2007 SME ANNUAL MEETING
FEBRUARY 25-28, 2007, DENVER, CO

REFIT OF AN ELECTRIC SHOVEL OR DRAGLINE - A COST SAVING ALTERNATIVE BETWEEN FREQUENT REPAIRS AND THE PURCHASE OF A NEW MACHINE

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Introduction

Many mining operations have gained an impressive expertise in trouble shooting and maintenance with their existing fleet over the years. Whether it is an in-house maintenance group or an external service group - most of the systems weak points are well known and can be corrected by maintenance personnel. As some of these issues get more and more serious each year, too much time is lost in unscheduled downtime, often taking hours to be repaired and to find the failure with obsolete diagnostic tools.

Figure 1: First shovel with ABB LV AC Drives in Mexico, 1999

Many of the breakdowns result from failures that cannot be detected in advance. The maintenance system is much more reactive than preventative. The state of the art of mining equipment today uses advanced, efficient, and reliable systems for electrical drives, control and diagnostics of the machines.
The demand for highly sophisticated solutions on such mining equipment is well known. Mining operators need to ensure the highest level of productivity, lowest operating costs, least maintenance and highest reliability in a drive system.

The paper will introduce you to the state of the art of drives technology for shovel and dragline mining equipment.

Figure 2: Modernization of the Mechanical and Electrical equipment of the Dragline Type 15/90 in Estonia, 2005

Figure 3: Refit of the Shovel BE295 BIII with ABB AC Drives for Mining in Brazil, 2006

AC Drive System

Advanced Performance

In open pit mining there has been a tendency toward AC technology instead of conventional DC technology last 20 years. The arguments for AC Drives solution are various. It is well known that the AC Motor is more robust and requires less maintenance without need of brushes or commentator. At the same time frequency converter based solutions enable an comparable, or even better dynamic behavior than achievable with DC systems. The AC motor is totally enclosed and can be used with a separately driven axial mounted fan. For some motions, (swing, propel) no encoder feedback necessary. The ABB DTC (Direct Torque Control) Drive has the highest accuracy available on the market. The DTC motor model runs with a cycle time of 25µs which allows it to operate with a high level of torque dynamics.

ABB has developed a Drives for Mining version for the frequency converter ACS800 Multidrive. This version is modified for heavy vibration and shock loads which are experienced in Mining applications. Based on the well proven standard ABB ACS800 industrial drive, the Drives for Mining version has around 20 single adaptations which are changes to the cubicle design needed to withstand the specific requirements regarding shock and vibration normally encountered in an open pit mining applications.

LV IGBT Multidrive Converter Solution

AC drives with IGBT frequency converters and squirrel-cage motors meet the system requirements optimum efficiency and reliability. The Low voltage range of ABB Drives up to a single power of 5400 kVA covers all sizes of motions of a shovel or dragline applications encountered to date.

The ACS 800 multidrive has a common bus bar connection to all motor inverters at the same DC circuit, allowing energy equalization between the individual drives. All drives are fed by a common supply unit that can be effectively designed for the needed average energy to the drives.

Regenerative Line Supply Unit

Highest efficiency, low line harmonics ("green network") and reliable operation are issues in weak mining power supply grids. The IGBT Supply Unit (ISU), is an active rectifier and the best solution for such conditions:

- Almost sinusoidal AC current, much lower line harmonics
- Safe switch off in case of power cut
- Network re-generation of braking power, thus energy saving
- ISU can clear -30% line voltage drop, without under voltage problems
- Fast, linear and smooth motoring-generating-motoring transitions
- Power factor is always ~ 1.

Modular system, higher reliability and better service

The fully digital frequency converter and its control system ensure highly reliable operation. The modular design of the hardware and the IGBT power semiconductors allow quick and easy replacement. The structure of the module is designed as a 3 phase unit which has benefit to operate with part load depending on the number of modules. Standardized 3 phase power modules R8 are used over the complete power range. The modules are interchangeable between inverter and supply unit power ratings.

The motor control software ensures the various hardware-protective functions. The control hardware is also interchangeable between the power ranges. Control components are located in separate "Drive Control Unit" cabinets to specifically protect them from dust and moisture.

ABBs Drives for Mining

Development

To ensure the highest requirements regarding the reliability for shovel and dragline drive applications it is necessary to modify the standard frequency converter for the harsh environmental conditions. This is the reason that ABB has investigated the design of the converter cubicles concerning the specific shock and vibration conditions in open pit hard rock mining.

Based on different measurements in various shovel and dragline machines, ABB and a specialized aerospace consultant, Wölfel (1), developed an excitation spectrum which represents all typical shock and vibration loads. After the evaluation of the test spectrum, an ACS800 multidrive test unit has been simulated as a model in detail. The overall mechanical parts such as frame profiles, bolts, sheets and drive modules were simulated in 3D model to investigate weak structures and components. After some findings during different simulation runs the test unit was modified accordingly.

	Resonance Search	Vibration test	Shock test	Vibration test
Excitation	Sinusoidal	Sinusoidal	Half Sinusoidal	Sinusoidal
Frequency range	4 – 100Hz	4 –100Hz		5 – 50Hz
Frequency range	1 oct./min	1 oct./min	-	1 oct./min
Acceleration	0,15g	0,5g/0,7g/1,0g	5g (10g)	0,5g/0,7g
Spectrum		4 – 11Hz / 13,4-50Hz / 51 – 100Hz	3 Shocks / Axis	4 – 11Hz / 13,4-50Hz
Duration			16ms	2h
Axis	1	3	3	3

Figure 4: Performed test runs

The test unit consisted of an ISU (IGBT Supply Unit) with 2 x R8i inverter modules which has been tested at IABG 300kN test facilities in Germany. The performance test started with resonance search, thereafter vibration test and shock test has been executed.

All tests have been performed while the drives were in operation. At the DC bus was an ACS800 single drive connected to a load, which was running the entire testing time without any disturbances.

The test cubicle withstood all planned sine sweep tests according to the design spectrum, as well as 10g shock in vertical direction, and 5g shock test in horizontal direction.

Additionally performed was an endurance test which had 5 cycles (5hz – 50Hz - 5Hz) and exposed one weak item, but also demonstrated the stability of the drive system, especially the robust module design.

Figure 5: Shaking table and test unit, Munich, 2005

Equipment Reliability

Shovel or dragline availability is the most important figure for the output of the machine. But the machines have substantial mechanical systems and parts, as well as a more or less complex electrical system. Most mining operations do not differentiate the figures to evaluate mechanical or electrical systems separately and hesitant in providing this type of data to external partners. That is why we would like to focus on the main electrical system, the drives system.

The availability is defined by A=MTBF/MTBF+MTTR. Because of the relevance of the availability for the every day business the MTBF (Mean Time between Failures) and MTTR (Mean Time to Repair / Restore) are certain criteria

to evaluate quality and reliability of the drives system. Today it may also be common to measure the MTBF and MTRR of the manufactured products in comparison. These figures depend mainly on the number of produced units and reported or recorded failures, and also depend upon the longevity of the product line. This means that a new product line, with a low number of units produced may have a higher failure rate. The ACS800 multidrive has been on the market two years with the ramp-up period included. Therefore it is remarkable that the ACS 800 could reach the following levels of availability:

MTBF ACS800 multidrive: 38.1 years, 4183 delivered units (data 08/2005)
MTTR ACS800 Module R8i: 35min

MTTR is the expectation of time interval during which an item is in a down state due failure. This characteristic mainly depends on the maintenance logistic. In mining, regularly the customer would get a spare part package with complete drive modules. Because the module exchange is the easiest and fastest service, it is with this reason that we have to consider the repair time of the exchanged module which is mentioned above.

The latest application of a shovel with the new ACS800 Drives for Mining is running since July 2006 and could be improved in the availability of machine from 70% in average to 87% in the first month. The responsible maintenance manager with CVRD was glad to notify that the AC drives retrofit shovel has achieved over 92% availability after 3 month. On the mechanical side the existing gears has been used but they are protected by special drives software, which is reducing backlash and the peak overload during breakaway torque and dynamic process of the shovel motions.

Productivity and Energy Efficiency

Drives Concepts
There are different methods to operate electric shovels and draglines. Most shovels today have a DC converter drives system. With draglines the majority has a DC MG-Set solution for all the main drives and is working with DC motors. A certain number of shovels have also AC drives of various types with different frequency converter technologies. Therefore we have to consider 4 different main drive system technologies.

- AC / DC Motor Generator Set (MG-Set)
- DC converters with RPC
- AC Frequency converter with brake chopper
- AC Frequency converter with active rectifier

Energy Consumption
All these technologies have advantages and disadvantages, but it has become more and more relevant to focus to the energy efficiency and in that respect the technologies have significant differences. For example between the MG-set solution and AC drives, there is potential savings on the order of 30% less energy consumption.

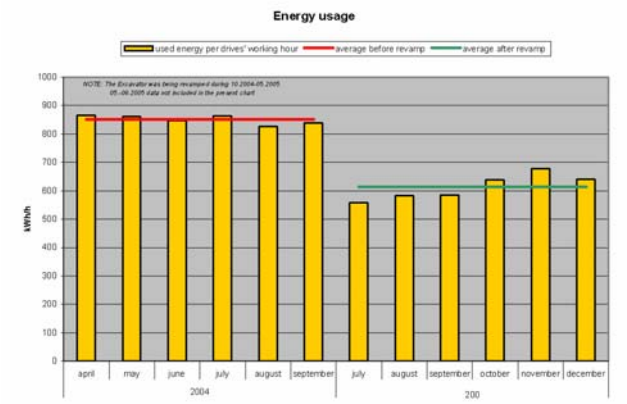

Figure 6: Energy consumption of Dragline Esch 15/90 No.83 with ABB AC Drives

ABB has investigated specific production data from dragline applications with AC Drives in comparison to the former MG-set solution. The figure 4 shows one dragline before and after a retrofit with AC Drives. The reason for the difference in energy consumption is due to the fact the MG-sets are running all the time. If there is a minor failure, short stop or shift change the AC Drive will be stopped, as well as in any case of down-time. The machine is mechanically the same and compared under similar working conditions and within the same seasonal time period of July, August and September.

Productivity Increase
The dragline machine was also improved regarding its dynamic behavior and overall productivity. We have slightly better ramp profiles for swing and a more load independence in the field weakening area which results in faster swing cycle. The actual torque values for hoist and drag has a higher accuracy during the entire speed range. Of course the higher reliability of the electrical system has its impact as well. This contributes to a productivity increase of about 20% after a retrofit with AC Drives. See comparison 2004 to 2005 in figure 5.

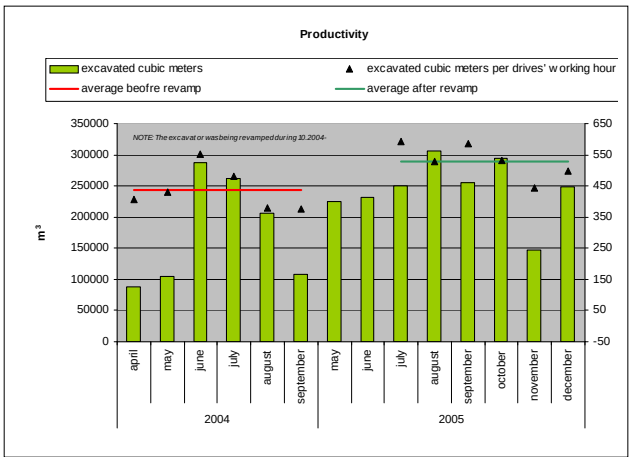

Figure 7: Productivity of Dragline Esch 15/90 No.83 with ABB AC Drives

Summary

The ABB AC Drives retrofit solution for electric mining shovels and draglines is a proven system which is based on long experience with AC technology in open pit mining applications. Innovative IGBT drives with most advanced torque control (DTC) ensure a higher level of productivity, lower operating costs and less maintenance.

The new ABB Drives for Mining are made for the requirements in hard rock open pit mining by combining the robust, modular design with high performance regarding drives dynamics and efficiency. The ABB ACS800multidrive has demonstrated excellent results for MTBF and low MTTR.

These facts speak well for the ABB Drives systems, with a lower total cost level than for a conventional MV drives solutions. The ABB Drives for Mining will bring benefits to many Open Pit Mining applications and particularly those mining operations well suited to an AC Retrofit.

Technical solutions and their advantages

- DriveIT Low Voltage AC Drive
- ACS Multidrive Concept
- IGBT-Technology
- Direct Torque Control (DTC)
- IGBT- Supply Unit
- Drives Visualisation with HTML-based diagnostic and remote access
- Adapted Mining Solution
- Compact and modular design
- Energy efficient system design
- ABB Service with world wide support

- The fully digitalised frequency converter and its drive control provides high functional safety
- The operation can be implemented without sensors as the essential parameters, torque and speed, are provided in the drive control
- Based on the modular design and the IGBT power semiconductors the components can be exchanged easily
- The efficient drive control (ADVANT controller) allows a minimisation of interfaces.
- The retrofit time of the entire machine is shortened.
- The system design meets the harsh environmental conditions in hard rock mining.
- AC motors are almost maintenance-free.
- A power cut can be managed taking the technological and safety aspects into account.
- Emergency operation with a reduced number of motors is supported.

References

(1) Kennerknecht, H. Dr., Vibration Design of Switch Gear Cabinets in big Excavators Machines Vibration and Shock tests with the Cabinet ISU 2xR8i, Würzburg, 2006

(2) Rathmann, B., Retrofit of an Electric Shovel or Dragline - a cost saving alternative between frequent repairs and the purchase of a new machine, Open Cut Coal Conference, Mackay, 2005