Electrical equipment for the materials handling system at the copper mine of El Abra, Chile (1996)
1. Introduction

The newly developed copper mine of El Abra is located in the Atacama desert in the north of Chile, about 70 km away from Calama. The copper ore is extracted at a height of 4000 metres and transported by trucks to a gyratory crusher where it is broken down to particles of <300 mm. A belt-conveyor system consisting of three flights of 400 m, 5058 m and 9525 m, respectively, and a rated capacity of 8700 t/h, then carries it to an elevation of 3500 metres where it is dumped on a stockpile via a shifting head.

Further crusher units, arranged in three parallel lines, reduce the particle size to a maximum of 19 mm. With sulphuric acid added in rotating drums, the ore gets on a 2358 m long conveyor which separates the leach pad (1600 m long) into two parts, each 400 m wide. A rail-bound tripper car transports the acid-treated ore to a 430 m long mobile stacking bridge travelling on 11 crawlers. A mobile discharge boom on that bridge serves to pile the material on the leach pad up to a height of about 6 m.

After some 60 days the leached ore residue, taken up by a bucket-wheel reclaimer, is fed on a mobile reclaim bridge of similar construction as the one describe above, from where it gets, via a loading hopper on the feed-out conveyor (2432 m long) in the middle between the two halves of the leach pad. A 2200 m long shiftable residue conveyor and another tripper car carry the material to a spreader (consisting of a 60 m long intermediate conveyor and a 60 m long disposal boom) dumping it on the stockpile.

The materials handling system described above has an initial capacity of about 95 000 t/d. An increase to 140 000 t/d is envisaged with the same system configuration for the future when the copper content of the ore will be lower.

The output of the El Abra plant will be 225 000 t of electrolytic copper a year. Towards the end of 1994, the Industry Division of ABB Cottbus received the order for engineering, supply and erection supervision of the entire electrical equipment from MAN TAKRAF Fördertechnik GmbH, the supplier of the materials handling system. The equipment was delivered to Chile between June and October 1995. Trial runs of the three overland conveyors and the stacking system started in June 1996, the reclaiming system followed in August, and on 25 October 1996 the complete project was officially handed over, in the presence of the Chilean President, to the mining company Sociedad Contractual Minera El Abra (SCM).

In addition to the extremely short implementation period, it is the unusual ambient conditions which result in high demands on functional safety that distinguish this project from many other materials handling systems for which ABB Cottbus has designed and supplied the electrical equipment during the past forty years.
Which problems had to be faced?

<table>
<thead>
<tr>
<th>Problem</th>
<th>Consequence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elevation of 3500-4000 m</td>
<td>reduced air insulation</td>
</tr>
<tr>
<td></td>
<td>increased UV radiation</td>
</tr>
<tr>
<td></td>
<td>higher ozone influence</td>
</tr>
<tr>
<td>Big temperature differences between day</td>
<td>condensation problems</td>
</tr>
<tr>
<td>and night</td>
<td></td>
</tr>
<tr>
<td>Permanent wind</td>
<td>highly abrasive dust</td>
</tr>
<tr>
<td>Transport of acid-drenched ore</td>
<td>danger of corrosion</td>
</tr>
</tbody>
</table>

Under these circumstances it was necessary to use special sealing material for outdoor equipment boxes and installations as well as special rubber mixtures for cables, and to refrain completely from installing galvanised cable trays and tubes.

2. Main electric components

The following briefly describes major component parts which have been used throughout the system. Due to its special drive solution, overland conveyor CV-103 will be characterised in detail under item 3.

2.1. Power supply

The incoming power supply is made from a 23 kV grid with 5/6.25 MVA transformers of 23/6.6 kV standing next to the conveyor drive stations.

For the supply of power to mobile units, the tripper or hopper cars moving along the conveyors 202, 205 and 206 are equipped with cylindrical cable reels for 6.6 kV trailing cables. The mobile units on the two bridges (discharge boom and loading hopper) are fed via helical reels.

It should be mentioned that the cable reels are equipped, in addition to the 6.6 kV sliprings, with rotary connectors for the transfer of data through the optical-fibre conductor integrated in the trailing cable.

The operating voltage of the conveyor drive motors is 6.6 kV, and low-voltage drives are fed with 400 V.
2.2. **Electric-house containers / switchgear**

The electric houses for permanently installed conveyors have been put on concrete foundations near the drive stations. The houses for mobile units and the shiftable conveyor 206 have been integrated into the mechanical structure.

The time for erection and commissioning could be considerably reduced by installing all electrical equipment into the containers in Germany, i.e.

- installation of the 6.6 kV switchplant consisting of
  - incoming-feeder panel
  - motor-feeder panels
  - feeder panels for DC braking (conveyor 103)
  - panel for 400 V auxiliary transformer
- installation of the 400 V switchplant and the rotor-contactor panels - in fuseless execution, according to the specification
- panels for the control hardware including an uninterruptible power system (230 V, 1000 VA)

The above equipment had been, as far as possible, wired and tested in the workshop of the container manufacturer (particularly all control connections from the PLC panels to the HV and LV switchgear). 17 containers were shipped as complete transport units. The largest of them was 10.5 m long.

The size of the containers varies according to the number of panels they have to take up, but the structural principle is the same:

The supporting structure consists of 400 mm U-shaped girders all around the bottom on which the side walls are fixed. The side walls have a double sheet-steel wall (2 mm thick outside and 1.5 mm inside) with 60 mm of insulation in between. The roof insulation is 80 mm thick.

The girders have supports for switchgear installation and serve also as cable basement. The cables are accessible through removable sections of 6 mm sheet steel. Outside cables pass through lateral openings in the girders that were closed with fireproof seals after installation.

Special attention has been paid to corrosion proofing because of the increased UV radiation due to the high elevation and possible damages from the sulphuric acid-treated ore. Three coats of two-component polyurethane paint have been applied, with a total thickness of 180 µm.

The principle described above (U-shaped girders all around the bottom as supporting structure) has been chosen also for the platforms on which the starting and braking resistors are installed. In order to reduce the lengths of cables, those platforms have been placed right next to the electric houses.
2.3. Control concept

Fig. 5 shows a schematic view of the control busbar system. The busbars of the overland conveyor (Datahighway +) and the leach pad conveying system are coupled to a process controller. The optical-fibre cables are either separate lines or integrated into the 6.6 kV trailing cables. Both versions operate on a wavelength of 1300 nm. The fibre optics element consists of six gradient-index fibres of 50/125 µm within a protecting sheath. Plug connections have been made by splicing pigtails. This has been done, as far as possible, in the workshop of the cable manufacturer.

The global positioning system (GPS) is connected to the PLC by twisted pair conductors. The data required for operational purposes are made available at the corresponding points of operation, e.g. the cabin on the first crusher (for the overland section), on the mobile discharge boom of the stacking bridge (for the stacking section), on the bucket-wheel reclaimer and the spreader (for the reclaiming section).

The complete volume of operational and fault indication data can be seen at a „panel view“ unit in the PLC panel of every conveyor station and, in parallel, at a second unit outside the electric houses. Thus all process data can be viewed also by those persons who have no access to the locked electric rooms.

2.3.1 Control of the bucket-wheel reclaimer

As briefly described above, the bucket-wheel reclaimer serves to take up the leached-out ore. It travels on two crawlers parallel to the stockpile which is 400 m long and about 6 m high (in the x direction). Course corrections and manoeuvres at the two ends of the pile, where the cutting depth can be chosen up to a maximum of 1.4 m, are made possible by changing the speed of one of the crawlers. That regulation is particularly demanding at the ends of the pile because it is important to shape a plane surface for the crawlers of the reclaimer and the 11 crawlers of the bridge following behind.

For an automatic operation of the machine, the following conditions had to be observed when the control algorithm was developed:

- The reclaimer must follow the general inclination of the leach pad of about 5° in the x direction (that inclination is necessary for the copper compounds leached out to flow in a controlled way to the outer sides of the two halves of the pile).

- The base of the pile in longitudinal direction (y direction) is not even but marked by differences in height because of the geological conditions. Those height differences have to be taken into account for reclaiming, so that the ore residue can be completely removed while it is absolutely ensured that the plastic foil spread to seal the bottom is not damaged by the reclaiming process.

- The reclaim bridge follows the movements of the reclaimer when it turns at the ends of the pile. While the reclaimer passes the bridge, manoeuvres of the bridge can correct possible changes of the distance between the two mechanisms.

- The loading hopper travelling on the bridge must keep exactly the speed of the reclaimer so that it stays all the time within the range of the discharge boom.
Measuring systems used:

- **Global positioning system (GPS)**

  It must be ensured that the measuring signals of at least 5 of the 24 existing GPS satellites can be received in order to determine the positions of reclaimer and bridge (accuracy = 2 cm). The base station receiving the satellite signals is located on a 15 m high tower in the middle of the leach pad. The data are radio-transmitted to the GPS receivers which are installed on the cabin roof of the reclaimer and on the bridges (two each). The actually measured three-dimensional co-ordinates are compared with the setpoints of the two halves of the leach pad stored in the PLC programme. For that purpose the pre-measured 10 m x 10 m grid of height co-ordinates (corresponding to about 13 500 data records) has been stored in the memory of the control system. The elevation lines between the grid measures are approximated through linear functions. Deviations between actual values and setpoints are evened out by repositioning the luffing cylinder. The continually changing inclinations of the travelling gear and the wheel boom are considered in the calculation.

  The GPS serves, in addition to reclaimer performance optimisation, for checking the straight forward motion of the two bridges. Furthermore, the bend travel of the bridges from one leach pad side to the other is also controlled by GPS.

- **For the first time ever, a gyrocompass has been used to monitor the angles between the bridges and their transversal conveyors as well as to determine the travel of the reclaimer at the ends of the leach pad (S curve). During these manoeuvres, and angle of about 6.5 to 7° has to be held constant, and the reclaimer bridge has to follow exactly the S curve. This solution has shown excellent results under the prevailing harsh conditions of operation.**

- **Other sensors**
  - inclination angle sensor for monitoring the longitudinal and lateral inclination of the reclaimer
  - incremental sensors to determine the speed of the reclaimer's bucket wheel
  - range finders to measure the distance in x-y direction between the discharge conveyor of the reclaimer and the loading hopper on the bridge (a rope length transducer for the y direction and the GPS on reclaimer and bridge for the x direction).

  The whole process is fully automated because the operator of the reclaimer cannot monitor all the relevant points, such as wheel cutting depth and transfer chutes. If necessary, he can even leave the cabin.
3. **Some particular aspects of the electrical equipment of the long-distance conveyor 120-CV-103**

3.1 **General characteristics**

With a distance between axles of 9525 m and a total drop of 465 m, this conveyor certainly is one of the biggest of its kind in the world. As all conveyors of the overland conveyor line this one, too, has been designed for a permanent performance of 8700 t/h.

The main parameters defined by MAN-TAKRAF have been:

- Width of belt 1600 mm
- Rated speed of belt 5.85 m·sec\(^{-1}\)
- Tensile strength of belt ST 6800
- Profile of conveyor see Fig. 5

In accordance with the surface conditions it was necessary, in addition to vertical adaptation to the ground, to integrate a horizontal bend with a large radius.

The profile shows clearly that the load situation at a given moment is of paramount importance for the drive and brake performance and the mass moment of inertia. Therefore, the underlying data for calculation are just key figures for the interconnection of transport performance, capacity requirements and the corresponding mass moments of inertia.

At the discharge end, the conveyor has a shifting head which makes it possible to dump material in a variable manner on an intermediate pile serving as an operational buffer store. The possible dumping spots are controlled and monitored according to the data arriving from 6 ultrasonic sensors.

3.2 **The concept**

The specific character of the drive results from the drive loads varying widely between about 0.6 \(M_n\) and about -1.1 \(M_n\), depending on the load situation.

When the algorithms for controlling and regulating the braking and starting processes were established, special attention had to be paid to the results of dynamic simulations of the conveyor in order to avoid overstressing the belt while at the same time obtaining clear algorithms.

That is why the technological preparation of the conveyor system was characterised by thorough discussions of the components and controls to be used. What was most important was the safety aspect in the context of the very high dynamic stress affecting the belt.

When the decision was made to use slipring motors, this carried the advantage that varying load conditions in stationary operation of the conveyor were not a problem, due to the automatic changing of the motors from drive to generator operation and vice versa.
The result of that systematic investigation into the matter was a classification of starting and braking sequences.

The schemes that were finally selected for application have thus emerged from calculations, computer simulations, practical trials on a test stand and experience gained while the system was being commissioned.

3.3 Project preparation

Because of the characteristic features of the conveyor it would not have been possible to carry out comprehensive tests during the commissioning period. This is why special precautions had to be taken beforehand in order to minimise risks.

1. Test installation at Cottbus University
   The software for controlling the switching processes in the commutation phases was tested with the help of low-performance slipring motors, switchgear and actuators corresponding to the original functions in the power circuit and the original components of the PLC.

2. Tests on simulated software for the entire software of the station
   That work concentrated on testing the complex volume of fault signals to be processed and checking the required reaction of the system. Simulations were made on a powerful PC with WinMod** software coupled via remote bus RIO to the decentralised data channels of the control system. Tests 1 and 2 have led to safely functioning programme modules.

3. Measurement of DC braking efficiency
   The calculated torques reached by motors in the DC braking mode have been confirmed. At the same time, major original components, such as the battery unit, DC actuators and rotor resistance were put to a load test.

   The tests have largely contributed to confirming the functionality of the solutions we had developed.
3.4 Power supply

Power is supplied to the station via two 23/6.6 transformers feeding a medium-voltage switchplant, with the possibility of a separate connection to provide for continued operation with limited capacity if one transformer fails.

There is a 160 kVA 6.6kV/400 V transformer for station service.

All components that have an impact on the braking system are fed through an uninterruptible power system (UPS). As the hydraulic pumps and the valves of the hydraulic braking system also belong into that category, a three-phase UPS has been installed which has sufficient power to guarantee the starting of a 5.5 kW pump motor and the simultaneous operation of 3 pumps. Another UPS mainly feeds the control components.

The power supply to the braking valves works in such a way that if one UPS fails the system automatically switches over to the intact second one. This precaution has been a necessary conclusion from the understanding that the strain on the belt would rise to an extreme degree if the total mechanical braking capacity came to be applied abruptly and at the same time.

3.5 Control System

The three PLCs on the overland conveyor line and one PLC on the primary crusher serving as a control station for the overland line are coupled via Datahighway+. Optical-fibre cables with special monomode converters are used in order to overcome the comparatively long distance of about 15 km.

Software tools for analogue and digital data recording integrated into the programme software proved very helpful during commissioning so that costly external measuring arrangements were largely unnecessary.

3.6 Drive Control

3.6.1 Starting

Starting mode 1 Starting with rotor resistance circuit time-controlled
Every resistance value is subsequently applied to every motor; the switching sequences of upper steps can be influenced.

Starting mode 2 Starting with DC braking speed-controlled
Commutation into generator operation at about rated speed, motor by motor, with a small rotor resistor; switchover to rotor resistor for permanent operation.

According to the number of calipers released at the moment when a movement of the belt can be clearly recognised, it is decided which starting
mode to apply. This information also serves to determine the increase and deceleration of the speed setpoint curve.

The release of calipers leads to unavoidable torque influences in the first phase of the starting process. This is why starts with DC braking are made with such setpoints in the lower speed range as to achieve a considerable calming down of the drive through DC braking.

### 3.7.2 Breaking

**Braking mode 1**

- DC braking
- load-controlled
- without commutation
- simultaneous switchover of all motors to DC braking

**Braking mode 2**

- DC braking
- load-controlled
- with commutation
- stepped switchover of motors to DC braking

The criterion for the decision which braking mode to apply is the torque developed by all motors before the braking process, calculated from speed and active power. That value is also used for calculating suitable data for the braking current to be set.

Since the conveyor transports material directly to the pileyard, there is no need to observe a certain braking time very strictly. This is why it has proved suitable and sufficient simply to set a braking current and keep it throughout the braking process. The continuous speed decrease is, of course, monitored.

### Braking in case of power failure

As the power supply is assured for all components needed for DC braking, mode 1 is applied.

### Braking in case of PLC failure

Modern systems have a comprehensive self-diagnostic capability to analyse faults within the PLC and signal them by dropping one output. So-called active PLC faults are not excluded in that case.

Solidly wired interlocks prevent the actuation of switch elements for the DC installation in the case of the pre-determined mechanical braking capacity being applied, so that active PLC faults cannot trigger double braking.

Throughout the operation of the conveyor, the torque values are measured and evaluated at 30-second intervals. As a result of that evaluation, the number of calipers is calculated which are needed to brake the system safely without causing danger through too high a braking torque. Each caliper has been assigned an electromagnetic memory which assures, through its contacts,
that only the calculated number of calipers are applied in case of a failure of the PLC or the DC braking system. By means of a rotation circuit (software) it is made sure that calipers that have been used during a purely mechanical braking operation are, if possible, replaced by others during the following mechanical braking operation, so that wear and tear is not concentrated on particular brakes.

4. Summary

With the electrical equipment for the materials handling system at the El Abra copper mine in Chile, ABB Cottbus has made its contribution to a project which in that form has been done for the first time and could be handed over to the customer SCM after a short implementation period. In demanding conditions such as elevations up to 4000 m, the large extension of the plant and the presence of aggressive substances (sulphuric acid), new technical solutions have been applied for the first time. This concerns mainly the drive concept for the declining conveyor of a length of 9500 m and the incorporation of satellite-assisted position monitoring of the bucket-wheel reclaimer and the bridges into the control system.

The plant has been in operation since October 1996 and quickly reached its designed performance thanks to further optimisations we have carried out together with the specialists of SCM.

*) Datahighway+ registered trade mark of Rockwell Automation
**) WinMod registered trade mark of Mewes & Partner
## Principal technical data of conveyors and machines

<table>
<thead>
<tr>
<th>Conveyor Length [m]</th>
<th>Height Difference [m]</th>
<th>Drive Capacity [kW]</th>
<th>Kind of Braking</th>
<th>Main Drives [kW]</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Head</td>
<td>Tail</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Overland Conveyor

<table>
<thead>
<tr>
<th>Conveyor CV-101</th>
<th>400</th>
<th>+ 20</th>
<th>3 x 450 cage</th>
<th>-</th>
<th>electro-hydraulic</th>
<th>-</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conveyor CV-102</td>
<td>5 058</td>
<td>- 80</td>
<td>3 x 900 slipring</td>
<td>2 x 900 slipring</td>
<td>electro-hydraulic/DC</td>
<td>-</td>
</tr>
<tr>
<td>Conveyor CV-103</td>
<td>9 525</td>
<td>- 465</td>
<td>-</td>
<td>4 x 1600 slipring</td>
<td>disk /DC</td>
<td>-</td>
</tr>
</tbody>
</table>

### Leach Pad Stacking System

<table>
<thead>
<tr>
<th>Conveyor CV-202</th>
<th>2 358</th>
<th>3 x 900 slipring</th>
<th>1 x 900 slipring</th>
<th>electro-hydraulic</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Tripper Car 202</td>
<td>-</td>
<td>-</td>
<td></td>
<td></td>
<td>travelling gear 28 x 2.2</td>
</tr>
<tr>
<td>Stacking Bridge with Stacking Conveyor</td>
<td>-</td>
<td>2 x 450 cage</td>
<td>-</td>
<td>electro-hydraulic</td>
<td>stacking conveyor: 1 x 200</td>
</tr>
</tbody>
</table>

### Leach Pad Reclaiming System

<table>
<thead>
<tr>
<th>Reclaimer</th>
<th>-</th>
<th>2 x 200 cage</th>
<th>-</th>
<th>electro-hydraulic</th>
<th>hydraulic bucket wheel. 3 x 200</th>
<th>bucket wheel, travelling/ luffing gear hydraulic drives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reclaiming Bridge with Hopper Car</td>
<td>-</td>
<td>2 x 450 cage</td>
<td>-</td>
<td>electro-hydraulic</td>
<td>with helical cable reel</td>
<td></td>
</tr>
<tr>
<td>Conveyor CV-205</td>
<td>2 432</td>
<td>4 x 900 slipring</td>
<td>1 x 900 slipring</td>
<td>electro-hydraulic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hopper Car 205</td>
<td>-</td>
<td>-</td>
<td>travelling gear 10 x 2.2</td>
<td></td>
<td>with helical cable reel</td>
<td></td>
</tr>
<tr>
<td>Conveyor CV-206</td>
<td>2 200</td>
<td>4 x 900 slipring</td>
<td>2 x 900 slipring</td>
<td>electro-hydraulic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tripper Car 206</td>
<td>-</td>
<td>-</td>
<td>travelling gear 38 x 2.2</td>
<td></td>
<td>with helical cable reel</td>
<td></td>
</tr>
<tr>
<td>Spreader</td>
<td>-</td>
<td>2 x 450 cage</td>
<td>-</td>
<td>electro-hydraulic</td>
<td>travelling gear 2 x 75</td>
<td></td>
</tr>
</tbody>
</table>

for receiving and discharge conveyor
Remark: The software and the electrical equipment for the crawler drives of the two mobile bridges have not been supplied by ABB.

**Profile of 110-CV-103 conveyor**

**Mass moment of inertia (J) at no-load run**

**Required drive performance (Perf) related to installed capacity**
Speed-torque characteristics, starting mode 1
No-load run is case with highest motoric load

Arrangement of equipment at tail station of 110-CV-103 conveyor
Electrical equipment for the materials handling system at the copper mine of El Abra / Chile

Energieversorgung und Verteilung der Antriebsstation 110-CV-103 und 110-CV-102
Electrical equipment for the materials handling system at the copper mine of El Abra / Chile

Startsequenz

Bremsvorgang

Start-befehl

Lineare Bremszange

Zeitverzögerung

Anzahl der gelösten Bremszangen

Letzte Bremszange

Eingang Drehzahl

30 min

Überwachung der kontinuierlichen Verringerung der Drehzahl

Eingang Bremsbefehl

Bremsbefehl

gespeicherter Momentenwert

Gleichstrom

Kommutierung Drehstrom

Errechnung des berechneten Bremsstromes

Aktivierung des berechneten Bremsstromes

Bremsbefehl

Eingang Drehzahl

Ausgang Schalter der Bremszangen

Ausgang Sollwert GS-Bremse MOTOR 1

Ausgang Sollwert GS-Bremse MOTOR 2

Ausgang Sollwert GS-Bremse MOTOR 3

Ausgang Sollwert GS-Bremse MOTOR X
Electrical equipment for the materials handling system at the copper mine of El Abra / Chile

<table>
<thead>
<tr>
<th>Drive motors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number: 4</td>
</tr>
<tr>
<td>Rated capacity: 1600 kW; service factor 1.15</td>
</tr>
<tr>
<td>Rated voltage: 6600 V</td>
</tr>
<tr>
<td>Rated speed: 994 min⁻¹</td>
</tr>
<tr>
<td>Rated torque: 17310 Nm</td>
</tr>
<tr>
<td>Construction type: IM 1002</td>
</tr>
<tr>
<td>Cooling: IC 0161 air/air</td>
</tr>
<tr>
<td>Insulation: F=ß B</td>
</tr>
<tr>
<td>Measuring heating: 5x500 W</td>
</tr>
<tr>
<td>Motor speed: pulse generator, 1000 pulses per rotation, centrifugal switch</td>
</tr>
<tr>
<td>Drum speed: proximity switch on drum, 60 pulses per rotation of drum</td>
</tr>
<tr>
<td>Performance/torque: active stator power, active rotor power, dynamometer pin (on drive torque arm)</td>
</tr>
<tr>
<td>Current: in stator circuit</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Electric brakes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number: 4</td>
</tr>
<tr>
<td>Type: DC braking</td>
</tr>
<tr>
<td>Type of power supply: battery</td>
</tr>
<tr>
<td>Voltage of power supply: 110 V</td>
</tr>
<tr>
<td>Capacity of power supply: 1000 A through 5 cycles of 80 sec.</td>
</tr>
<tr>
<td>Converters: DC, 400 A each</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mechanical disk brakes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number: 4</td>
</tr>
<tr>
<td>Calipers per brake: 3 (independent actuation)</td>
</tr>
<tr>
<td>Torque per caliper: about 7000 Nm</td>
</tr>
<tr>
<td>Actuation: by hydraulic valves</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Starters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number: 4</td>
</tr>
<tr>
<td>Type: dual step resistor in rotor circuit</td>
</tr>
<tr>
<td>Resistor material: stainless Cr Al Fe alloy</td>
</tr>
<tr>
<td>Segmentation: 7 segments</td>
</tr>
<tr>
<td>Trimming resistor: 4 segments</td>
</tr>
<tr>
<td>Ventilation: natural</td>
</tr>
</tbody>
</table>

Electrical characteristics of the 110-CV-103 drive

**Autoren: Michael Just, Dietmar Simke, ABB**

ABB, Open-pit mining, Cottbus/Germany
Electrical equipment for the materials handling system at the copper mine of El Abra / Chile