increase the system availability by integrating a comprehensive set of protections and diagnostic features. Its compact design, combines high performance with a series of enhanced benefits.

This paper presents a summary of new features that have been introduced with the controller, as: differential protection, frozen charge remover, power ride through, controlled roll back, rotating air gap monitoring and integrated transient recorder.

On big milling applications, mainly above 10 MW, gearless mill drives (GMD) are used.

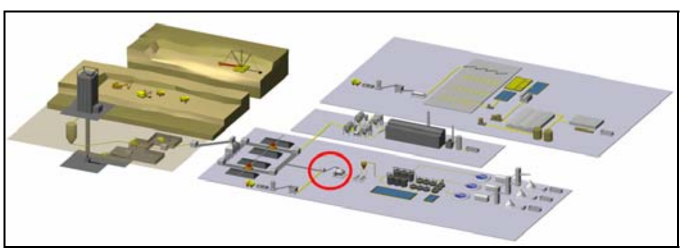

Figure 1. Mining process and Mill-Motor location in the concentrator.

A GMD is built on three major components:

- Ringmotor (Figure 2);
- Frequency converter with controller, where the frequency converter (Figure 5) has a Cycloconverter for the stator current and a DC converter for the rotor excitation; and
- Converter transformers.

The functionality of the Gearless Mill Drive System is strongly influenced by the controller. ABB Switzerland Ltd has developed the AC 800PEC hardware family. Since 2001, the AC 800PEC controller have been released and continuously improved to meet the actual market requirements by offering a very fast, reliable and precise controller with up-to-date technology. It can be found in many ABB power converters and drives, for example for power transmission, excitation systems for motors and generators, wind power applications, and since 2007 also in the Cycloconverter for the GMD. Since this year (2009), the previous controller PSR has completely been replaced by the AC 800PEC controller. There is a long list of benefits for the customer regarding reliability, availability, simplification and amount of hardware needed. Also for the testing and commissioning, the time and procedures are simplified and reduced.

Figure 2. Ringmotor of the Gearless Mill Drive (GMD) System.

CYCLOCONVERTER

Principle

The Cycloconverter is a frequency changer which converts a poly-phase voltage with the frequency **f1** into a single or poly-phase voltage with a different, lower frequency **f2**. On Gearless Mill Drives (GMD), the operational output frequency varies from 0.3 Hz up to about 6 Hz. Energy can be transferred in either direction directly without a DC link. Consequently, the Cycloconverter is classified in the group of line-commutated converters.

When the output current of a converter is controlled to obtain a sinusoidal shape with a given frequency (Figure 3), the arrangement acts as a frequency converter and is called a Cycloconverter (**n1**).

By virtue of its design, the Cycloconverter consists of reversible, usually half-suppressed thyristor converters used for years with DC drives. The basic unit is generally a three-phase bridge with which a three-phase voltage can be converted into a direct voltage. In this way, the converter output is a positive, rectified voltage in rectifier operation, or a negative, rectified voltage in inverter operation (Figure 4).

By means of phase-angle control this voltage can be continuously varied from zero to roughly the maximum phase-to-phase AC voltage, both in the positive and the negative polarity.

For more details please refer to [2].

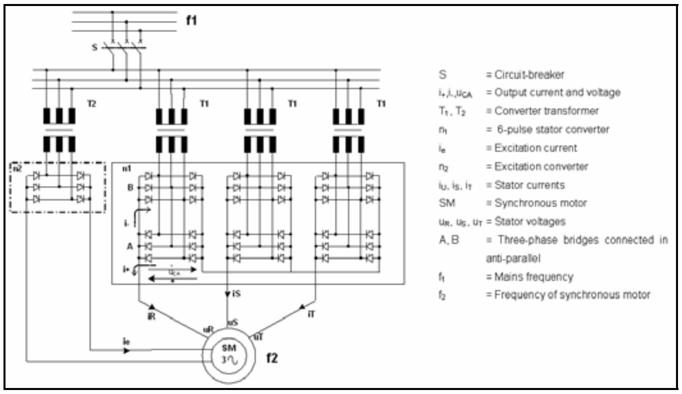

Figure 3. Principle design of a 6-pulse Cycloconverter.

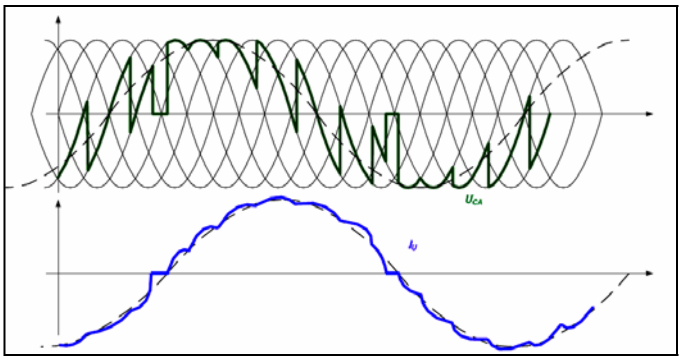

Figure 4. Cycloconverter output voltage UCA, current IU and the active B6 thyristor bridge.

Protection functions

The controller is comprised of several hardware and software protection functions to prevent the Cycloconverter, and also the Ringmotor, from sustaining any damage if any potentially harmful event should occur. The AC800PEC controlled Cycloconverter (Figure 5) features some of these new and improved functions. All the measurement equipment used for the following protection functions, such as current transducers (CT) or voltage transducers (VT) are installed inside the Cycloconverter.

Figure 5. Cycloconverter racks with AC 800PEC controller.

Differential protection for Cycloconverter

Differential protection detects phase-to-phase short-circuits inside the Cycloconverter. Each of the Converter Transformers (T1 in Figure 3) secondary currents (3-phase, 50/60Hz) is compared with the corresponding Ringmotor phase current (1-phase, 0…6Hz) (Figure 6). In case of a deviation, a fast shutdown will be executed and the system will be taken off the network.

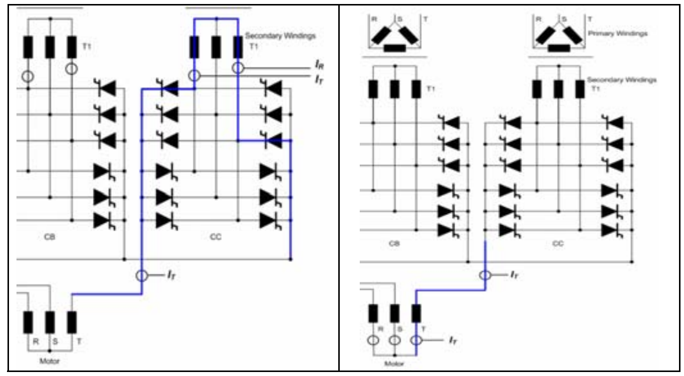

Figure 6. Differential protection of the Cycloconverter and the Ringmotor.

Overcurrent protection, incoming and outgoing side

The incoming overcurrent protection function supervises the current levels of the Converter Transformers (T1) secondary sides (50/60Hz), whereas the outgoing overcurrent protection function monitors the current levels of the Ringmotor phases (0…6Hz).

In case the levels are exceeded, a fast shutdown will be executed and the system will be taken off the network.

Overvoltage protection, incoming and outgoing side

The incoming overvoltage protection function supervises the network voltage and is used to detect exceeding voltage levels. Both the incoming and outgoing overvoltage protection is realized with additional hardware, a so-called overvoltage arrester which sends a digital signal to the controller when high voltage is detected. In case of detecting an overvoltage a fast shutdown will be executed and the system will be taken off the network.

Over/Under-frequency protection, network side

The network frequency (f1) is supervised by measuring the 3-phase network voltage (synchronization voltage) and converting it into a polar system to receive the orbiting speed which represent the frequency.

In case of exceeding the frequency band a fast shutdown will be executed and the system will be taken off the network.

Undervoltage protection, incoming side

The network voltage protection function supervises the network voltage level and detects an exceedingly low level. In case of voltages lower than the minimum threshold, a fast shutdown will be executed. If the network recovers to a normal level, in certain period of time, a start-up will proceed automatically; so-called "Power ride through". Otherwise, the system will be taken off the network.

Thyristor short circuit detection

Thyristor faults (short-circuit) are detected by the thyristor firing printed circuit board by supervision the Anode-Cathode voltage. The system compares the pulse recorded from the drive controller with actual status of each thyristor. In case of a faulty thyristor a fast shutdown will be executed and the system will be taken off the network.

RINGMOTOR

Protection functions

The Ringmotor contains several hardware and software protection functions to prevent the Ringmotor from sustaining any damage if any potentially harmful event should occur. As with the cycloconverter protection functions, some of the functions are only possible with the new AC 800 PEC controlled Cycloconverter. The measurement equipment used for the following protection functions is installed inside the Cycloconverter and the Ringmotor.

Differential protection for Ringmotor

Differential protection detects phase-to-phase short-circuits inside the Ringmotor. Each Ringmotor phase current at input connections (close to the cycloconverter), is compared with the corresponding phase current at the star-point connection (Figure 6).

In case of a deviation, a fast shutdown will be executed and the system will be disconnected from the network.

Two phase short-circuit detection, outgoing side

Depending on the Ringmotor speed, a two phase short-circuit can generate a very high current of the 2nd harmonic frequency which can be very close to the eigen-frequency of the Ringmotor stator structure and/or foundation.

In case a two phase short-circuit is detected, a fast shutdown will be executed and the system will be taken off the network. This will be followed by initiating a three phase short circuit in the Ringmotor by firing all thyristors at the same time (creating a 3-phase short circuit significantly reduces the torque produced by the Ringmotor). Please refer to Figure 7.

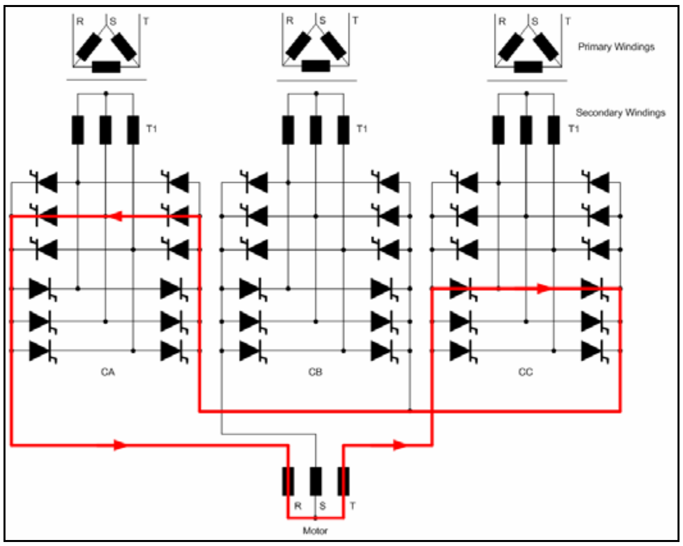

Figure 7. Two phase short circuit in Ringmotor.

Stator earth fault protection

The whole GMD system, from Converter Transformers to Ringmotor is connected to an isolated network, so one connection from phase to ground is allowed without doing any damage to the system. A second phase to ground connection would create a full short-circuit.

The high-impedance ground fault protection is able to detect an arcing earth fault by a voltage variation at the motor star point against ground. The detection of any voltage variation by the voltage protection relay is within 130ms, and will immediately open the medium voltage switchgears. By using the high-resistance grounding method, the failure current of a single earth fault will be very low and limited, and will not create unnecessary stress on the equipment of the GMD system.

Due to the redundant design of the voltage relay, the reliability of the protection is increased. This protection covers the upper 90% of the stator winding. The remaining 10% of the winding towards the motor star point are covered by the insulation measurement relay during standstill and operation.

Rotor earth fault protection

This protection function is identical to the “Stator earth fault protection”.

Frozen Charge Protection

The controller features critical monitoring during the starting period, protecting the mill against damage when dropping a frozen charge. As the loaded mill starts up, the control system evaluates torque build-up, ensuring that appropriate decisions are taken before a frozen charge can drop and damage the mill body or the mill bearings.

Air gap supervision (static - on stator and rotating - on rotor)

The Ringmotor stator is supported on the floor or on concrete pedestal and the rotor poles are mounted on the mill flange (the rotor is the mill itself). To prevent the rotor from touching the stator, the air gap level is supervised on the stator with 12 sensors mounted around the stator circumference.

With the installation of an additional sensor mounted on the rotor, it is possible to monitor the air gap around the complete circumference of the Ringmotor and display the stator and rotor air gap actual shape and magnitude (rotating air gap monitoring system). This is an additional feature that increases the reliability of the GMD system.

The sensor installed on the rotor pole for the rotating system is the identical to the one used on the static. The rotating signal is sent through a transmitter/antenna installed on the rotor cover. The rotating air gap signal conditioner and transmitter are powered by the DC supply voltage of the rotor poles. The receiver is installed outside on the stator frame.

In the case of detecting a low air gap, a fast shutdown will be executed and the mechanical brake of the mill will be applied.

AC 800PEC CONTROLLER

AC 800PEC stands not only for a controller but for a family of various hardware components designed for converter control, containing the controller PEC800, I/Os, firing cards, etc.

Technical data

The CPU is based on a PowerPC 750FX with 64-bit RISC processor. A 16 MB non-volatile Flash memory is used to store programs and data; a 64 MB SDRAM with clock frequency is used to operate programs. For communication, a series of interfaces are a available, e.g. two 10/100Base-TX Ethernet links, one RS-232 interface used for service purposes, two 3rd parties interfaces or custom modules and up to six optical modules, each supporting six bidirectional optical links used for fast communication with external hardware.

Hardware Platform benefits

New benefits can be achieved by using the AC 800PEC hardware platform. Not only the up-to-date technology and the powerful controller, but also new components and increased resistance against environmental distortion mean a much more reliable and high performance system.

Transient Recorder

The transient recorder is integrated in the AC 800PEC controller and is used to record various signals with high sample rate in case of any eventual malfunction of the Cycloconverter. It supports the maintenance personnel by remarkably reducing time during fault tracing and by helping such personnel to take the right action. Up to 74 different signals are recorded continuously and stored on the flash memory in case of a fault. The stored signals can be displayed (Figure 8) on the Control Terminal.

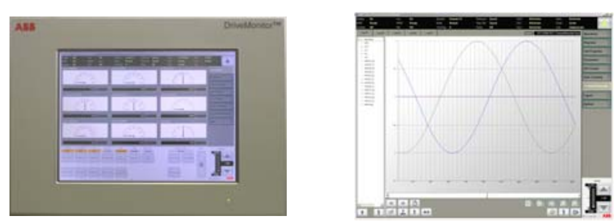

Figure 1. AC800PEC - Control Terminal and Transient Recorder display.

Control Terminal

A touch screen industrial PC (Figure 8), based on MS-Windows, is installed for local control of the GMD. It displays command buttons for maintenance and parameter settings, status indication and analogue values, a graphical single line, water cooling system and air gap supervision diagrams, the alarm and fault list, slow signal trending and transient recorder.

Optical fiber interconnection and thyristor firing system

Connection to and from the AC 800PEC controller is realized by optical fiber. This has the advantage of less cabling, therefore reduced sources of error and a better overview for fault tracing. Due to optical thyristor firing, the power part of the Cycloconverter is totally galvanically isolated from the control part. Additionally it makes the whole GMD system more resistant to any electromagnetic interference (EMI) from the environment.

GMD CONTROL

Control overview

The implemented control is state of the art for synchronous motors with flux, speed, current and excitation current controllers (Figure 9). In this particular case the actual speed is not measured by sensors, it is calculated from the flux, as integrated Ringmotor voltage.

For high accuracy and fast reaction, the control is implemented in a level of the controller with fast cycle time.

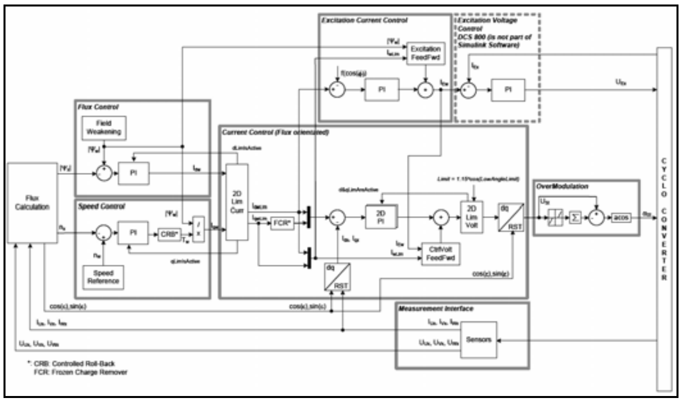

Figure 9. AC800PEC-Control Structure in brief.

New Control functions

The new control features are of high importance for production, mill operators and maintenance personal. Maintenance procedures are simplified and downtimes are shorter. Precise positioning of the mill minimizes the time required for changing liners and controlled rollback reduces time to restart the mill. In case a frozen charge occurs inside the mill, it can be easily removed without digging out the material of the mill.

The major function increasing the mill availability is essentially the "power ride through" of network undervoltage.

Power ride through

If the supply voltage to the frequency converter disappears or has disturbances, the drive may continue to run without external power supply, utilizing the kinetic energy of the rotating motor and driven equipment. The power loss ride-through time depends on the relationship between the load and the inertia of the rotating mass.

If the main power supply voltage drops below 85% of nominal (default setting) or a phase angle deviation is detected, the main power ride-through function will be activated (if enabled by parameter setting). The maximum allowed duration of the power ride through is settable from 0 to 1s, default is 200ms. In this time span the rotating mass of the mill load and the rotor inertia must keep the mill running forward. Power ride through is only active in normal operation, and not active in creeping & inching mode.

"RideThrough" immediately ramps down the stator current to zero, followed by thyristor pulse blocking. In case the supply voltage recovers (from undervoltage and/or angle deviation) within 200ms, and the mill speed is still above a certain level, the thyristor pulses will be released again while the mill is still turning. The mill speed will be slowly ramped up to the previous speed reference. If the supply voltage does not recover within 200ms or the mill speed drops below a certain level, a fast shutdown will be executed and the system taken off the network.

This is a very important feature for the mining industry, since most of installations are in remote areas subjected to frequent network variations.

Controlled Roll Back

Controlled Roll Back reduces heavy rocking of the mill when stopping the system with a normal stop. The mill will slow down to almost zero speed and remain there for a predefined time. When this condition is reached, the actual torque will be sampled and held, and will then be ramped down to zero.

Frozen Charge Remover

If the load of the mill is frozen and got stuck to the mill shell, the Frozen Charge Remover function can help to break up the solidified charge and to loosen it from the mill body.

Remote Diagnostic

ABB specialist's support, by remote access, can be provided through a secure internet connection. This allows fast access to check drive status from any global location. This supports site maintenance personnel during service and trouble-shooting and minimizes downtime and production losses.

CONCLUSION

This paper has shown that modern protection systems are able to prevent many damages that could occur if harmful events take place. This is especially important because GMD systems are usually installed in remote areas with less stable network boundary conditions. Further functionalities can increase reliability and availability to make the mills more productive and efficient.

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