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Increasing availability through advanced Gearless Drive Technology

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Answers for industry.

Declining ore grades, leading to increased material transport and plant throughput requirements, are one of the major challenges in the current mining environment. This is accompanied by rising energy and labor costs, decreasing plant productivity and the requirement for highest plant availability. Siemens' answer is the latest gearless drive technology for grinding and conveying. Gearless drive solutions are surpassing the mechanical limits of conventional drive systems serving to utilize the principle of economies of scale. By elimination of various components of the drive train, the maintenance activities and spare parts inventories are reduced. The advantages are culminating in the incomparable availability of the Siemens' gearless drive technology of about 99.5% – as confirmed by detailed real operational data from the Antapaccay mine in Peru. It was the first plant worldwide to use gearless drives for both applications.

INTRODUCTION – THE GEARLESS PRINCIPLE

The principle idea behind a gearless drive system is to reduce the number of components and diversity of parts. Especially those components that are at the edge of current manufacturing or power limits are eliminated. The used equipment provides the possibility to scale up and increase the power transmitted to the driven machine. This finally results in a possible increase of throughput respectively transported or processed material.

In order to apply this principle of simplification, we will take a look at the components of a conventional drive system consisting of:

- Driven equipment (mill, conveyor, slurry pump...)
- Components altering the rated speed (gearboxes, girth gear / pinion)
- The electric motor
- Starting devices for the motor (VSD, CCV, LRS, clutch...), which are necessary because a direct across-the-line start of high power motors with load would result in a significant drop in the line supply voltage
- Alternatively, a variable-speed drive (VSD) or cycloconverter (CCV) to utilize the possibility of speed variation during operation
- The electrical supply system (cables, switchgear, transformers, protection equipment)

Intermediate gearboxes are not required when a motor is used with a rated speed that directly matches the speed requirement of the driven equipment. Furthermore, the VSD can be used to smoothly start the motor and to vary speed during operation, which means that it satisfies both requirements.

The comparison of a conventional drive train to a gearless drive for a grinding mill is shown in figure 1.

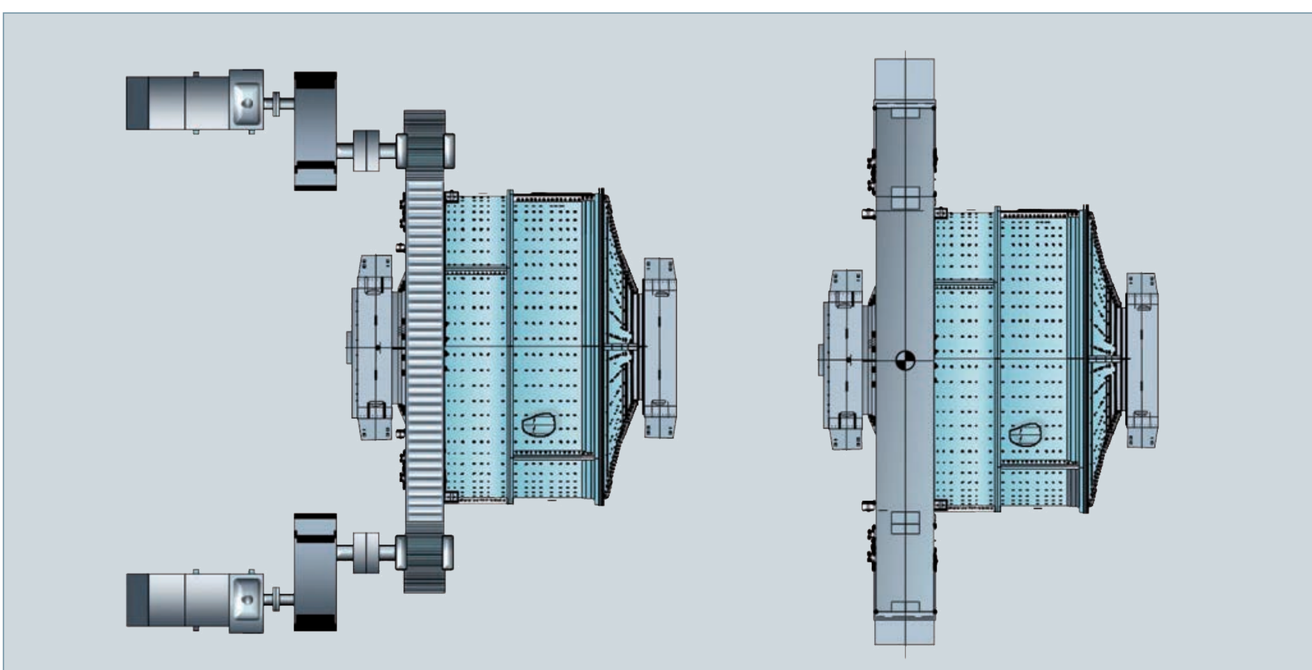

Figure 1 – Top view of SAG mills with alternative drive options; left side: dual pinion drive including motor, gearbox, pinion and girth gear; right side: gearless ring motor

What's the benefit?

The following benefits are achieved when using gearless drive solutions compared to conventional drive systems (Sehl & Dirscherl, 2012):

- Reduced maintenance and minimized risk of downtime by eliminating electrical components, couplings, bearings, and gearboxes – respectively girth gear and pinion
- Higher plant productivity due to higher availability
- Up to four (4) percent higher energy efficiency – can be achieved with gearless drive technology (at nominal power and speed)
- Higher available power at the driven component, surpassing the mechanical limits of systems with gearboxes
- Fewer spare parts resulting in lower inventories
- Smaller footprint of complete drive train
- Lower operational expenses
- Critical open gear power trains are avoided (Dugalic & Tischler, 2009)
- Robust design (Dugalic & Tischler, 2009)

There are various applications within a typical mine site that can utilize gearless drive systems. Starting along the process from the extraction, e.g. with mine winders, excavators or draglines further to the material transport (conveying) and in the concentrator plant for the grinding mills and cyclone or slurry pumps. In this paper, we focus on the ore grinding and conveying applications, for which the gearless principle was expanded even further so that the motor and the mill respectively conveyor and pulley were combined in such a way that the motor becomes an integral part of the driven machine. The details are provided in the following sections.

GEARLESS DRIVES FOR LARGE ORE CONVEYORS

Over the past few years, belt conveyors that demand high drive power and performance are being increasingly used. Due to the critical nature of these drive solutions, reliability and efficiency is essential; ThyssenKrupp and Siemens favor a straightforward design with a limited amount of components to accomplish this objective.

The drive train simply comprises the drive pulley and two inclusive bearings; this means that the motor is directly connected to the pulley shaft, completely eliminating the motor bearings (figure 2).

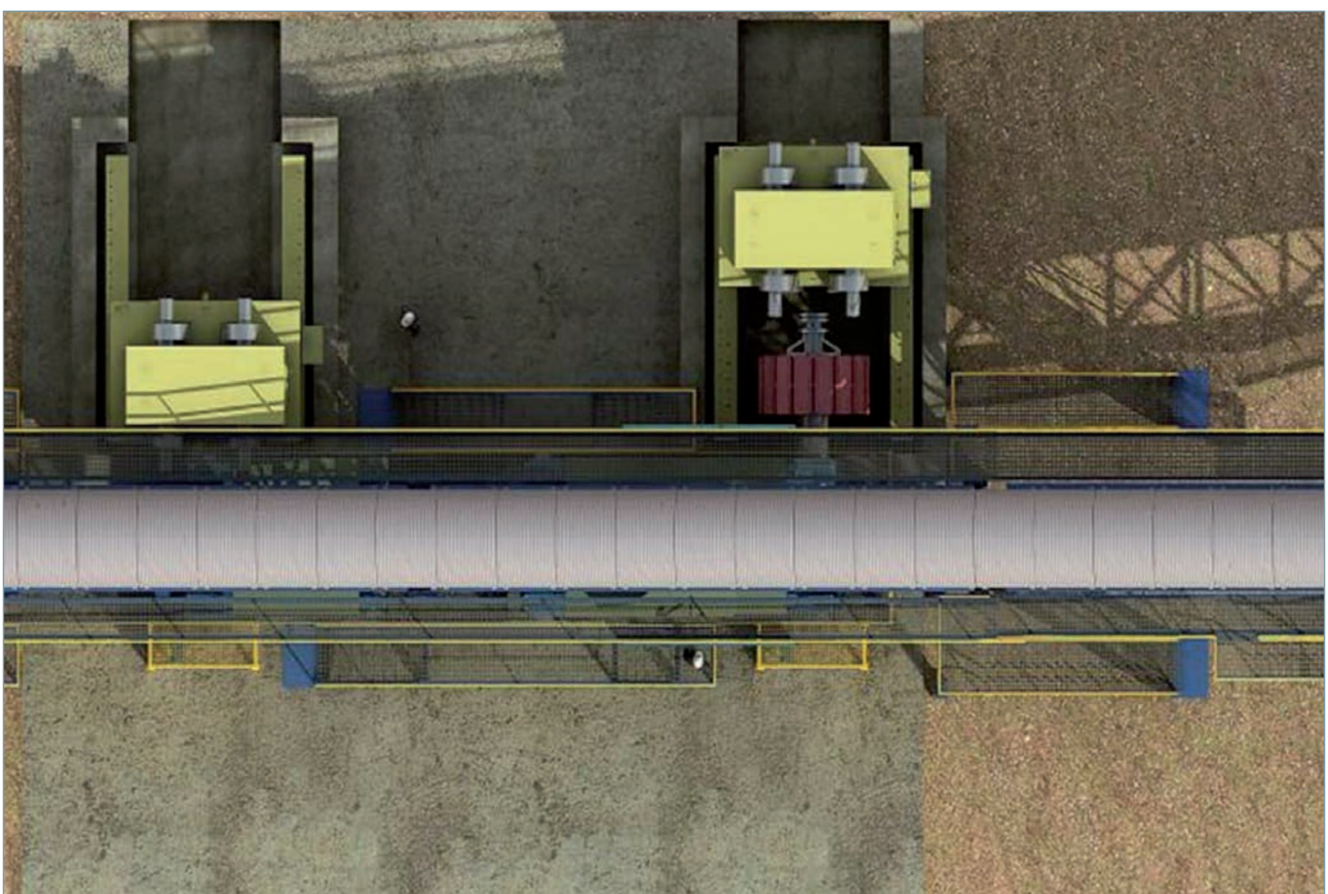

Figure 2 – Top view of two (2) gearless drive synchronous motors; one is in the maintenance position with a shifted stator

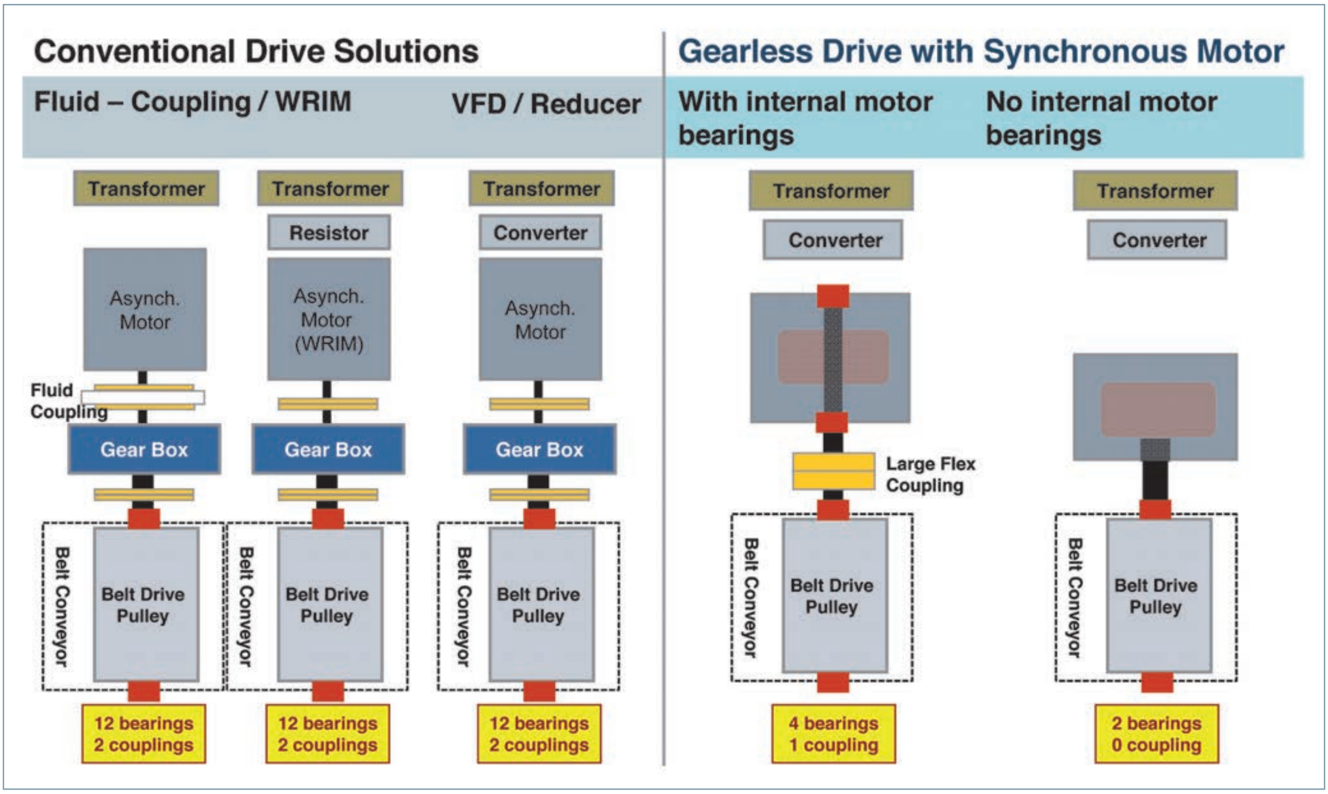

Figure 3 – Overview of different drive solutions for conveyors

When using a motor without bearings, the whole drive system only has two (2) pulley bearings and no couplings versus conventional design which requires twelve (12) bearings and two (2) couplings (figure 3). A low-speed synchronous motor with bearings would need two additional bearings and a large coupling between the motor and drive pulley. Reducing the number of couplings and motor bearings means that there are far fewer moving parts. Fewer moving parts results in higher reliability and lower maintenance requirements.

For the gearless drives installed at Antapaccay, Siemens used cycloconverters (CCV) instead of voltage source inverters. Cycloconverters have the highest reliability and efficiency (99.5%) as well as high overload capabilities which are especially required for low speed operation. On the other hand, cycloconverters have a low power factor and generate harmonics. Furthermore, cycloconverters were selected for the Antapaccay gearless grinding mills as they are the only economical solution for large Gearless Mill Drives.

GEARLESS DRIVES FOR GRINDING MILLS

Gearless Mill Drive (GMD) systems are characterized by having the motor wrapped around the mill like a ring. For this reason, they are often referred to as ring motors. The rotor poles are attached directly to the mill (head) flange, and hence the rotor becomes an integral part of the mill, as shown in figure 4.

Figure 4 – 38 ft SAG mill with GMD in installation phase; rotor poles bolted onto the mill flange and stator shifted back to the maintenance/installation position

Any mechanical contact for the power transmission is avoided, generating the advantages mentioned in the introduction. Additionally, the following advantages specific to mill drives apply:

- No alignment of the drive train required, as necessary for pinion drives; girth gear, pinion, bearings, gear boxes (optionally) and motors require a precise alignment
- Lubrication costs are significantly reduced (tens of thousands USD annually)

- Energy savings typically up to 750,000 USD per annum for a 20 MW SAG mill considering a power supply price of 11 US Cents per kWh.
- Erection and commissioning works on site are reduced by using a completely installed, wired and pre-commissioned E-house. Details of the installed components are listed below in the next paragraph.
- For high altitude installations (>3,000 meters above sea level): pinion drives with standard electrical motors and drives necessitate current and voltage deratings which accumulate to power derating factors; e.g. of up to 0.60 for the reference project Antapaccay at 4,200 meters above sea level. GMD's do not require such a high derating as they can be designed for such conditions in the first place.

The Gearless Mill Drive system consists of the ring motor with its feeding cycloconverter, pre-installed in an E-house. It also includes the excitation rectifier, the automation system (for mill and motor) including HMI, monitoring and diagnostic system, MCC's (for mill and drive auxiliaries), differential protection, UPS, the cross-redundant converter cooling system and the E-house infrastructural systems. Externally installed converter and excitation transformers complete the supply.

Variable speed for process optimization

The speed of the GMD can be adapted to the operational requirements at any time across the full operating range. Variable speed allows to compensate for throughput changes as well as for harder ore, and to prevent meta-to-metal contact between the grinding media and the mill liners. This leads to optimized operation and significantly less wear to the mill liners and ball consumption, as explained by a concentrator's operation and maintenance supervisor in the US. Furthermore, the mill's direction of rotation can be simply changed with a switch, so that the wear on the liner is distributed equally at both sides. Reduced wear of the liners prolongs the mill maintenance intervals.

Additionally, the following benefits result out of the flexibility with speed variation:

- Mill speed can be adapted to upstream and downstream processes – avoids overgrinding, and optimizes load distribution between SAG and ball mill (Mular, Halbe & Barratt, 2002).
- Power consumption is influenced by load respectively torque and mill speed. This means that further energy can be saved if a mill speed below the rate speed is required.
- Speed adjustment to worn liners results in optimized throughput and less wear of grinding media as cited by a representative of a German mill supplier representative.
- Ball mill speed can be reduced during short maintenance measures, e.g. inspections of the SAG mill. This avoids time-taking grinding out of the ball mill. Ball mills with fixed speed pinion drives have to be stopped with a prior grinding-out / drain-out process before interruption and the necessary time to restart. As a consequence, variable-speed capability helps the operator to reduce downtime. This is confirmed by an operation and maintenance supervisor at a large Chilean copper mine.
- Rather than adjustment of the ball charge to suit harder or softer ore entering the mill it is far more practical to adjust the speed – as stated by a senior process engineer of an Australian EPCM.
- Reduced short-circuit level required at the electrical network. This is in contrast to direct across-the-line starting of large synchronous motors, which can generate disturbances to other grid users when the mill starts. These disturbances are caused by large inrush currents and resulting line voltage drop.

Operation modes ensure easy operation and minimize mill downtime

Operation of the GMD is very simple. It is facilitated – either fully automatic or manually – for remote control from the operators' central control room, at the E-house which is forming part of the GMD system, or directly at the mill from the local control panel.

Operators and maintenance personnel are supported by a highly sophisticated control system with advanced diagnostic features. The data is displayed and monitored on the easy-to-use HMI system – see example in figure 5.

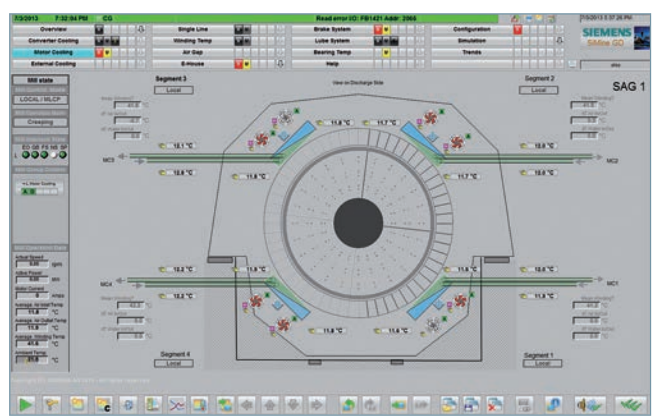

Figure 5 – Siemens' HMI system showing the cooling system of the motor (equally distributed around the circumference of the motor – in all 4 stator segments)

Shortening the required maintenance time for the mill is the design guidance for the special operating modes of the GMD. To commence a maintenance task on the mill, the GMD (commanded by the operator) stops the mill automatically in a balanced position, thus preventing any subsequent time-consuming mill oscillations.

By using the specialized inching and creeping modes, a fast setup of all mill maintenance procedures without endangering the safety of the staff is ensured.

In the **inching** mode the maintenance operator selects the desired angle to turn the mill (e.g. 90° – referred to as angle X). The automatic controller accelerates the mill to 1 rpm. In order to stop the mill in a balanced position, the GMD overturns this desired angle of the mill by the additional angle that the charge requires to cascade (angle Y). When this calculated angle is reached, which is required to balance the mill (angle X + Y), the GMD automatically changes the direction of rotation and turns the mill back to the requested angle X, thereby stopping without oscillations. The brake is automatically applied.

Creeping at 0.3 rpm is useful for slow movements, which the maintenance operator can observe directly by standing next to or in front of the mill. This allows to precisely trim the mill to a certain position. Operated from a handheld local control, with a simple pushbutton, the GMD lifts the charge in the selected direction. The pushbutton is released to stop movement; the GMD holds the load and then applies the brake. The movement can be repeated as required, which is very useful for mill or liner inspections. As the mill stops in an unbalanced position, the mill can be balanced out easily by switching over to the **balancing** mode.

A “frozen” or “baked” charge is capable of severely damaging or destroying the mill body and/or bearings when dropping from the top of the mill after a 180° rotation. The resulting damage and its consequential production losses are tremendous and could amount to millions of USD. In order to prevent this risk, the **Frozen Charge Protection®** was developed. In normal operation, the charge starts to slide or cascade after the mill reaches a certain rotation angle of between 40° and 70° and the load torque noticeably dips. At every start, the system closely monitors this torque dip behavior. Surpassing certain torque limits, the system detects the frozen charge and stops the mill safely before any damage to the mill occurs.

This controlled mill stopping prevents damage, but does not completely solve the problem. After stopping the mill, the charge remains in a “frozen” condition and must be broken up mechanically or by flushing with water. This takes time and causes production losses of multiple hours or even days. **The Frozen Charge Shaker™** from Siemens provides the solution. It has the capability to automatically break up the frozen charge and remove it from the mill body. The Frozen Charge Shaker™ lifts the charge to a risk-free angle, and shakes the mill with varying speed and acceleration. The angle and movement are designed to break the frozen charge and remove it safely from the mill body. This whole procedure only takes a few minutes.

The required high precision for the movements is achieved by using an enhanced tachometer with the appropriate high resolution.

<u>Gearless Mill Drives to assure high productivity and operational reliability</u>

In conjunction with the mill-dedicated operation modes, the Siemens GMD provides a variety of additional features which are oriented to keep the production time of the grinding mill as high as possible.

- Using a remote access connection, maintenance personnel can be assisted by experts either from the factory or from worldwide service hubs who connect to the plant network via online secure communication. After permission is granted, manufacturer’s experts can securely enter the automation system with the highly sophisticated diagnostic system. It provides the user and the supplier’s experts with the required data to monitor the equipment condition, compare it with historical data, derive trends, identify abnormalities, conclude preventive maintenance measures and conduct corrective maintenance. Furthermore, it also eases commissioning work or any kind of update or upgrade works.
- A short-circuit-proof design is an important characteristic for electrical systems, as it is not possible to completely avoid short circuits. This requirement is met by various measures. For example the cycloconverter utilizes thyristors designed to extinguish short circuit currents. The motor on the other hand has proven its mechanical and electrical withstand capability to short-circuit forces in several events already. The benefit for the users is that the GMD system can resume normal operation at the earliest as there is no need for replacement of e.g. the cycloconverter fuses or other components. Further details on this requirement have been published on many occasions for example by Kümmlee & Meinke (2001), by Tischler (2003), or by Diaz, Errath & Riquelme (2004).
- The structural design of the motor provides the optimum balance of highest stiffness at a reasonable motor weight. For proper examination of the mechanical design, every GMD undergoes a highly sophisticated FEM analysis. This not only takes into consideration the motor but also the mill body, bearings, foundation and soil to assure an integral approach. The user’s main benefit of this robust design is the withstanding of any arising mechanical forces – also for extreme conditions like earthquakes, where Siemens fulfills the stringent UBC, Zone 4 requirements.
- Numerous additional features combined with stringent manufacturing quality standards and the high level design know-how have been continuously developed over 30 years of experience in the field of Gearless Mill Drives for the mining industry. Discussing all of these features in detail would exceed the scope of the paper and can be provided individually by approaching the corresponding author. Siemens has one main focus for this continuous development and improvement process – namely to maximize the uptime of the user’s grinding circuit. An excellent case study of the operational experience with recently installed Gearless Mill Drives and Gearless Conveyors at the Antapaccay mine in Peru is illustrated in the next section.

The Antapaccay mine

Antapaccay is a brownfield expansion project of the Tintaya copper mine, located at 4,200 meters above sea level in the Cusco region of the Peruvian Andeans. The mine pertaining to Glencore Xstrata comprises new mine facilities, material transport equipment and a new 70 ktpd concentrator, while utilizing some of the existing Tintaya infrastructure.

The deposit, with an estimated mineral resource of over 1,000 Mt at 0.49% Cu using a cut-off grade of 0.15% Cu, is scheduled to produce annually 160,000 tons of copper in concentrate in the first few years of its minimum 20 years mine life (Mining Journal, 2012). The plant started up on time and delivered its first concentrate in November 2012. In May 2013, the concentrator reached its design capacity and is now operating 10% above this level.

ThyssenKrupp and Siemens supplied the 6.5 km overland conveyor to transport the copper ore from the mine to the processing plant. The conveyor has a 1,370 mm wide belt, travels at 6.2 m/s and has a design capacity of up to 5,260 tons of ore per hour. It is featured with the innovative gearless drives system providing a power output of 3,800 kW on each of the two (2) drive pulleys. Both drive systems are located at the same drive station.

Antapaccay was initially designed with a conventional drive system: Variable frequency inverters with squirrel cage induction motors together with couplings and gearboxes. The design comprised four (4) motors with 1900kW each. The gearless drives system in comparison uses only two (2) drive pulleys, each with a 3,800 kW rating.

Hence only two cycloconverters and two medium-voltage switchgears were needed as opposed to the original four VFD's and four medium-voltage switchgears. By reducing the electrical equipment, the E-house footprint was half of the original size.

From the mechanical side, the gearless drives now only require the maintenance attention of four pulley bearings instead of 48 bearings and 8 couplings. This can be seen in figure 6.

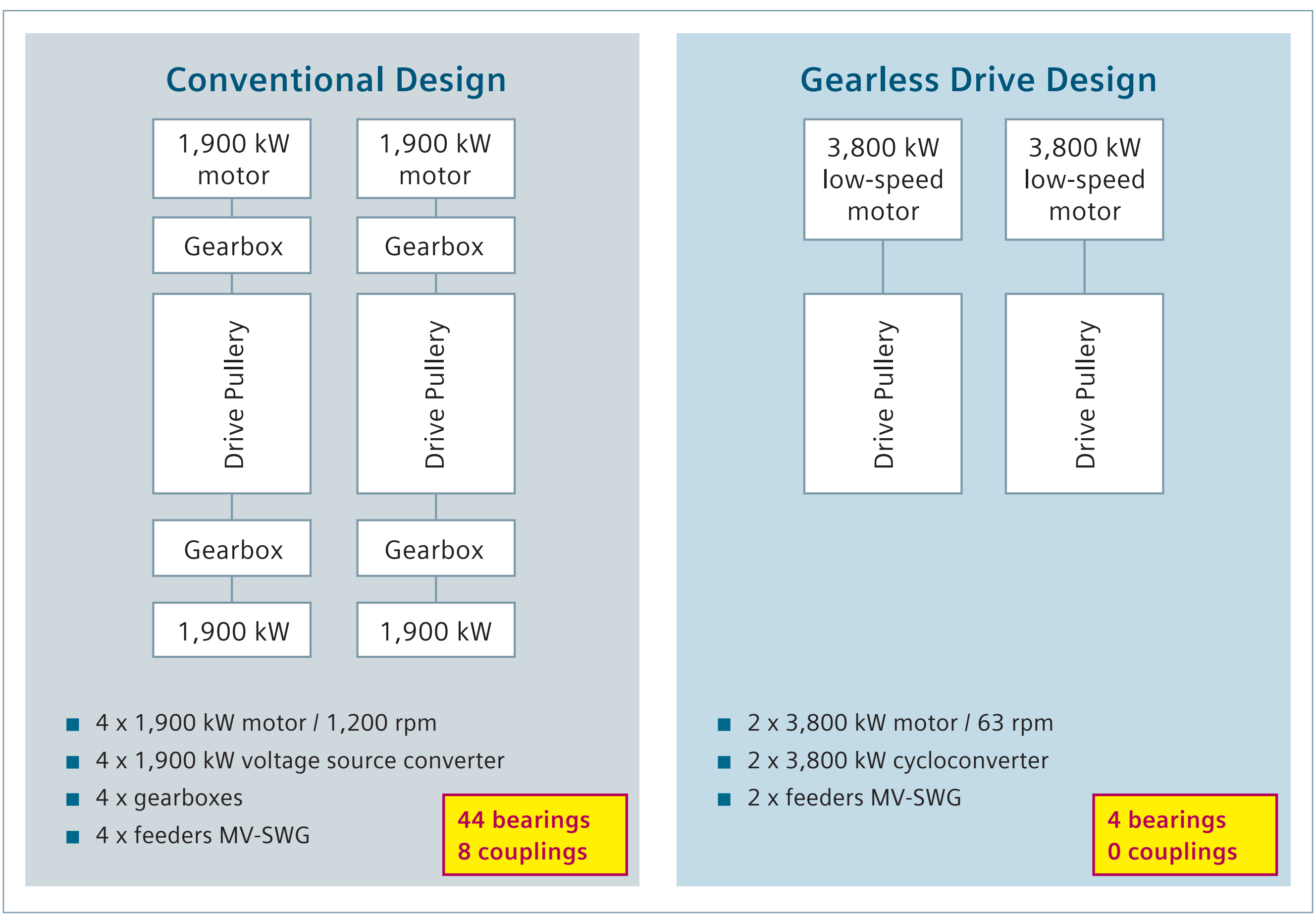

Figure 6 – Comparison of equipment count for a conventional and the gearless drive system for the Antapaccay overland conveyor

The gearless drive system for Antapaccay was realized with the same capital expense (CAPEX), as originally estimated for the conventional design. However, the operational expense (OPEX) is greatly reduced from a combination of approximately 3% to 4% lower power consumption and the requirement of fewer spare parts. This innovative solution completely eliminates high-cost spare parts, such as gearbox, couplings and squirrel cage induction motors.

The annual OPEX costs of the gearboxes are completely eliminated with the gearless drives solution. Furthermore, with the significant reduction in mechanical components of the gearless solution, there is a direct link to an increased reliability, thus preventing potential downtime. In mines of this magnitude, loss of production can easily cost several hundreds of thousands USD per hour.

The motors themselves are air-cooled, but an air-water exchanger is mounted on top of the stator. The heat exchanger cools the air drawn into the motors. For the Antapaccay facility, a closed-loop water circuit equipped with an external water-air heat exchanger is used to cool the cooling water. The external heat exchanger uses a redundant pumping station.

A key aspect of eliminating gearboxes is, of course, precision. The maximum air gap allowed between the rotor and stator is 8 mm with a 20%, or 1.6 mm, room for deflection. ThyssenKrupp's mechanical design used stiff / high-quality steel to ensure this gap is never compromised. Four sensors were installed to monitor the air gaps, and over the course of one year in operation, a deviation of greater than 0.6 mm has yet to been seen.

In order to process the 70,000 tons of ore per day, a typical SAG/Ball mill grinding circuit is implemented. The SAG mill has a 40 ft inner diameter (ID), an effective grinding length (EGL) of 25 ft and a rated power of 24,000 kW. The two (2) ball mills have an ID of 26 ft, an EGL of 40.5 ft and a rated power of 16,400 kW (figure 7).

Figure 7 – Both Antapaccay Ball Mills with Gearless Drives of 16,400 kW each

All three mills are utilizing the advanced Siemens Gearless Mill Drive technology. In order to address Xstrata's project requirements best, the concentrator design has been standardized and can therefore be used for various other Xstrata copper projects.

Siemens, as a partner throughout the complete life cycle of the mine project, supports the customer with its wide service spectrum for both systems – the Gearless Conveyor Drives and Gearless Mill Drives. This comprises the joint implementation of an individual and effective service concept including training of users operation and maintenance personnel, start-up accompany by field service engineers on site, predictive and preventive maintenance with remote data analysis, 24/7 on-call service as a helpdesk with remote diagnosis, spare parts monitoring and annual preventive maintenance visits by specialists from the factory.

In addition, the Siemens' scope of supply also included the main electrical distribution equipment, namely the 220 kV high-voltage gas-insulated switchgear, 33 kV medium-voltage gas-insulated switchgear and the low-voltage distribution.

Most important operational data – availability

Availability is an absolute key figure for mineral processing plants. In the specific case of Antapaccay every hour of downtime would lead to far more than 100,000 USD of production loss based on current CU market prices. In order to facilitate a common understanding of availability, we first define this KPI as a metric for operational productivity.

Availability – definition

Essentially, it is the ratio of the operation time of a machine over the time a machine is expected to be available and ready for operation. With regard to grinding and material transport equipment with all of their respective drives, many users factor in all unavailable hours of the mill or belt conveyor including its planned maintenance time. (Tischler & Kennedy, 2011)

In this paper, we focus on the availability of the gearless drive system with all of its auxiliaries. Then there are different approaches within the industry on how to treat planned maintenance measures. The first possibility is to consider all maintenance downtimes – independent of their nature – as unavailable time of the gearless drive equipment. The resulting equation uses a denominator of 365 days or 8,760 hours for calculating the availability ratio for one year (see equation no. 1). However, usually the scheduled maintenance measures of the gearless drive are accommodated within the time frames for planned maintenance of the mechanical equipment; e.g. for liner exchange or idler / chute maintenance. Therefore, additional downtime for the purpose of drive maintenance is not required. Consequently, the planned mechanical downtime and the preventive maintenance measures during that time would be excluded from the availability equation of the gearless drives, since the gearless drives are not expected to be fully available during these periods. Experience indicates that the resulting denominator then varies between 345 and 355 days per year for grinding mills respectively 320 to 330 days for long overland conveyors.

The approach used at Antapaccay is first one with the following formula:

Equation No. 1:

$$\text{Availability} = \frac{\text{(8,760 hours per year – hours for preventive and corrective maintenance of the gearless drive system)}}{\text{8,760 hours per year}} * 100$$

Having defined the KPI, we will subsequently take a look at the real data of the Antapaccay mine.

<u>Availability figures for the Gearless Conveyor Drive</u>

As the plant started up in late 2012, we will consider the availability data for the first months of continuous operation from November 2012 to November 2013 (being the last month available at copy date for this paper and its respective presentation). The Gearless Conveyor Drive system required a total preventive maintenance time of 37.0 hours during that period, whereas the system comprises of two (2) synchronous motors with their respective cycloconverters installed in the pre-commissioned E-house which also accommodates the excitation system, automation and diagnostic system and the MCC's for the auxiliaries of the complete drive station. Converter transformers as well as the corresponding internal and external cooling systems are also considered part of the system. All the preventive tasks for this drive equipment were carried out when the conveyor was down for other maintenance measures anyway. Additionally, corrective maintenance work was performed in the same time frame from November 2012 to November 2013. This is a total of 8.4 hours. Consequently, as per equations (1) and (2) – the availability of the Gearless Conveyor Drive (AVGCD) is 99.52%.

Equation No. 2:

$$AVGCD = \frac{(9480-(37.0+8.4))}{9480} = 99.52\ \%$$

System	Corrective Maintenance Times (Hrs.)	Preventive Maintenance Times (Hrs.)	Availability (%)
MOTOR GEARLESS OVERLAND CONVEYOR	8.4	37.0	99.52

Table 1 – Availability of Gearless Conveyor system provided as a courtesy of Antapaccay mines; translated from Spanish original

As the corrective maintenance resulted in additional downtime for the complete conveyor system, we have analyzed the reasons in detail based on the failure logbook provided by the operation team:

Overland conveyor – gearless drive system		
Months	Hours – Corrective M.	Description
January-13	5.90	Stoppage of drive due to PROFIBUS communication failure
February-13	0.00	
March-13	1.42	Stoppage of drive due to signal failure of air gap sensor
April-13	0.00	
May-13	0.75	Stoppage of drive as emergency pull cord on the right side activated
June-13	0.00	
July-13	0.00	
August-13	0.33	Stoppage of drive as different operation modes on the (2) drives selected; DCS changed to remote operation

Table 2 – Detailed failure logbook on the overland conveyor drives; translated from Spanish original

Most of the downtime is attributable to typical events that happen during the ramp-up phase of a plant – such as communication and signal failures. Once they have been corrected, the probability that they show up again is very low.

<u>Availability figures for the Gearless Mill Drives</u>

Subsequent to the ore conveyor, the grinding mills are the next major potential bottleneck in the process and therefore require paramount availability, too. For the Gearless Mill Drives, almost only preventive maintenance measures have been conducted during the same period between November 2012 and November 2013, being the first months of plant operation. As usual, these precautionary maintenance tasks have been performed in the normal scheduled downtimes of the process equipment. Therefore, they do not require an execution under time pressure, as would be the case for troubleshooting, as they are not generating any additional downtime. All of the details of the availability, which is also calculated based on equation (1), taking into account the corrective and preventive maintenance periods, are listed in table 3. Measured over the three (3) Gearless Mill Drives the availability ranges at excellent values of around 99.5%.

System	Corrective Maintenance Times (Hrs.)	Preventive Maintenance Times (Hrs.)	Availability (%)
SAG Mill – GMD	0.0	56.0	99.41
Ball Mill 1 – GMD	2.1	40.5	99.55
Ball Mill 2 – GMD	0.2	61.5	99.35

Table 3 – Overview of the availability of the Gearless Mill Drive systems during ramp-up of plant provided as a courtesy from Antapaccay mine

In the tables 4-6 the detailed split-up of the availability data mentioned in table 3 is provided. The data is shown for every GMD system separately and listed for every month of operation. The preventive maintenance is referred to as PM and the corrective maintenance as CM. The times are provided in hours.

SAG Mill – Gearless Drive				
	PM	CM	Availability (%)	Comments
November 2012	14	0	98.1	
December 2012	0	0	100.0	
January 2013	2	0	99.7	
February 2013	2	0	99.7	
March 2013	2	0	99.7	
April 2013	0	0	100.0	
May 2013	10	0	98.7	
June 2013	2	0	99.7	
July 2013	10	0	98.7	
August 2013	3	0	99.6	
September 2013	9	0	98.8	
October 2013	0	0	100.0	
November 2013	2	0	99.7	
Average			**99.41**	

Table 4 – Details on the availability of SAG Mill Gearless Drive system of Antapaccay mine

Ball Mill 1 – Gearless Drive				
	PM	CM	Availability (%)	Comments
November 2012	10	0	98.6	
December 2012	0	0	100.0	
January 2013	0	0	100.0	
February 2013	2	0	99.7	
March 2013	4	0	99.5	
April 2013	5	0	99.3	
May 2013	3	0	99.6	
June 2013	0	0	100.0	
July 2013	0	0	100.0	
August 2013	3	0	99.6	
September 2013	6	2.1	98.9	Inspection of motor ventilator ball mill 1
October 2013	0	0	100.0	
November 2013	7.5	0	99.0	
Average			**99.55**	

Table 5 – Details on the availability of Ball Mill Gearless Drive 1 of Antapaccay mine

Ball Mill 2 – Gearless Drive				
	PM	CM	Availability (%)	Comments
November 2012	24	0	96.7	
December 2012	0	0	100.0	
January 2013	1	0	99.9	
February 2013	0.6	0	99.9	
March 2013	6	0	99.2	
April 2013	0	0	100.0	
May 2013	3	0	99.6	
June 2013	0	0.17	100.0	Failure in ventilator sensor
July 2013	5.4	0	99.3	
August 2013	3	0	99.6	
September 2013	7	0	99.0	
October 2013	4	0	99.5	
November 2013	7.5	0	99.0	
Average			**99.35**	

Table 6 – Details on the availability of Ball Mill Gearless Drive 2 of Antapaccay mine

Focusing primarily on the corrective maintenance, just two (2) hours and sixteen (16) minutes of downtime occurred over the 28,440 hours of total operation of the three (3) GMD systems. So in the case that only the extra downtime generated by the GMD systems would be considered in the equation, the availability would be even 99.99%. The corrective maintenance at the GMD of ball mill 1 was necessary due to an inspection at one of the motor cooling fans and at the ball mill 2 due to a fault at one of the motor cooling fan sensors.

CONCLUSION

Gearless drive systems bring multiple – mainly operational – advantages. The most important one is the high availability of the system itself and the possibility it provides to increase the overall availability of the mechanical process equipment, like grinding mills, even further.

This is due to its inherent variable speed capability and additional features specially designed for the application. The real live data from the Antapaccay mine, installed in Peru at 4,200 meters above sea level, underpins the conclusion as the data shows an average availability of 99.5% for all the gearless drive systems on the overland conveyor and the grinding mills during the ramp-up phase of the mine.

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