ABB Mine Hoisting System at Pyhäsalmi Mine

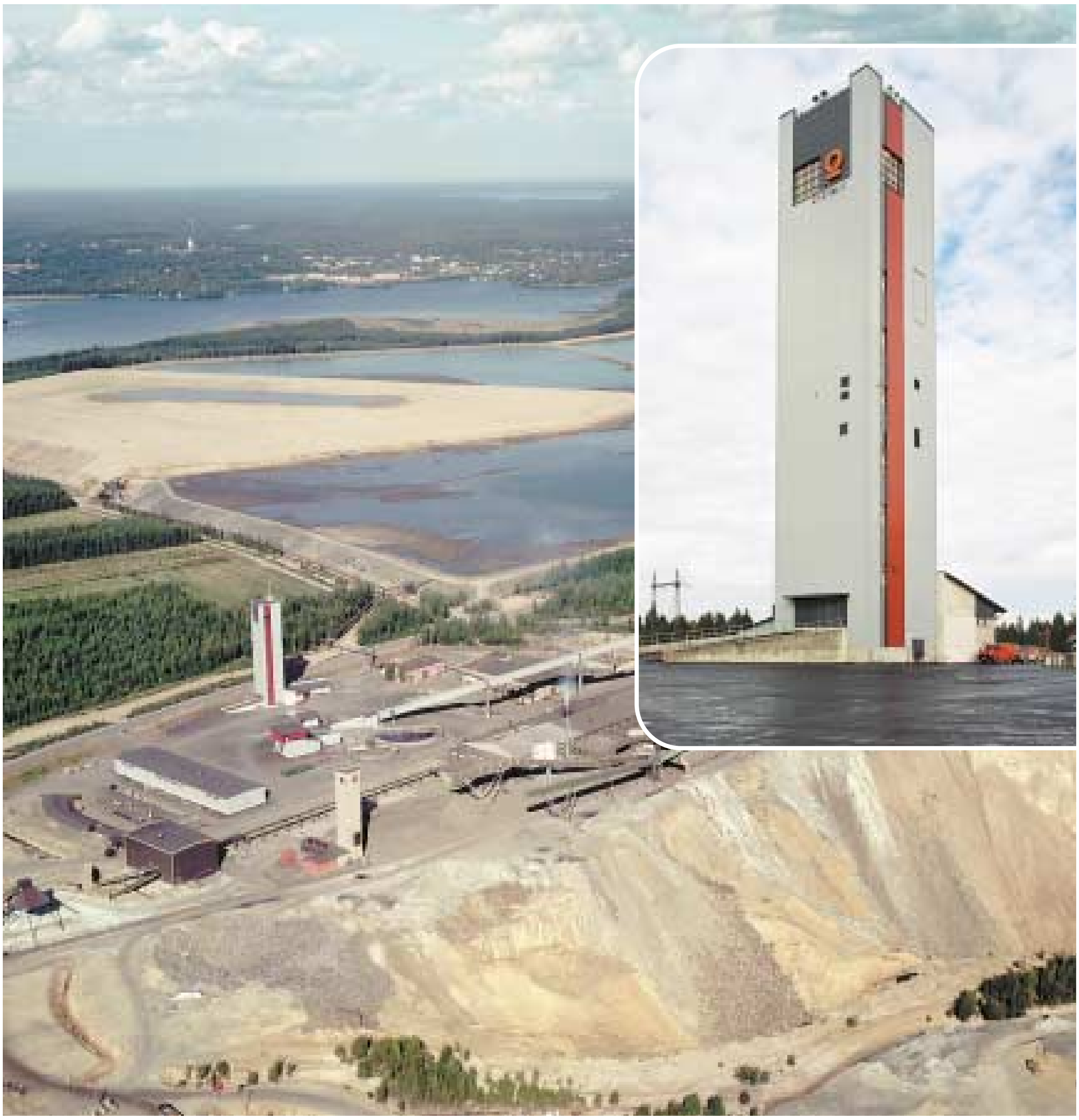

ABB has supplied one of Europe's most sophisticated and technologically advanced fully automatic mine hoist for the new shaft of the Pyhäsalmi zinc and copper mine in central Finland. With a shaft depth of 1,450 metres, the Pyhysälmi Mine is the deepest in northern Europe. ABB's delivery included the mine hoist incorporating a number of advanced technological solutions, the ancillary electrical equipment and the mine heat recovery and ventilation systems.

General background

The Pyhäsalmi Mine is located in central Finland, 160 km south of Oulu and180 km north of Jyväskylä. Outokumpu Oy (Outokumpu Mining Ltd) discovered the zinc/copper ore deposit with reserves of over 30 million tonnes in 1958. Open-cast mining started in 1962 and continued until 1976, when it was switched over to underground mining. ABB supplied the mine hoist system. The shaft depth was then only about 660 metres but was later extended to 1,000 metres. In the early 1990s, when the original reserves were nearing exhaustion, it seemed that the life of the mine was about to come to an end. However, continued exploration revealed the presence of a deep ore body and ore reserves were doubled.

In 1996, after comprehensive studies, Outokumpu decided to go ahead with deep mining at a depth of some 1,410 metres. This would necessitate, however, the transport of ore from around the 1,400-metre level by trucks up ramps over considerable distances to the mine hoist's loading station. It was therefore decided to build a new head frame, sink a 1,450-m-deep shaft as replacement for the existing shaft, to extend the ramps from the 1,000-m level to the 1,450-m-level and install a new mine hoist system. Outokumpu invested over Euro 65 million in this project over a 4-year period. The contract for the new mine hoist system was then awarded to ABB.

Production started in July 2001 and the new shaft with mine hoist system was officially inaugurated on September 6, 2001.

Production

Pyhäsalmi Mine's average annual production, after the 5-stage concentration, smelting and refining processes, is 14,000 tonnes of copper, 30,000 tonnes of zinc, 750,000 tonnes of pyrite (sulphur), 375,000 oz of silver and 8,500 oz of gold, obtained from 1.3 million tonnes of ore. The average grades of the ore are 2.76% zinc, 1.1% copper, 38.6% sulphur (pyrite) and 0.4 g/t gold. It is estimated that the current reserves amount to 17 - 18 million tonnes and that the mine with the new shaft and the present reserves will have a life of 10 - 14 years.

Cosmic ray research

The Pyhäsalmi Mine is also being used for underground cosmic ray research by the Center for Underground Physics in Pyhäsalmi, CUPP, under the auspices of Oulu University and the Finnish Academy of Sciences and Physics. There are at present two underground laboratories for these studies.

Mining method

Hydraulic rigs are used for drilling prior to blasting to extract the ore. The ore is then transported by loaders (LHDs) direct to a gravity shaft, from which it is dumped into the crushers on level 1,405 metres. The finely crushed ore is transferred on a belt conveyor to an ore bin adjacent to the mine hoist. Via a 58.6-m-long conveyor resting on six load cells the exact quantity of ore is dumped into the skip and hoisted to the ground level. From here the ore is transported on a belt conveyor to the adjacent ore dressing plant. Finally, the ore concentrates are transported to Outokumpu's smelter and refining facilities (Fig. 1).

Hoist system parameters

Outokumpu selected a configuration based on a single mine hoist with combined skip and cage and counterweight. The 4-rope, 4.5-metre-diameter friction hoist has deflection sheaves to match the 5-metre shaft layout. The hoist is powered by a directly coupled overhung 2.5 MW synchronous motor with Direct Torque Control. The skip has a payload capacity of 21.5 tonnes and the cage can accommodate 20 people. The mine hoist is designed to operate at 15.5 m/s for ore hoisting and 12 m/s for men hoisting. It has a hoisting capacity of 275 tonnes of ore per hour.

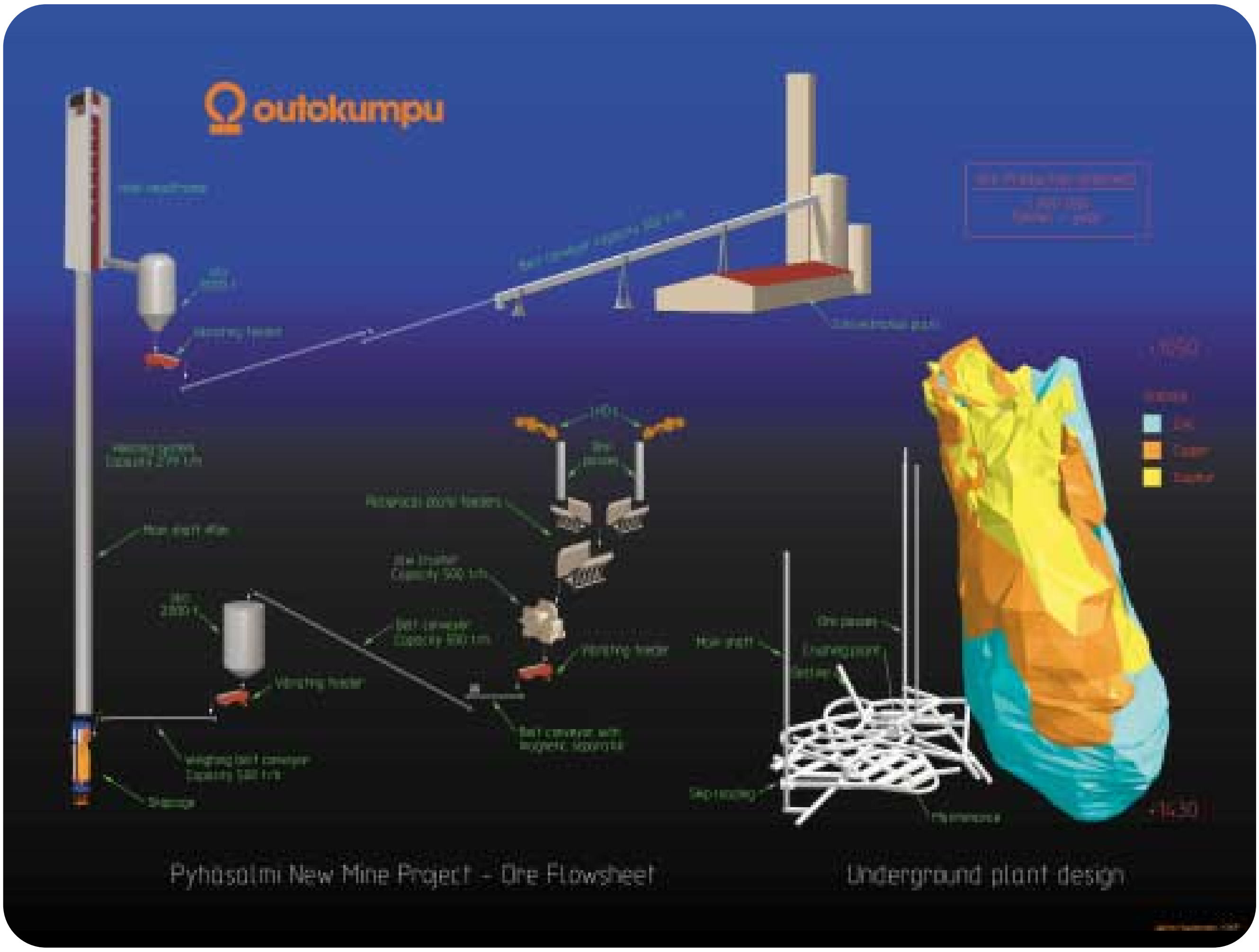

Fig. 1. The ore flow.

Head frame

Since the 8,000-tonne ore bin was built underground, the height of the head frame could be reduced to 54 metres. The footprint of the head frame is only 11 x 11 metres, which is exceptionally small. This could be achieved thanks to the compact design of the ABB mine hoist with roller bearings and overhung motor, which in itself is also very compact.

Shaft

The shaft has a diameter of 5 metres and a depth of 1,450 metres. Fig. 2 shows the shaft layout. At midshaft there is a maintenance station to simplify the maintenance of the ropes and conveyances. A hydraulic lifting device is then used to lift the conveyances and the tail ropes in order to unload the head ropes.

Heat recovery and mine ventilation systems

Another unique feature of the Pyhäsalmi Mine is the system, based on an air-to-water heat exchanger, used to recover heat from the losses of the electrical equipment in the head frame. The recovered heat together with heat recovered from the gas scrubber in the adjacent ore dressing plant is sufficient to heat the head frame and the mine's ventilation air when the outdoor temperature is as low as –20 °C. The ventilation system supplies about 150 m^3/s of air through a separate ventilation shaft.

Mechanical components

Mine hoist

The mechanical parts of the mine hoist follow the ABB design philosophy. The 4.5-metre pulley is bolted directly to a flange on the shaft. The hoist is designed to be 'homogeneously flexible', which means that it is rigid where required and flexible where stress concentrations have to be avoided. The pulley consequently has a relatively low mass and inertia, which reduces the need for a massive supporting structure. The overhung 2.5 MW synchronous motor powering the hoist is directly coupled to the pulley.

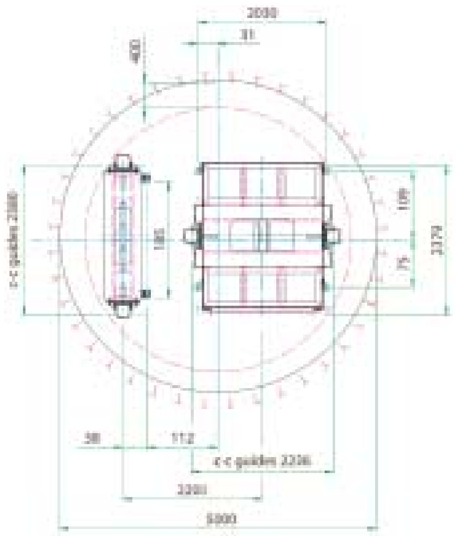

Fig. 2. Shaft layout drawing.

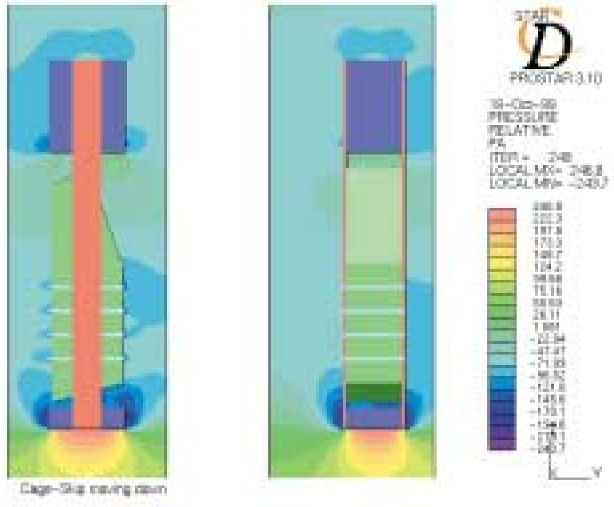

Fig. 3. CFD simulation of shaft dynamic forces.

Hydraulic disc brakes

The mine hoist is equipped with nine disc brake units controlled by a hydraulic system with three different oil release branches to achieve maximum safety. The brake control system provides controlled retardation. This means that the same retardation is maintained irrespective of the load and the direction in which it is moving, thereby increasing the safety margins to rope slip and lowering the stresses on the hoist.

Ropes

The mine hoist system includes a total of 300 tonnes of ropes. They comprise four head ropes with a diameter of 44 mm, three balance ropes and six guide ropes.

Using rope-guided conveyances at Pyhäsalmi for a hoisting distance in excess of 1,400 metres is something that is rather unique. Another special feature is the use of only two guide ropes for the counterweight, without any rope rubbing ropes. This concept has not previously been applied in similar applications. Computational Fluid Dynamics, CFD, simulation was used to verify this topology (Fig. 3). The simulations, which took into account factors like aerodynamic forces, rope torsion, buffeting and Coriolis forces, showed that this system was feasible. Measurements on site after the commissioning verified the calculations.

An advanced function, Rope Oscillation Control, ROC, dampens the vertical oscillations in the head ropes. Such oscillations would otherwise lead to fatigue stresses and poor position control.

The tension of the head ropes is measured by transducers in the rope attachments on the skip. The measured values are continuously transmitted to the control room via a radio link. It is possible in this way to measure the net load in the skip and to obtain information on when it is necessary to adjust the rope length and/or machine the pulley rope grooves.

The guide ropes are fixed suspended at the bottom of the shaft. The rope attachments in the head frame incorporate load cells to measure the rope tension. This can be adjusted with the help of hydraulic jacks. Simulations showed that all ropes should have the same pretension, contrary to common practice.

The tension of the six guide ropes is measured and monitored to ensure that they are correctly prestressed. This ensures that the correct distance is maintained between the conveyances and the shaft wall. This distance is as little as 40 cm, and the conveyances travel at a speed of 55 km/h.

Skip, cage and counterweight

The skip, cage and the 33-tonne counterweight are of ABB´s well proven design. The skip, with a payload capacity of 21.5 tonnes, is designed to ensure fast, automatic loading and dumping. The hoist control system also controls the loading of the skip. Skip supports are installed at the loading station to keep the skip in position during loading. Without such supports, the skip would move down during loading, due to the elongation of the 1,450-m-long head ropes. Hydraulically controlled skip supports are also installed at the dumping station to prevent horizontal movement of the skip due to the lateral forces occurring during dumping.

The cage can accommodate 20 persons. During men hoisting the cage is pushbutton-controlled from the control boxes at the landing levels.

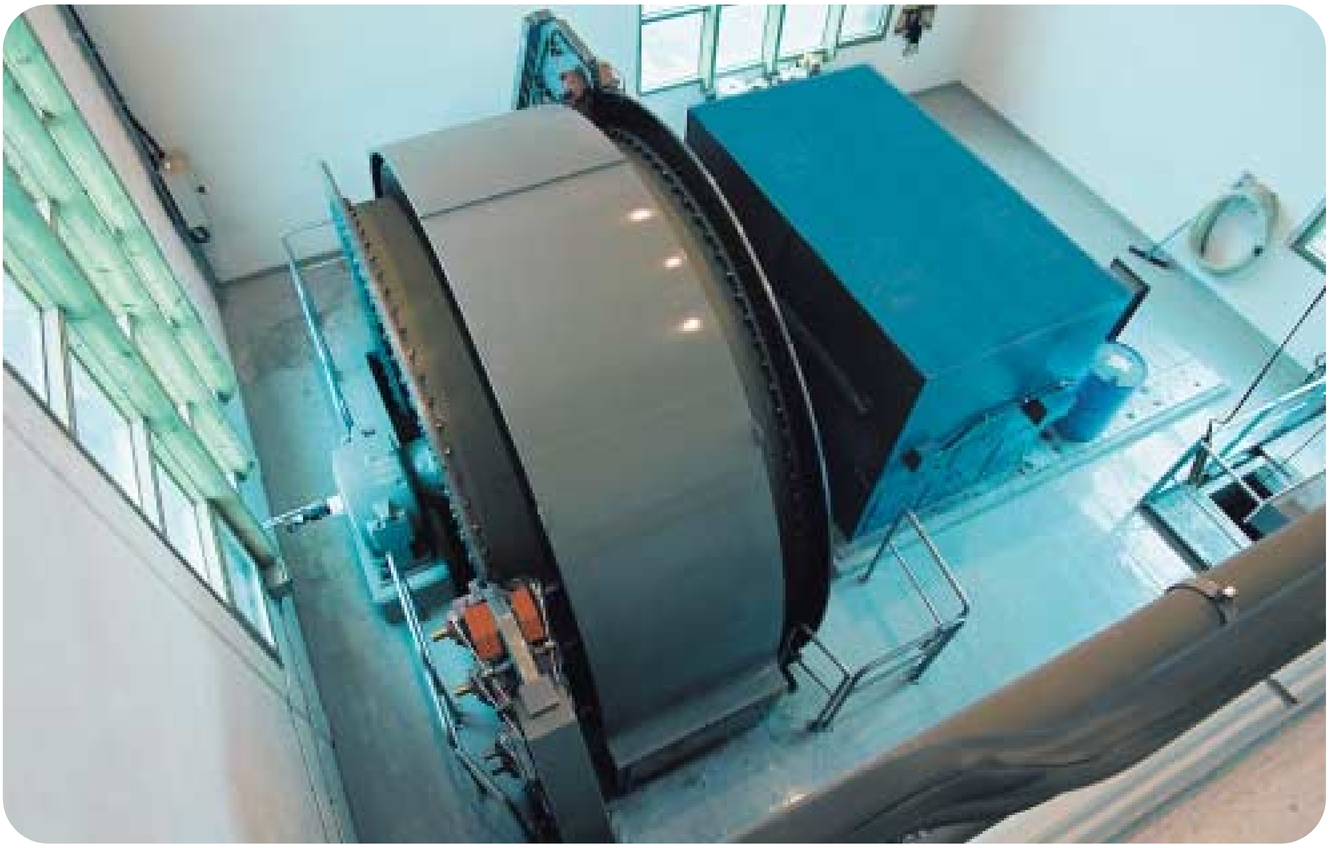

Fig. 4. 4.5 diameter friction hoist with synchronous motor drive.

Electrical equipment
Synchronous motor drive

The Pyhäsalmi Mine hoist is the first in world to use ABB's state-of-the-art synchronous machine drive, ACS 6000SD (see Figs. 4 and 5) to power the mine hoist. The drives in this series cover the power range 3 – 27 MW.

An overhung 16-pole 2.5 MW medium-voltage synchronous motor is directly coupled to the mine hoist. Its speed and torque are controlled by an ACS 6000SD frequency converter with Direct Torque Control, DTC. This new technology offers several advantages over alternative systems like DC, cyclo-converter and conventional PWM control.

Main features of ACS 6000SD include high reliability, small footprint, high torque control performance over the entire speed range, four quadrant operation, an active rectifier unit and lower energy consumption.

ACS 6000SD uses IGCTs (Integrated Gate Commutated Thyristors), which combine high-speed switching with high blocking voltages and low conduction losses to give more efficient and reliable converters.

The DTC platform (Fig. 6) offers the highest torque and speed performance for drives in the MW range. It has a response time that is up to ten times faster than that of conventional control methods using flux vector or PWM control. In addition, DTC provides optimum process control, exact motor performance with minimum torque ripple and machine wear.

Another bonus with ACS 6000SD is that it has a favourable impact on the supply network, particularly in the case of weak ones. Both the motor and the drive normally operate with unity power factor, which reduces losses in both the hoisting system and the supply network. Unity power factor also means that voltage drops will be low. Less transformer power, too, is needed, being only 50 percent of that required by a cyclo-converter drive. A normal hoisting system does not require any harmonic filtering, because the ACS 6000SD converter generates a low level of harmonics. Basically, all harmonics below the 25th will be eliminated as a result of the pulse pattern in the control software. DC circuit-breakers are not required either, thanks to the fast action of the IGCT power semiconductors. Finally, the synchronous motor has a higher efficiency than corresponding DC and induction motors. Overall, with the lower losses due to the lower transformer power, the lack of fuses and the elimination of harmonic filters, the new ABB ACS 6000SD technology offers the best total efficiency.

Fig. 5. ACS 6000SD synchronous motor drive.

Ancillary electrical equipment

The incoming voltage, 6 kV, is stepped down to 3.15 kV by a 2,000 kVA dry-type transformer. Other electrical equipment includes 6 kV medium-voltage switchgear with SF_6 (vacuum) circuit-breakers, standard low-voltage apparatus, a battery system, etc.

Automatic control system

The fully automatic control system controls and monitors the hoisting speed, position of the conveyances and the safety of the complete hoisting system, including the loading of the skip. The control system is based on the ABB Advant® OCS (Open Control System) platform. The hardware is based on the Advant AC110 controller, two server/client Operator Stations (Workstations) using AdvaSoft 2.0 for Windows NT. An AF100 bus is used for communication between the dumping level and the men levels. One of the Operator Stations is located in the head frame and the other in the ore dressing plant, connected by a 300-m-long optical fibre link. The purpose of the Operator Stations (Fig. 7) is to provide information during maintenance work in the shaft and to generate production, availability and fault reports.

The mine hoist is normally operated fully automatically without the need for any operator. During maintenance work the mine hoist is operated manually from the Operator Station in the head frame.

One Advant AC110 controller is used for the fully automatic control of the mine hoist. In addition, two AC70 controllers, a number of repeaters and totally 68 S800 I/Os are used for data acquisition from the field devices.

The Advant Hoist Monitor System AHM 110 monitors and protects the mine hoist. It provides very accurate monitoring of essential parameters such as speed, acceleration, retardation and position of the conveyances. It operates independently of all other control equipment. AHM 110 initiates an emergency stop in the event of overspeeding and overwinding. A display on AHM 110 is used to set the hoist parameters and present data logging functions.

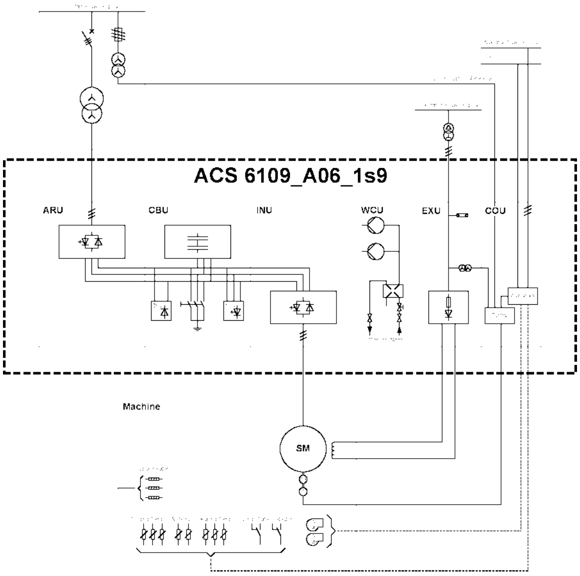

Fig. 6. Block diagram of DTC, Direct Torque Control drive with synchronous motor.

Fig.7. Hoist driver's desk.

Remote support

As part of ABB's undertakings, the delivery included remote monitoring and diagnostics. This enables ABB specialists and service technicians to provide the customer with support without having to visit the site. The software PC Anywhere with a modem makes the remote monitoring/diagnostics possible.

Delivery and installation

ABB Sweden was responsible for all the engineering work, in close co-operation with the customer, with good assistance from ABB Finland. ABB companies in Sweden, Finland and Switzerland were involved in the manufacturing of different components. ABB Finland was responsible for the engineering and installation of the heat recovery and mine ventilation systems.

A transport shaft in the head frame was used during the installation of the electrical equipment. The hoist pulley and shaft, on the other hand, were lifted into position in the head frame by a mobile crane.

Operating experience

As part of the contractual undertakings, ABB performed reliability and availability tests after the commissioning of the hoisting system. Those tests, performed over a period of three months, showed that the total availability of the complete hoisting system was 99.7 percent, which must be considered to be a very high value.

"For us as customer the major benefits of the new hoisting system from ABB is that it saves both space and energy consumption," comments Pekka Perä, Outokumpu's project manager responsible for the mine extension. "Overall, this system has been largely tailored to meet the needs of the Pyhäsalmi Mine. We have had close co-operation with ABB regarding not only the installation in the mine but also the engineering of the system."

General data of the hoisting system for the Pyhäsalmi Mine

Shaft diameter	5 m
Hoisting capacity	275 t/h
Hoisting distance	1,407 m
Design speed (ore hoisting)	15.5 m/s
Men hoisting speed	12 m/s
Weight of skip	20.5 t
Skip payload	21.5 t
Weight of cage	930 kg
Cage capacity	20 persons
Counterweight, incl. rope attachments	33.2 t
Pulley diameter	4.5 m
Synchronous motor rating	2.5 MW, 3 X 3,050 V, 8.7 Hz, 65.8 rpm

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