ABB's new Gearless Mill Drive generation: Maintenance-friendly features raise availability and productivity

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ABSTRACT

This paper presents modifications made to the motor design and concentrates on those points that have reduced, simplified and shortened the motor maintenance such that motor maintenance is easily combined with other service activities. The success of the rapidly evolving solid gearless mill drive (GMD) services - as is being demonstrated at the Yanacocha mine - is emerging. The Yanacocha mine is now enjoying lower shut-down times and higher plant availability figures than ever before.

A service-devoted portfolio with a dedicated service organization has been incrementally put into place over recent years. The new approaches and technology incorporate the many well-proven GMD services gained from decades of development and operation. The service portfolio constitutes a very solid, comprehensive set of cutting-edge GMD services. Each portfolio pillar – life-cycle management, maintenance services, spare part services, remote services, training services and special service projects – combines multiple services of varying customer and ABB involvement.

Such advances can only be made when customer and supplier closely cooperate and contribute the technology and operating knowledge that both possess. The synergies deliver the highest productivity and availability.

ABB critically examines behaviour and practices, performs intense root cause analysis and makes modifications without exception to components that exhibit improvement potential. The new generation of GMD, first installed 4 years ago, operates very successfully today. The maintenance-friendly features deliver significant operating results. Remote monitoring tools are used to anticipate and predict possible malfunctioning/failures in the GMD at an early stage. Effective inputs are generated to plan longer term maintenance work accordingly.

INTRODUCTION

New design features

The gearless mill drive (GMD) has been continuously developed since its introduction in 1969. The structural design, the electrical parts and of course motor monitoring and control have all experienced major developments that have enabled larger, more efficient operations and higher productivity.

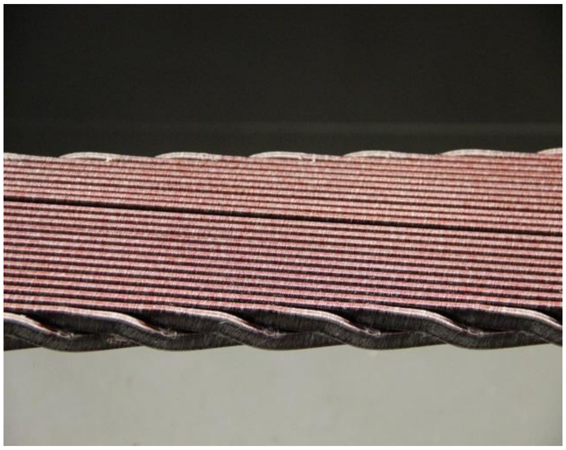
The continuous improvements and stream of service-related features being built into the new generation of GMDs reduce maintenance actions and result in execution of the necessary work in less time. Indeed, ABB's goal is to confine any service activity to 24h or less. This increases the mine productivity even further. Planning of the service work in advance is a cirtical goal, so recent improvements in monitoring and motor control are now providing more information to considerably enhance the planning of service stops.

More recent ABB developments on the core equipment are vital to the future success of GMDs. Particular focus has been given to the winding insulation, core pressing, access inside the motor and the cooling system.

Insulation

The core of an electrical motor is its electrical winding. The new GMD generation uses a full Vacuum Pressure Impregnation (VPI) insulation system since its introduction to GMDs in 2007.

The winding consists of a bar winding with individually insulated strands (*Figure 1*) that are intertwined ("Roebeled") to use the entire copper cross-section almost evenly while reducing losses and lowering eddy currents. These strands are packed in a Mica-based VPI insulation. Each bar is first put in a vacuum and then immerged in pressurized resin to guarantee a void-free insulation system without internal partial discharge. It is this internal partial discharge that is the origin of electro-corrosion. This corrosion becomes very aggressive at high operational altitudes. The whole stator bar is "VPIed" including the slot section and the winding overhang.



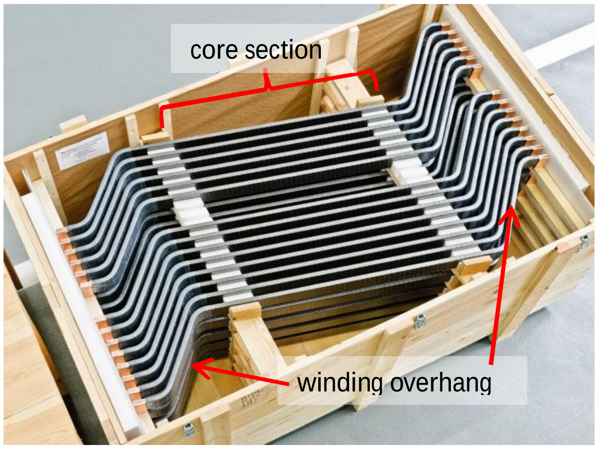


Figure 1 Intertwined "Roebeled " bar with transposed strands and full VPI bar

Core pressing

The stator core consists of a pack of stacked core sheets that are clamped together by a multitude of bolts. The core has the tendency to "settle" during the first months of operation. Consequently, the core bolts have to be retightened regularly at the beginning of the machine's operational life. Thereafter the bolts are checked generally every second year of operation.

When designing a bolt connection, it is required that the connection is dimensioned with an elastic elongation in the region of 1 mm according to text books and design guidelines like the VDI (The Association of German Engineers) guideline 2230. This ensures that the nut does not loosen as a consequence of operational load cycles.

In practice the core bolts elongate more than 1 mm, so further spring washers have been introduced to increase the elastic length of the core bolt connection. This design feature (*Figure 2*) helps to reduce the retightening work required at the beginning of the operational life of a GMD to a minimum. The re-tightening statistics confirm that the core "settles". The first re-tightening after about six months of operation (*Figure* 2) is generally about 60 degrees on average, corresponding to 1/6 of a turn. This reduces further with time as the statistic illustrates.

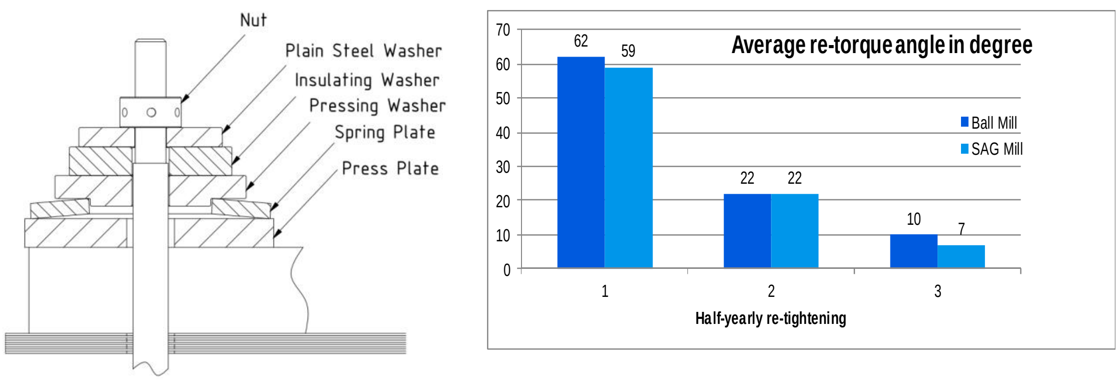


Figure 2 Core pressing system with spring plate/washer and re-tightening statistics in a typical installation

Access to the inside of the motor and the cooling system

The easier the access to the inside of the motor is, the more convenient and efficient is the work on the motor.

The motor has to be disconnected from the power supply by opening the knife switch prior to opening and entering the motor for service work. Top covers and the lower access points are opened to accelerate the motor cool down and to help vent any fumes that might have accumulated in the motor. The motor access points have hinged doors to facilitate access to the cooler boxes below and motors are equipped with fixed ladders for a rapid and safe access inside the machine (Figure 3).

Figure 3 Access door and ladders inside the motor

ABB GMD MAINTENANCE

A comparison of the current GMD maintenance manual with the manuals from the preceding generation can give the impression that more maintenance is needed nowadays. This impression is actually misleading. The difference is in the depth of detail with which the maintenance procedures are described and this is good evidence of the progress made in GMD maintenance generally with the new generation.

The manuals contain the maintenance guidelines. Just how the maintenance work is carried out and to which level of detail is strongly dependent on the maintenance management and staff. They know best what has to be done and how, based on their experience and the guidelines. For instance, the maintenance instruction says that the bolts have to be checked and eventually tightened. If in previous maintenance work the tightness of the bolts was checked and only some were slack, it would be practical to only check the bolt tightness in some key areas. If none were found to be slack, then one can expect that the others are behaving similarly.

There remain however sacrosanct rules that have to be followed precisely regardless of which GMD drive generation is installed, for instance: prohibition of unauthorized modification; trained maintenance staff; no compromises on safety for whatever reason; constant availability of tools and spares.

Less maintenance and checks due to the developed and implemented smart measuring, visualization and monitoring systems

In general much more smart monitoring equipment is applied in the new generation of GMDs to reveal deviations and abnormalities that arise in the motor, E-house and associated equipment. The condition is displayed on the operator screens. Consequently, experienced operators are informed long before any automatic alarms and trips are activated.

The number of probes has been drastically increased to permit more detail monitoring of the motor's condition.

New supervision systems and concepts now available include a completely independent rotating air gap supervision that cross-checks the air gap from a rotating sensor installed on the rotor. This has made the air gap information absolutely reliable. The additional static air gap supervision operates autonomously and has proven to be very reliable.

Rotor pole temperature and magnetic flux monitoring transmits via radio signals online and qualifies today as best practice. The necessity to check these parameters manually has been significantly reduced.

An example of what is possible today with the remote access

An excellent example is what happened during a routine remote connection to a plant site to check the GMD condition. The plant was in the normal operating condition. The remote examination of the air gap measurement signal identified an irregularity on pole #20 (*Figure 4*).

The irregularity was analysed via ABB's remote motor access and the analysis of problem sent immediately to the customer. The diagnosis was that a 4 mm-sized object was possibly stuck on pole #20. The customer checked the area of pole #20 and found the foreign object (*Figure 5*).

The object was removed and the problem logged-in as solved in a few hours without any harm to the equipment. A detailed investigation revealed that the source of the foreign object was not the ring motor itself. Therefore, the danger of any further damage can be ruled out.

This example illustrates well the role of supporting tools for the maintenance of GMDs. The aim of the supporting tool is first to detect at an early stage a possible failure/malfunction that could become later the cause of an undesired and/or unscheduled stop in the production process.

The idea behind remote diagnostics is not to calm the fear that something is going wrong but more to confirm that nothing is wrong - like with a car: You check the level of the oil in the motor not because you believe it could be low but to be confirmed that the level of the oil is in a normal range.

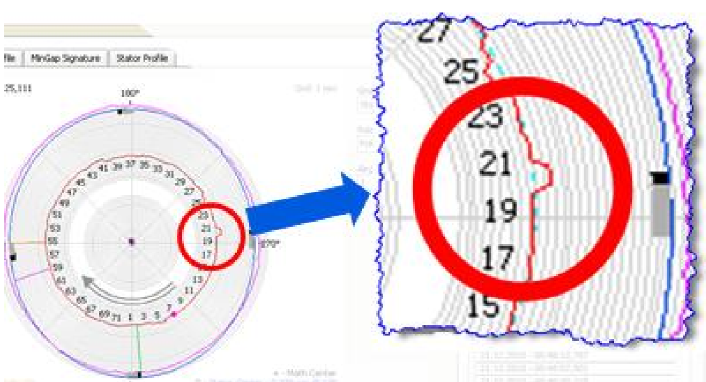


Figure 4 Air gap measurement

The plant was in normal operating condition while on pole #20 some irregularity was found

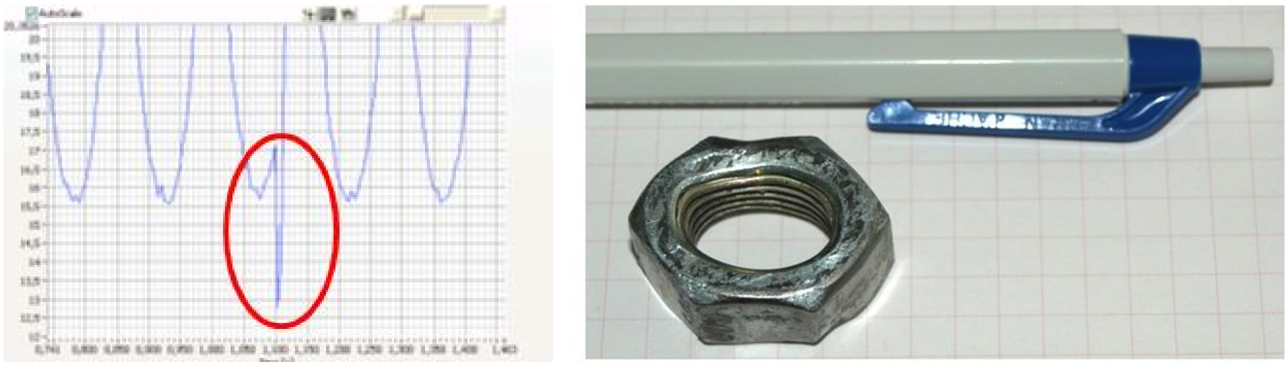


Figure 5 Air gap measurenment in detail and root cause of the problem

Best practice GMD maintenance procedure

Over the years best practices have evolved for GMD maintenance procedures. Typically inspections, tests, adjustments and replacement of parts subject to wear characterize maintenance procedures. These activities are scheduled activities. They can be performed by the end user or the supplier.

Table 1 Typical inspection activities for a motor depending on the motor model

Stator	Foundation bolts, anchoring bolts, joining bolts, humidity detector, make-up fan, space heater, sealing, skate roller Air filter
Stator core	Visual inspection Core bolts
Stator winding	Wedging for winding, recondition work, WIDIPRO Winding RTD Air gap probes
Slip rings and brushes	Slip rings, cleaning brush mechanisms Wearing of the brushes Brush changes
Ventilation and cooling system	Motor fans, heat exchanger, water flow meter, water leakage detector, air and water RTD
Rotor pole	Visual check, axial position (magnetic centering), rotor winding
Cleanness	Cleaning from dust and dirt inside and outside the motor

One such best practice is the monthly inspection. This is executed generally by the end user with other activities executed by the equipment supplier and their professional staff. Naturally other maintenance sharing models can be agreed and contractually arranged.

One month is just one time frame for maintenance. Further examples exist for other maintenance timing such as the 6, 12 and 36 month services defined in the maintenance manual. The frequency of maintenance is proposed in the manuals and can be adapted. For instance, longer or shorter periods can be decided upon depending on the experience of the operators or other factors. These factors can be new findings related to dust pollution, re-defining of needs for activities in general, etc. Automatic tracking of information in the electrical, mechanical or operational field are in place and are used to justify an adaptive maintenance program.

In addition, the maintenance procedure list defines which kind of trained specialist is entitled to perform the work. The execution is either planned by the plant maintenance staff or the equipment supplier staff. Many of these activities can be combined with other work at the mill so that no extra burden to productivity goals exists.

THE CUSTOMER'S VIEW AND EXPERIENCE OF MAINTENANCE ON THE NEW GENERATION OF GMD'S AT THE YANACOCHA MINE

History

The installation of the 650 t/h plant was commissioned early in 2008 and successfully ramped up to full production. The gold mill plant processes oxide minerals from its La Quinua open-pit mine and produces more than 50% of the gold production of Yanacocha, Peru.

The Process Maintenance Department takes care of the GMD since its installation using reliability centred maintenance (RCM) concepts as a key strategy. GMD equipment inspections have helped the company achieve high availability, a good record and excellent productions levels. The various types and scopes of the maintenance activities are performed by trained engineers and technicians. Inspections are one crucial aspect - as are corrective maintenance planning, preventive maintenance and safety

GMD preventive maintenance plan - Inspections

Regular inspections of the electrical connections are key factors for good performance. Every inspection point is tagged in the field (stickers)for future logging. The registering of these points is most important.

The monthly or bi-monthly mill shutdowns are the perfect opportunity to perform these inspections.

The ERP system (Ellipse) is used to register all the details after the inspections. The registered information is a reference for next activities and every activity is registered with work orders.

GMD corrective maintenance plan - Carbon brushes, stator and cooling system

The carbon brushes are usually inspected monthly. The slip ring conditions define the life of the carbons.

In 2009, different slip ring levels were resulting in the breakage of the carbon contact surface. The problem required a re-adjustment of the slip ring levels and could be resolved.

The level of the mill must be measured each year and the ground level recorded. This information forewarns the occurrence of any misalignments.

The cooling water temperature is usually 10°C. Water condensation was found inside the cyclo converter during a shutdown. Two pneumatic closing valves were installed in the water loop. These valves are now automatically closed if the mill stops. Problem solved.

GMD MBC maintenance plan – Windows for thermal inspection

Rotor and stator knife switches have inspection windows for online monitoring with conventional thermal cameras. The thermal monitoring helps avoid losing connections and prevent severe damage in the system. The original plastic windows do not allow the thermal pictures.

Yanacocha applies its "maintenance based on condition" (MBC) techniques and detected a miss connection in the cyclo converter 24 VDC power supply. This condition was corrected during the programmed shutdown. Those inspections can avoid electrical failures and prevent severe damages in the system. Periodic inspections are completed during normal operation of the system.

GMD preventative maintenance – wireless temperature monitor

Overheating conditions were detected in the rotor. A wireless temperature monitor system was installed to gather information on the causes. The precise conditions for the high temperature were detected.

A significant change in the original logic was completed in coordination with ABB and tested. The overheating case is now safeguarded with an interlock in the GMD and the supervisory control system. The future GMD at Yanacocha will have the same setup.

Other GMD-related best practices – Safety

Safety is an important part of availability. Should an accident occur, then the plant could be shut down for days until investigation of the accident are finished. In this context safety clearly has a potentially large influence on availability and productivity.

Safety signals can avoid personal injuries. For instance, the main access doors for the e-house now have warning signals for safety alerts and risk warnings. Safety national laws are fulfilled. During maintenance lock-out, tag out-points (LOTO) were identified. The break system is one of the main LOTO points and the operators and electricians are aware of that.

The original design does not consider personal access for GMD inspection windows. Those installations help the maintenance people during regular inspections. This practice should be considered as part of the original project.

A further safety point is exemplary. It is important to lock out the knife switches when they are open or closed. Periodically the magnetic package is inspected and adjusted. A report of the inspection is kept.

GMD availability – plant availability

Table 2 GMD and plant availability figures in 2011 and 2012 (4 months), Yanacocha plant, Peru (*Source: Yanacocha*)

2011

GMD availability	99.97%	
Plant availability	94.86%	
Detail breakdown:	Hours	Remarks
Shutdowns due to operations	62.35	
Shutdowns due to power supply	59.91	
Shutdowns due to mechanical maintenance	308.34	Includes liner changes
Shutdowns due to electrical issues	18.52	
due to electrical and instrumentation issues	16.42	
due to GMD Communications, Fan failure, Ground failure, bad signal, High temperature e-house (A/C), Unknown failure	2.10	availability 99.97%

2012

GMD availability	99.99%	4 months
Plant availability	97.22%	
Detail breakdown:	Hours	Remarks
Shutdowns due to operations	20.97	
Shutdowns due to power supply	3.77	
Shutdowns due to mechanical maintenance	53.42	Includes liner changes
Shutdowns due to electrical issues	2.47	
Due to electrical and instrumentation issues	2.10	
Due to GMD	0.37	availability 99.99%

GMD Future actions – 2012-2013-2014 action plan

ABB maintenance contract

Yanacocha and ABB are in the process of concluding a maintenance contract for the next three years. The scope includes the execution of additional specialized inspections (DIRIS[1]) and other services solely focussed on maintaining the already high availability and improving wherever possible while extending the operations lifetime projected until 2020.

Remote monitoring

The ABB DriveMonitor has been purchased and is currently being installed. This device has the ability to access remotely the condition monitor of the electrical and electronic system during operations. The "status report" is issued by ABB with a complete report of conditions.

A/C e-house system

The air conditioning system will be replaced during 2013. Current spare parts are different to those in the plant. After the modifications there will be three units with a high level of local support and better availability due to the standardization of units.

UPS for VMS and TR

The UPS was updated in 2008. The local support for the specific brand is no longer available in Peru. The type will be changed and the brand standardized.

CONCLUSION

The new generation of GMDs from ABB needs definitely less maintenance compared to past generations.

This positive development is based on several facts. The elimination of weaknesses in the winding insulation system in GMDs operating at high altitude is one such key source achieved through the use of VPI-insulated windings. Other sources are i) the improved stacking compression for the stator core, ii) the improved wedging system with the use of ripple springs, iii) the more balanced cooling and the better thermal distribution of heat inside the stator core due to the change from radial to axial cooling, iv) the significant increase in sensors to automatically check online the behaviour of the motor, and v) the use of new sensors with their associated sensor technologies to drastically reduce the need for visual checks generally and, specifically, for checks of vital conditions and functions in the stopped, safe-mode motor condition.

Remote diagnostic tools have now shown that upcoming failure/malfunctions can be detected long before they harm the GMD and cause unscheduled downtime. The analysing software in the control and monitoring systems is capable of locating possible malfunctions fast and prolong valuable productive operations time.

[1] DIRIS is a registered name used in conjunction with DIRIS Air gap Robot – Diagnostic Inspection