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Innovation has allowed Siemens to remain both a pioneer and a leader in the mining industry. One result is a highly reliable design for the 42-foot gearless drive, which features above 99% drive availability. The cover picture shows a 40-foot SAG mill at Minera Los Pelambres, Chile.
Dear Readers,

Mining is a very challenging business. And the main requirements to succeed in this business – especially in the face of changing market conditions – are maximum plant availability and reliability as well as operational flexibility. Naturally, this must all come at the lowest-possible operational and capital costs. Today, stricter mining regulations and environmental concerns call for the sustainable use of key resources such as water and energy. Luckily, environmentally compatible practices do not necessarily lead to higher costs: for example, numerous opportunities exist to cost-effectively increase efficiency and thus reduce energy and fuel consumption, which account for some of the highest expenditures in mining operations.

The answer to tackling the wide range of challenges in the mining industry is continuous innovation, a discipline to which Siemens is highly committed. For over 150 years, Siemens’ researchers and developers have acquired vast knowledge and experience in electricals and electronics. Their insight naturally comes to play in Siemens trendsetting gearless drives as well as in Transvector Control, Frozen Charge Protection and Shaker systems, and other innovations that are integrated in mills, conveyer systems, and bucket-chain and drag-chain excavators all over the world.

Our pioneering work pays off. Thanks to constant innovation, our 40- and 42-foot semi-autogenous grinding mills boast higher throughput, lower energy consumption per ton of ore, higher availability and lower maintenance requirements. This energy efficiency “made by Siemens” is truly sustainability in action.

Yours sincerely,

Bernd Zehentbauer
Head of Mining Technologies
40 years of Siemens gearless drive technology

Driving Tomorrow’s Technology
In 2008, Siemens started up the world’s first ore-grinding mill with the Frozen Charge Shaker function at the Rio Paracatu gold mine.

The history of humankind is a story full of innovation: For instance the wheel, whose inventor remains unknown, continues to have a huge impact on life today. The same goes for the printing press, electricity and atomic energy – to name just a few. But as important as Johannes Gutenberg, Werner von Siemens and Albert Einstein may have been, thousands upon thousands of bright minds have also contributed to humankind’s progression.

Innovation drives competition,” wrote economist Joseph Alois Schumpeter in “The Theory of Economic Development,” published in 1911. Schumpeter, the Austrian Minister of Finance turned Harvard professor, compared the competition between the old and the new to a “powerful sourdough” that in the long term increases competition and creates price pressure. As a result, a process is started that “incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one.” As such, inventiveness is an important driver for the process.
Innovation is what keeps the economy going, and for any company the best investments are those made in innovations. Ultimately, they are the ticket to take part in tomorrow’s marketplace. Creativity is the foundation upon which innovation emerges. And many innovations are actually a combination of what already exists. So the more that exists, the more products, processes and services that can be created. This was Werner von Siemens’ viewpoint when he presented the dynamo-electric principle to the Berlin Academy of Science on January 17, 1867, pointing out that the technology existed to produce unlimited amounts of electrical energy inexpensively and comfortably. However, it took more than a decade for heavy-current technology to have a wide-ranging impact with the advent of developments like the first electric street lighting featuring a self-regulating differential carbon arc lamp, the first electric tram, the first electric mine locomotive and the first electric elevator. The company Siemens became a worldwide symbol for electrical engineering, and since its establishment 150 years ago it has not stopped realizing new ideas. The list of pioneering inventions is witness to the company’s innovative spirits as well as the commitment of its employees to deliver the best possible products, systems and facilities.

This spirit of innovation has been integral for the development of gearless drives, whose most important features include a small footprint and less weight than conventional drives. By doing without a range of mechanical and electrical components, the drives’ reliability increases and the effectiveness of the entire system increases by 3% to 4%. Maintenance requirements are considerably lower: over the course of a year maintenance activities for conventional drives can constitute up to 5% of the original investment volume. Lubrication and cooling systems for the gears as well as maintenance are also unnecessary. Gearless drives are especially suited for use in cement and ore mills, conveyer belt systems as well as for mills, ship drives and wind-power facilities.

In 1970, Siemens developed the first gearless drive for the Südbayerisches Portland-Zementwerk in Rohdorf, Germany.

A pioneering innovation

In 1970, Siemens developed the first gearless drive for the Südbayerisches Portland-Zementwerk in Rohdorf, Germany, producing 4,900 kW of power. And while the cycloconverter and control have been modernized several times since installation, the ring motor is still operating as it was delivered more than 40 years ago – which speaks for the reliability and consistency synonymous with the Siemens brand.

This first gearless drive was equipped with a tachometer comprised of small magnets positioned on a wheel located in the rotor of the ring motor. Hall sensors at the stator counted the magnets of the wheel. While this technology was state-of-the-art at the time it was developed, it yielded a somewhat unreliable performance and as a result, a major research and development (R&D) project was initiated by Siemens in 1976 to increase the dependability of the drive.

The extensive R&D resulted in a tacho-free location and a speed detector, known as Transvector Control, which calculates the vector of the motor-flux by measuring the voltage and the stator motor current. Furthermore, the Transvector Control provides for the optimization of the motor torque and efficiency, locating the accelerating current vector orthogonally to the flux vector of the motor. This concept prevents the motor from falling out of synchronism to the feeding frequency. In 1996, this patent expired and others introduced Transvector Control to the market under the name Vector Control.

During the 1970s, Siemens delivered a total of seven gearless drives for cement plants with a power range of 3,500 kW to 4,900 kW. By the end of the decade, the company received its first order for a gearless drive for use in the mining industry: the Norwegian mining company Aktieselskabet Sydvaranger ordered a gearless drive with an output of 8,100 kW of power for an iron ore-mill with a 21-foot diameter ring motor. The project was completed in 1980 and opened the door for subsequent projects.

As output volumes continue to rise in ore mines, the demands on mill drives are also growing. In 1988, Siemens provided the first gearless drives for semi-
autogenous grinding (SAG) mills in the framework of an order for two 32-foot SAG mills with a performance of 11,200 kW. This project for the Chuquicamata mine in Chile represented a monumental achievement, as the difference between creating a drive for a 21-foot diameter ring motor and a 32-foot ring motor required a significant development effort as well as careful analysis and verification.

Another first came in 1991 when Siemens supplied gearless drives for two 36-foot ring motors, developing a 12,000 kW gearless drive for the Kennecott, Utah, SAG mill and a 11,200 kW gearless drive for the El Teniente, Chile, SAG mill. In a continued call for larger, even more powerful drives, Siemens kept pace. In 1996, Freeport ordered the first gearless drive for a 38-foot SAG mill located at the company’s Grasberg plant in Indonesia. This gearless drive provides an astonishing 20,400 kW of power. In 1998, Siemens supplied the first gearless drive for a 40-foot SAG mill at the Cadia Hill Mine in Australia. While the details vary, there is a theme that links these projects – careful development and analysis, timely results and ultimately the delivery of reliable, efficient gearless drives. Since 1998, Siemens has been providing gearless drive systems for 40-foot SAG mills. And over the past three years the company has received ten orders for this type of mill, rated at up to 28 MW.

In 2010, Siemens proudly announced the sales release of a 42-foot gearless drive. The 42-foot drive allows throughput to be nearly doubled compared to the 38-foot mills commonly used in the mining industry. The principal component of the new drive system, which was designed and constructed within just two years, is a ring motor with a width of 25 meters and a staggering height of 20 meters. The company used strict rules in pioneering the ground-breaking 42-foot drive:

- There would not be any new, unique components or elements used in the drive.
- New technology components could only be applied to the gearless drive if already in operation in similar applications (i.e., they had been tested and successfully installed previously).
- All steps of improvement had to be well engineered and verified with sophisticated design tools.
- All engineering and design tools must be validated with measurements in the field.

The main tool for motor design verification is the Finite Elements (FE) model. During the design of the motor, all components were subjected to comprehensive and detailed risk analysis. Therefore, Siemens validated and refined the FE model with data measurements taken from an operating gearless drive at Peñasquito, Mexico. To further verify the motor design, a Failure Mode, Effects and Criticality Analysis (FMECA) was also performed to test reliability and availability. The result is a highly reliable design for the 42-foot gearless drive, which features above 99% drive availability.

The right time for innovations
An advantage of Siemens’ integrated design approach is the application of proven system components. For example, the fixation of the laminated iron core in the stator housing is identical to those that have provided fault-free service for decades. The insulation of the stator windings is made of Micalastic, a technology Siemens has used in all medium-voltage motors since 1966 and all gearless mill drives since their market introduction more than four decades ago. All components of the gearless drive were investigated for their applicability.
also in altitudes between 4,000 and 5,000 meters. In 2008, Anglo American Chile performed electrical tests for Siemens on stator windings in its high-voltage laboratory at Collahuasi, Chile, located at an altitude of 4,250 meters. The samples were taken from the stator windings for the gearless drives of Anglo America’s Los Bronces Project. The windings showed excellent results in terms of reliability and efficiency during these tests. The measured values of dielectric loss factor and of partial discharges were more than ten times lower than the specified standard and also lower than the experts at Collahuasi had expected.

Fixation of windings in stator core slots (1966)
Beginning in 1970, Vacuum Pressure Impregnation (VPI) was used on groups of windings within the vacuum tank because the stator segments did not fit properly. Therefore, winding specialists began installing the insulated windings in the slots of the stator core. The windings were smaller than the slots and a special filling material sealed the remaining space between windings and slots. The top fixation was done with two elements: a filling strip over the complete length of the winding slot and several wedges per slot. This configuration formed a very
In 2010, Minera Peñasquito assigned Siemens to service the gearless drive systems of two ore mills, initially for a period of one year.
reliable fixation, and a winding of a Siemens ring motor has never moved during operation. This technology has been in place for over 40 years and is just one of the tested technologies that make Siemens gearless drives leading within the mining industry.

As output volumes continue to rise in ore mines, the demands on mill drives are also growing.

**Fixation of magnetic core in stator housing (1995)**

Beginning in 1995, Siemens began using one pressure finger per tooth of magnetic core. The fixation occurs by pressure and by welding. The laminations are stacked on pressure fingers, which are welded to the stator housing. To avoid tilting of a pressure finger, the width and height of the finger are equal and each finger is welded to the housing with penetration welding seams on both sides. A pressure finger has never failed in a Siemens ring motor. The pressure fingers on the top of the magnetic core are welded to a pressure ring. Tension to the pressure finger is applied via tension bolts. After tightening the bolts, the pressure of each finger is checked. The pressure ring is then welded to the frame. Following pressure fixation, the core is fastened additionally by welding to the stator housing. Additional wedges fix the core to the housing in tangential, radial and axial directions. The wedges form the shape of a “T” and are inserted during fabrication into slots in the back of the core. After pressure fixation is complete, the wedges are welded to the core and to the housing. Since 1995, magnetic cores have been part of all installations completed by Siemens, with a total operating time of 64,000 machine days.

**Cycloconverter, fuseless and short-circuit proof (1988)**

First applied in 1988, the cycloconverter in Siemens gearless drives is both fuseless and short-circuit proof. The over-current protection of the converter detects a short circuit current and extinguishes it by blocking the gate pulses. Additionally, the cycloconverter sends a trip signal to the feeding circuit breaker. The cycloconverter is designed to resist the short-circuit current without damages to thyristors or other components. When a trip by the over-current detection occurs, the gearless drive can simply be restarted after a required inspection by an electrician. The obvious benefits to this technology are that no additional time is necessary for changing burned fuses, and spares do not have to be stocked. The cycloconverter provides drive availability above 99%.

**Cooling system (1991)**

Siemens initially developed a cooling system with cooling elements located at the bottom of the ring motor. Two fans in the bottom of the ring motor pushed the cool air to the top on one side of the motor. The cooling air flowed axially through the active part of the motor. The warm air flowed back on the other side of the motor, down to the circulating fans. Air-to-water heat exchangers cooled the air down just before it entered the fans. This cooling concept assured excellent cooling in the bottom area of the motor, but the cooling effect is markedly less in the top area of the motor. Seeing an opportunity for improvement, Siemens engineers redesigned the cooling system in 1991 and developed a satellite cooling system. Fans and heat exchangers are distributed around the motor circumference assuring a continuous and homogenous cooling effect throughout the motor. Measurements taken during operation confirm that the maximum difference between the hottest spot and coldest spot is only 4°C in large 38- and 40-foot motors. The excellent distribution of the cooling effect throughout the motor also allows axial cooling for large and powerful ring motors.

**Frozen Charge Protection (1986)**

Siemens developed and patented its Frozen Charge Protection in 1986, and the first application of this technology appeared in 1988 in the gearless drives installed at Chuquicamata, Chile. Frozen Charge Protection uses the torque characteristic of the grinding mill. Essentially, the mill’s torque increases during the start of the drive until the material cascades the first time. The torque then reduces due to the cascading material. Before reaching the turning angle of 90 degrees, the Frozen Charge Protection verifies whether the torque has reduced, respective of whether the material cascaded. All Siemens gearless drives built after 1988 are equipped with Frozen Charge Protection. Several protection trips have

Frozen Charge Protection is an integral part of gearless drives produced by Siemens.
been reported and no frozen charge damage occurred in any of the instances. Frozen Charge Protection is an integral part of gearless drives produced by Siemens and ensures consistent drive availability and production.

In most cases, it is simply not enough to protect a mill by switching it off in the event of cemented charge. The material remains stuck together and glued to the mill body where it must be loosened by mechanical means, for example with jackhammers or water jets. Loosening the material is time consuming and can bring production to a complete standstill.

To eliminate this issue, in 2004 Siemens developed and patented a device to loosen the frozen charge and remove the material from the mill body. The Frozen Charge Shaker moves the mill up and down within a safe range to remove the cemented charge from the mill shell. Damages to the mill are avoided and downtime to remove the frozen charge is reduced to a minimum. The Frozen Charge Shaker significantly increases productivity of the concentrator plant.

Verification with the Finite Element model (1999)
Siemens began comprehensive motor design verification using a Finite Element (FE) model in the early 1990s. The FE model placed low demands on the drives and required several simplifications due to the limited calculation capabilities of computers available at that time. The simple model worked for frame sizes up to 38-feet. Siemens delivered the first 40-foot gearless drive in 1998; however, the FE model could not predict the resonance of the stator in the operating range. As a result of the demands related to larger gearless drives, Siemens developed a new FE Model, which also calculates the electromagnetic behavior of the air gap. Beginning in 1999, the design on all ring motors was verified by Siemens engineers using this innovative new model.

In 2009, Siemens validated the new FE model by measuring the data at the operating gearless drive at Peñasquito, Mexico. The design engineers defined 40 locations for measurement points in the stator of the ring motor, and they installed acceleration sensors in three orthogonal directions at each point of measurement. In addition, they designed a mechanical shaker to inject forces and movement to the stator housing. For all measurement configurations, the shaker excited the stator housing with a sine sweep of 2 Hz to 20 Hz. Using the results from the measurements, further refinements were made to the FE model to ensure the highest efficiency and reliability.

Outlook
At the moment, we are at the cusp of the fifth Kondratieff wave, which started in about 1990 and is all about information and communication technology. With the rash developments of these technologies, the demand for raw materials is also growing.

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Today Siemens provides a gearless drive system for 42-foot SAG mills. This enables throughput to be almost doubled in comparison with the 38-foot mills commonly used.
Stronger drives and larger mills allow materials with low ore content to be processed even more economically. Siemens is already developing the next wave of the future, and the company’s engineers will use their ingenuity, experience and professionalism to come up with viable solutions. Siemens is committed to answering the call for larger and more powerful gearless drives, thus ensuring its principal role within the mining industry.

And around ten years ago Leo A. Nefiodow, the most admired IT mastermind, described the sixth Kondratieff wave in his book “The Sixth Kondratieff: Productivity and Full Employment in the Information Age.” Especially health and the environment in the holistic sense play an important role. Environmental protection and prudent use of natural resources – including raw materials as well as drinking water and a clean atmosphere – still need to become a matter of course. Technology offers opportunities to work more and more effectively and with a lower impact on the environment.

This brand of innovation – the development of state-of-the art technologies, the perfecting of those technologies and ultimately the application of those technologies across industries – has allowed Siemens to remain both a pioneer and a leader in the mining industry. This approach will continue to serve as the foundation for the company’s strategy now and in the future.

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Standardized solutions strengthen competitiveness in mining

Partner to The Industry
A successful mining operation must reduce its excavation and processing costs continually while maintaining material quality. Meeting both objectives requires robust yet sensitive technology.

Enterprise optimization and logistics
The key to combining robustness with sensitivity is the reliable linkage of process automation to information technology. Examples of successful solutions include the consistently transparent process chain from the excavation in the mine to the beneficiation (mine-to-mill optimization) or the fully automated control of complex material flows (ore intelligence system). Advanced control techniques based on mathematical models and neural networks further optimize the milling process. IT systems can keep the quality of mined coal or ore constant by varying the mix of material. As the material is piled, the systems monitor volume and quality, which ultimately improves productivity while reducing operating costs. Modular mine concepts synchronize the material and information flows. This inclusion of process equipment in the value and logistics chain leads to horizontal integration, and the linking of this chain to business processes promotes vertical integration. Both offer potential for better mine and mill utilization through greater rationalization.

Manufacturing execution systems (MES) link the automation of production processes with enterprise resource planning (ERP) systems at the management level. An MES provides basic data for improving productivity and for statistical quality assurance, and contains the history of individual charges. All important values can be made available to staff in real time. The Simine PIMS management information system...
system from Siemens gives senior management an online overview of individual equipment groups, provides the maintenance manager with planning information needed to initiate preventative maintenance, and supports operating personnel in reaching operational decisions or proactive solutions to problems.

The Simine product family combines process and automation technology, drive systems, energy supplies, MES and others into efficient solutions.

Excavation und transport
The solution platforms Simine CONT for continuous mining, Simine Winder for mine winders, and Simine DICONT for discontinuous mining are integrated mining concepts that cover both primary and secondary processes. Their modular components are designed especially for mining applications, providing all electrical and IT solutions from a single source. Industry standard automation controls, such as Simatic PCS7 or Simatic IT, can be combined virtually at will to meet a wide range of mining and milling control challenges. Simine CONT manages all process steps in continuous mining, including energy supply, automation, and drive systems for bucket-wheel excavators and Simine EXC storage bunker systems. Especially for bucket-chain excavators, gearless drive technology saves energy and reduces operating and maintenance costs significantly. For conveyors in open-pit mines, Simine CON ensures safe and energy-saving operation of curved, downhill and long-distance conveyors. Advanced variable-speed drive technology increases the life cycle of conveyor belt splices, drum bearings and mechanical brakes. A special technology controller ensures that the belts are always loaded optimally and saves up to 20% of operating energy at the same time.

Simine DICONT optimizes individual process steps in discontinuous mining operations for draglines, shovels and trucks with the objective of increasing availability and reducing maintenance and operating costs. For the transport of material with mining trucks, Simine TR improves performance and productivity, which reduces the number of trucks required on-site. Siras (Siemens Remote Access System) helps to monitor and update the drive and control system of excavators and trucks from a remote location via radio link. All operating and diagnostic information can be called up in the mine control center, leading to rapid localization and correction of faults.

Ore processing plants
A major challenge of processing plants is the sustained reduction of harmful emissions as well as of energy and water consumption while ensuring optimal material throughput and low operating costs. Simine Pellet provides a tailor-made technological, mechanical and electrical solution for pelletizing plants. Intelligent design of the traveling grates and the control of emissions reduces pollutants significantly and improves the quality of the pellets. High-performance MES and automation systems rely on mathematical process models to optimize quality, throughput and energy utilization. Siemens also provides process turnkey water solutions for the mining industry, from treatment technology to process automation and controls. A single-source provider reduces the coordination effort and accelerates the timeline from project creation up to start-up.
Gearless Simine Mill GD drives have been synonymous with wear-free operation for years. To date, more than 32 gearless drive solutions have been provided. The patented control concept enables precise adaptation to every requirement, right down to operation with the lowest speed during inspection. Shorter downtimes and greater overall productivity are the result. The gearless Simine Pump GD drive system for cyclone pumps improves energy utilization by up to 30% and increases pump availability. Simine Hybrid Flot combines a pneumatic spray-in principle with a column method, resulting in an increased recovery while consuming less energy, water and gas compared to conventional cells at comparable capacities. Yet it takes more than superior individual solutions to run mining and milling operations with optimal efficiency. These individual solutions must also be linked into a straightforward process chain. This is done using Simine CC. With its integrated diagnostic tools, the Simine CC control stand solution sets standards for efficient maintenance and reduced life-cycle costs.

**Services for every requirement**

As a globally operating service provider, Siemens supports the mining industry with a unique combination of industry-specific experience and mechanical and electrical engineering know-how, together with a wide portfolio ranging from operational support and maintenance to plant modernization and optimization. Customizable solutions enable optimized operation of customer plants and equipment.
Minera Los Pelambres continues to place its trust in Siemens

A New Addition
For More Copper

Since January 2010, Chile’s Minera Los Pelambres has increased processing capacity for copper ores – thanks to a new semi-autogenous grinding mill and a new ball mill, both equipped with Siemens gearless drive systems. Siemens already equipped two mills for Los Pelambres in 1999 and has been responsible for maintenance of the conveyor-belt equipment for more than ten years.
In 2009, Minera Los Pelambres, an operation of Antofagasta Minerals plc, produced 311,600 tons of copper concentrate and 7,800 tons of molybdenum. The new ore-grinding mills that went online at the beginning of 2010 were built as part of an expansion program aimed at increasing copper production by approximately 100,000 tons. Siemens supplied the gearless drives for a 36-foot semi-autogenous grinding (SAG) mill with a rated power of 15 MW and a 26-foot ball mill with 15.5 MW of rated power.

In contrast to gear motors, gearless drive systems feature higher system efficiency of up to 5% and the highest levels of torque utilization, because mechanical parts between the motor and the mill are eliminated.

These GD motors in the Simine Mill are connected directly to the grinding drum. A cyclo-converter with Transvector Control ensures exact settings of the motor’s operating point and highest efficiency also in the partial-load range, for example to process changing material hardness or to realize various modes of operation.

Simple control of inching and creeping modes lets mill maintenance procedures be set up quickly without endangering the safety of the staff. When Simine Mill GD is in inching mode, one rotation of the mill is all that is needed to achieve the exact angle that was preset by the operator, and it is not necessary to repeat the procedure. At the end of the inching operation the mill stops with balanced charge. During the creeping mode with 0.3 rpm, the operator can directly control the mill while observing the mill and the material. The result is shortened maintenance times.

Frozen Charge Shaker: optional
All gearless drive systems can be equipped with the patented Frozen Charge Shaker, which enables controlled detachment of hardened charges stuck in the mill shell. Manual cleaning is no longer necessary. The Frozen Charge Shaker lifts the charge to an uncritical angle and moves the mill in a harmless range with varying speed and acceleration. The angle and movement are designed to break the frozen charge.

Siemens has years of experience in the supply of gearless drives.

In more than 40 years, Siemens has installed over 36 mills with a total of 820 MW installed power and has provided more than 36 solutions for optimal productivity. This track record is proven by over 335 machine years of successful operation time with more than 99% drive availability. By continually applying innovations, Siemens ensures that gearless drives will provide even higher availability and that they will be more productive and more economical in the future.

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Usualy the grinding mills are the “bottleneck” of a mine, so reliability and availability of the mills are of paramount importance. With more than 30 years’ experience in design, planning and building of reliable gearless drives for mining operations and more than 35 installed mills, Siemens has developed modernization packages to improve the life cycle and availability of the installed Simine Mill GD.

With the application of innovations and new ideas, the Simine Mill GD standard for gearless drives has been continually improved over the past decades in terms of higher availability, productivity and efficiency. These innovations, including significant and rapid advancements in the area of electronics and computer technologies that have impacted the control technology employed in Simine Mill GD, will be made available for existing systems with modernization packages. The Siemens modernization concept for Simine Mill GD makes it easy to modernize the mill step by step, as new and old systems can be operated in tandem. This enables investments to be stretched out over time.

Thanks to the extremely rigid, reliable and robust design of motor and transformer and an optimally designed modernization package for the drive system, further significant savings for the modernization investment can be achieved due to the reuse of motor and transformer.

**Selection of a suitable modernization strategy**

Special emphasis should be placed on selection of a suitable modernization strategy. One important goal is to identify obsolete parts of the mill with significant problems based on the availability of essential spare parts. Optimization of mill downtime is the next essential aspect of every modernization. Using a step-by-step process, it can be implemented over several standard downtimes of the mill as follows: first, replacement of the automation and visualization system; second, replacement of the technological drive control system; and, finally, replacement of the power section of the cycloconverter. Furthermore, the following will optimize downtime: pretested components and a final system test, use of standard packages with minimal delta engineering, and reuse of existing I/Os to avoid rewiring, or as an alternative, adapter plugs for reuse of Simatic S5 plugs on new ET200 systems (installation of new I/O cards but no need for rewiring).

**Modernization of the technological drive-control system**

In older Simine Mill GD installations, the existing drive systems, analog or early digital closed-loop control systems such as Simadyn C/D are the weakest link in the control chain. If these systems are replaced with...
Modernized gearless drive mills at Codelco’s Chuquicamata copper mine in Chile

Main PCS7 overview screen of the Grinding Mill system
modern digital closed-loop control systems, greater precision, better resolution of actual values and greater chronological control constancy are achieved. A complete new control cubicle for the cycloconverter based on the new Sinamics drive family is now available and ready to replace the old Simadyn-based control cubicle. Besides the optimized switchover due to the 1:1 compatibility with the remaining power section of the cycloconverter, the new Simatics solution leads to improved diagnostic and maintenance possibilities thanks to a standardized engineering and diagnostic interface for the complete Sinamic drives family.

Modernization of the automation and visualization systems
For the migration of the automation system the Simine Mill GD standard software for automation and drives will be the basis for all mills. Thus the old automation systems, mainly Sinamic S5 as PLC and Coros as visualization system, will be replaced with Sinamic S7 and PCS7. The modernization of the automation system will lead to a significantly improved visualization and message system and thus advanced possibilities for fault diagnostics.

Reuse of the main equipment and service contracting
Siemens delivered the first gearless drive motor for mills in 1972. It is still in operation. Recently, a motor from the early 1980s was disassembled and rebuilt at a new mine in Australia. This shows that there is no need to replace the motor and transformer, thanks to the optimized designed-migration package for the drive system, which leads to significant savings for the necessary modernization budget.

The standard service contract for Simine Mill GD drives is the right choice to ensure the highest possible reliability and availability for the remaining equipment as well as the newly modernized equipment. Especially for remaining equipment such as the motor, a service concept with preventive maintenance is essential for ensuring highest reliability and availability over the coming decades. In addition, modernization add-ons like a high-speed data recorder and a newly available remote diagnostic feature ensure the best possible and fastest support from highly qualified engineers from the Metals & Mining Support Center in Germany. This applies equally to remote mines.

Modernization of gearless drive mills at Codelco
Codelco (Corporación Nacional del Cobre de Chile) owns around one-fifth of all the copper deposits in the world and operates several mines in Chile. Currently eight gearless drives are in operation at mines in Chuquicamata, El Teniente and Andina. Siemens has a long tradition of continual support of the largest copper producer in the world with modernization solutions. Since the first modernization of a gearless drive mill in 1992, Siemens has successfully performed several modernizations, mainly for the electrical portion of the mill (automation and control of the cycloconverter). Siemens also recently modernized several Simine Mill gearless drives at Codelco.

The first such modernization was performed in Codelco’s Chuquicamata mine in 2007. The largest open-pit mine, with an annual production of around 600,000 metric tons of copper, Chuquicamata is located 1,650 km north of Santiago de Chile at 2,870 meters above sea level. Thanks to the newly installed equipment from Siemens, it is now possible to control the gearless ore mills more flexibly. A new line of controllers based on the Simatic S7 PLC and Simadyn D (32-bit) automation modules ensures optimum acceleration and braking as well as precise stopping of the mills. In the newly available creep mode, the mills can be positioned without time-consuming test runs. As a result of the new modes, mill operation can be adapted to different material characteristics. In addition, the new closed-loop control system will make operation highly energy efficient. The local conversion work took less than ten days.

In the wake of the successful implementation in Chuquicamata, Codelco placed further modernization orders based on the highly adaptable and proven Simine Mill modernization solutions. Just one year ago a gearless drive mill at the El Teniente mine was modernized. Once again, a downtime of less than ten days was needed to install the new equipment. This shows that the modernization can be implemented during standard downtime for a necessary liner exchange – no need for additional downtime for the modernization. Currently a modernization for a gearless drive of the mill at the Andina mine is in progress.
The first gearless drive for a grinding mill in a mining plant was installed in 1979 in the Sydvaranger iron ore concentrator in Kirkenes, Norway. Today, more than 50 gearless drives are in operation in the mining industry, driving grinding mills with inside diameters of 21 feet to 40 feet in a power range from 5,000 to 30,000 hp. The variable speed of the gearless drive is used to adjust the mill speed to the requirements of the grinding process, but also to provide low-speed operation for positioning of the mill during liner maintenance.
Today’s state-of-the-art electronic control allows easy operation of the mill with the gearless drive. The HMIs are conventional operation panels as well as operator workstations. Operation control is put in a location that is convenient for the operator. The local control panel of the mill’s lubrication system, for example, is positioned close to the lubrication system itself and used mainly for maintenance of the lubrication system of the mill’s bearings. The local control panel of the mill drive (MLCP) is located near the mill, where the operator can observe mill and motor directly and verify the results of his actions. The creeping panel (CP) is a small transportable hand panel for local operation and detailed inspection, as well as for maintenance purposes. It is stored in a cabinet when it is not in use. The central control room (CCR) of the plant houses the computer-type HMI to operate the mill remotely.

Starting and stopping
Normal operation can be conducted locally at the MLCP or remotely in the CCR. For local operation, the operator in the CCR must give authorization. Once operating in local mode, the CCR can only operate with local permission. On the MLCP, the operator starts the auxiliaries of the mill and drive. With all interlocks confirmed, the PLC signals that the mill is ready for operation. The operator now starts the mill with one push of the button on the MLCP. The gearless drive control applies the same speed ramp and accelerates the mill to the selected speed. During each start, the gearless drive control verifies whether there is a frozen charge, and switches the mill off if that is the case. To stop, the operator presses the stop button on the MLCP. The gearless drive deaccelerates the mill over a speed ramp to zero. When the speed reaches zero, the charge in the mill is still unbalanced. The mill would oscillate if simply switched off at this point. The oscillation can last up to 20 minutes, because the only friction in a gearless drive mill is the charge itself and the friction of the bearing’s oil film. To avoid such oscillation, the gearless drive changes the direction of rotation and turns the mill back until the charge is balanced.

Inching toward the correct position
Inching is an operation mode for the positioning of the mill to gain access to liners for exchange. It is done at a speed of 1.2 rpm. Since it is a maintenance mode of the mill, inching is operated locally from the MLCP. The operator indicates the angle to be turned on the MLCP (inching angle). To facilitate selection of the turning angle, the selection is based on the number of bolts around the circumference that the mill is to be turned. Inchng starts and stops with a balanced mill charge and with the brake open.

The gearless drive turns the mill and lifts the material. The angle at which the material cascades the first time is measured and stored. The drive turns the mill by the requested angle, and then overturns the mill by the cascading angle. Upon reaching the sum of the requested and cascading angle, the drive stops the mill and changes the direction of rotation. The gearless drive turns the mill back by the cascading angle, switching over to torque control. It turns the torque-controlled mill back until the torque is zero. With the torque at zero, the charge is balanced and there are no oscillations. The brake is open.

Creeping with and without brake
The creeping mode has the same application as the inching mode, namely to position the mill to a certain angle for liner change. During inching mode, the mill operates at a low speed of 1.2 rpm. This is about 10% of the normal operating speed, but still too fast to follow the mill with the eyes and to position the mill with start/stop signals. Creeping is performed at a speed of 0.3 rpm, slow enough to turn the mill manually to a certain position. For the creeping mode, a separate handheld creeping panel (CP) is used. In creeping with the brake, the gearless drive starts turning and first lifts the charge. While the mill is running, the operator observes the liners coming out of the charge. When the requested liners come out, the mill is stopped by releasing the push button of the CP. The gearless drive stops immediately, providing the necessary torque to the mill. Then its PLC closes the brake and shuts off the motor.

The creeping operation is also possible without applying the brake, which is beneficial if the mill has no brake or a brake of low capacity. The procedure starts out the same as with the brake. But when the operator releases the run button of the CP, the gearless drive turns the mill automatically back to a balanced position. This version of creeping is less convenient and more time-consuming than creeping with the brake, because restart has to be performed
from the balanced position, and the material must be lifted to the cascading angle first before the charge inside the mill starts to move.

**Protection against frozen charge damage**

Depending on the content of fines, the mill charge can solidify during a standstill and the solidified charge can stick to the mill body. This effect is called “frozen charge” and can damage the mill if the solidified charge is lifted during start-up and falls from the upper part of the mill. The Frozen Charge Protection feature measures the torque of the charge, and verifies during each start whether the charge has cascaded. If it has not cascaded before reaching an angle of 85°, it switches the drive off and lets the mill oscillate. This procedure loosens the solidified charge from the mill body.

The Frozen Charge Shaker increases the availability of the grinding mill.

But often it is not enough to switch the drive off and let the mill oscillate. The charge remains solidified and stuck to the mill body. Repeated starts of the mill and trips by the Frozen Charge Protection may help to remove the stuck charge, but often it is necessary to apply mechanical means to solve the problem. In the worst case, jackhammers and shovels are necessary to remove the solidified charge from the mill. Siemens has developed and patented an operation mode for the gearless drive called the Frozen Charge Shaker, which helps to break up the solidified charge and to loosen it from the mill body. The Frozen Charge Shaker can be operated from the MLCP. The operator must be authorized to perform this exceptional operation, and a key-operated switch has been installed in the MLCP for this operation mode.

When the start button is pressed, the gearless drive turns the mill, lifts the charge up to the maximum safe angle for the mill, and moves the mill up and down. It then returns the mill to the balanced position, lifts the charge on the other side up to the maximum safe angle, and again moves the mill up and down. The automatic Frozen Charge Shaker operation is now finished. The operator can verify whether there is still a solidified charge by starting the mill in any of the operation modes. The total time for breaking up a solidified charge with the Frozen Charge Shaker, including preparation and a test run afterwards, is estimated to be 30 minutes.

**Convenient and easy-to-manage mill operation**

The gearless drive provides easy-to-manage operation modes for normal operation and positioning of the mill for liner change. These automatic procedures reduce the downtime of the mill drive considerably and increase the availability of corresponding mills. New developments such as the Frozen Charge Shaker increase the availability of the grinding mill significantly.

**Contact**

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New drive systems for draglines

Gearlessly Into The Mine

Until now, draglines all over the world were outfitted with geared drive system motors only. Siemens and Bucyrus have jointly developed a gearless AC drive system – Simine DRAG. One of the first systems to be employed is in the Zhungeer coal mine in China. Draglines already in use can be retrofitted.

The 13,000 hp drive systems with a performance of 9.7 MW are used for hoist and drag motion of the dragline. By eliminating the gears, the costs of maintenance and operation are lowered in comparison to conventional drives. The extended service intervals reduce maintenance and increase the excavator’s availability. Gearless AC drive systems also offer up to 20% more efficiency and use less energy, thus reducing operating costs.

Simine DRAG combines reliable electronics and controls proven in thousands of Siemens-powered locomotives and mining shovels, with gearless ring motors that have been in reliable service in grinding mills, mine winders, chain excavators and conveyors for more than 25 years. Siemens combined these proven, reliable components into a revolutionary dragline drive system.

A new drive in coal mining

Siemens outfitted the first Bucyrus 8750 excavator with the new drive system for use in the Zhungeer coal mine, 120 km south of Hohhot, the capital of the Nei Mongol province (Inner Mongolia). The mine is operated by the state-owned Shenhua Group Corporation based in Beijing. In the Nei Mongol province, coal has been strip-mined for some time. Near the city of Zhungeer, four coal-fired power plants are currently in operation and one or two more are planned.

The dragline’s ring motors are outfitted with nine winding systems. The ring motors were delivered in two halves and had to be assembled on-site. The assembly was especially difficult as 90% of the work had to be done outdoors. The roof was added later and all hoisting jobs had to be carried out by mobile crane. Bad weather and coal dust from the nearby mine further impaired the work. Sandstorms appeared almost every day and heavy winds made assembling the poles difficult. “Testing was done sometimes under extreme conditions. Aside from some starting problems, the unit has proven to be very successful. A top result for a new technology!” reports project director Ralf Lechtenfeld. The drives are controlled by AC IGBT inverters supplied and installed by Siemens Energy & Automation. The excavator has been in operation since December 2007.

Seamless integration of Siras and Midas

To achieve high uptime and short MTTR (Mean Time to Repair), Siemens offers the most advanced and user-friendly maintenance computer in the industry. It shows the mine electrician where the problem is, and which part is needed to fix it. The dragline system also seamlessly integrates with Siras and Midas. Siras remote diagnostics uses Internet technology to “keep the factory on the machine.” Siemens and Bucyrus service technicians and other experts can log on from around the world and can do the same work as the electrician on board the dragline with the exception of tightening a screw. Midas harvests a wealth of data during normal operation and makes it available for productivity analysis and optimization.

Main Benefits

• Higher machine productivity
• Higher drive-system efficiency
• Less maintenance
• Lower life-cycle operating costs
• Seamless integration of Siras and Midas

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The Bucyrus excavator with the new drive system for use in the Zhungeer coal mine in China

Gearless drives for the dragline
Simine Services – life-cycle support for mining

The Key to Sustainable Success

On the one hand, maintenance of mining machines and systems is a sizable cost factor. On the other hand, the costs incurred by unscheduled downtimes can significantly reduce the profitability of an entire mining company. The goal: minimize risks while keeping expenditures as low as possible. The answer: Simine Services as the key to reliable operation and maximum protection against equipment failure. The Simine maintenance strategy is tailored for each mining company and for the individual mining processes, and covers the life cycle of the entire plant.
Two years ago Simine Services became an integral part of the mining group within Siemens. The main driver for this decision was to improve the life-cycle support for the mining business. As a globally operating service provider, Siemens supports the mining industry with a unique combination of industry-specific experience and mechanical and electrical engineering know-how. This competence, together with a wide portfolio of customizable solutions, enables Siemens to ensure optimum operation of mining plants and equipment, even under difficult conditions. Simine Services covers numerous technical functions for every phase of operation, from rapid provision of necessary maintenance and operating materials right up to comprehensive life-cycle management.

Siemens is represented globally at 250 locations in over 190 countries. More than 40 of these locations offer Simine Services to assist the mining industry with all service, maintenance and modernization assignments. To be even closer to the mining companies, Siemens has recently opened new service centers in Calama, Chile; Arequipa, Peru; Monterrey and Zacatecas, Mexico; and Belo Horizonte, Brazil. Additional service centers in India and Russia will be established within the year.

Simine Services provides optimum support for all maintenance work. Various services can be individually combined to meet the requirements of the specific mining plant. The offering begins with operational support and maintenance services and ends with plant modernization and optimization.

Service contracts to minimize downtime of technical faults
A core element of a service agreement is the development of effective maintenance programs and the implementation of preventive maintenance measures – all established jointly with the customer to provide reliable protection against faults and equipment failures. Our service technicians and engineers have practical experience combined with in-depth technical expertise in automation and drive technology, measurement and control technology, process and production control systems, and energy technology.

In the case of faults, the service technicians and engineers ensure that errors in electrical systems are cleared quickly and reliably on-site. A rapid reaction is guaranteed by a 24/7 service hotline. Individualized agreements relating to technical specifications and response times ensure that problems are resolved quickly and directly. Remote monitoring of mining systems and equipment, such as teleservice for electrotechnical components, is also available. This allows technical problems to be identified and corrected even faster, and faults can be avoided from the outset.

Service contract references for customers with mine winder and gearless mill drives include the Südwestdeutsche Salzwerke AG in Germany; Somincor in Portugal; Iberpotash in Spain; Olympic Dam, Cowal and Cadia in Australia; Minera San Cristobal in Bolivia; Lumwana Mining Company in Zambia; Rio Paracatu Mine in Brazil; and Peñasquito (Goldcorp) in Mexico.

Material and spare-parts supply
We assure the availability of required materials and spare parts at a reasonable cost – for everything from inventory and process analysis to optimization of purchasing processes. Our offering also extends to the ordering of materials. We carry out any repairs in our certified services centers or in cooperation with the manufacturer.
Consulting and engineering
In the framework of a plant performance audit, we analyze the condition of plants and processes. Our engineers also identify bottlenecks in the production process and develop suitable countermeasures. Furthermore, on the basis of process parameters we examine the degree of automation in the production process as a whole in order to find possible ways to increase yield through optimized control loops and fewer manual operations. Based on an investigation of the plant’s entire energy consumption, engineers make suggestions to boost energy efficiency and reduce consumption peaks.

Training
Qualification of the customer’s own employees is a key task. Simine Services offers comprehensive training courses in the areas of technology, equipment, operation, management and maintenance.

Maintenance services
Simine Services maintenance packages cover defined maintenance activities with a guaranteed life-cycle performance for electrical systems, drives and automation, switchgears and motor management, as well as ready-to-use solutions for the management of secondary processes and general overhauls.

Maintenance contracts
For those companies that outsource plant maintenance, Siemens offers a win-win partnership. Apart from carrying out scheduled proactive and preventive maintenance, daily maintenance work, repairs and special assignments during general overhauls, we can also take over maintenance management. Together with the customer we define the performance metrics such as plant reliability and availability as well as actual performance figures for the plant or machinery in question.

This data is laid down in a success-related contract. On the basis of these metrics it is possible to establish key performance indicators. According to your requirements we perform maintenance either for complete plant sections or for individual components and systems such as conveyor systems, electric motors and power-supply systems.
Maintenance contract references include Minera Los Pelambres and Radomiro Tomic Mine (Codelco), both in Chile; Vattenfall Europe Mining AG in Germany; and Minera Peñasquito in Mexico.

**Plant modernization and optimization**

With our mining-specific and standardized modernization solutions, we replace the systems used in machines and equipment with state-of-the-art solutions that ensure the overall availability and reliability of production. The investment generally pays off after a short time through increased availability, improved production quality and reduced maintenance requirements. In addition, our modernization activities usually target the main electrical and mechanical parts of the installation. By doing so, the downtime needed for modernization is reduced to an absolute minimum.

Our comprehensive range of modernization solutions for mining covers complete large-scale solutions, the modernization of Simine parts, and mining equipment from other suppliers.

**Faster, better, more productive – Simine modernization measures pay off.**

**Newly developed modernization solution for mills**

Siemens developed new modernization packages to improve the life cycle and availability of Simine Mill GD installations. Along with bringing the automation system up to the latest version of Simatic S7 and Simatic PCS7, the new modernization solution for gearless or twin-pinion mills also includes a newly developed retrofit solution for the drives control system. This solution makes it possible to replace analogue or early digital drive control systems like Simadyn C/D without the having to replace the motor, transformers or even the power section of the existing cycloconverter. Together with new diagnostics and remote-service features, the modernization solution helps increase reliability and availability of the plant while reducing necessary maintenance.

Only a short shutdown of less than ten days was needed to implement the highly standardized modernization solution at the SAG mill of Codelco Andina in Chile. During the modernization in March 2010, Siemens migrated the control system of the mill into Simatic S7 and Simatic PCS7. Another reference project is the migration of an early version of the digital drive-control system Simadyn D at the Robinson open-pit copper mine in Nevada. The twin-pinion drive of the SAG mill is equipped with a new control system based on Simatic S7 and a new drive-control system based on Sinamics.
Rio Paracatu Mineração’s Morro do Ouro mine is an open-cast operation owned by the Kinross Gold Corporation. The mining site is near the historical gold-digger city of Paracatu, around 220 km to the southeast of the capital, Brasília. Rio Paracatu Mineração is the largest active single gold mine in the world in terms of ROM (run-of-mine) processing and uses modern technology to increase its production. As part of the expansion project, Siemens supplied a Simine Mill GD gearless drive system with 20,000 kilowatts of rated power. With a diameter of approximately 12 meters and a length of around 7 meters, the new SAG (Semi-Autogenous Grinding) mill is one of the largest mills in the world.

First step: Detect the frozen charge and avoid damages

When maintenance has to be carried out, grinding mills used in mining installations have to be shut down for several hours or even days. In this time, the remaining mill charge can easily solidify, firmly attaching itself to the shell of the mill. This is called “frozen” (i.e., hardened) charge. When the mill is restarted, there is a danger that the frozen charge will not detach itself from the mill shell immediately, but will initially be lifted up by the mill and then dropped from a great height. The resulting damage to the mill can be severe. To detect firmly attached charge in good time and switch off the mill, Siemens developed a frozen charge protection function for gearless mill drives of the type Simine Mill GD. In normal operation the charge starts sliding after the mill reaches an angle of between 40° and 70° and the load torque decreases. This decrease in torque is monitored and used by the frozen charge protection to stop the mill.
before falling frozen charge damages it. This prevents damage but does not automatically eliminate the frozen charge. Frequently, the material does not break up and remains stuck to the mill’s shell. Only with labor-intensive mechanical means such as jackhammers or pressurized jets of water can the firmly attached charge be removed. This is time-consuming work, which causes loss of production.

**Second step: Remove the solidified charge and increase productivity**

With the help of the Frozen Charge Shaker function integrated in the Simine Mill GD system, deposits can be loosened by causing the mill to move systematically. To do this, the operating personnel initiates the mill drive’s Frozen Charge Shaker mode from the local control desk. Defined forward and reverse movements of the mill lift the charge to a less critical angle and move the mill in a harmless range with varying speed and acceleration. The angle and movement are designed to break the frozen charge and remove it from the mill body. The motor is the same one that is used for grinding. The Frozen Charge Shaker avoids production from being interrupted for the removal of a solidified charge attached to the mill shell. This prevents the mill from being damaged as a result of charge falling down in an uncontrolled manner and simultaneously reduces maintenance times considerably. Given that production is worth thousands of dollars per hour, maintenance cycles costing several million dollars can be avoided.

**Next steps: New projects in Zambia and Chile**

At the Equinox Copper Ventures Ltd. of Zambia, Siemens equipped two ore-grinding mills for the Lumwana copper project with gearless Simine Mill GD drive systems. The Frozen Charge Shaker function will also be used there. The Lumwana copper mining district is around 220 km west of the Copperbelt in Zambia’s North-Western Province. A SAG mill and a ball mill will be used to grind the ore.

At Los Bronces, part of the Anglo American Chile company, Siemens supplies a 22 MW gearless drive for a 40-foot SAG mill and two 16.4 MW gearless drives for two 26-foot ball mills. Thanks to this development project, Los Bronces will be one of the biggest copper and molybdenum mines worldwide. The gearless drives are designed to provide mill drives with the lowest possible power consumption and are equipped with the Frozen Charge Shaker function.
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For us, increasing conveyor availability and energy efficiency is a single task.

Siemens gearless drives support the mining industry in meeting the challenges of the 21st century.

Mining Technologies

The first conveyor system to operate with AC gearless drives was installed in 1986 by Siemens and ThyssenKrupp (formerly O&K) in the Prosper-Haniel mine belonging to Deutsche Steinkohle AG – and it achieves an availability of over 98 percent. Besides its outstanding availability and performance the gearless drive solution has a number of advantages over the combination of high-speed motor and gearbox typically used on conventional conveyor systems.

The required power levels for the large overland conveyor can be achieved with fewer drives and a reduced footprint. Longer single conveyors with less conveyor transfer stations can be designed. Due to the efficient drive system without a gearbox overall efficiency can be increased by approximately 4 percent. And because gearless drives require fewer mechanical and electrical components, higher reliability can be achieved with lower maintenance costs.

www.siemens.com/mining-conveyor