SIEMENS
Ingenuity for life

SIMINE Gearless mill drives

Raising the bar for performance and productivity

siemens.com/mining

Your challenge: High availability, lower costs, better performance

Grinding is a crucial process step in ore processing – and for a mine's overall performance. That's why a grinding mill's gearless drive is the crucial piece of equipment in the concentrator – and why it is subject to very rigorous demands. High availability and reliability throughout the entire lifecycle are a must, while unplanned downtime needs to be minimized by proven design and skillful maintenance planning.

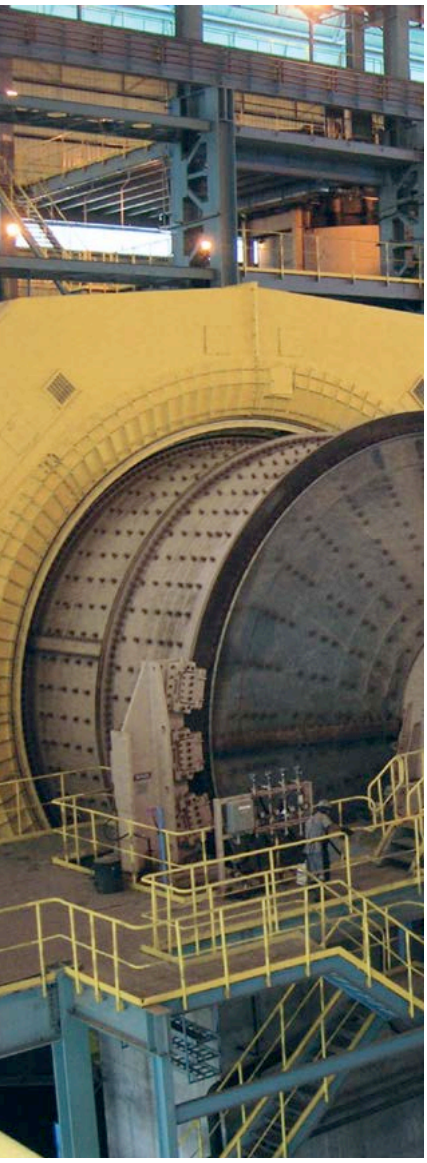
Operating expenditure also needs to be kept down to ensure economic viability and competitiveness. Energy consumption swallows up the majority of operating costs so the solution needs to take account of low energy consumption and be flexible enough to adapt to production volumes as well as to ore characteristics.

You expect …

- **Operational reliability**
- **High productivity**
- **Lower operating costs**
- **Minimized downtime**
- **Comprehensive service**


SIEMENS

Our solution:
SIMINE Gearless mill drives – outstanding reliability for your mine



The gearless concept

The gearless drive avoids any contact between the rotating mill and the static parts of the motor. This allows for continuous workflow without maintenance on the gears or the pinions. What used to be downtime is now productive time.

Vibration-free, low-weight, short-circuit-proof design with high stiffness

Designing highly complex capital goods like a gearless drive means starting with a perfect concept. Siemens offers a minimum-weight, short-circuit-proof design featuring maximum stiffness especially for motors. This is why the motor's resonance frequency is considerably higher than its operating frequencies.

Reliability and availability

The extremely high reliability and availability of Siemens SIMINE Gearless mill drives is based on mature technology, which we continually update with new, proven features. Cycloconverters, for example, are just one of the reasons why Siemens solutions excel. Their decisive advantage over other products on the market? They are fuseless and short-circuit-proof. And thanks to innovative software solutions, short power breaks can be bridged without interrupting operation of the SIMINE Gearless mill drives.

Longer service intervals thanks to low-wear drive processes

SIMINE Gearless mill drives' rpms can be tailored to your operations at any time, and are infinitely variable and uncomplicated. Whether manually or fully automatic – rpms can be adjusted to account for the properties of the ore, resulting in significantly less wear to the mill lining. The mill's direction of rotation can be changed simply with a switch so that wear on the liner is distributed equally from both sides.

Shorter maintenance time for mills

Simple control of the inching and creeping modes lets you quickly set up mill maintenance procedures without endangering employee safety. When the SIMINE Gearless mill drive is in inching mode, one rotation of the mill is all you need. The mill will reach the exact angle that was preset by the operator, and the procedure does not need to be repeated. At the end of the inching operation, the SIMINE Gearless mill drive stops the mill with balanced charge, and with no time-wasting oscillations.In creeping mode at 0.3 rpm, the operator can directly control the mill while observing the mill and the material. Whether inching or creeping, you can dramatically shorten the mill's maintenance time, and thereby significantly boost availability and mill productivity.

Good reasons to choose SIMINE Gearless mill drives

- **Operational reliability**
  through the less vulnerable gearless concept and a vibration-free, sophisticated design with a proven track record that reduces unplanned downtime to a minimum
- **Lower costs**
  through optimized electrical efficiency and reduced wear
- **Comprehensive service**
  with a multitude of features that help keep your mill up and running
- **Minimized downtime**
  through dedicated maintenance modes such as creeping or inching with rollback of mill
- **High productivity**
  due to outstanding availability and the highest reliability on the market

Comprehensive services

Online monitoring

Find out instantly how the mill and gearless drives are operating. Monitor operations from any plant office, maintenance office, management office, the Siemens office, or from any connection that allows online Ethernet communication.

Fault analysis

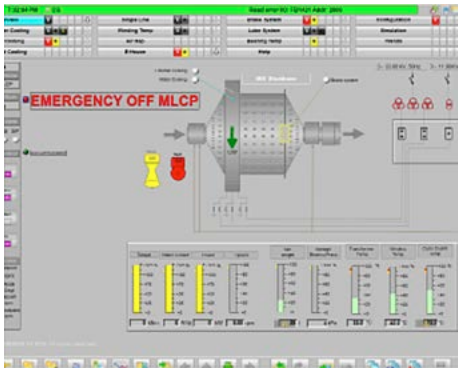
To facilitate quick and efficient fault analysis, our reliable diagnostic system includes transparent fault documentation (using the WinCC visualization system), and features a high-speed data recorder that displays all procedures involving electrical variables.

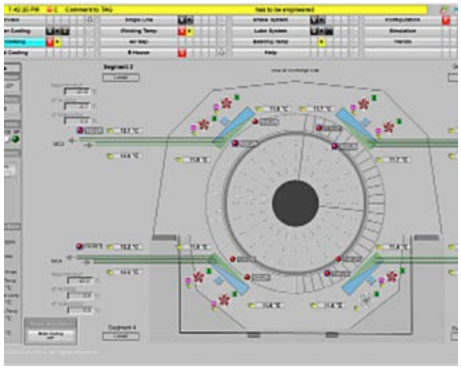
Maintenance by Siemens

Siemens has service engineers who are trained in gearless drive technology in major mining countries. Siemens offers maintenance contracts tailored to your specifications. The main types of contracts are preventive maintenance with on-call service and performance-based maintenance contracts.

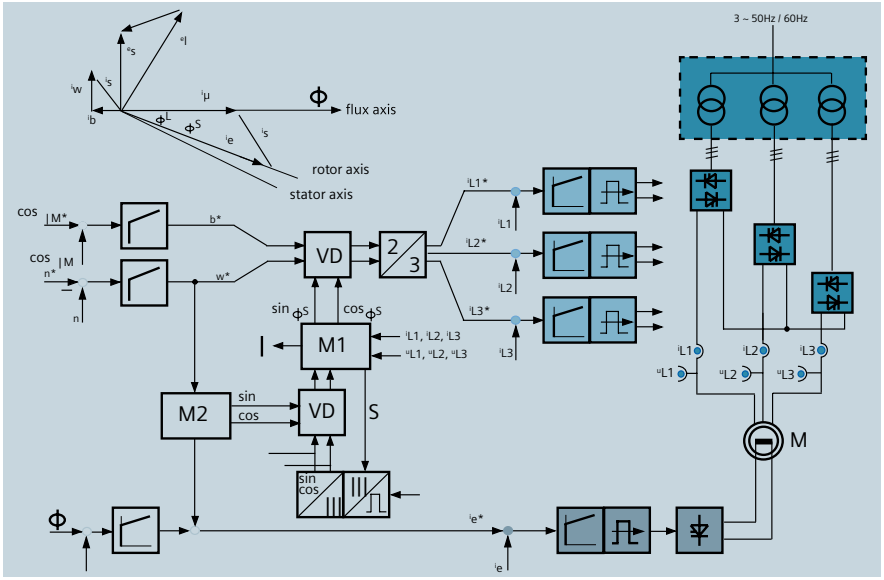
Remote service

The user's local maintenance personnel or Siemens' maintenance personnel are assisted by experts at the factory who provide remote diagnostics via online Ethernet communication, recommendation-based troubleshooting, direct fault diagnostics and downloading, and software installation while the machine is operating.

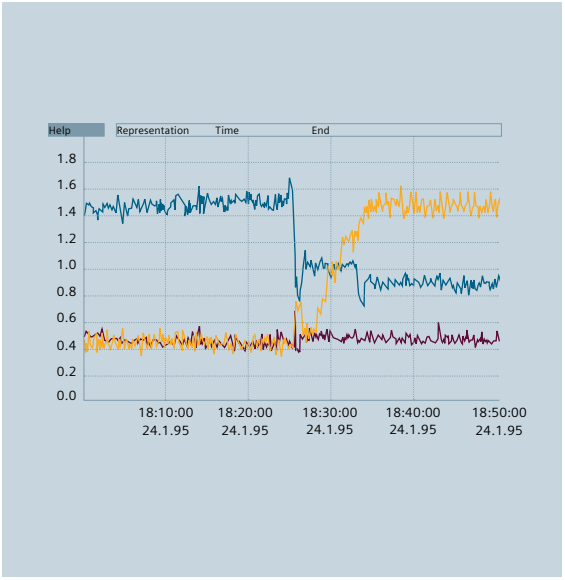




More than 50 years of experience in reliability



Control and vector diagram for field-oriented operation



Typical recording of filter/compensation equipment in operation

Control principle

The substantial demands on the operating performance of mill drives require a powerful control system. Excellent performance characteristics can be obtained by applying TRANSVEKTOR® control. The control principle shown above is based on aligning the stator current's phase angle with the angle of effective flux. To calculate flux conditions, the motor is simulated by two mutually supplementary models, thereby permitting machine currents to be injected optimally at any time throughout the entire speed and load ranges. This means that the synchronous machine, as seen from the speed control system, behaves like a DC machine.

The TRANSVEKTOR control system used on high-power mill drives has gone through a long development phase. A lot of experience has been gained with this system during the last 33 years. The first gearless drive with this control has been operating successfully for more than 30 years.
A phase of continuous improvement and further development followed its launch. Today, the TRANSVEKTOR control system is entirely digital, resulting in a relatively small number of different hardware modules, absolute reproducibility of settings and substantially improved diagnostics for easy troubleshooting.

Filter and compensation

The need for filter and/or compensation equipment is not a given issue for a gearless drive system. A harmonic study determines on a case-by-case basis whether the plant configuration and network in question need harmonic filtering. As the drive concept is a 12-pulse system, only the 11th and the 12th harmonics and their related sidebands have to be looked at. Harmonics with higher harmonic order exist, but their magnitude is negligible. The first step is to develop a complete plant single line with all users and their respective loads and to get complete information about the network. This, together with the restrictions imposed either by the code or the power company, allow a harmonic study to be performed. The results of the study determine the need for filtering. If filtering is necessary, the compensation of the power factory is taken into account.

Sophisticated design – from engine to project management

Whether you're talking about SAG or a ball mill, space is a delicate issue, especially in the concentrator. That's why we always design our Gearless mill drives drives to combine maximum performance with limited space requirements.

Suitable foundation and adequate ground conditions

Since our solutions have a low motor weight, this noticeably reduces the demands on the foundation and ground conditions. The layout needed for the buildings and the installation cranes is therefore simpler than that required by others.

Open-air installation

The outdoor version of SIMINE Gearless mill drives has been successfully in operation since 1998. The outdoor version's design takes into account tough ambient conditions as well as the absorption of solar radiation. The SIMINE Gearless mill drives' sealing system has a proven design incorporating extremely low maintenance with ingress protection that is rated at IP 55, and complemented by a purpose-built rain shield. The outdoor version of SIMINE Gearless mill drives means that a concentrator building is not needed, a considerable investment capital saving.

Optimal project development

Special attention is paid to Siemens project management in order to achieve: optimum project development; milestones on the client's project schedule; perfect coordination with other equipment and service providers; minimum start-up time; rapid attainment of production; maximum uptime, and specific quality objectives. Siemens designates an experienced engineer as the project manager, who is the contact for the customer and therefore the focal point when it comes to Siemens resources that are necessary for the project. The key responsibility of project management is to lead and coordinate Siemens' project activities throughout the project in accordance with the client's schedule. A main factor in meeting these objectives is transparency for the client and the active involvement of the customer's personnel.

Clearly defined interfaces

The project manager is also responsible for ensuring that all activities are properly coordinated with the activities of others involved in the project, e. g., mill supplier, civil engineer, installation contractor and the client's consultant engineer. All interfaces to others are defined and clarified in a very early stage of the project and documented in drawings for approval by the client. The clarification of the mill-motor interface is a multifaceted task, a procedure which has been repeated successfully many times in the past.

Siemens has earned a quality systems certificate for standard ISO 9000 and has implemented quality systems in accordance with ISO 9001.

Operational reliability: a direct path to greater productivity

Electrical equipment and automation of a drive system

Larger grinding mills are at the heart of every grinding section. Stringent demands to achieve high throughput, highest availability, optimized grinding circuits and power consumption optimization require high-performance electrical equipment in addition to the technological and mechanical prerequisites. Besides conventional equipment, which essentially consists of the energy supply and power section of the gearless drive and the associated auxiliaries, increasing importance is being attached to plant automation and diagnostic systems.

Short-circuit-proof cycloconverter

The synchronous machine is fed by a cycloconverter (CCV). This cycloconverter transforms the three-phase system of the line with fixed frequency to the variable frequency of the motor. The converter's output voltage consists of parts of the line voltage which, when arranged in series, produce a sinus curve.

A number of measures taken in the closed-loop control system make it possible to use a cycloconverter in this simple configuration and yet achieve excellent torque variation with negligible harmonics. The harmonics produced in the torque are significantly below 2 %. This satisfies the requirements of all grinding motors. The reversible converters are operated without circulating current, thus leading to a relatively simple design of the power selection and low reactive-power demand. Siemens' cycloconverter is fuseless and short-circuit-proof.

Its thyristors are designed to disconnect the short circuit. The benefit to you is that fuses or other components do not need to be replaced if this type of failure occurs.

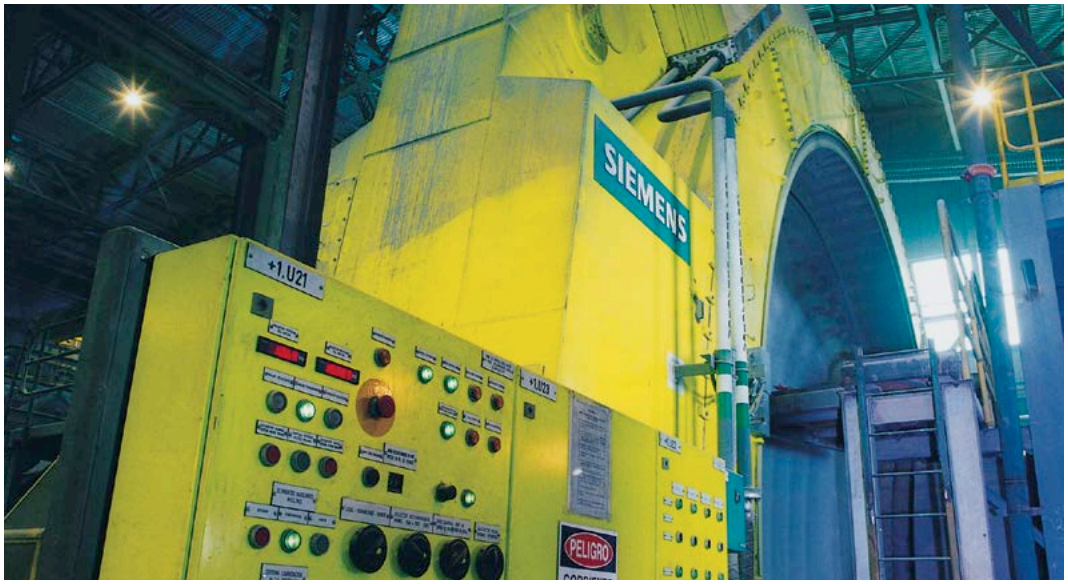
Short-circuit-proof motors

As it is not possible to completely avoid short circuits in electrical systems, all electrical standards require that electrical equipment is resistant to the high forces resulting from short-circuit currents. SIMINE Gearless mill drives have proven their resistance to short-circuit forces in several scenarios. High absorbability and damping attributes are required to resist abnormal operation conditions such as those which result from short-circuit forces.

The gearless drive's motor provides an optimum solution balanacing damping attributes and high stiffness. High stiffness together with low weight is required for high resonance frequencies in order to prevent vibrations.

Stiffness and vibration analysis

Every mechanical system must undergo stiffness and vibration analysis. This verification is more complex for the gearless drive system because the rotor is an integral part of the mill body and the motor has no bearings of its own.



These calculations have to take into account the complete system, consisting of motor, mill and foundation in order to ensure an optimized system. The calculations therefore must be performed together and involve the mill supplier, motor manufacturer, and a civil foundation engineer.

Siemens applies the highly sophisticated FEM model for design and examination. The FEM model considers mechanical relations as well as non-linear electrical equations and deflection as a function of location, without blowing the safety factors out of all proportion.The highly sophisticated FEM model was developed based on experience with the Cadia ring motor. When designing large structures, such as a gearless drive's stator, high stiffness is required in order to increase the values of resonance frequencies and resonance modes.

There are therefore many reasons why low weight is advantageous:

- For installation, because cranes have to move stator segments
- For concentrator building design, because the overhead traveling crane has to be supported by the building structure
- For foundation design, because it reduces foundation costs
- To increase resonance frequencies, because the value of resonance frequency is reciprocal to the weight

Instead of a heavy-weight solid structure, Siemens has equipped the stator structure with attributes that are designed to attenuate extreme forces caused by possible short circuits. Siemens' highly sophisticated FEM model allows you to find the optimum design for gearless drive motors with the highest stiffness and lowest possible weight.

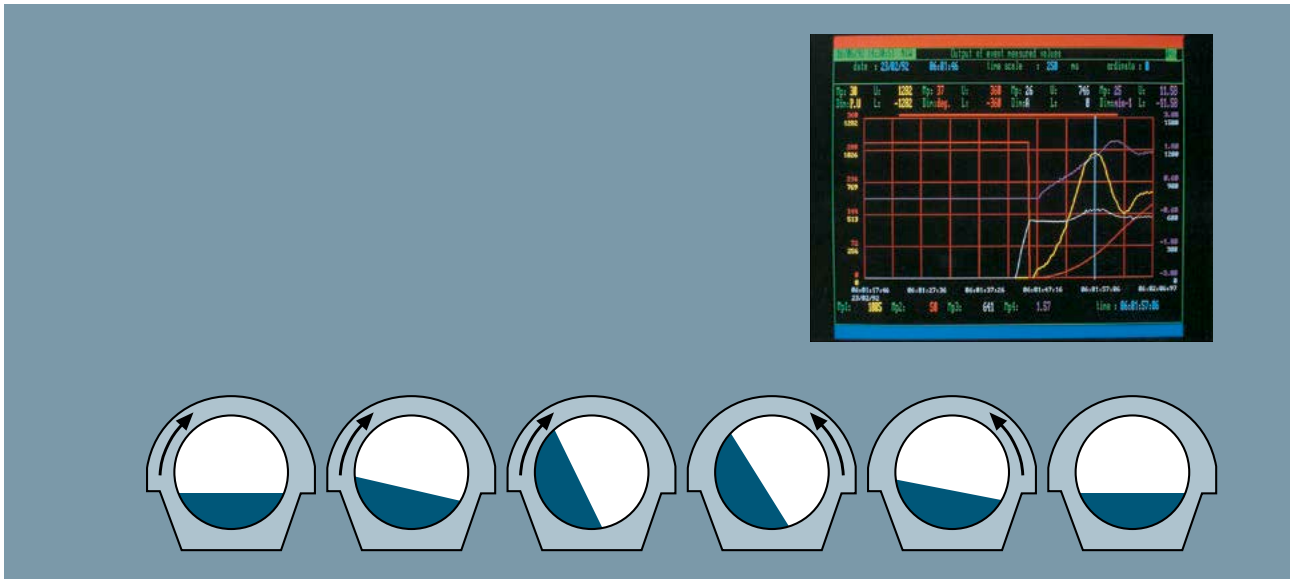
Seismic proof calculation

Since decades dozens of SIEMENS Gearless Mill Drives are in operation in areas of tough seismic activities, as Chile and Peru. All those GMDs were designed according to the state of art at the time of delivery, mainly according to the Uniform Building Code (UBC) of 1994 and 1997, considering the seismic zone 4 of that code.

Most of the seismic proof calculations were performed using the Static Force Procedure defined in chapter 1630.2 of the UBC '97.

There are also Siemens GMDs in operation, designed according to the International Building Code (IBC) and other according to the Official Chilean Standard NCh2369 (Earthquake-resistant design of industrial structures and facilities).

Enhanced control for better operation – inching, creeping, succeeding



Inching procedure

Easy operation

A simple control panel based on a highly sophisticated system helps the operator handle the mill by simply pressing a few buttons. The design facilitates the mill's operation and reduces maintenance. Normal operation is implemented from the local control panel or remotely from the central control room. Each normal stop ends with a balanced charge of the mill, preventing any subsequent mill oscillation. A change in rotation direction is initiated by turning a switch during standstill.

Inching

Inching is fast and ends with the balanced charge of the mill, and no subsequent oscillations. The maintenance operator selects the required angle at the local control panel.
The SIMINE Gearless mill drives accelerate the mill to 1 rpm. While the mill is starting, the turning angle with the maximum required torque (when the charge starts to cascade) is stored together with the measured torque value itself. Using these values, the closed-loop control system automatically calculates the angle that is required to balance the mill during the stop procedure. The SIMINE Gearless mill drives turn the mill to the requested angle indicated on the local control panel, and it overturns it by the calculated angle which is required to balance the mill. Then it automatically changes the direction of rotation and turns the mill back to the requested angle, stopping with a balanced charge.
The brake is applied automatically.

There is no waiting time. Nor is any additional operation needed to balance the mill's charge. Maintenance personnel can safely enter the mill on an even surface without risk of moving material.

Creeping

Creeping at 0.3 rpm is useful for slow movements, which the maintenance operator can observe directly in order to trim the mill precisely to a certain position. The portable creeping panel allows for mill operation, e.g., standing at the feed side and looking inside the mill (with the chute removed). This enables the operator to turn the mill exactly into a position where the requested liner just leaves the material.

With the portable creeping panel, the operator can move freely around the mill, and is able to observe the mill from different places. Pushing the "Run" button on the creeping panel starts the motor turning the mill slowly at 0.3 rpm in the direction selected on the local control panel. The SIMINE Gearless mill drives lift the charge. The operator will most likely wait until the charge cascades. To stop the mill, the operator releases the push button, and the SIMINE Gearless mill drives hold the load, apply the brake and the charge remains in an imbalanced position. From this imbalanced position the operator can continue turning the mill by pushing the "Run" button.

The SIMINE Gearless mill drives now start the mill directly from this imbalanced position. This mode allows different points on the mill shell or inside the mill to be inspected quickly one after the other without the need to balance the mill in between. The operator can even change the direction of rotation at the local control panel and let the mill turn in the other direction.

Balancing

To balance the mill from any position, the operator can simply switch over to balancing mode and start the mill. This makes the gearless drive balance the mill without any oscillations to give the maintenance crew immediate and safe access. The inching and creeping procedures and their easy handling considerably reduce downtime for mill maintenance, and increase mill availability and productivity.

These goals can be achieved by using our high-precision tachometer, which has a resolution of 3 mm.

Frozen Charge Protection

A "frozen" or "baked" charge is capable of destroying the mill body and bearings if it drops from the top of the mill after a 180° revolution. This can cause extended downtime and considerable production losses. This specific problem of wet grinding mills has been discussed by our customers and our system experts. Detailed knowledge of the technological problem together with the capabilities of the TRANSVEKTOR closed-loop control system enabled Siemens to develop Frozen Charge Protection.

In normal operation, the charge starts sliding after the mill reaches a specific angle of between 40° and 70° and the load torque decreases. This decrease in torque is monitored and used by the Frozen Charge Protection system to stop the mill before dropping frozen charge damages the mill.

Frozen Charge Shaker™

Stopping the mill in case of frozen charge prevents damage to the mill, but does not completely solve the problem. After stopping the mill, the charge stays in "frozen" condition and must be broken up with mechanical means and water. These efforts take time and cause production losses.

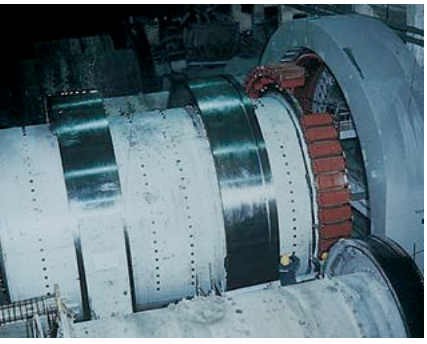
The SIMINE Gearless mill drives provide a Frozen Charge Shaker that breaks up the frozen charge and removes it from the mill body. The Frozen Charge Shaker lifts the charge to a risk-free angle, and moves the mill in a harmless range with varying speed and acceleration. The angle and movement are designed to break the frozen charge and remove it from the mill body. This feature is patented in all mining countries.

Excellence from experience

Selected success stories with SIMINE Gearless mill drives

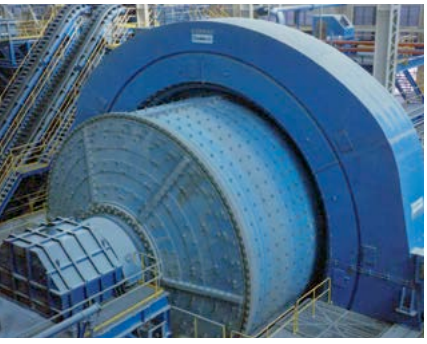
Our more than 40 years of experience in the design, planning and building of reliable gearless drives for mining operations mean that you can count on us to help you improve your position. We have installed more than 70 gearless drives for mills with a total of more than 1 million kW power.

We have also provided more than 70 solutions for optimal productivity, demonstrated by over 780 machine years of successful operation time. The success stories presented below provide just a brief impression of our comprehensive experience.



The world's first gearless drive for the ore industry (1979)

Customer:	A/S Sydvarangar, Norway
Plant type:	Ball mill, 21 ft
Our solution:	Replacement of an existing 240-t mill and a drive power of 1,100 kW
Technical data:	1,000-t mill with 8,200 kW drive power
The result:	The new mill was positioned where the smaller mill had operated before – on the same limited floor space. Speed control was designed for 25 % downward from rated speed at constant torque and 5 % upward at constant power.



The world's first gearless drive for an SAG mill (1988)

Gearless drive for two SAG mill copper ore grinding circuits, commissioned in 1988

Customer:	Chuquicamata, Chile
Plant type:	SAG mill, 32 ft
Our solution:	Installation, commissioning and testing of two gearless drives
Technical data:	Two gearless drives rated 8,200 kW each at 10.2 rpm
The result:	A cycloconverter (CCV) drive system designed with fuseless water-cooled and short-circuit-proof thyristor equipment was used for the first time, as was a containerized electric package (E-house) instead of a standard electrical room.

First gearless drive for a 40-ft SAG mill (1998)

Customer:	Cadia Gold Plant, Newcrest Mining, Australia
Plant type:	SAG mill, 40 ft
Our solution:	Development of a new drive with unprecedented dimensions
Technical data:	20,000-kW drive for a 40-ft SAG mill
The result:	The first gearless drive for a 40-ft SAG mill was installed at Newcrest Mining's Cadia Gold Plant in Australia. The drive provides nominal power of 20,000 kW to the mill shell. The gearless drive for Cadia's 40-ft SAG mill has been running since 1999 at optimum availability and to the complete satisfaction of the user.

First Gearless Drives at an altitude above 4000m (2011)

Customer: Cia Minera Antamina, Peru (2011)

Plant type:
- One gearless mill drive for a 38 ft SAG mill
- One gearless mill drive for a 24 ft ball mill

Our solution: Installation, commissioning and testing of the gearless drives at an altitude of 4,300 m

Technical data:
- Power: 20,142 kW for a 38 ft SAG mill
- Power: 11,190 kW for a 24 ft ball mill

Customer benefit:
- Minimized downtime
- Operational reliability
- High productivity

Some of the world's biggest and most powerful gearless drives for a copper mine

Customer: Kalumbila Minerals Ltd., a subsidiary of First Quantum Minerals Ltd., Zambia

Plant type: SAG mill, 40 ft; ball mill, 28 ft

Our solution: Providing and commissioning a one stop solution with motors and gearless drive systems for two 40-ft SAG mills and two 28-ft ball mills, including a preventive maintenance program, frozen charge protection, SIMATIC PCS 7 and SINAMICS SL150 cyclo-converter technology.

Technical data: 28-MW drives for two 40-ft SAG mills; 22-MW drives for two 28-ft ball mills

The result: The Siemens gearless mill drives' high availability of 99.5 % allows downtime to be minimized while offering additional production time, lower operational costs and high performance. Beyond end-to-end technology, mine operators also benefit from services for the life of the mine.

World´s largest Gearless Drives for six 40-ft AG mills (2016)

Gearless Drives for six AG mills magnetized iron ore grinding circuits, commissioned in 2016

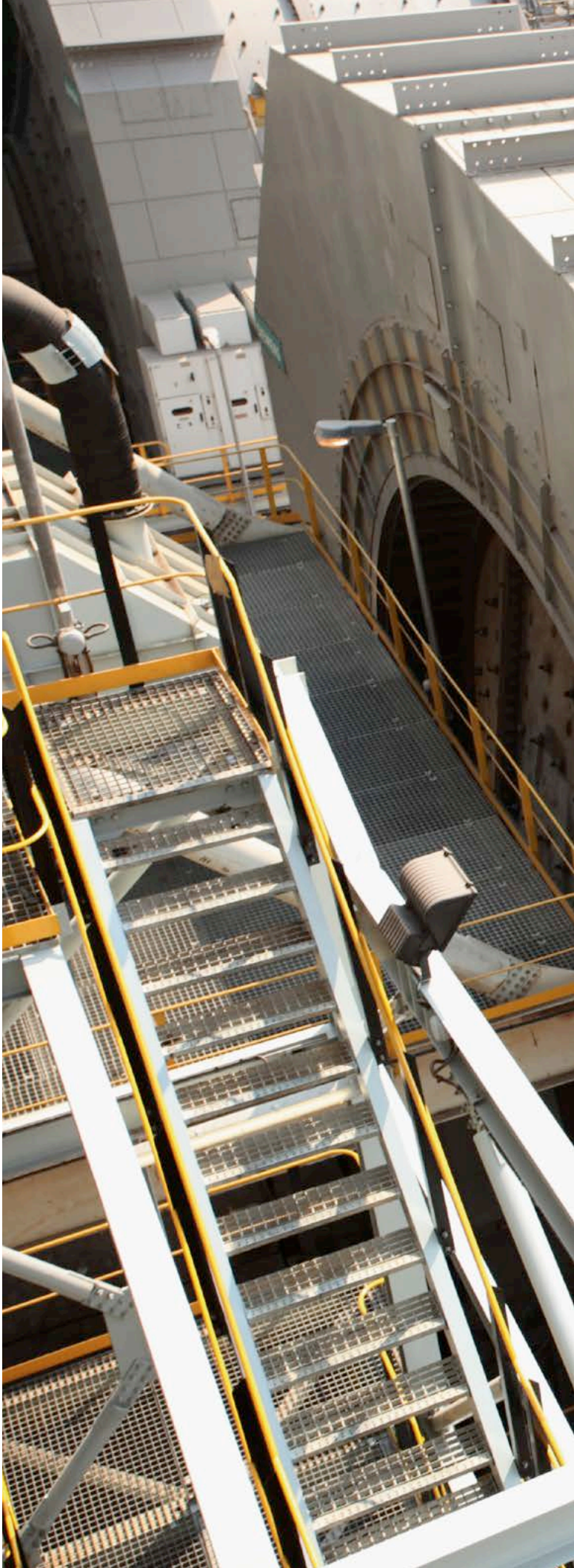
Customer: CITIC Heavy Industries Co., Ltd., China

Plant Location: Western Australia

Our solution: Engineering, Installation, commissioning and testing of six Gearless Drives

Technical data: 28,000 kW for six 40 ft AG mills

Customer benefit:
- Minimized downtimes
- Highest availability in the market
- High productivity



Published by
Siemens AG 2019

Minerals - Mining
Schuhstr. 60
91052 Erlangen, Germany
Email: mining@siemens.com

Article-No.: VRMI-B10023-00-7600
Dispo 21662
gB180270 BR 12180.0